Globalisation, Transport and the Environment

OECD

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Foreword

What impact has globalisation had on transport? And what have been the consequences for the environment? This book analyses these issues in detail. It is based on a series of papers prepared for an OECD/ITF Global Forum on Transport and Environment in a Globalising World, held in Guadalajara, Mexico, 10-12 November 2008 (see www.oecd.org/env/transport/GFSD)*. The original papers have been updated and edited, primarily in order to avoid overlap from chapter to chapter, and have been brought together in this volume to provide policy makers with a comprehensive overview of the interactions between globalisation, transport and the environment.*

This book looks in detail at how globalisation has affected activity levels in maritime shipping, aviation, and road and rail freight, and assesses the impact that changes in activity levels have had on the environment. The book also discusses policy instruments that can be used to address negative environmental impacts, both from an economic perspective and from the point of view of international law.

It is emphasised that the main research for all the chapters was carried out prior to the sharp deterioration of the global economic situation in the autumn of 2008. The economic recession has, inter alia, *lead to an unprecedented contraction of international trade.*

The editing of the chapters was done by Nils Axel Braathen of OECD's Environment Directorate.

OECD and ITF would like to thank the Mexican authorities for having hosted the Global Forum.

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Acronyms

AIS	Automatic Identification Systems
AMVER	Automated Mutual-assistance Vessel Rescue system
ASA	Air Service Agreement
ATK	Available Tonne-Kilometre
BOD	Biological Oxygen Demand
CER	Community of European Railway and Infrastructure Companies
CH_4	Methane
CIT	Comité International du Transport Ferroviaire – International Railway Transport Committee
CNG	Compressed Natural Gas
COD	Chemical Oxygen Demand
COADS	Comprehensive Ocean-Atmosphere Data Set
CTL	Coal-to-Liquid
DME	Dimethyl Ether
dwt	Deadweight Tonnage
EEA	European Environment Agency
ERTMS	European Rail Traffic Management System
FDI	Foreign Direct Investment
FEH	Factor Endowments Hypothesis
FTK	Freight Tonne-Kilometre
GATS	General Agreement on Trade in Services
GATT	General Agreement on Tariffs and Trade
GT	Gross Tonnage
Gtkm	Giga-Tonne-Kilometre (= 10^9 tkm)
GTL	Gas-to-Liquid
HFO	Heavy Fuel Oil
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICT	Information and Communication Technologies
IFO	Intermediate Fuel Oil
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
ITF	International Transport Forum
LPG	Liquefied Petroleum Gas
LPI	Logistics Performance Index
LRIT	Long Range Identification and Tracking
MDO	Marine Diesel Oil
MGO	Marine Gasoil

MOU	Memorandum of Understanding
Mt	Million tons
NEDC	New European Driving Cycle
N_2O	Nitrous Oxide
NO_x	Nitrogen Oxide
OECD	Organisation for Economic Co-operation and Development
OH	Hydroxyl
PHE	Pollution Haven Effect
PHH	Pollution Haven Hypothesis
PRK	Passenger Revenue Kilometre
RF	Radiative Forcing
RFID	Radio-Frequency Identification
SARP	Standards and Recommended Practices
SECA	Sulphur Emissions Control Area
SO_2	Sulphur Dioxide
TEU	Twenty-foot Equivalent Units containers
tkm	Tonne-Kilometre
TTFSE	Trade and Transport Facilitation in Southeast Europe Program
UIC	Union Internationale des Chemins de Fer – International Union of Railways
UNCTAD	United Nations Conference on Trade and Development
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile Organic Components
VER	Voluntary Export Restraint
WHO	World Health Organization
WTO	World Trade Organization

Executive Summary

The increased flow of knowledge, resources, goods and services among nations that has occurred as a result of globalisation has led to a major increase over the years in transport activity. This has had an impact on the environment in a number of ways: through increased economic activity in general; through shifts in the location of production activities; and through developments in the volume and type of transportation required to meet demands of global trade. This report reviews the linkages between globalisation, transport and the environment, and identifies the policy challenges and potential solutions to address the environmental consequences that arise.

Globalisation and environment: Overall impacts

In general, increased economic openness seems to have had, at worst, a benign effect on emissions of localised pollutants, such as SO_2, NO_2 and PM (particulate matter). However, it is not clear how the relative price changes that result from openness will affect the environmental composition of economic activity: some countries will produce more environmentally intensive goods, others will produce fewer. On the other hand, liberalisation will raise incomes, perhaps increasing the willingness-to-pay for environmental improvements: such income effects could well outweigh the negative scale effects associated with increased economic activity. When combined with the positive effects associated with technology transfer, the net effect of globalisation on local pollutants is quite possibly a positive one.

However, the evidence concerning carbon dioxide and other greenhouse gas emissions is less encouraging. Here, the evidence suggests that the net effect of trade liberalisation could be negative. One of the explanations for the pessimistic assessments of trade's impact on greenhouse gas emissions is their global nature. Not only are the costs of CO_2 emissions shared with citizens abroad, but many greenhouse gas emissions are associated with fossil fuel use, for which few economically viable substitutes have emerged to date. The income and other technique effects that are largely responsible for reductions in local air pollutants do not seem to have the same force when the pollutant in question burdens the global population – and requires global solutions – rather than just citizens residing within any one government's jurisdiction.

Globalisation and transport activity levels

Increasing globalisation has led to strong growth in international shipping activity. Trade and shipping are closely linked, although some disagreement remains about the degree to which energy use in shipping is coupled with the activity level. Considering the range of current estimates, ocean-going ships now consume about 2% to 3% – and perhaps even as much as 4% – of world fossil fuels.

Air transport has also played a key part in fostering globalisation. However, airlines have had to respond to changing demands for their services. These demands come from the requirements for high-quality, fast and reliable international transport. Many structural changes have taken place in the aviation sector as a result of globalisation. Air markets have been liberalised, the networks that airline companies operate have changed (often to hub-and-spoke networks), many new (often low-cost) companies have entered the market, and many airline companies have gone out of business or merged. Some 40% of world trade by value now moves by air.

With new developments to remove bottlenecks, combined with operational improvements, there is scope for considerable improvement in the efficiency of international road and rail freight in many regions. Of course, it is not simply a question of transit time and reliability; it is also a question of cost. Air transport has the highest cost, but very short transit times. Sea transport provides the lowest cost, but long transit times. Road freight falls between air and sea, both in terms of cost and transit time. Rail transport has a very wide range of costs and transit times, and major differences between the officially scheduled transit times and the actual transit times achieved.

Within the next 15 years, there seem to be limited opportunities to dramatically increase the speed of either ships or aircraft. Indeed, concern about CO_2 emissions could lead to changes in the role of air freight within the supply chain. There have even been calls for sea freight transport to operate at slower speeds, in order to save fuel. Given these uncertainties, the potential for rail movement to offer opportunities for shorter transit times, and possibly, reduced costs is interesting. Road freight times may not have the scope to be reduced to the same extent. For both road and rail freight transport, border crossings represent an important barrier. Safety for drivers and cargo is also a major issue, especially for road transport.

Environmental impacts of increased activity levels

The climate change issue clearly lies at the heart of efforts to deal with the environmental impacts of transport that result from globalisation. No other environmental issue has so many potential implications for transport sector policy today.

Global CO_2 emissions from maritime shipping almost tripled between 1925 and 2002. The corresponding SO_2 emissions more than tripled over the same period. The majority of today's ship emissions occur in the northern hemisphere, within a well-defined system of international sea routes. Most studies so far indicate that ship emissions, in contrast to emissions from other transport sectors, lead to a net global cooling, due *i.a.* to cooling effect stemming from sulphur emissions. However, it is stressed that the uncertainties with this conclusion are large, in particular for indirect effects, and global temperature is in any event only a first measure of the extent of climate change.

Projections up to 2020 indicate growth in maritime fuel consumption and emissions in the range of 30%. However, even larger increases in ship emissions could take place in the coming decades. By 2050, CO_2 emissions from maritime shipping could reach two to three times current levels. Most scenarios for the next 10 to 20 years indicate that the effects of regulations and other policy measures will be outweighed by increases in traffic, leading to a significant global increase in emissions from shipping. Global emission scenarios also indicate that the relative contribution to other pollutants from shipping could increase, especially in regions like the Arctic and South-East Asia, where substantial increases in ship traffic are expected.

Expected technological innovations are unlikely to prevent an increase in CO_2 emissions from aviation either, in light of the expected increase in demand – but the rate of technological progress will likely depend on the extent to which the sector faces a price on the CO_2 it emits. Depending on the technology and scenario used, the average external environmental cost of air travel is about EUR 0.01 to EUR 0.05 per passenger-kilometre. Major airlines use hub-and-spoke networks, which means that selected airports receive a relatively large share of all take-offs and landings in the network. As a result, noise pollution in the surrounding areas is relatively high, and passengers travelling indirectly have to make a detour (thereby increasing the total emissions related to their trip). But hub-and-spoke networks might also have environmental benefits, due to environmental economies-of-scale: larger aircraft with lower emissions per seat can be used because passenger flows are concentrated on fewer links. The literature suggests, however, that the negative environmental effects of hub-and-spoke networks tend to exceed the positive effects. If the large airline companies focus their networks on a few intercontinental hubs, traffic levels will increase at these hubs due to the generally expected increase in demand, but also because more people need to make transfers.

International road and rail freight transport account for a minor share of global transport emissions of local air pollutants (*e.g.* NO_x) and noise. The contribution of these emissions to local air pollution is actually decreasing in most parts of the world, mainly due to various vehicle emission standards that have been implemented (and periodically tightened) all over the world. Only in those parts of the world that have an extremely high growth in transport volumes have overall transport-related emissions of local air pollutants not yet decreased.

On the other hand, CO_2 emissions from international road freight transport are increasing all over the world and there is no sign as yet that this trend is to be curbed soon. For this challenging problem, there is no single cure available, and the scale effects will likely outweigh the technological options unless price signals are radically changed. A mix of measures, such as road pricing, higher fuel taxes, stricter fuel efficiency standards for vehicles, use of alternative fuels and logistical improvements, will be needed to limit these trends.

Policy instruments

The international regulatory framework for greenhouse gases does not assign responsibility to nations for managing emissions from shipping and aviation. A multilateral approach may be preferable on both efficiency and effectiveness grounds (especially over the long term), provided sufficient political will exists internationally to co-operate on solving the underlying environmental problems. Although international regimes can sometimes constrain governments' ability to regulate activities that are harmful to the environment, this study demonstrates that international law *does* provide many opportunities to adopt new instruments to regulate environmental impacts from increased international transport.

International coalitions to address problems like climate change or acidification may need to be built from the bottom up. One element of this approach would involve regional arrangements among like-minded countries, or among countries that share a common environmental problem (*e.g.* SO_x). These regional agreements can then serve as building blocks or demonstration experiments toward broader international action over the longer term (*e.g.* linking up emission trading systems in different regions). One caveat here, of course, is the difficulty of regional systems to include important emitters (*e.g.* China, and India, in the case of greenhouse gas emissions). This will inevitably mean that a regional approach would be less efficient than a global approach.

Unilateral action also has a role to play, even at the international level. Not only is unilateral action often the most appropriate approach (especially when the pollution involved affects only the national territory, which is mostly the case for much of land-based transport); local policies can sometimes help to force subsequent changes within the international regime (*e.g.* EU noise standards for airplanes were eventually adopted by ICAO). This example could also play an important role regarding climate change in the future, inasmuch as the EU is poised to apply its greenhouse gas emission trading system unilaterally to international air (and potentially, even to sea) transport.

The most suitable use of policy instruments vary among environmental problems. Movements of *highly hazardous substances* should continue to be controlled essentially by *regulatory* means: bans, prior informed consent rules, etc. Some other environmental impacts, *e.g.* exhaust emissions, may most effectively be addressed by standards, which, however, should provide as much flexibility as possible for producers to come up with low-cost solutions. But the bulk of the "heavy lifting" in the policy response should be given over to market-based instruments (taxes and tradable permits).

Inclusion of *aviation and maritime transport* in cap-and-trade systems would be especially desirable from a cost-effectiveness point of view. For both of these modes, technological abatement options are limited in the short run because of slow fleet turnover. In the maritime sector, operational measures seem capable of reducing CO_2 emissions in the short run, and at low cost. In aviation, there is also some scope for abatement through better air traffic control and airport congestion management, but the main abatement is likely to come from lower demand. Available estimates put an upper bound of about 5% on demand reductions, at prices of around EUR 20 per tonne of CO_2. Imperfect competition and airport congestion limit the extent of pass-through, and hence limit the demand responses. The aviation sector, hence, is likely to be a net buyer of emission allowances.

When it comes to *road transport*, the optimal policy response to *fuel-related* externalities (such as climate change) is different from the optimal policy responses to *distance-related* externalities (such as congestion, accidents and air pollution). Imposing a fuel tax induces *some* improvement in both distances travelled and fuel efficiency. But it does not reduce distance-related externalities much, while most studies suggest that distance-related externalities in road transport are significantly higher than fuel-related ones.

A more efficient approach would therefore seem to be to use *distance-related taxes* such as road pricing. But the problem with this approach is that the distance travelled is not the most important contributor to GHG emissions. For *climate change*, fuel efficiency will remain the primary goal, and distance-related taxes would be too indirect.

It is sometimes argued that stricter standards are needed to increase the dispersion of more fuel-efficient vehicles through the fleet, because the market provides relatively weak incentives to improve fuel economy. If consumers are not willing to pay much now for fuel economy improvements that only provide economic benefits over a long timescale, producers may not be willing to supply fuel-efficient vehicles either. One way around this problem could be for the government to force fuel economy into the marketplace via a fuel-economy standard. The case for such standards would be strongest if fuel taxes were low and incomes were high (in these cases, drivers care even less about the fuel economy of their vehicles). However, in such a situation, it could be more cost-efficient to increase the fuel taxes.

Chapter 1

Introduction and Main Findings

1.1. Introduction

OECD and the International Transport Forum (ITF) held a *Global Forum on Transport and Environment in a Globalising World*, 10-12 November 2008 in Guadalajara, Mexico.* There were around 200 participants from 23 countries at the Global Forum, representing national and local governments, academia, business, environmental organisations, etc. The main purpose of the Global Forum, and of this book, was to discuss the impact globalisation has had on transport levels, the consequences for the environment and the policy instruments that can be used to limit any negative impacts for the environment. This book is based on the papers addressing globalisation issues that were prepared for that forum. The papers have been somewhat edited, in an attempt to present a continuous story, and to avoid much overlap among chapters. Some additional or updated material has also been added, but the *systematic* research for the various chapters was ended in the autumn of 2008.

Box 1.1. **What is globalisation?**

The term "globalisation" is often used to describe the increased flow of knowledge, resources, goods and services among nations. The term is sometimes defined as "the development of an increasingly integrated global economy marked especially by free trade, free flow of capital and the tapping of cheaper foreign labour markets".*

Globalisation can also be described as a process by which the people of the world are unified into a single society and function together. This process is a combination of economic, technological, socio-cultural and political forces. The term is, however, often used to refer in the narrower sense of economic globalisation, involving integration of national economies into the international economy through trade, foreign direct investment, capital flows, migration and the spread of technology.

OECD (2005) highlights that three major forces have contributed importantly to the globalisation process: *i)* the liberalisation of capital movements and deregulation, of financial services in particular; *ii)* the further opening of markets to trade and investment, spurring the growth of international competition; and *iii)* the pivotal role played by information and communication technologies (ICT) in the economy.

* See *www.merriam-webster.com/dictionary/globalization.*

1.2. Main findings

How globalisation affects the environment – Overall impacts

In general, increased economic openness (mainly trade and investment liberalisation) seems to have had, at worst, a benign effect on emissions of *localised pollutants*. It has, for example, been found that (for the statistically average country), a 10% increase in trade intensity leads to approximately a 4% to 9% reduction in SO_2 concentrations (Antweiler,

* See *www.oecd.org/env/transport/GFSD.*

Copeland and Taylor, 2000). Other studies have found that openness appears to have a beneficial impact on SO_2 and NO_2, but no statistically significant impact on PM emissions. Still another study found that trade intensity *increases* land releases, but either reduces or has no statistically significant effect on air, water and underground releases (Chintrakarn and Millimet, 2006).

In broad terms, the evidence suggests that it is not clear how the relative price changes that result from openness will affect the environmental *composition* of economic activity: some countries will produce more environmentally intensive goods, others will produce fewer. On the other hand, liberalisation will raise incomes, perhaps increasing the willingness to pay for environmental improvements: these potential *income effects* could well outweigh the negative *scale effects* associated with increased economic activity. When combined with the positive effects associated with *technology* transfer, the net effect on local pollutants is quite possibly a positive one.

However, the evidence concerning *carbon dioxide and other greenhouse gas emissions* is less encouraging. Here, the evidence suggests that the net effect of trade liberalisation is likely to be negative. One study, using a cross-section of 63 countries (and correcting for trade intensity and income) concluded that a 1% increase in trade leads to a 0.58% increase in CO_2 emissions for the average country in her sample (Magani, 2004). Other studies similarly find openness raises CO_2 emissions, but also find the detrimental impact disappears when corrections are made for income levels, etc.

One of the explanations for the consistently pessimistic assessments of trade's impact on greenhouse gas emissions is their global nature. Not only are the costs of CO_2 emissions shared with citizens abroad, but many greenhouse emissions are associated with fossil fuel use, for which few economically viable substitutes have emerged to date. The *income* and other *technique* effects that are largely responsible for reductions in *local* air pollutants do not seem to have the same force when the pollutant in question burdens the global population – and requires global solutions – rather than just citizens residing within any one government's jurisdiction.

For example, unlike emissions by nationally based emission sources, international transport-related emissions often involve third parties, *i.e.* many goods are moved via vessels not bound by operational regulations in the importing or exporting country. This is a particular issue for ocean shipping. Thus, even if voters in high-income countries want stringent environmental regulations attached to the transport of traded goods they consume, shipping emissions may be outside their government's jurisdiction. An international response may be the only practical approach to this problem.

Globalisation and international transport activity

The 21st century has seen the continued internationalisation of the world's economy. There is also evidence of greater globalisation of cultures and politics. Economically, globalisation helps to facilitate the greater division of labour, and to exploit its comparative advantage more completely. In the longer term, globalisation also stimulates technology and labour transfers, and allows the dynamism that accompanies entrepreneurial activities to stimulate the development of new technologies and processes that lead to global welfare improvements.

Increasing globalisation has led to a strong increase in *international shipping* activity. Trade and shipping are closely linked, although some disagreement remains about the degree to which energy use in shipping is coupled with the movement of waterborne commerce. The estimates depend *inter alia* on the number of at-sea or in-port days that are assumed in the analysis. The available evidence largely indicates that world marine fleet energy demand is the sum of international fuel sales, plus domestically assigned fuel sales. Some debate continues about the best estimates of global fuel usage, but the major elements of activity-based inventories are widely accepted. Considering the range of current estimates using activity-based input parameters, ocean-going ships now consume about 2% to 3% – and perhaps even as much as 4% – of world fossil fuels (see Chapter 3).

Air transport has also played a key part in fostering globalisation. However, airlines (and to an even greater degree, air transport infrastructure) have had to respond to changing demands for their services. These demands come from the requirements for high-quality, fast and reliable international transport. Globalisation, almost by definition, means demands for greater mobility and access, but these demands are increasingly different for different types of passengers and cargoes, to different places, and over different distances, than was previously the norm.

Many structural changes have taken place in the aviation sector as a result of globalisation. Air markets have been liberalised, the networks that airline companies operate have changed (often to hub-and-spoke networks), many new (often low-cost) companies have entered the market, and many (low-cost and other) airline companies have gone out of business or merged (most of the remaining airlines have already united into three major alliances).

International air transport is now a major contributor to globalisation and is continually reshaping to meet the demands of the economic and social integration that globalisation engenders. Some 40% of world trade (by value) now moves by air (see Chapter 4). To allow the flows of ideas, goods and persons that facilitate efficiency on a global scale, air transport has played a key role in the past, and is poised to continue this role in the future. Yet, as the strong growth in air transport activity is straining air-related infrastructure (such as airports), future economic growth in the sector could well be constrained by capacity limits.

With new developments to remove bottlenecks, combined with operational improvements, there is scope for considerable improvement in the efficiency of international *road and rail freight* in many regions. Of course, it is not simply a question of transit time and reliability (although both are important), it is also a question of cost.

One study has compared total door-to-door transport costs and transit times for a range of transport solutions carrying cargo from Asia to Europe (Chamber of Commerce of the United States, 2006). Air transport had the highest cost, but very short transit times. Sea transport provided the lowest cost, but had long transit times. The road freight results fall between air and sea, both in terms of cost and transit time. Rail transport exhibited a very wide range of costs and transit times, and showed major differences between the officially scheduled transit times and the actual transit times achieved.

Within the next 15 years, there seem to be limited opportunities to dramatically increase the speed of either ships or aircraft. Indeed, concern about CO_2 emissions could lead to changes in the role of air freight within the supply chain. There have even been calls for sea freight transport to operate at *slower* speeds, in order to save fuel. Given these uncertainties, it is interesting to note the particular potential for *rail* movement to offer opportunities for shorter transit times, and possibly, reduced costs. *Road* freight times may not have the scope to be reduced to the same extent. For both road and rail freight transport, border crossings represent an important barrier to trade. Safety for drivers and cargo is a major issue, especially for road transport.

A major increase in road and rail transport from eastern parts of Asia to Europe would require major infrastructure investments, in particular for road transport. Although the Trans-Siberian rail connection already exists, gauges of rail networks still differ among countries involved.

There are many opportunities to improve the efficiency and reduce the environmental impact of international road and rail freight transport. Many of these developments require government intervention in the form of changes to regulatory policy, improvements to infrastructure and the breaking up of public monopolies that currently often offer ill-adapted services. This is a complex area when considered within one country; when it concerns international developments, it is even more complicated.

When looking ahead 15 years, it is important to note the growing role played in international transport by *major logistics companies*. The consolidation that is evident means that single companies are now able to provide truly integrated services in a way that was not possible a few years ago.

Environmental impacts of increased international transport

Shipping

Global CO_2 *emissions* from maritime shipping (estimated based on sales of bunker) almost tripled between 1925 and 2002 (Endresen *et al.*, 2007). The corresponding SO_2 *emissions* more than tripled over the same period. The majority of today's ship emissions occur in the northern hemisphere, within a well-defined system of international sea routes.

Activity-based modelling for 1970-2000 indicates that the *size* and the *degree of utilisation* of the fleet, combined with the *shift to diesel engines*, have been the major factors determining yearly energy consumption. One study indicates that (from about 1973 – when bunker prices started to raise rapidly) growth in the fleet was not necessarily accompanied by increased energy consumption (Endresen *et al.*, 2007). The main reason for a large deviation among activity-based emissions estimates is the number of days assumed at sea. Data indicate a strong dependency on ship type and size: activity-based studies have not considered ships less than 100 GT (*e.g.* some 1.3 million fishing vessels), and this fleet could account for a substantial part of additional fuel consumption.

Recent studies indicate that the emission of CO_2, $NO_{x,}$ and SO_2 by ships correspond to about 2% to 3% (perhaps 4%), 10% to 15%, and 4% to 9% of global anthropogenic emissions, respectively. Ship emissions of *e.g.* NO_2, CO, NMVOCs, SO_2, primary particles, heavy metals and waste cause problems in coastal areas and harbours with heavy traffic. Particularly high increases of short-lived pollutants (*e.g.* NO_2) are found close to regions with heavy traffic *e.g.* around the North Sea and the English Channel. Model studies tend to find NO_2 concentrations to be more than doubled along the major world shipping routes. Absolute increases in surface ozone (O_3) due to ship emissions are pronounced during summer months, with large increases again found in regions with heavy traffic. Increased ozone levels in the atmosphere are also of concern with regard to climate change, since ozone is an important greenhouse gas.

Formation of sulphate and nitrate resulting from sulphur and nitrogen emissions causes acidification that might be harmful to ecosystems in regions with low buffering capacity, and lead to harmful health effects. Coastal countries in western Europe, western North America and the Mediterranean are substantially affected by ship emissions in this way.

The large NO_x emissions from ship traffic lead to significant increases in hydroxyl (OH), which is the major oxidant in the lower atmosphere. Since reaction with OH is a major way of removing methane from the atmosphere, ship emissions *decrease* methane concentrations. (Reductions in methane lifetimes due to shipping-based NO_x emissions vary between 1.5% and 5% in different calculations, see Chapter 6.) The effect on concentrations of greenhouse gases (CO_2, CH_4 and O_3) and aerosols have differing impacts on the radiation balance of the earth-atmosphere system. Ship-derived aerosols also cause a significant *indirect* impact, through changes in cloud microphysics.

In summary, most studies so far indicate that ship emissions actually lead to a *net global cooling*. This net global cooling effect is not being experienced in other transport sectors. However, it should be stressed that the uncertainties with this conclusion are large, in particular for indirect effects, and global temperature is only a first measure of the extent of climate change in any event.

The contribution to climate change from the different components also acts at different temporal and spatial scales. A long-lived well-mixed component like CO_2 has *global* effects that last for centuries. Shorter-lived species like ozone and aerosols might have effects that are strongly *regional* and last for only a few days to weeks. The net cooling effect that so far has been found primarily affects *ocean areas*, and thus does not help alleviate negative impacts of global warming for human habitats.

Projections up to year 2020 indicate growth in maritime fuel consumption and emissions in the range of 30%. However, if more weight is given to the large increase in emissions during the last few years, even larger increases in ship emissions could take place in the coming decades. By 2050, CO_2 emissions from maritime shipping could reach two to three times current levels (Eyring *et al.*, 2005).

More specifically, most scenarios for the next 10 to 20 years indicate that the effects of regulations and other policy measures will be outweighed by increases in traffic, leading to a significant global increase in emissions from shipping. Global emission scenarios for non-ship (land-based) sources also indicate that the relative contribution to pollutants from shipping could increase, especially in regions like the Arctic and South-East Asia, where substantial increases in ship traffic are expected.

Limiting the sulphur content in fuel in the North Sea and English Channel seems to be an efficient measure to reduce sulphate deposition in nearby coastal regions. Several technologies also exist to reduce emissions from ships beyond what is currently legally required (*e.g.* by the use of scrubbers and filters to capture emissions from the exhaust gases and by the use of low-NO_x engines).

Aviation

Expected technological innovations will probably not prevent an increase in CO_2 emissions from aviation either, in light of expected increase in demand – but the rate of technological progress will likely depend on the extent to which the sector faces a price on the CO_2 it emits. Depending on the technology and scenario used, the average "external" (*i.e.* environmental) cost of air travel is about EUR 0.01 to EUR 0.05 per passenger-kilometre (Dings *et al.*, 2003).

Major airlines use "hub-and-spoke" networks, which means that selected airports receive a relatively large share of all take-offs and landings in the network. As a result, noise pollution in the surrounding areas is relatively high, and passengers travelling indirectly have to make a detour (thereby increasing the total emissions related to their trip). But hub-and-spoke networks might also have environmental *benefits*, due to environmental economies of scale: larger aircraft with lower emissions per seat can be used because passenger flows are concentrated on fewer links. The literature suggests, however, that the negative environmental effects of hub-and-spoke networks tend to exceed the positive effects. If the large airline companies focus their networks on a few intercontinental hubs, traffic levels will increase at these hubs due to the generally expected increase in demand, but also because more people need to make transfers.

Air travel connects regions to the world economy, and gives individual travellers the opportunity to explore the world. But as long as the full external cost is not covered by the ticket price, environmental damage caused by aviation will continue to grow beyond socially optimal levels.

Road and rail

International road and rail freight transport account for a minor, but increasing, share of global transport emissions of air pollutants (*e.g.* NO_x) and noise emissions. The contribution of these emissions to local air pollution is actually *decreasing* in most parts of the world, mainly due to various vehicle emission standards that have been implemented (and periodically tightened) all over the world. Only in those parts of the world that have an extremely high growth in transport volumes have overall transport-related emissions of local air pollutants not yet decreased.

On the other hand, CO_2 emissions from international road freight transport are increasing all over the world (and could roughly double to 2050), and there is not yet a sign that this trend is to be curbed soon. For this challenging problem, there is no single cure available, and the scale effects will likely outweigh the technological options. A mix of measures, such as road pricing, higher fuel taxes, stricter fuel efficiency standards for vehicles, use of alternative fuels and logistical improvements, will be needed to reverse these trends.

Policy instruments

Theory suggests that *all* policy instruments, if properly designed, will reflect the right level of policy ambition (*i.e.* where marginal benefits just equal marginal costs). However, theory also suggests that a cost-effective result is more likely to be realised via market-based instruments (such as taxes and tradable permits) than by using regulatory or voluntary approaches.

On the other hand, there is no silver bullet that can solve all the environmental problems created by transport activity. In some cases, for example regarding emissions of local air pollutants, standards will be the most effective and efficient instruments. A *mix of instruments* will in many cases be needed. It is, however, important to assess carefully what each instrument adds to the mix, and how the instruments interact. Policy needs in OECD countries are likely to be different from policy needs in developing countries. The optimal instrument mix will therefore vary from situation to situation.

On the one hand, a *multilateral approach* is preferable on both efficiency and effectiveness grounds (especially over the long term), provided sufficient political will exists internationally to co-operate on solving the underlying environmental problem. The international regulatory framework for greenhouse gases does, however, not assign responsibility to nations for managing emissions from shipping and aviation. Although international regimes can sometimes constrain governments' ability to regulate activities that are harmful to the environment, international law *does* provide many opportunities to adopt new instruments to regulate environmental impacts from increased international transport.

On the other hand, the constraints to successful international negotiations will sometimes be rather imposing. International agreements take a long time to put in place; they are also hard to enforce. They might also be characterised by significant "leakage" problems, in the sense that emitters might be able to shop around for less stringent jurisdictions. It may also be that emission control is actually too narrow an approach for such a complex sector as transport. In principle, an optimal international agreement related to transport and climate change should also include such elements as adaptation and technology development, rather than being limited to just controlling emissions.

International coalitions may also need to be built from the bottom up. One element of this approach would involve *regional arrangements* among like-minded countries, or among countries that share a common (regional) environmental problem (*e.g.* SO_x). These regional agreements can then serve as building blocks or demonstration experiments toward more international action over the longer term (*e.g.* linking up emission trading systems in different regions). One caveat here, of course, is that the difficulty of regional systems to draw important emitters into the regional system (*e.g.* China, and India, in the case of greenhouse gas emissions) will inevitably mean that a regional approach would be less efficient than a global approach.

Unilateral action also has a role to play, even at the international level. Not only is unilateral action often the most appropriate approach (*e.g.* when the pollution involved affects only the national territory, which is mostly the case for much of land-based transport), local policies can sometimes help to force subsequent changes within the international regime (*e.g.* EU noise standards for airplanes were eventually adopted by ICAO). In the case of climate change, this example could also play an important role in the future, inasmuch as the EU is poised to apply its greenhouse gas emission trading system unilaterally to international air (and potentially, even to sea) transport. The power of unilateral action to eventually lead to positive outcomes at the international level over the medium term should therefore not be underestimated.

Although international transport regimes have historically focused on *protecting transport activity*, there is now a trend toward countries recognising the need for the global transport regimes to deal with *environmental* problems. Two international organisations in particular – ICAO and IMO – have been explicitly tasked to address climate change and other environmental challenges arising from international transport. These are encouraging developments.

The *interface between global and local regulation* is key. Both forms of regulation are clearly legitimate in their own contexts, but there should be more energy expended on making these two sets of objectives compatible with each other. In particular:

- Global regimes should not be perceived as limitations on intelligent national action. National action has historically been the cornerstone of environmental policy, and this important role deserves explicit recognition when international agreements are being negotiated.

- On the other hand, any national action that is being considered should explicitly respect the basic principles of non-discrimination and national treatment, principles that are systematically built into all existing international regimes to protect against economic distortions.

Lowest priority for international action would seem to be to try to use Article XX of the GATT. Using trade-based regulation to resolve environmental problems in the transport sector seems a very indirect way of reaching transport-environment policy integration objectives.

Priorities for policy action

The *climate change* issue will clearly lie at the heart of efforts to deal with the environmental impacts of transport that result from globalisation. No other environmental issue has so many potential implications for transport sector policy today. Although the specific estimates vary, transport-based CO_2 emissions are projected to grow significantly in the coming years. Light duty vehicles on roads will continue to be the largest contributors to this problem, but air-based emissions will grow more rapidly. Some shift toward less carbon-intensive technologies is foreseen, but no significant shift to truly low-carbon technologies is anticipated in most of the current estimates. In other words, incremental, rather than drastic, technological change is foreseen.

Modes for which pre-existing policies are relatively weak, such as shipping and aviation, seem to be ideal candidates for integration into broader efforts to introduce climate change policy frameworks. Surface transport, on the other hand, is characterised by stronger existing policies, so its further integration into such broader frameworks seems less straightforward.

Global economic activity also leads to problems *other than climate change* (including local air pollutants, such as NO_x, SO_x, particulates and noise): these problems will need to be addressed.

At the national or local level, the road transport sector is already quite heavily regulated in one form or another (through standards, taxes, etc.). This implies that further abatement in road transport emissions may be relatively more costly. More cost-effective opportunities may exist in other transport sectors (especially in aviation and shipping) but measures in these sectors will primarily have an impact near airports, harbours and major sea lanes.

At the international level, it may be possible to develop common fuel-efficiency standards, but this would not be straightforward. The international regime related to shipping in particular is still in its early stages of development, so there are opportunities to mould that regime. The IMO/MEPC is trying to work toward effective and efficient control polices for shipping, so there are some initiatives being taken toward this goal:

- First, movements of *highly hazardous substances* should continue to be controlled essentially by *regulatory* means: bans, prior informed consent rules (*e.g.* Rotterdam Convention), etc. When the problem involves serious health hazards, the environmental effectiveness objective should always take precedence over the economic efficiency goal. Outright bans, combined with total transparency, are the safest ways forward in these circumstances.

- Second, some environmental impacts, *e.g.* exhaust emissions, may effectively be addressed by standards, which should provide as much flexibility as possible for producers to come up with low-cost solutions.
- Third, as mentioned above, the bulk of the "heavy lifting" in the policy response should be given over to market-based instruments (taxes and tradable permits).

Inclusion of *aviation and maritime transport* in cap-and-trade systems would be especially desirable from a cost-effectiveness point of view. For both of these modes, technological abatement options are limited in the short run because of slow fleet turnover. In the maritime sector, operational measures seem capable of reducing CO_2 emissions in the short run, and at low cost. In aviation, there is also some scope for abatement through better air traffic control and airport congestion management, but the main abatement is likely to come from lower demand. Available estimates put an upper bound of about 5% on demand reductions, at prices of around EUR 20 per tonne of CO_2. Imperfect competition and airport congestion limit the extent of pass-through, and hence limit the demand responses. The aviation sector, hence, is likely to be a net buyer of emission allowances. Both in aviation and in shipping, there is considerable scope for leakage as long as trading schemes are not comprehensive. Nevertheless, inclusion of these modes in trading schemes is desirable if overall abatement is to be cost effective in the long run.

When it comes to *road transport*, however, taxes and tradable permits present a particular problem. The optimal policy response to *fuel-related* externalities (such as climate change) is different from the optimal policy responses to *distance-related* externalities (such as congestion, accidents and air pollution). Imposing a fuel tax induces *some* improvement in both distances travelled and fuel efficiency. But it does not reduce distance-related externalities much, while most studies suggest that distance-related externalities in road transport are significantly higher than fuel-related ones.

A more efficient approach would therefore seem to be to use *distance-related taxes*, such as road pricing. But the problem with this approach is that the distance travelled is not the most important contributor to GHG emissions – the most important target of climate policies. For *climate change*, fuel efficiency will remain the primary goal, and distance-related taxes would be too indirect.

For example, the EU has high fuel taxes and may soon introduce fuel economy standards. The US has relatively low fuel taxes, but fuel economy is regulated by a fuel-economy standard that is now being tightened. In the EU, road transport is not included in CO_2 emission trading system. In various US proposals, one idea is to eventually include the sector in carbon trading schemes, possibly through "upstream" trading. Since existing policies are relatively stringent, abatement costs for CO_2 in road transport are also relatively high (and exceed current and expected prices for carbon permits). Further tightening of regulations would therefore seem undesirable from only a climate change point of view, but since these prevailing policies serve other purposes than just greenhouse gas reductions, it is not clear if the welfare cost of further tightening would be very high. For example, higher fuel taxes in the US seem justified if the primary policy goal is to reduce *congestion*; this policy would also reduce greenhouse gas emissions.

On the other hand, the case for tighter fuel economy standards taxes in road transport to reduce *greenhouse gas emissions* is weak, at least within the static welfare economic framework used above. It is, however, sometimes argued that these policies are needed to increase the dispersion of more fuel-efficient vehicles through the fleet. The reason is said to be that the market provides relatively weak incentives to improve fuel economy, given consumers' response to various uncertainties surrounding investments in fuel economy. If consumers are not willing to pay very much now for fuel economy improvements that only provide economic benefits over a long timescale, producers may not be willing to supply fuel-efficient vehicles either. If the goal is to change engine technologies, one way around this problem could be for the government to force fuel economy into the marketplace via a fuel-economy standard. The case for such standards would be strongest if fuel taxes are low and incomes are high (in these cases, drivers care even less about the fuel economy of their vehicles). However, a more cost-efficient approach could be to increase the fuel taxes.

Possibilities exist in both IMO and ICAO to find new ways of regulating GHG emissions (see Chapter 10). This could follow the partly successful model of regulating NO_x, SO_x and *noise* emissions from air and sea transport.

Aggressive GHG emission abatement strategies will inevitably require *technological change*. In particular, because of the point made earlier that the road transport market will not provide enough private incentives to improve fuel economy, government technology policies will be needed to overcome this reluctance. Similarly, the slow fleet turnover rates in both aviation and shipping may also need to be increased, via technology-based public policies. Carrots are always more easily implemented in policy practice than sticks, so well-designed *subsidy arrangements* could hold some promise for future policy directions – but there is always a risk that the cost-effectiveness could be low, as the subsidised activities would have been undertaken in any case.

A few other policy approaches also seem to have some issues associated with them:

- *Public procurement* policies can create competition problems.
- *Labelling* runs the risk of not generating more environmental benefits than would have been generated in any case (the "baseline" problem).

More generically, wider use could be made of the common interest of *shipping ports* in controlling environmental pollutants. Ports also have a regional context (not only a local/ domestic one) that could be built upon more creatively in designing response strategies. Most shipping passes through a port of an OECD country at some time during the course of a shipment: this represents a key opportunity for more concerted action.

The *corporate responsibility angle* should also be more fully exploited. Although 75% of the global merchant vessel fleet is registered in non-Annex 1 countries, this fleet is mostly owned by shipping interests in Annex 1 countries. This represents an interesting opportunity to work towards *coalitions of shippers* that might eventually develop common guidelines related to environmental protection in the shipping community.

And finally, information programmes could be aimed at Flag states to illustrate that their competitiveness need not suffer from a more environmentally friendly approach, and might therefore be in their own long-term marketing interests.

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Chapter 2

Globalisation's Direct and Indirect Effects on the Environment

by
Carol McAusland[1]

This chapter explores research into the relationship between globalisation and the environment, looking at patterns and rates of growth in international trade and foreign direct investment. It provides a summary of knowledge of globalisation's indirect effects, focusing largely on current estimates of the size of the scale, composition and technique effects of globalisation. The chapter concludes with a brief discussion of the various direct effects of globalisation, notably transport-related emissions and biological invasions, and attempts to put these into the broader context of overall effects. The chapter concludes that, although recent evidence concerning trade and local pollution is encouraging, the evidence concerning carbon and other greenhouse gas emissions is less so. One explanation for the pessimistic assessments of trade's impact on greenhouse gas emissions is their global nature. Not only are the costs of CO_2 *emissions shared with citizens abroad (who have no political voice outside their own country), but many greenhouse emissions are associated with fossil fuel use, for which few economically viable substitutes have emerged to date. The income and technique effects that are largely responsible for reductions in local air pollutants do not seem to have the same force when the pollutant in question burdens the global population.*

2.1. Introduction

For over a quarter century, researchers have recognised the potential for increasing trade to negatively impact the environment. Highly publicised events, such as the fate of the Khian Sea,[2] the leak of an internal World Bank memo signed by Chief Economist Lawrence Summers (in which Summers appeared to urge World Bank economists to *encourage* pollution-intensive industry migrate to developing countries[3]) and riots at the 1999 World Trade Organization meetings in Seattle brought the question of whether the surge in international trade is good or bad for the environment onto the world stage.

Research into the net effect of globalisation on the environment has matured, although there remain many outstanding questions. Moreover, there has been little or no effort at linking up the two broad schools of thought on the direct and indirect effects of globalisation on our natural environment. The *direct effects* include emissions and environmental damage associated with the physical movement of goods between exporters and importers. This includes emissions from fossil fuel use, oil spills and introductions of exotic species. At the same time, growth in trade and foreign direct investment (FDI) has numerous *indirect effects*. These indirect effects are often classified in *scale*, *composition* and *technique effects*.

2.2. Growth of trade and FDI

Trade has grown substantially over the past 50 years, in both value and volume. Between 1951 and 2004, the average annual growth rate of world trade by tonnage was 5.7%. When measured by present value, the average growth rate was 7.4% (Hummels, 2007).[4] Projections are for continued strong growth in the longer term. Using a gravity model of trade, based on measures of economic, geographical, political and cultural variables over the 1948 to 1999 period, the Hamburg Institute of International Economics (HWWI) forecasted trade value among industrialised countries to grow at 5.7% per annum until 2030, while trade within South Asia, East Asia and Pacific, and Latin America was projected to grow at 10.9%, 12.6%, and 8.5% per annum respectively (Berenburg Bank and HWWI, 2006).

FDI has also been growing at a rapid pace. Between 1986 and 2000, 65 countries saw inward FDI grow by 30% or more. The growth rates in 29 other countries ranged between 20 and 29% (UNCTAD, 2003). FDI has increased most quickly for industrialised countries. During the 1998-2000 period, just three regions accounted for over 75% of global inward FDI and 85% of global outward FDI: the European Union, the United States and Japan. Developed countries account for more than 75% of global inward FDI (UNCTAD, 2003).

A number of factors explain the growth of trade and FDI. Bilateral and multilateral negotiations have reduced average tariff rates on manufactured goods to 1.8% in high-income countries, 5.5% in middle-income countries and 14.2% in low-income countries[5] (World Bank, 2007). At the same time, technological improvements have lowered shipping and communication costs.

2.3. Early research

The earliest empirical research on how globalisation impacts the environment tended to ask the reverse question: how does environmental regulation impact trade? The prevailing wisdom was that, if trade impacts the environment, it must be the case that environmental regulation affects trade flows. Only then would the argument that trade worsens the environment by shifting pollution-intensive production to low-regulation (and often low-income) countries make sense. This proposition – that globalisation facilitates the relocation of dirty industry to poor countries – is known as the Pollution Haven Hypothesis (PHH). The earliest empirical work found little evidence in support of a PHH. In fact, by the time of Levinson's 1997 survey, the general consensus was that, while the PHH was theoretically persuasive, the data just did not support it.

Nevertheless, subsequent empirical research has found evidence of a weaker relationship between regulatory stringency and trade patterns and volumes, known as the Pollution Haven Effect (PHE). The PHE is the hypothesis that stringent environmental regulation has an impact on comparative advantage *at the margin*, but that it does not necessarily lead to a wholesale migration of industry to regions with weaker regulation. This research has focused on providing econometric solutions to problems plaguing the early studies, most notably the endogeneity of regulation, trade flows and investment in the first place. For example, Levinson and Taylor (2008) examined the relationship between industry spending on abatement and pollution control on the one hand and import penetration (measured as the sum of imports and exports as a ratio to total domestic output) on the other side, in the United States. Amongst other things, they found that industries whose abatement costs increased the most experienced the largest increases in net imports. They also found that for the 20 industries facing the largest relative pollution control costs, more than half of the increase in trade volume can be attributed to changes in domestic regulation. Similarly, Ederington *et al.* (2005) found that import penetration is higher for industries with high pollution abatement and control expenditures relative to total costs. This correlation is stronger for industries protected by import tariffs. They also found that the pro-import effect of tariff reductions is stronger for clean industries than for dirty ones. They concluded that "if anything, trade liberalisation has shifted US industrial composition toward dirtier industries, by increasing imports of polluting goods by less than clean goods", a result at odds with the popular sentiment that trade liberalisation has shifted dirty industry out of the United States and into its less-developed trading partners, but consistent with the proposition that the United States has a comparative advantage in dirty goods (to be discussed further below).

2.4. Indirect effects

In their review of the literature on the PHH and PHE, Copeland and Taylor (2004) credited some of the recent success in uncovering impacts of globalisation on the environment to the pairing of theory and empirics. In the early 1990s, researchers identified that globalisation is likely to impact the environment through three principle channels – *composition*, *scale* and *technique* effects:

- The composition effect measures changes in emissions arising from the change in a country's industrial composition following trade liberalisation.[6] If, for example, liberalisation induces an economy's service sector to expand and its heavy industry to contract, the country's total emissions will likely fall, since the expanding sector is less emission intensive.

- Under the scale effect, more efficient allocation of resources within countries shifts the global production possibilities frontier, raising the size of the industrial pollution base and resulting in greater global emissions.
- The technique effect refers to the plethora of channels through which trade liberalisation impacts the rate at which industry and households pollute. These channels include changes in the stringency of environmental regulation in response to income growth or the political climate surrounding regulation. The technique effect also includes technology transfer facilitated by trade.

2.5. Composition effect

Trade liberalisation changes relative prices: eliminating tariffs and non-tariff barriers lowers the relative price of import-competing goods. Suppose this leads to an increase in the output of Sector E (for Expanding) and a reduction in the output of Sector C (for Contracting). Changes result from, say, capital and labour moving from the contracting sector to the expanding sector in response to a change in relative goods prices. This resource reallocation will lower a country's total emissions if the expanding sector is less pollution-intensive than the contracting sector. Specifically, holding the scale of economic activity and production techniques constant, the composition effect can be summarised as the following change in the country's total emissions Z: $\Delta Z = e_E \Delta Q_E + e_C \Delta Q_C$ where Δ indicates changes, e_i indicates emission intensity in Sectors i and Q_i is output. If, for example, prices were equal across sectors, then an income- and scale-preserving reallocation of resources across sectors would require $\Delta Q_E = -\Delta Q_C$, such that the change in emissions can be written as $\Delta Z = [e_E - e_C]\Delta Q_E$. That is, trade will lower national emissions if and only if the expanding sector is relatively less pollution intensive.

This begs the question of which sectors will expand as a result of liberalising trade. The Heckscher-Ohlin theory of trade suggests that the industries most likely to face competition from imports (and so to contract following tariff liberalisation) are those that depend relatively heavily on the country's scarce factor. A case in point: textiles and clothing are amongst the most heavily protected sectors in the United States, a country whose endowment of unskilled labour is small relative to its capital and land endowments (when compared to international averages). Moreover, for some pollutants at least, there is a strong correlation between an industry's emissions and its capital intensity. Using OECD's *Environmental Data Compendium* (1999), Cole and Elliot (2003) calculated: a 0.42 correlation between SO_2 intensity and capital intensity; the correlation for NO_x was 0.44; both correlations were statistically significant.[7] Similarly, Cole and Elliot (2005) calculated a correlation between pollution abatement and operating costs (per dollar of value added) and physical capital per worker of 0.69 and 0.53 at the 2- and 3-digit SIC code levels respectively.

Because of the often strong correlation between emission intensity and capital intensity, Antweiler *et al.* (2001) postulated a Factor Endowments Hypothesis (FEH). This predicts that trade liberalisation will lead to an increase in emissions in capital-abundant countries, and a reduction in capital-scarce countries. They tested this hypothesis, as well as several other hypotheses maintained in the literature, using panel data on city-level ambient SO_2 concentrations, and found evidence that concentrations of SO_2 were increasing in a country's capital-to-labour ratio. They calculated the composition elasticity, and found that, for most specifications, "a 1-per cent increase in a nation's capital-to-labour ratio – holding scale, income and other determinants constant – leads to perhaps a 1-per cent point increase in pollution". Cole and Elliot (2003) replicated Antweiler *et al.*'s (2001) study for SO_2 and extended the analysis to consider CO_2, NO_x, and biological oxygen demand (BOD) as well; their estimated composition elasticities are 2.3 and 0.45 for SO_2 and CO_2, and statistically indistinguishable from zero for NO_x and BOD. Using Chinese data, Shen (2007) calculated composition effects for SO_2, dust fall, chemical oxygen demand (COD), arsenic and cadmium, in each case finding that higher capital/labour abundance corresponds to more pollution (with elasticities of 3.025, 1.079, 0.788, 1.325 and 2.416 respectively).

Another source of comparative advantage is regulatory stringency itself. The preponderance of microlevel studies of the relationship between income and willingness-to-pay (WTP) for environmental amenities suggests that *demand* for environmental quality increases with income. This is consistent with the logic that environmental amenities are "normal" goods: as we get richer, we want more of them. To the extent that demand for environmental amenities influences environmental regulation, high-income countries are likely to set stricter environmental regulation than do low-income countries, giving rich countries a comparative advantage in relatively clean industries. Accordingly, trade liberalisation that drives each country's industry to restructure along the lines of its comparative advantage should lead clean industries (*e.g.* services) to expand in rich countries. Similarly, dirty industries will expand in poor countries. This can generate a Pollution Haven Effect as discussed above, whereby strict regulation gives countries a comparative disadvantage in dirty goods. There is evidence that income and regulatory stringency are highly correlated. Thus one interpretation of the PHE is that poor countries have a comparative advantage in dirty goods, other things (specifically capital abundance) being equal.

Because there is a strong correlation between per capita income and capital abundance per capita (Welsch [2002] calculated a raw correlation of 0.95), in theory we expect the PHE and FEH to offset each other in empirical tests that only control for either national income or factor abundance, but not both. Recognising this, Antweiler *et al.* (2001) and Cole and Elliot (2003) each constructed indices of comparative advantage, where the comparative advantage index is the sum of quadratic functions of per capita gross domestic product (GDP) and capital-labour ratios, each measured relative to a global average. They then interacted these comparative advantage indices with measures of openness, to calculate trade-induced composition elasticities. In the Antweiler *et al.* (2001) sample, the statistically average country had a comparative advantage in clean goods, with a corresponding trade-induced composition elasticity between –0.4 and –0.9. Stated alternately, for the mean city in their sample, Antweiler *et al.* (2001) calculated that a 1% increase in openness reduced SO_2 concentrations by between 0.4 and 0.9%, holding income and scale constant.

Santos-Pinto (2002) similarly estimated a trade-induced composition elasticity, focusing exclusively on CO_2 emissions (as imputed using United Nations data on fossil fuel use). For the average country in his sample, Santos-Pinto (2002) estimated that a 1% increase in the trade ratio (exports plus imports, divided by gross national product, GNP) leads to a 0.1% reduction in CO_2 emissions, holding income and scale constant. Santos-Pinto points out that this trade-induced composition effect, although favourable to the environment for the average country in his sample, is only about one-fifth as large as the (negative) scale and pure composition effects. In contrast, in the Cole and Elliot (2003) sample, the median observation had a comparative advantage in dirty goods; specifically, for the statistically median country in their sample, a 1% increase in trade (holding income and scale constant) *raised* SO_2, CO_2 and BOD levels by 0.3%, 0.049% and 0.05% respectively.[8] Shen (2007) used concentration data from China and found mixed effects. Shen's (2007) estimates of the trade-induced composition elasticity were as follows: 1.556, 1.962, –2.148, –0.236 and –3.884 for SO_2, dust fall, COD, arsenic and cadmium respectively, such that, holding income/scale and composition fixed, an increase in trade intensity leads to higher SO_2 and dust concentrations, but lower COD, arsenic and cadmium for the average province in China.

Frankel and Rose (2002, 2005) similarly tested whether the impacts of openness on the environment are stronger when a country has a capital-labour ratio that is above the global average, or per capita income that is below average. They tested the impact of openness on concentrations of NO_2, SO_2 and particulate matter (PM), CO_2 emissions, deforestation, energy depletion and rural clean water access. Their approach was distinct from earlier assessments in that they used instrumental variables to account for the endogeneity of trade volumes and income levels. Because there was little variation in their instrument for trade volumes, they restricted their attention to cross-sectional data. They included an interaction term between relative capital abundance and openness to see whether capital-abundant countries have a comparative advantage in dirty goods, and found the signs are mixed and the large standard errors render the interaction term statistically insignificant.

To test the PHE, Frankel and Rose (2002, 2005) ran separate regressions that included an interaction between income and openness; their results were statistically insignificant except for PM and SO_2, for which they found that income has a deleterious effect on concentrations in more open economies. They concluded "*there is no evidence that poor… or capital-abundant countries use trade to exploit a 'comparative advantage' in pollution*" (Frankel and Rose, 2005). Although their evidence is informative, one should hesitate to conclude it refutes the FEH and PHE. As noted above, income and capital abundance are highly correlated. If only one variable is included in the interaction, the fitted coefficient may well reflect the influence of the excluded variable. Since the FEH and PHE work in opposite directions on pollution levels, a statistically insignificant interaction between capital abundance and openness, for example, may simply reflect two counteracting effects, rather than absence of a factor endowment effect.

The majority of the empirical evidence seems to suggest that there is an economically and statistically significant interaction between measures of trade intensity and relative capital abundance for local air pollutants. Whether this interaction favours or harms the environment varies among countries, depending on whether they are capital rich or poor, relative to the rest of the global economy.

Measures of aggregate capital and labour supplies are crude measures of comparative advantage. Other industry characteristics, such as the importance of transport costs and timeliness, may be equally important. Hummels (2007) argued that transport costs and times are currently a larger barrier to trade than tariffs[9] in industrialised countries. "[F]or the median individual shipment in US imports in 2004, exporters paid USD 9 in transport costs for every USD 1 they paid in tariff duties." Reduced transport times favour industries with time-sensitive products disproportionately, but no empirical investigation seems to have been made into the relative pollution intensity of time-sensitive and -insensitive products. Reduced transport costs will similarly favour industries for which transport costs make up a large portion of delivered costs (Hummels, 2007). Investigating the relationship between import penetration and abatement costs at the industry level in the United States, Ederington *et al.* (2005) found evidence that industries facing substantial transport costs are relatively insensitive to changes in environmental regulation.

Another dimension where empirical evidence into the composition effects of trade is lacking concerns consumers and agriculture. For example, Costello and McAusland (2003) argued that an increase in the volume of trade expands the platform for biological invasions (more goods coming in on more ships translates to more material in which an exotic species can stow away), but that crop-related damages from exotic species may nevertheless decline with trade, if the agricultural sector contracts as a result of trade liberalisation. They pointed to the protection of the US sugar industry as an example of how protectionism can therefore *raise* damages from invasive species. The price of sugar in the US is roughly twice that in international markets. This has led the land area in the US planted with sugar to expand even though land planted for all crops has been contracting. The accidental introduction of Mexican Rice Borer now leads to damages of between USD 10 million and USD 20 million for the sugar sector in Texas alone, compared to annual revenue from the Texas sugarcane crop of USD 64 million (Costello and McAusland, 2003).

Trade liberalisation also alters prices facing households, inducing consumers to change the mix of goods consumed. To the extent that consumers generate emissions or deplete resources when goods are *consumed*, trade liberalisation should have an impact on the emission intensity of a dollar's worth of goods consumed. For example, many countries subsidise (at least implicitly) fossil fuel consumption. Some countries do this through implicit export taxes on energy, or implicit subsidies to consumption. Venezuela is an extreme example, where the 2006 price per litre of premium gasoline was only USD 0.05.[10]

2.6. Global net composition effect

The discussion above focused on the impact of trade liberalisation on industrial composition at a national level. Holding the scale and techniques of production constant, trade liberalisation will lead to a reduction in national emissions if the contracting sector is more pollution intensive than the expanding sector, *i.e.* if $e_E < e_C$. A similar analysis holds for changes in global emissions. Suppose reductions in output of Sector C in one country are exactly matched by increased output in that sector abroad. Then whether a scale- and income-neutral trade liberalisation raises or lowers global emissions depends on the relative emission intensity in each trading partner. Specifically, using asterisks to indicate changes in the rest of the world, the change in global emissions, Z^G, will be $\Delta Z^G=[e_E - e_C - (e_E^* - e_C^*) + 2e_T]\Delta Q_E$, where e_T are emissions per unit traded.[11] Thus, total emissions will rise unless production techniques in the rest of the world are relatively clean by a non-negligible margin. But there is evidence that, for some products at least, countries with a natural comparative advantage in production of agricultural goods, for example, use less energy-intensive production techniques.

A case in point is the distinction between food miles and carbon footprints. Since the 1990s, it has been increasingly common for retailers in the UK and Europe to label food products indicating the number of miles a food item was transported. The presumption has been that food shipped smaller distances is less pollution intensive. However, Saunders, Barber and Taylor (2006) showed that importing dairy and meat into the UK from New Zealand would lead to *fewer*, not more, carbon releases than producing the same goods locally, even accounting for emissions associated with transport. For example, Saunders *et al.* (2006) calculated that raising (and transporting to the UK) one tonne carcass of lamb in New Zealand resulted in 688 kilograms of CO_2 emissions, while producing that same amount of lamb in the UK and forgoing transport would result in 2 849 kilograms of CO_2 emissions.[12] Similar carbon savings are associated with importing dairy and out-of-season apples into the UK: 1422.5 *vs.* 2902.7 per tonne of milk solids, and 185 *vs.* 271.8 per tonne of apples (Saunders *et al.*, 2006). In some cases the differences in emission intensity stem from something as simple as differences in energy sources. Based on estimates of total primary energy supply, IEA (2007) estimated that carbon emissions per million tons of oil equivalent (MTOE) vary by as much as 100 times across countries: CO_2 emissions per MTOE are 0.13 and 0.15 for Democratic Republic of Congo and Mozambique, compared to 3.46 and 3.75 for North Korea and Mongolia.[13]

2.7. The technique effect

How much a country emits per unit of a particular good produced or consumed depends on the techniques of production or consumption. To the extent that globalisation changes these techniques, either through policy channels or technological changes, globalisation impacts the environment itself. Most attention to technique effects has focused on changes in environmental policy associated with income gains from trade. Accordingly, much of the discussion below addresses empirical estimates of income effects. However, subsequent sections also discuss evidence concerning additional channels through which globalisation impacts techniques, such as changes in the political environment shaping regulation, regulators' ability to assess abatement potential and producers' ability to abate in the first place.

Technique effect – Income

The most widely studied channel through which liberalisation affects emission intensities is the income growth associated with trade liberalisation. Estimates indicate that the impacts of trade on income may be substantial. Using cross-country data on per capita incomes, instrumented measures of trade shares (specifically, the value of a country's imports plus exports, divided by the value of its national output) and other control variables, Frankel and Romer (1999) concluded that "a one percentage point increase in the trade share raises income per person by 2.0 per cent".[14, 15] Frankel and Rose (2002, 2005) similarly estimated per capita income as a function of (instrumented) trade shares, population (levels and growth rates), per capita income (measured at a 20-year lag), investment per capita and school enrolment rates. They did not, however, test for interactions between trade and any measures of factor abundance. Frankel and Rose (2002) found that a one percentage point increase in the ratio of trade to GDP led to a 1.6% increase in income.[16]

Any trade-generated income growth is important for the environment, as there is general consensus from microlevel studies that *raising incomes fuels demand for environmental amenities*. In fact, even though a handful of studies find a negative relationship between income and environmental demand, the debate instead is whether demand for environmental amenities rises more or less than proportionately with income;[17] this is equivalent to asking whether the income elasticity of the demand for environmental quality is above or below unity. Examining parkland and forestation, Antle and Heidebrink (1995) found "the income elasticity of demand for environmental services… [for high-income countries is] positive and generally greater than one". Shafik (1994) found an income elasticity of demand greater than one for a variety of environmental amenities, including access to clean water and sanitation, as well as ambient air quality. Boercherding and Deacon (1972), and Bergstrom and Goodman (1973) found evidence that WTP for environmental improvements increased more than proportionately with income. However, McFadden and Leonard (1992), and Kriström and Riera (1996) found

WTP as a fraction of income declined with income (suggesting an income elasticity of WTP of less than unity).

There is a separate body of evidence using macrolevel data and environmental outcomes that posits an inverted U-shape relationship between pollution concentrations (on the vertical axis) and per capita income (on the horizontal axis); this inverted-U is known as an Environmental Kuznets Curve (EKC). In one of the earliest papers on the subject, Grossman and Krueger (1995) used GEMS data to estimate the cubic relationship between economic growth (as proxied by per capita income) and concentrations of urban air pollutants and other contaminants. They found that the negative relationship between growth and pollution reversed itself at turning points. For example, for SO_2, smoke, BOD, arsenic and mercury, concentrations fall with income when per capita income exceeded USD 4 053, USD 6 151, USD 7 263, USD 4 900 and USD 5 247 respectively. However, subsequent authors raised several concerns with the EKC estimation exercise. Holtz-Eakin and Selden (1995) found that, even though the marginal propensity to emit ultimately declines with income, rapid growth in developing countries dominates, such that global CO_2 emissions were projected to rise at roughly 1.8% per year for the foreseeable future.

Theoretically, an EKC can be explained using Engel curves or changes in the types of factor accumulation (see Copeland and Taylor, 2003). However, a decomposition of emissions into emission intensities and input (*e.g.* energy) use suggest that regulation likely plays an important role. Hilton and Levinson (1998) examined the relationship between automotive lead emissions and income, for which they found an EKC. However, they decomposed lead emissions into emissions intensity and energy use. Because energy use is consistently increasing in per capita income, any emission reductions must come through declining emission intensity, for which regulation is necessary. They also pointed out that emissions intensity was declining, even holding income constant, for countries on the upward sloping portion of the EKC. They took this as evidence that, during their study period, there were technological changes that cannot be explained by income.

Others have raised issue with the econometrics underlying research finding evidence of an EKC. Harbaugh *et al.* (2002) showed that the evidence for an inverted U in the GEMS data

> "is much less robust than previously thought. … [T]he locations of the turning points, as well as their very existence, are sensitive both to slight variations in the data and to reasonable permutations of the econometric specification. Merely cleaning up the data, or including newly available observations, makes the inverse-U shape disappear".

Another problem with interpreting results from the EKC literature as measuring a causal relationship between income growth and environmental quality is that most of these analyses do not investigate the underlying causes of income growth. Frankel and Rose (2002, 2005) provided an exception. Using instrumental variables to account for the endogeneity of income and trade intensity, Frankel and Rose tested the relationship between predicted per capita income and pollution concentrations. Their estimates confirmed an inverted U-shape relationship between instrumented per capita income and concentrations of air pollutants. Based on the point estimates from one of their estimations, PM peaks at an income level of USD 3 217 per capita, SO_2 at USD 5 710 per capita and NO_2 at USD 8 134 per capita.[18] For CO_2, however, Frankel and Rose found no evidence of a turning point.[19, 20]

Frankel (2009a) updated the Frankel Rose (2002, 2005) study, to include data more recent than 1990. The results were not quite as strong as before, especially for particulate matter.[21] The results for CO_2 are interesting. An Environmental Kuznets Curve appeared this time, suggesting that emissions may eventually turn down at high levels of income[22] after all, perhaps as a result of efforts among some high-income countries since the 1997 Kyoto Protocol established a modicum of multilateral governance. Trade, however, continues to show up as exacerbating CO_2 emissions.

In light of the micro- and (controversial) macrolevel evidence that incomes and environmental quality are positively correlated, it seems logical then that income gains from trade will translate into increased demand for environmental quality. One channel through which consumers express this demand is calls for tighter environmental regulation. Using panel data on SO_2 concentrations in 108 cities from 43 countries, Antweiler, Copeland and Taylor (2001) obtained point estimates of the technique elasticity between –1.577 and –0.905. Accordingly, they argued that if trade raises incomes by 1%, the technique effect will lead to a reduction of SO_2 concentrations of approximately 0.9% to 1.6%. Looking at the relationship between trade restrictions, income growth and COD in China, Dean (2002) similarly found evidence of a technique effect. A "1 per cent reduction in the level of trade restrictiveness produces an increase of 0.09 per cent in the growth rate of income… (which) causes a decline in the growth rate of emissions by… –0.03 per cent".

Needless to say, growth in trade is not the only channel through which globalisation may raise incomes. FDI has also increased substantially over the past quarter century. FDI now accounts for "over 60 per cent of private capital flows" (Carkovic and Levine, 2005) and is four times as large as commercial lending was to developing countries in the 1970s. Although inward FDI should have many of the same composition, income and scale effects as trade, researchers have instead focused on the reverse question: do strict environmental regulations attract or repel inward FDI? As with early research on the Pollution Haven Effect, the evidence is mixed. Some of the earliest complaints about FDI (in an environmental context at least) have concerned the Pollution Haven Hypothesis: the supposition that freeing up trade and investment rules will lead multinational corporations (MNCs) to relocate their production activities to low-income and inadequately regulated developing countries. There has, however, been little evidence that such capital flight has occurred. Explanations include the substantial disparity between pollution abatement and control costs relative to capital and labour costs. For example, in the United States, the ratio of pollution abatement and operating costs (PAOC) to value added is 9.9% in the US petroleum and coal products sector, but no more than 3.5% in any other sector (primary metal industries: 3.5%; paper and allied products: 2.7%; chemicals and allied products: 2.4%; tobacco products: 2.3%) (see Cole and Elliot, 2005). At a country level, Jaffe *et al.* (1995) calculated pollution abatement and control expenditures (PACE) as a percentage of GDP in the 1980s, finding highs of 1.6% in West Germany and 1.5% in the US,[23] the Netherlands and the United Kingdom. Instead, the lion's share of payments goes to labour and capital. In the US, labour's share of national income is consistently about two-thirds (Pakko, 2004).

Subsequent research asked whether differences across countries, provinces or states might influence the pattern of inward or outward FDI. See, for example, Becker and Henderson (2000),[24] List and Co (2000),[25] Keller and Levinson (2002),[26] and Fredriksson, List and Millimet (2003).[27] Brunnermeier and Levinson (2004) provided a review of this literature. By and large these studies took environmental outcomes as a given and asked how variation in regulations impact investment flows. In this chapter, the interest is in the flip side of this question: how does FDI affect environmental outcomes? This question seems not to have been answered empirically.[28] However, it is reasonable to expect that lowering barriers to international investment may raise GDP in recipient countries, largely through the technology transfer imbedded in FDI. Borensztein, De Gregorio and Lee (1998) examined the impact of inward FDI on per capita income in developing countries, concluding that, for the statically average country in their sample, "an increase of 0.005 in the FDI-to-GDP ratio (equivalent to one standard deviation) raises the growth rate of the host economy by 0.3 percentage point per year".

Should this causal relationship bear scrutiny, one would expect the income boost associated with inward FDI to have beneficial impacts on the environment akin to trade. In the same vein, some FDI advocates suggest that outward FDI may also raise incomes in the source country (for example, by increasing demand for white collar employment at a multinational's home office), with potential impacts on the environment via the income effect, but empirical evidence is lacking. Similarly, the environmental scale and composition effects of inward and outward FDI seem to have gone without scrutiny.

Technique effect – Environmental politics

Much of the research on income effects assumes that households are effective at translating their preferences to policy. The usual presumption is that regulators and politicians are sensitive to the tastes of their constituents, and so will tighten environmental regulations in response to increased demand for such. In practice, of course, voters are only one input in the political process; industry and factor owners may be similarly interested in influencing policy in their favour. Moreover, trade liberalisation can *alter* the political economy surrounding regulation. McAusland (2003) showed that opening a country to trade changes the incidence associated with regulating industrial emissions: in a closed economy, the burden of regulation is shared by dirty good producers and consumers through price changes. However, in an open economy, consumers are insulated from the price effects of local industrial regulation since they are able to buy substitutes from unregulated competitors. McAusland (2003) argued that, even if trade liberalisation leaves the price of dirty goods unaffected (so composition, income and scale effects are absent), this incidence-shifting will lead to stronger industry opposition to regulation and weaker environmental policy if industry has undue influence over regulators. Conversely, if the regulation in question concerns *consumer-generated pollution*, openness shifts incidence in the opposite direction: producers will be the ones whose payoffs are insulated in the open economy, *reducing* industry opposition to environmentally motivated product standards (McAusland 2008). Gulati and Roy (2007) similarly argued that trade liberalisation can lead an import-competing industry to prefer stricter environmental regulations when exposed to international competition. They showed that this "greening" of domestic industry can occur whenever domestic firms have a cost advantage in complying with regulation, such that strict product standards have a "raising rival's cost" effect. McAusland (2004) similarly argued industry may want strict local product standards governing the intermediate products they use (even if these standards are not legally binding on overseas competitors) if there is a "California effect" via international input markets.

Aside from changes in regulatory incidence, trade liberalisation also changes the stakes associated with lobbying. Fredriksson (1999) argued that an increase in the price of dirty goods (as per trade liberalisation in a country with a comparative advantage in pollution-intensive industrial goods) raises the stakes for industry and environmental lobbyists alike, with ambiguous effects on environmental regulation.

Another concern surrounding trade liberalisation is that it will facilitate inter-jurisdictional competition. If footloose firms can serve their markets from any number of locations, this may give governments an incentive to bid down their environmental regulation so as to attract industry. Oates and Schwab (1998) argued that governments may set inefficiently weak environmental regulation so as to attract capital that complements local fixed factors. Markusen *et al.* (1995) argued that governments attempting to attract lumpy investment might similarly bid down environmental regulations. Levinson (2003) provided some evidence that governments do indeed "compete" in environmental regulation. Using the 1992 US Supreme Court decision prohibiting discriminatory taxation as a turning point, Levinson (2003) found that the slope of state government's reaction functions (mapping local regulation to that of geographic neighbours) is statistically insignificant before the 1992 decision, but statistically significant and positive in the post-1992 era.

Technique effect – Technology transfer

There are several channels through which globalisation may facilitate technology transfer between countries. Trade is one obvious channel: engineering firms that develop clean technologies engage in the direct sale (and support) of their technologies to firms overseas. Alternately, technology may be embodied in traded capital equipment; additionally, these products may be reverse engineered, allowing competitors in the importing country to incorporate the new technology into domestically produced capital goods.

Another channel is through subsidiaries of multinationals. There is substantive evidence that the technology embodied in inward FDI is greener than local technology. Eskeland and Harrison (2003) looked at plant-level energy use in Mexico, Venezuela and Côte d'Ivoire. Using the ratio of energy inputs to output (both measured in value), they concluded that:

> "[F]oreign ownership is associated with lower levels of energy use in all three countries. To the extent that energy use is a good proxy for air pollution emissions, this suggests that foreign-owned plants have lower levels of emissions than comparable domestically owned plants. The results are robust to the inclusion of plant age, number of employees, and capital intensity – suggesting that foreign plants are more fuel efficient even if we control for the fact that foreign plants tend to be younger, larger, and more capital-intensive", Eskeland and Harrison (2003).

Blackman and Wu (1998) similarly pointed to embodied technology as an explanation for the high fuel efficiency of foreign-owned energy-generation plants in China (relative to domestically owned), noting that 52% of the generating capital used in the foreign-owned generating plants in their sample was foreign produced, while in domestic plants, only 24% of equipment was foreign produced. Observations that inward FDI tends to be more energy efficient than domestic enterprises is consistent with a 1990 survey of 169 MNCs; most of these firms indicated their overseas health, safety and environmental practices reflect regulations in their home country (Brunnermeier and Levinson [2004], UNCTAD [1993]).

If inward FDI displaces local producers, this embodied technological transfer can reduce domestic emissions. Alternately, even if inward FDI does not displace local production, there may be spillovers to local producers. Research on the strength of technology spillovers usually focuses on wages and output. Most early research on this topic found positive spillovers; see, for example, Caves (1974), Globerman (1979), Blomström and Persson (1983), and Blomström (1986). However, subsequent work using plant-level data (and which controlled for the endogeneity of the siting and sectoral allocation of inward FDI) found evidence of negative spillovers. For example, Aitken and Harrison (1999) looked at productivity spillovers in Venezuela and found a negative impact of inward FDI on domestic productivity. They calculated that an increase in a sector's foreign ownership from 0% to 10% can lower overall productivity in that sector by as much as 3%. Görg and Strobl (2001) provided a survey of the FDI spillover literature.

Even if the technology accompanying inward FDI is not shared with domestic firms, there may still be a spillover via yardstick competition: regulators set standards for one region or firm based on what its neighbours are doing. Fredriksson and Millimet (2002) examined the relationship between the stringency of a US state's environmental regulations and that of its neighbours. They found that, in the Northeast US, "a 10% increase in [income-weighted] neighboring relative abatement costs increases own state environmental stringency by over 30%". Moreover, the pull is asymmetric: while stricter standards next door pull up local standards, Fredriksson and Millimet (2002) found that relatively weak standards in a neighbouring state have no statistically significant impact on local regulation. Although there is evidence that regulators use yardstick competition at the firm level, Bhaskar *et al.* (2001) found evidence that local governments use yardstick competition between firms to restrict rents accruing to public sector managers in Bangladesh. Estache *et al.* (2002) found evidence that yardstick competition in regulation of port infrastructure operators in Mexico would enhance efficiency. Yardstick competition at the firm level does not seem to have been studied in an environmental context.

Technique effect – Trade-induced innovation

Globalisation may also affect the environment through globalisation-induced technological change. An example is containerisation, which reduces the amount of time ships must spend in port loading and unloading, raising the rate-of-return on capital investments, leading to investment in larger, faster ships (Hummels, 2007). One of the by-products of containerisation has been the emergence of a hub-and-spoke system, which has two potential impacts on the environment. First, the hub-and-spoke system may increase the effective distance between a given exporter-importer pair, potentially increasing the amount of transport-related emissions associated with USD 1 worth of trade. The hub-and-spoke system also creates stepping stones for biological invasions: if exports from region A to region B are routed through a hub in region C, the pool of species region B is exposed to is the set of all species in region A *and in every other region whose exported goods travel through the hub in region C*. Simulating a network-flows model, Drake and Lodge (2004) found that seven key ports serve as bottlenecks for pathways for marine invasions: Chiba (Japan), Durban (South Africa), Las Palmas de Gran Cana (Spain), Long Beach (US), Piraeus (Greece), Singapore (Singapore) and Tubarao (Brazil). Nevertheless, they concluded that changes in technology that reduce the per-ship propogule pressure would be a more effective means of reducing marine invasions worldwide than rerouting shipping traffic away from these seven hotspots. Fernandez (2007) collected data on marine transport and biological invasions at ports along the pacific coast of Mexico, the United States and Canada and argued that co-operative prevention strategies dominate reactive strategies for all parties.

2.8. Scale effect

Although they are quite different in theory, in many empirical applications the scale and technique effects are difficult to separate. Using GDP per km^2 as a proxy for scale, Antweiler *et al.* (2001) estimated a scale elasticity of between 0.112 and 0.398 for SO_2: holding income and capital per capita constant, a 1% increase in the density of economic activity corresponds to an increase in SO_2 emissions of between 0.1% and 0.4%. Because they use country-level data, Cole and Elliot (2003) were unable to measure scale and technique effects independently of one another. Using per capita national income as the independent variable, Cole and Elliot (2003) found that, for a statistically median country in their sample, a 1% increase in national output or income through trade lowers SO_2 and BOD by 1.7% and 0.06%, respectively. In short, for SO_2 and BOD, the technique effect appears to dominate. However their results suggest that for NO_x and CO_2, the scale effect dominates: a 1% increase in national output or income corresponds to 1% and 0.46% increases in NO_x and CO_2 through the combined scale and technique effects. (In comparison, Antweiler *et al.*'s combined scale and technique elasticity was approximately 1.0.) Using Chinese data, Shen (2007) calculated net scale and technique elasticities, finding a negative net environmental effect of income or scale for SO_2 and dust fall, while for COD, arsenic and cadmium, the net effect was beneficial to the environment (with elasticities of 4.0, 2.4, –0.982, –1.659 and –3.039 respectively).

2.9. Globalisation and the environment – Direct effects

The scale, composition and technique effects considered above are best described as the *indirect* effects of globalisation. They all stem from changes in relative prices that result from integration with the global economy. Surprisingly, much of the economics literature has ignored the *direct* effects of increased trade, specifically increases in emissions and other externalities from the transport sector responsible for moving goods and embodied services (personnel and tourists) between countries. The following section provides a very brief overview of environmental damages and other spillovers from the transport sector. These impacts are discussed in further detail in subsequent chapters.

Surface transport

Just under one quarter of global trade (measured by *value*) is between countries sharing a land border, although this average largely reflects the trade patterns within North America and Europe, where between-neighbour trade accounts for between 25% and 35% of trade. In Africa, Asia and the Middle East, in contrast, between-neighbour trade accounts for between 1% and 5% of trade. For Latin America, between 10 and 20% of trade is between land neighbours (Hummels, 2007). Data concerning the mode of neighbour trade is not available at the global level, however, Hummels (2007) reported that "US and Latin American data suggest that trade with land neighbours is dominated by surface modes like truck, rail, and pipeline, with perhaps 10 per cent of trade going via air or ocean". Fernandez (2008) calculated that 90% of US-Mexico trade and 66% of US-Canada trade is by truck.

Environmental damages arising from land transport vary considerably depending on, amongst other things, the density of the area through which traded goods are routed.[29] Forkenbrock (2001) estimated the costs associated with one ton-mile of rail transport in rural counties (based on volatile organic compound [VOC], NO_x and PM_{10} emission intensity estimates): heavy unit train: 0.009; mixed freight train: 0.011; intermodal train: 0.020; and double-stack train: 0.013 (all numbers are 1994 USD 0.001 per ton-mile). Forkenbrock (2001) compared these with estimates of the damages from transport via truck: USD 0.0023 per ton-mile. Notably, these are estimates of average damage from transport within the United States.[30] For comparison, Parry and Small (2002, 2005) concluded that environmental damage per passenger-vehicle mile within urban areas is approximately USD 0.02 per mile. For Europe, Bickel *et al.* (2005) calculated the marginal damage from transport, paying particular attention to how it can vary across mode, energy source and location. They found that damages from air pollution associated with inter-urban transport via heavy goods vehicles

(HGV) ranges from EUR 0.0209 to EUR 0.0746 per vehicle-km, while the damages from global warming (associated with exhaust greenhouse gas emissions) for HGV ranges from EUR 0.0203 to EUR 0.0328 per vehicle-km.

As with other modes of transport, the fuel efficiency of surface transport continues to improve. For example, the US Department of Energy reports that average fuel economy improved by 3.2% for light trucks, 9.6% for medium trucks and 3.6% for heavy trucks, over the 1992-2002 period (Davis and Diegel, 2007).

One issue often overlooked in analyses of trade-related transport emissions concerns wait times at borders. Fernandez (2008) reported that wait times are often twice as long for northbound commercial traffic at US-Mexico border crossings as for southbound. In the El Paso-Ciudad Juarez area, as much as 22% of emissions may be attributable to vehicles idling at border crossings (Fernandez 2008).

Shipping-related emissions

For trade between countries that do not share a land border, the vast majority of goods are moved by ocean or air. Ton-miles transported by ship dominate shipments by air by a factor of 100. For example, in 2004, 8 335 billion ton-miles of non-bulk cargoes were transported internationally by ocean vessel, compared to only 79.2 billion ton-miles by air. However, growth rates are higher for air: for non-bulk cargoes, the annual growth rate of ton-miles was 11.7% for air shipments and 4.4% for ocean shipments (Hummels, 2007). Of course, an increase in the volume of trade need not imply an increase in emissions if the emission intensity of a ton-mile falls; this is plausible given that vessels have become more fuel efficient (as well as faster) over the past half century, in large part due to containerisation (Hummels, 2007).

Some projections for the future, though, suggest emissions will rise faster than fuel use. The International Maritime Organization projects fuel use by marine transport will increase by approximately one third over the 2007-20 period, with corresponding increases in marine CO_2, NO_x and PM_{10} by approximately one third, and a 40% increase in SO_x emissions (International Maritime Organization, 2007). Corbett *et al.* (2007) predicted that the number of deaths attributable to shipping-related PM_{10} emissions will rise by 40% by 2012,[31] with most of the deaths occurring in coastal Europe and East and South Asia. The majority of these deaths will be due to cardiopulmonary disease and lung cancer.

Another negative externality from ocean transport is the risk of oil spills. In the 1970s, total oil spilled averaged at 314 200 tons per year. In the 1980s and 1990s the average annual spill rate was 117 600 tons and 113 800 tons respectively. For the first eight years of the 2000s, the average spill rate was only 21 778 tons. The number of spills larger than 7 tons similarly declined: 25.2, 9.3, 7.8 and 3.4 spills per year for the periods 1970-79, 1980-89, 1990-99, and 2000-08 respectively (ITOPF, no date).

Aviation

The global transport sector accounts for approximately 14% of anthropogenic greenhouse gas emissions. Of this 14%, freight trucks account for 23%, ships 10% and international aviation 7% (Stern, 2007). Although aviation's direct greenhouse gas emissions are the smallest of the group, greenhouse gas emissions from aviation under-represent their actual contribution to climate change. "For example, water vapour emitted at high altitude often triggers the formation of condensation trails, which tend to warm the earth's surface. There is also a highly uncertain global warming effect from cirrus clouds

(clouds of ice crystals) that can be created by aircraft" (Stern, 2007). Although there is no agreed-upon conversion rate, the warming ratio is thought to be between 2 and 4, raising aviation's contribution to global greenhouse emissions from 1.7% to over 3%.

Moreover, the growth rate of air transport is nearly twice that of ocean transport. Over the 1975-2004 period, the annualised growth rate for ocean transport was 3.8%, while for air transport the growth rate was 8.4% (Hummels, 2007). Consistent with the disparity between growth rates of aviation and other modes of transport, Stern (2007) projected that "between 2005 and 2050, emissions are expected to grow fastest from aviation (tripling over the period, compared to a doubling of road transport emissions)".

2.10. Conclusions

As with any body of research, there are always exceptions to the general rule. The general rule concerning the indirect effects of trade on the environment seems to be that increased openness has a benign to beneficial effect on the local environment. Antweiler *et al.* (2001) concluded that, for the statistically average country in their sample, a 1% increase in trade leads to an approximately 1% lower concentration of SO_2. One concern regarding the Antweiler *et al.* (2001) approach is that the potential endogeneity of trade volumes was not accounted for. Frankel and Rose (2002, 2005) used instruments for trade volume and found that openness nevertheless appears to have a beneficial impact (*i.e.* lower concentrations) on SO_2 and NO_2, but no statistically significant impact on PM. Chintrakarn and Millimet (2006) similarly used instrumental variables to control for endogeneity, focusing instead on the relationship between subnational trade and toxic releases. They found that trade-intensity *increases* land releases, but either reduces or has no statistically significant effect on air, water and underground releases. One advantage of the Chintrakarn and Millimet (2006) approach is that the instruments employed control for endogeneity, while the use of data from a single federal jurisdiction entails some comparability of data across units. The drawback is that there is no reason *a priori* to expect that international and subnational trade flows impact the environment similarly. McAusland and Millimet (2008) built a theoretical model arguing that the pro-environment effects of subnational trade should in fact be smaller than those of international trade. They found that increasing the international trade intensity of the statistically average province or state by 10% lowers its total toxic releases by roughly 9%, while changes in subnational trade intensity, *ceteris paribus*, do not have a statistically meaningful effect on total toxic releases.

Although the recent evidence concerning trade and local pollution is encouraging, the evidence concerning carbon and other greenhouse gas emissions is less so. Using a cross-section of 63 countries and instruments for trade intensity and income, Magani (2004) calculated the scale, technique and composition effects of trade and concluded that the combined effect of a 1% increase in trade leads to a 0.58% increase in CO_2 emissions for the average country in her sample. Frankel (2009a) found that CO_2 emissions might start to decrease with income at some (as yet unquantified) point – but also that trade tended to exacerbate CO_2 emissions. In the EKC context, Neumayer (2004), Holtz-Eakin and Selden (1995), and Schmalensee *et al.* (1998) similarly observed a positive relationship between income and carbon emissions.

One of the most likely explanations for the consistently pessimistic assessments of trade's impact on greenhouse gas emissions is their global nature. Not only are the costs of CO_2 emissions shared with citizens abroad (who have no political voice outside their own country), but many greenhouse emissions are associated with fossil fuel use, for which few economically viable substitutes have emerged to date (again, arguably as a result of the international free-rider problem). The income and other technique effects that are largely responsible for reductions in local air pollutants do not seem to have the same force when the pollutant in question burdens the global population – and requires global solutions – rather than just the citizens residing within any one government's jurisdiction.

Seemingly, no studies have looked at how the income gains from trade will impact demand for, and ultimately regulation of, transport-related externalities. On the one hand, it seems hard to imagine that citizens suffering from transport-related damage, such as PM_{10}-related deaths along shipping corridors, will not demand stricter regulation as they become richer. But, as noted above, transport emissions associated with ocean and air travel are global and/or transboundary in nature, and so may suffer the same fate as CO_2 emissions absent global action. Moreover, unlike emissions by point sources (like power plants and factories), international transport-related emissions often involve third parties: many goods are moved via vessels not bound by operational regulations in either the importing or exporting country. This is a particular issue for ocean shipping. Although open registry fleets – ships registered under flags of convenience – accounted for only 5% of ocean trade (by weight) in 1950, by 2000 its share had expanded to 48.5% (Hummels, 2007). Thus, even if voters in high-income countries want stringent environmental regulations attached to the transport of traded goods they consume, shipping emissions may be outside their government's jurisdiction.

Notes

1. This chapter is an edited version of the paper *Globalisation's Direct and Indirect Effects on the Environment*, written by Carol McAusland, University of Maryland, United States, for the OECD/ITF Global Forum on Transport and Environment in a Globalising World, held in Guadalajara, Mexico, 10-12 November 2008, see *www.oecd.org/dataoecd/10/60/41380703.pdf*. The strong deterioration in economic prospects for the short to medium term that has taken place since the paper was drafted has only to a limited extent been incorporated into the present chapter.
2. The Khian Sea was a ship flying a Liberian flag that was hired to take incinerator ash from Philadelphia, United States, to dump at an artificial island in the Bahamas. The local government refused dumping permission and the ship began a 16-month journey which included requests to unload the ash in the Dominican Republic, Honduras, Panama, Bermuda, Guinea Bissau, the Dutch Antilles, Senegal, Morocco, Yugoslavia, Sri Lanka and Singapore, all of which were denied. Some ash was unloaded in the Bahamas under a false label (as topsoil) and the rest was later admitted to have been dumped into the Atlantic and Indian Oceans (Sinha, 2004; Wikipedia)
3. Although Summers took responsibility for the memo, it was originally written by staff economist Lant Pritchett who claimed editing of the memo prior to its leak changed its tenor. See *Harvard Magazine*, May-June 2001 for an interview with Pritchett.
4. Growth rates vary considerably by country. According to World Bank Trade Indicators (*http://info.worldbank.org/etools/tradeindicators/*), in the 2005-06 period, the countries experiencing the fastest real growth in total trade in goods and services were Mauritania (42.3%), Iran (38.0%), Azerbaijan (29.3%), Viet Nam (22.1%) and China (20.9%). The countries with slowest trade growth were New Zealand (–10.4%), Chad (–4. 8%), Benin (–0.2%), Senegal (0.0%), Tunisia (0.2%) and Syrian Arab Republic (0.4%). Trade growth rates for the United States, Canada and Mexico were 6.9%, 2.8% and 11.7% respectively.
5. Rates given are weighted mean tariffs for manufactured products. For countries reporting, the lowest mean tariff rate on manufactures is 0.0% (Singapore), the highest 76.7% (Bangladesh). Other rates are as follows: Canada (1.0%), China (5.3%), the European Union (1.8%), Japan (1.4%), Mexico (3.1%), the United States (1.8%) (World Bank, 2007).

6. As much of the econometric evidence concerning globalisation's environmental effects has concentrated on the growth in international trade in goods (as opposed to services), this discussion will similarly focus on goods trade.
7. For other indicators of resource use, the correlation is weaker. Cole and Elliot (2003) calculated a correlation between biological oxygen demand (BOD) and capital intensity of only 0.12. They speculated this correlation is weak because the major contributor to BOD is agriculture.
8. The trade-elasticity for NO_x is statistically insignificant.
9. This analysis does not include non-tariff barriers to trade, such as quotas and voluntary export restraints (VERs).
10. *http://dotstat.oecd.org/wbos/ViewHTML.aspx?Theme=OLADE&DatasetCode=OLADE*.
11. This formulation assumes all production reallocated to/from the rest of the world is subsequently traded.
12. Of course, producing agricultural goods abroad is not always more carbon efficient. Saunders *et al.* (2006) calculated that the CO_2 footprint of a tonne of onions shipped from New Zealand to the UK is 184.6 kg, while the comparable emissions from UK production were only 170 kg.
13. For comparison, CO_2 emissions per MTOE for other major countries are 1.57 (Brazil), 2.02 (Canada), 2.95 (China), 1.41 (France), 2.36 (Germany), 3.09 (Greece), 3.07 (Israel), 2.21 (Mexico), 2.99 (Morocco), the Russian Federation (2.39), 3.02 (Serbia and Montenegro), 2.27 (UK), and 2.49 (US).
14. A 95% confidence interval for the elasticity of per capita income with respect to trade share is (0.03, 3.9104).
15. They also estimated the channels for this income growth. They decomposed output into contributions from capital and labour stocks, education and productivity. "The estimates imply that a one-percentage point increase in the trade share raises the contributions of both physical capital depth and schooling to output by about one-half of a percentage point, and the contribution of productivity to output by about two percentage points."
16. Gains in per capita income may underestimate the actual consumption benefits from trade. Much of the trade between developed countries is *intra*-industry (*i.e.* a country imports goods in the same product class as it exports), which is often explained by trade in distinct varieties of otherwise similar goods. Some economists believe the variety gains from trade may be as large as the gains in nominal income. Broda and Weinstein (2006) estimated that "US welfare is 2.6 per cent higher due to gains accruing from the import of new varieties". Klenow and Rodriguez-Clare (1997) estimated that ignoring the benefits from increased variety can underestimate the benefits from trade liberalisation anywhere from 33% to 80%.
17. For example, Kahn and Matsusaka (1997) found that high-income voters are less likely to support certain environmental initiatives in California referenda. However, as McAusland (2003) pointed out, many of the initiatives in question were to be funded by bond measures, so the no vote by high-income voters may be explained by Ricardian Equivalence.
18. Based on calculations by Carol McAusland, using point estimates reported in Frankel and Rose (2005, Table 1).
19. Frankel and Rose (2002, 2005) concluded that *for a given level of income*, on average trade has a beneficial impact on the environment. Moreover, because there is evidence that trade raises incomes, trade also has an indirect effect on the environment, which is beneficial for high income levels but negative for low levels.
20. Kellenberg (2008) used a panel of 128 countries to study the relationship between trade intensity and emissions of four local pollutants (SO_2, NO_x, CO, and VOCs). He found that the trade intensity effect is negative and significant for the average country. However, trade intensity effects were not uniform across countries of different income levels. Countries with relative world incomes less than 0.5 or greater than 2.5 tended to have positive trade intensity elasticities, while countries with relative world incomes between 0.5 and 2.5 tended to have negative trade intensity elasticities.
21. While Frankel and Rose (2002, 2005) considered impacts on *concentrations* of pollutants, Frankel (2009a) estimates impacts of trade on *emissions* of the pollutants. And while Frankel and Rose (2002, 2005) covered all sizes of particulate matter, Frankel (2009a) focuses on PM_{10}.
22. According to Frankel (2009b), the author had not yet computed whether the CO_2 turning point that is implied by Frankel (2009a) occurs within a relevant income range.
23. Using EPA data, Jaffe *et al.* (1995) arrived at a higher 2.6% figure for the United States.

24. "Becker and Henderson (2000) examined the effect of air quality regulations on plant births in US counties between 1963-92. They estimated a conditional poisson model and found that at the county level, NAAQS nonattainment status reduced the births of new plants belonging to four heavily polluting industries by 26% to 45% during this period" (Brunnermeier and Levinson, 2004).
25. List and Co (2000) used cross-sectional data to examine the impact of state regulatory spending on inward FDI. They found environmental regulation has a negative and statistically significant impact on planned new foreign-owned manufacturing plants, but that the effects were stronger for *cleaner* industries.
26. Keller and Levinson (2002) used panel data to look at inward FDI into the United States. Based on their calculations, "a doubling of their industry-adjusted index of abatement cost is associated with a less than 10% decrease in foreign direct investment" (Brunnermeier and Levinson, 2004).
27. Fredriksson, List and Millimet (2003) used measures of per capita gross state product (GSP) and the share of legal services in GSP to create an instrument for environmental policy. They found evidence of a U-shaped relationship between regulatory stringency and inward FDI. They pointed out that, for California, a one-standard deviation increase in regulatory stringency "reduces employment by over 2 500 jobs, or about 6% of foreign affiliates' employment in the chemicals sector".
28. Although some authors have used instrumental variables (IV) to control for the endogeneity of pollution abatement policy – see Xing and Kolstad (2002), Ederington and Minier (2003), and Levinson and Taylor (2008) – none have estimated the elasticity of emissions with respect to FDI.
29. See Chapter 8 for further discussion.
30. These estimates are based on damage estimates obtained from Cambridge Systematics Incorporated, who assessed the costs per ton of VOC, NO_x, SO_x and PM_{10} emissions in US rural counties at 385, 213, 263 and 3 943 (1994 USD), respectively.
31. Corbett *et al.* (2007) estimated that current shipping PM_{10} emissions lead to 60 000 deaths per year.

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Chapter 3

International Maritime Shipping: The Impact of Globalisation on Activity Levels

by
James J. Corbett, James Winebrake, Øyvind Endresen, Magnus Eide, Stig Dalsøren, Ivar S. Isaksen and Eirik Sørgård[1]

This chapter explores how the maritime industry has transformed its technologies, national registries and labour resources over the past decades to serve the demands of globalisation. It looks at the global economic role of shipping, describing the marine transport system as a network of specialised vessels, the ports they visit, and transport infrastructure from factories to terminals to distribution centres to markets.

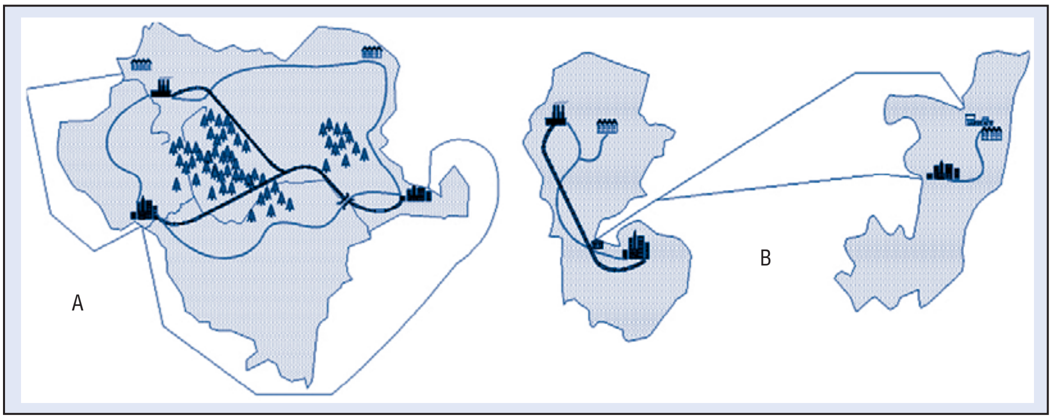
The chapter presents maritime transport as a necessary complement to, and occasionally a substitute for, other modes of freight transport. For many commodities and trade routes, there is no direct substitute for waterborne commerce. On other routes, such as some coastwise or shortsea shipping or within inland river systems, marine transport may provide a substitute for roads and rail, depending upon cost, time and infrastructure constraints. The chapter traces maritime transformations in response to globalisation, from the shift of human labour (oars) to wind-driven sail, and the shift from sail to combustion. Two primary motivators for energy technology innovation – greater performance at lower cost – caused this conversion. It explores current maritime shipping activity to explain why ocean-going ships now have an activity level making them consume about 2% to 3% – and perhaps even as much as 4% – of world fossil fuels. The chapter examines future developments by extrapolating historical growth trends, and looking at scenario-based estimates.

3.1. Introduction

This chapter demonstrates that transport (in general) and shipping (in particular) have been, and remain, key ingredients in fostering globalisation. In fact, the maritime industry has transformed its technologies, national registries and labour resources over the past decades to serve the demands of globalisation.

Global goods movement is a critical element in the global freight transport system that includes ocean and coastal routes, inland waterways, railways, roads and air freight. In some cases, the freight transport network connects locations by multiple modal routes, functioning as modal substitutes (see Figure 3.1A). A primary example is containerised shortsea shipping, where the shipper or logistics provider has some degree of choice on how to move freight between locations. However, international maritime transport is more commonly a complement to other modes of transport (see Figure 3.1B). This is particularly true for intercontinental containerised cargoes and for liquid and dry bulk cargoes, such as oil and grain. Here, international shipping connects roads, railways and inland waterways through ocean and coastal routes.

Figure 3.1. **Ocean shipping as (A) a substitute and (B) a complement to other freight modes**

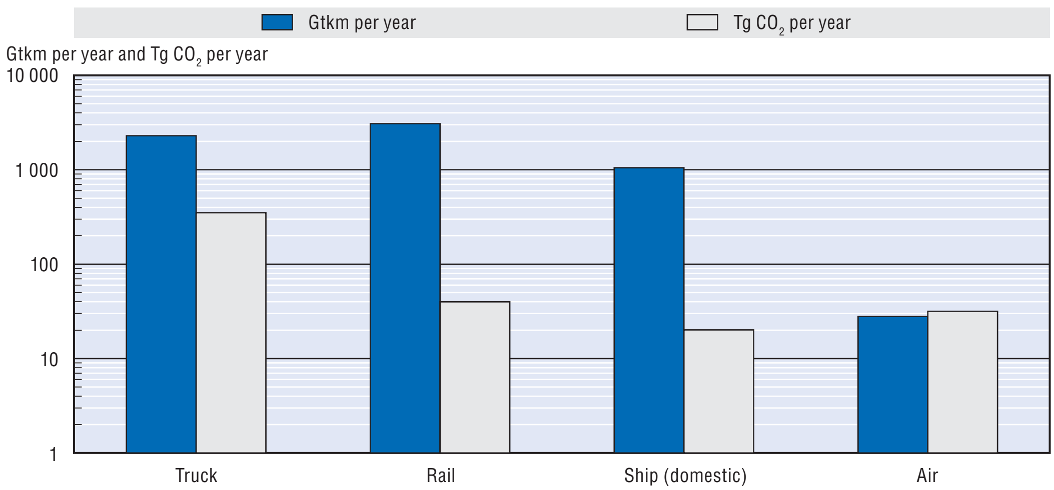


Source: First published in the *IMO Study of Greenhouse Gases from Ships* (Skjølsvik *et al.*, 2000).

Mode choice (especially for containerised cargo movement) involves balancing tradeoffs to facilitate trade among global corporations and nations. Competing factors are *e.g.* time, cost and reliability of delivery. Low-cost modes may be less preferred than faster modes if the cargo is very time-sensitive; however, slower, low-cost modes often carry much more cargo and, with proper planning, these modes can reliably deliver large quantities to meet just-in-time inventory needs. Analogous to a relay race, all modes are needed to deliver containerised cargo from the starting line to the finish line.

Mode share in freight transport can be measured in several ways, but a common metric is in terms of the work done in cargo tonne-kilometres (tkm). The European Union and the United States have similar mode shares for trucking, about 40% to 45% of total freight transport work (Environmental Protection Agency, 2005a; European Commission *et al.*, 2006b). However, it is important to note that European waterborne freight (inland river and shortsea combined) is second in mode share, moving about 40% to 44% of the cargo tkm in recent years (European Commission *et al.*, 2006a; European Commission *et al.*, 2006b). In the United States, rail freight tkm is slightly greater than road freight. Moreover, these statistics ignore seaborne trade which accounts for about 40 000 giga-tkm (one Gtkm = 10^9 tkm) of cargo movement among all trading nations from distances outside the domains from which national statistics are reported. Figure 3.2 summarises mode share comparisons in the US for 2005.

Figure 3.2. **Comparison of demand and carbon emissions by freight-mode share for the US**



Note: Units are on a log scale.

Source: Bureau of Transportation Statistics (2007); Energy Information Administration (2007).

3.2. Global economic role of maritime shipping

Marine transport is an integral, if sometimes less publicly visible, part of the global economy. The marine transport system is a network of specialised vessels, the ports they visit, and transport infrastructure from factories to terminals to distribution centres to markets. Maritime transport is a necessary complement to, and occasionally a substitute for, other modes of freight transport. For many commodities and trade routes, there is no direct substitute for waterborne commerce. Air transport has replaced most ocean liner passenger transport and transports significant cargo value, but carries only a small volume fraction of the highest value and lightest cargoes; while a significant mode in trade value, aircraft moves much less global freight by volume, and at significant energy use per unit shipped. On other routes, such as some coastwise or shortsea shipping or within inland river systems, marine transport may provide a substitute for roads and rail, depending upon cost, time and infrastructure constraints. Other important marine transport activities include passenger transport (ferries and cruise ships), national defence (naval vessels), fishing and resource extraction, and navigational service (vessel-assist tugs, harbour maintenance vessels, etc.).

Globalisation is motivated by the recognition that resources and goods are not always co-located with the populations that desire them, and so global transport services are needed (and economically justified, if consumer demand is great enough). For example, until the 1950s, most crude oil was refined at the source and transported to markets in a number of small tankers, sized between 12 000 and 30 000 deadweight tonnage (dwt). However, economies of scale soon dictated that oil companies would be better off if they shipped larger amounts of crude from distant locations to refineries located closer to product markets. Products could then be more efficiently distributed to points of consumption using a host of transport modes. This realisation ultimately led to the emergence of large tanker vessels greater than 200 000 dwt and drove down the per-unit cost of intercontinental energy transport.

Similarly, rather than palletise grains, minerals and other commodities, dry bulk cargo ships were designed to deliver cargoes in raw or semi-raw condition from where they were found or grown to processing facilities (*e.g.* mills and bakeries) closer to final market. Along with containerisation and advances in cargo handling and shipboard technology, these measures reduced crew sizes and long-shore labour requirements, which also reduced the per-unit cost of ocean cargo transport.

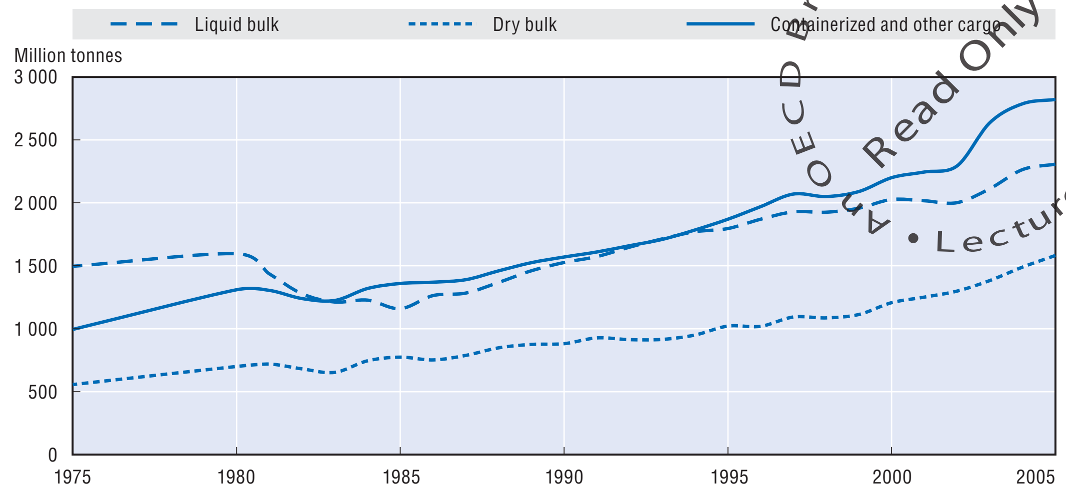
Lastly, globalisation identified labour markets overseas that encouraged transport of semi-raw materials and intermediate products where manufacturing costs were lower. With low-cost petroleum energy for vessel propulsion, facilitated by vessel economies of scale, the per-unit costs of semi-finished and retail products were minimised by multi-continent supply chains. Today it is common for agricultural products to be harvested on one continent, shipped to another for intermediate processing, transported to a third continent for final assembly and then delivered to market. For example, cotton grown in North America may be sent to African fabric mills, and then to Asian apparel factories before being returned to North America for sale in retail stores. Orange juice, wine and other products have also found markets on continents where seasonal or climatic limitations require an offshore source, or entered into competition with domestic production at higher labour costs.

Another trend associated with globalisation is the pace at which trade occurs. Globalisation has encouraged transactions of goods and services in smaller packets delivered "just-in-time". This has increased the "velocity of freight", which justified in the 1970s faster, small containerised vessels, and over the last two decades justified faster, large containerised vessels. In a globalised economy, containerisation offers the advantage of integrated freight transport across all modes. Analogous to the more uniform transport of liquid crude oil or unprocessed grains, containerisation standardised the shipping package, reducing the per-unit cost of transporting most finished goods.

Data on the effect of globalisation on unitised cargoes is shown in Figure 3.3, where increased container shipping represents a significant increase in global transport of finished and semi-finished products from regions with inexpensive skilled labour to consumer markets. The fact that containerised cargo has outpaced other bulk cargo is a testament to the impacts of globalised trade involving consumer products and international labour (as opposed to just raw materials).

The relationship between maritime shipping, economic growth and trade is depicted in Figure 3.4. This figure shows trends over 16 years for OECD countries in terms of gross domestic product (GDP, measured in year 2000 USD), trade (measured as exports plus

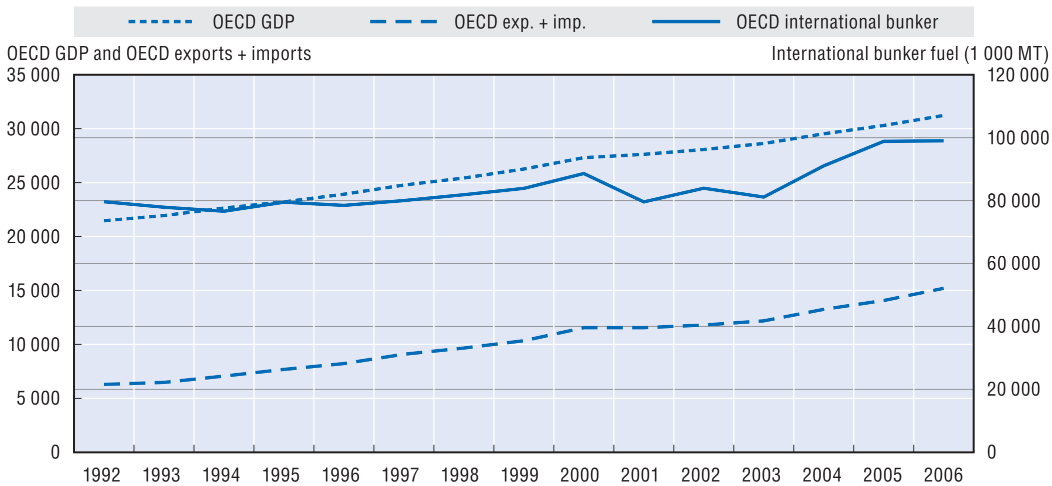
Figure 3.3. **The effect of globalisation on unitised cargoes**



Source: Shipping Statistics Yearbook 2006, p. 103.

Figure 3.4. **Trends in OECD GDP, exports and imports and international bunker fuel supply**

1992-2006, billion 2000-USD

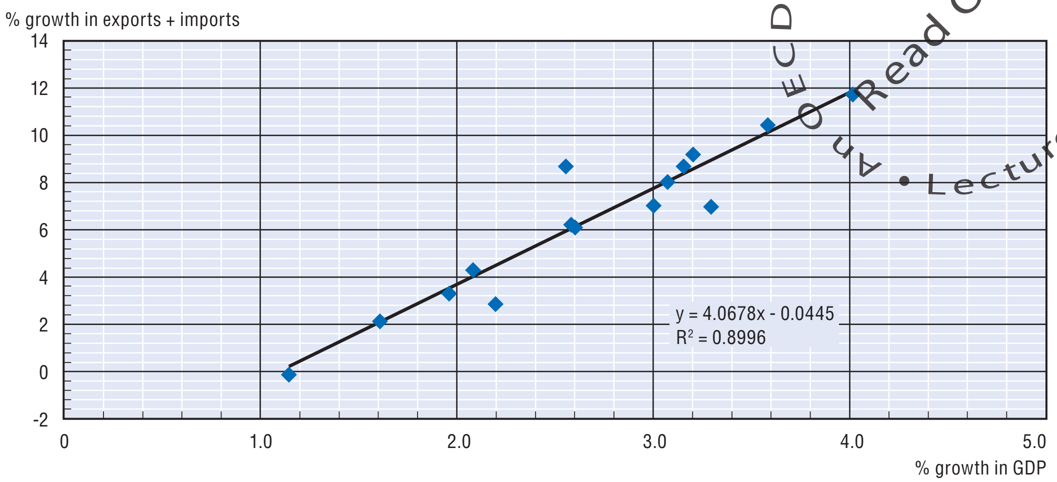


Source: OECD Economic Outlook No. 82: Annual and Quarterly data; OECD Product Supply and Consumption.

imports in year 2000 USD), and fuel sold for international maritime transport (measured in thousands of tons). Figure 3.5 shows the relationship between trade and GDP for OECD countries as measured in year-to-year per cent growth between 1992 and 2006. The figure and accompanying linear regression equation indicates that for every percentage increase in GDP for OECD, there has historically been ~4% rise in trade.[2] Similar data are shown for the United States in Figure 3.6. These figures show scatter plots relating US GDP and freight movement (measured in terms of ton-miles and container traffic in twenty-foot equivalent units, or TEUs).

Figure 3.5. **Relationship between OECD economic growth and growth in exports and imports**

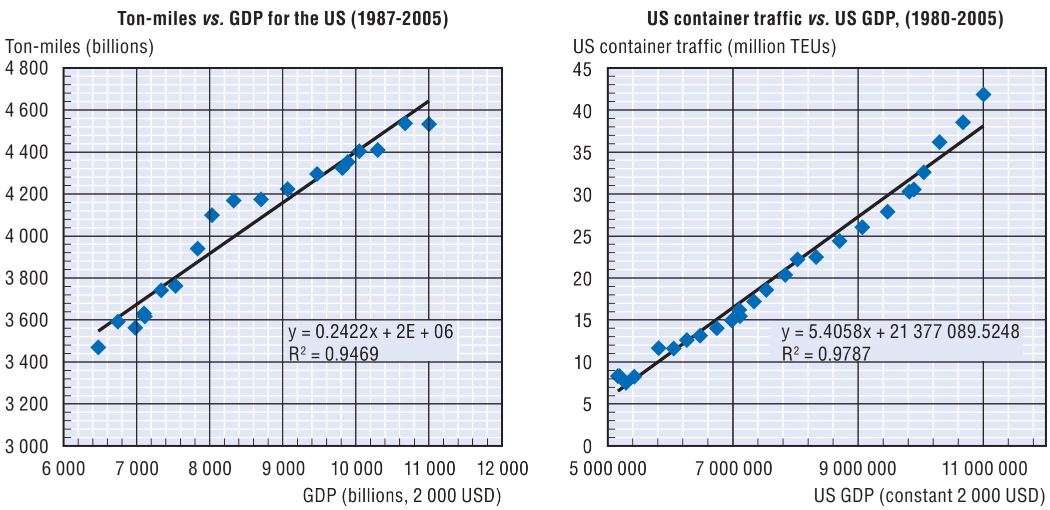
1992-2006



Source: OECD Economic Outlook No. 82: Annual and Quarterly data.

Figure 3.6. **Relationship between cargo shipments and container traffic and GDP**

As measured in ton-miles and million TEUs, for the US



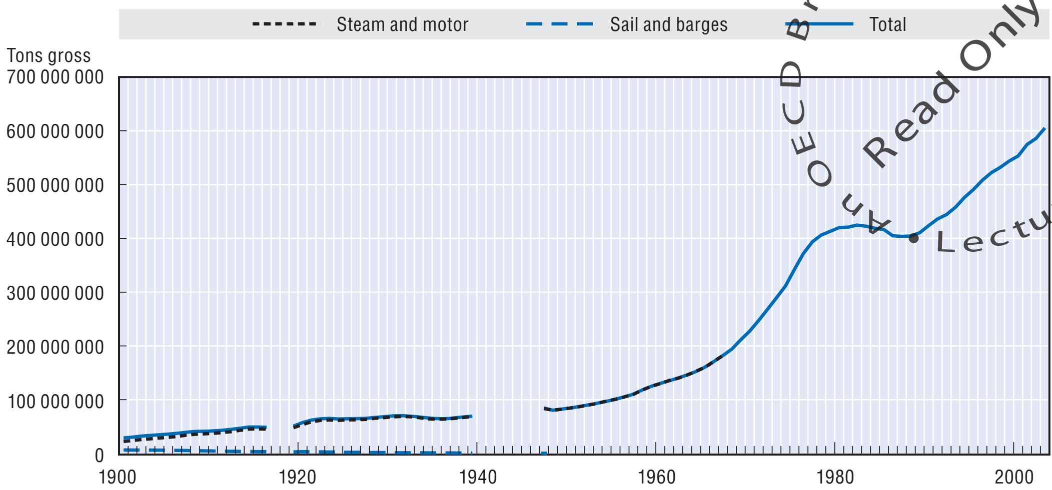
Note: Ton-miles are measured in short tons = 907.18474 kg.

Source: Left panel: US Department of Transport, Bureau of Transportation Statistics, special tabulation; *www.bts.gov/publications/national_transportation_statistics/*. Right panel: Bureau of Transportation Statistics (2007); and Bureau of Economic Analysis. National Income and Product Accounts Table 2007. Available from *www.bea.gov/bea/dn/nipaweb/index.asp*.

3.3. Maritime transformations responding to globalisation

Aside from the shift of human labour (oars) to wind-driven sail, the first modern energy conversion in marine transport was the shift from sail to combustion. Two primary motivators for energy technology innovation – greater performance at lower cost – caused this conversion. Figure 3.7 and Figure 3.8 illustrate how this shift was completed during the first half of the 20th century, using data from Lloyds Register Merchant Shipping Return for various years. Essentially, newer and larger ships adopted combustion technologies as part of an economy-of-scale. These technologies enabled trade routes to emerge regardless of

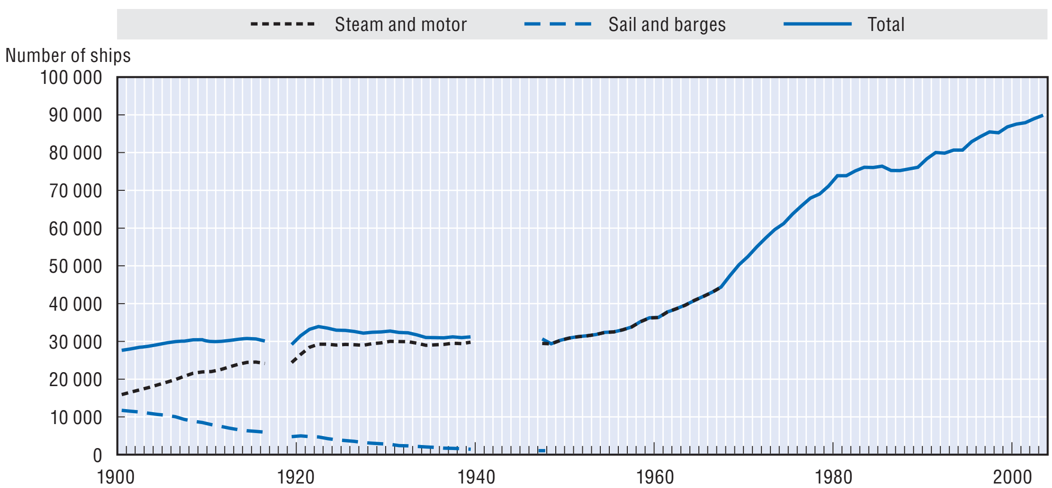
Figure 3.7. **Gross maritime shipping tonnage by vessel technology**



Source: Colton, T. (2004), "Growth of the World Fleet since WWII". Retrieved 25 March 2004 from *www.coltoncompany.com*; as presented in Corbett, J.J. (2004), *Marine Transportation and Energy*.

Figure 3.8. **Number of ships by vessel technology**

1900-2000



Source: Colton, T. (2004), "Growth of the World Fleet since WWII". Retrieved 25 March 2004 from *www.coltoncompany.com*; as presented in Corbett, J.J. (2004), *Marine Transportation and Energy*.

the latitudes without consistent winds (referred to as the doldrums), supporting both international industrialisation and modern political superpower expansion. As shown in these figures, the conversion of fleet tonnage to the preferred technology was achieved much more rapidly than the phase out of smaller ships using the outdated technology. This lead in conversion by tonnage was because the new technology was installed on the larger and newer vessels. Initially, these ships were powered by coal-fired boilers that provided steam, first to reciprocating steam engines and later to high-speed steam turbines that drove the propeller(s). Later, the introduction of the industry's first alternative fuel – petroleum oil – enabled the introduction of modern marine engines. This pattern is repeated in many technology changes for marine transport: some ship operators continue to use long-lived vessels purchased on the second-hand market while industry leaders replace their fleets to achieve new markets or realise economies-of-scale.

The switch from coal to oil was motivated by a desire to reduce costs and improve vessel performance. According to the British Admiral Fisher's remarks to Winston Churchill in 1911 (quoted in Yergin's 1991 book, *The Prize*, p. 155), a cargo steamer could "save 78 per cent in fuel and gain 30 per cent in cargo space by the adoption of the internal combustion propulsion and practically get rid of stokers and engineers". Essentially, the commercial sector (and soon followed by the military) converted to oil-fired boilers and oil-fuelled internal-combustion, compression-ignition engines in order to save money and achieve performance advantages.

Globalisation motivations to reduce the per-unit cost of shipping were the primary purpose for this conversion to "alternative fuel" in the early 1900s, rather than energy conservation, or even fuel cost savings. Oil-powered commercial ships required fewer crew and enjoyed a greater range of operations between fuelling. This was not only of commercial interest; military vessels appreciated these advantages – and the fact that refuelling at sea could be accomplished more quickly and easily. Oil-powered ships also accelerated more quickly than coal-powered systems, and could achieve higher speeds. Given these strong incentives, international shipping switched virtually the entire fleet from coal to oil over five decades.

Figure 3.7 and Figure 3.8 also illustrate the conversion from steam to motor power. In 1948, steam ships accounted for 68% of the ships in the fleet and 79% of the fleet tonnage, while motor ships accounted for 29% of ships and only 20% of the tonnage; sail still powered 4% of vessels, but only 1% of registered ship tonnage. By 1959, motor ships accounted for 52% of vessels and 39% of registered tonnage in the fleet, and in 1963, motor ships represented 69% of vessels and 49% of registered tonnage. By 1970, motor ships dominated the fleet both in terms of ships and cargo tonnage, with 85% and 64%, respectively.

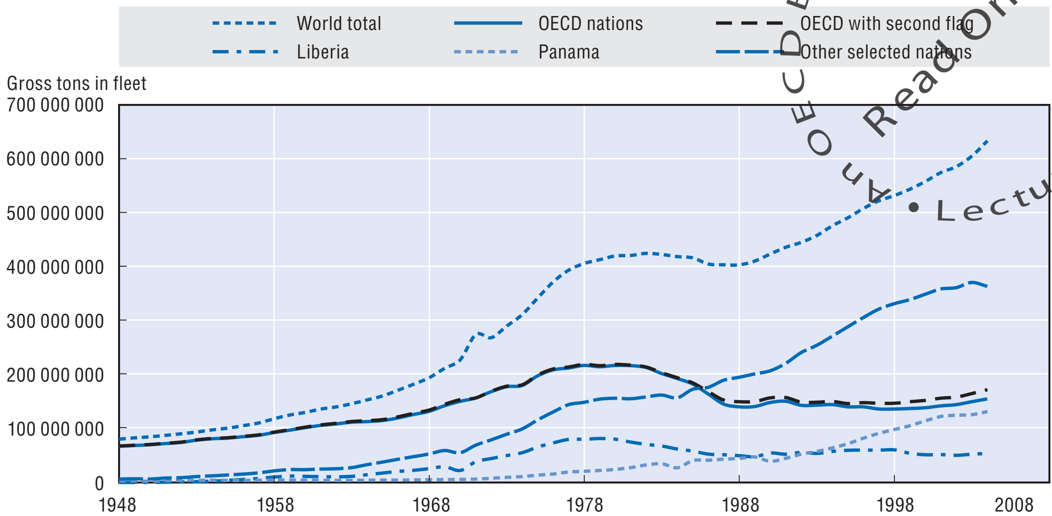
After the fuel conversion was implemented, the next big shift was to more fuel-efficient marine diesel engines, through gains in thermal efficiency in converting the energy potential of the fuel into mechanical work. Engine efficiencies increased from 35% to 40% in 1975 to more than 50% today (Corbett, 2004). This and other technological advancements allowed maritime shipping to meet the transport demands driven by a growing globalised economy.

Figure 3.9 shows the increases in gross tonnage in the worldwide fleet since 1948 by vessel flag. Globally, gross tonnage has increased rapidly, even though vessel flags have largely transitioned from OECD nations to others.

The shift to registering ships internationally was preceded by, and continues to be associated with, a shift to more international seafaring labour, although it must be noted that seafaring has long been an international industry. This has resulted in multinational crews (*e.g.*, officers largely from one group of nations and unlicensed crew from overlapping or different nationalities). With very explicit international qualification standards, crew training and port state authority to inspect ships, most modern ships are operated by talented international labour. Except where flag registry includes citizenship requirements, like in the United States, qualified seafarers are largely hired according to economic rather than residency criteria. A recent global labour market study obtained a sample of international seafarers by nationality and flag of service (Obando-Rojas, 2001).

Figure 3.9. **Gross tonnage by vessel flag**

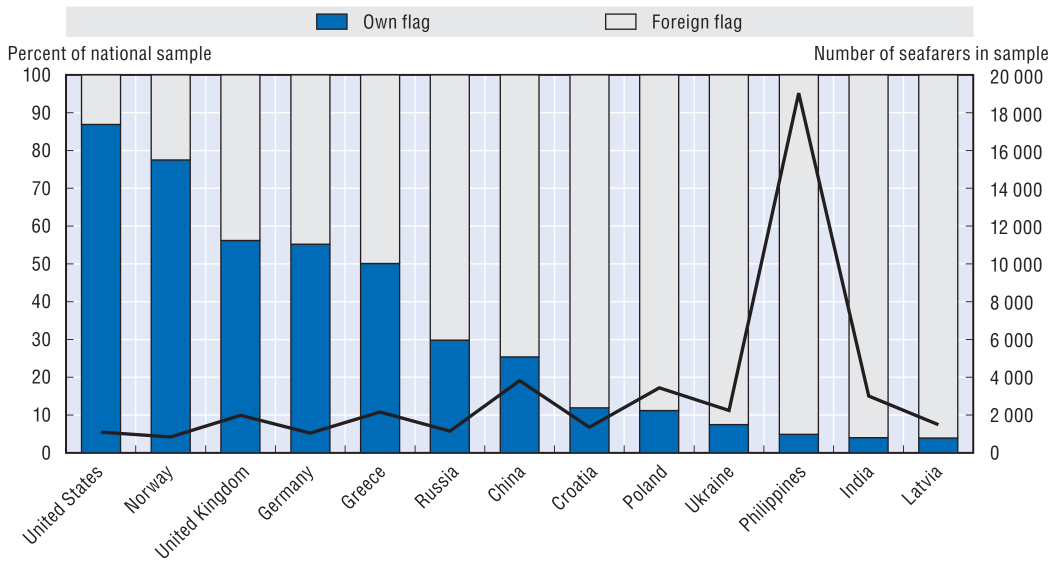
1948-2006



Source: Lloyd's Register of Shipping Statistical Tables; Lloyd's Register of Shipping, London, 1947, 1948, 1958, 1963, 1967, 1970; Lloyd's Register Merchant Shipbuilding Return; Lloyd's Register of Shipping, London, various years 1970-1994, Lloyd's Register of Shipping, Extracts from the World merchant fleet database for 2001 to 2006, Lloyd's Register of Shipping, London.

As shown in Figure 3.10, most seafarers work on vessels that are registered in nations other than their nationality.

Figure 3.10. **Flags of employment for selected nationalities**



Source: Obando-Rojas, B. (2001), The Global Labour Market Study (GLMS). Proceedings of SIRC's Second Symposium, Cardiff University, Seafarers International Research Centre, Data PG 91.

Maintaining a professionally skilled and motivated labour force of seafarers across ranks and nationalities remains an issue of international importance. Maritime transport involves labour that resides at their place of work, where between 10 and 35 crew per ship operate the largest moving vehicles ever constructed, 24 hours per day for most of the year. The working conditions routinely involve motion, noise, vibration and highly technical tasks that are associated with long working hours, varying shift patterns – all elements contributing to workplace fatigue that increases risk of human error during operations that can lead to environmental incidents and catastrophes. Although full discussion is beyond the scope of this chapter, these issues are part of the globalisation of maritime transport and of the environmental performance of shipping.

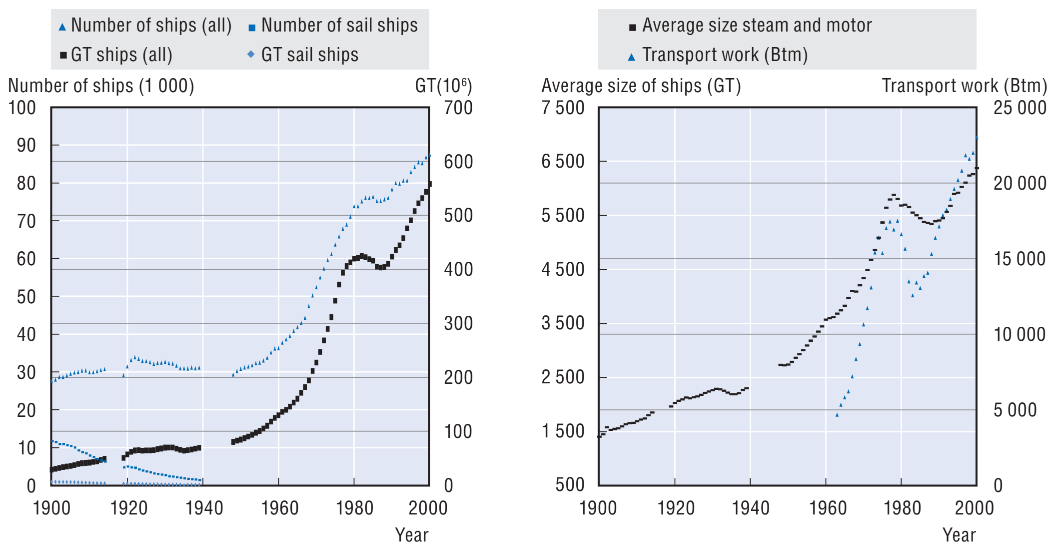
3.4. Maritime shipping activity

There is an ongoing scientific debate regarding both the historical and present activity level in maritime shipping; see for example Buhaug *et al.* (2008), Corbett and Koehler (2003), Dalsøren *et al.* (2009), Endresen *et al.* (2003), Endresen *et al.* (2007) and Eyring, *et al.* (2005). This section presents some of the evidence available.

The annual fuel consumption by the fleet is strongly affected by the demand for sea transport, technical and operational improvements, as well as changes in the fleet composition (Endresen *et al.*, 2007). During the 20th century, total fuel consumption of the ocean-going civil world fleet increased significantly, as the fleet expanded by 72 000 motor ships, to a total of 88 000 in year 2000. The corresponding increase in gross tonnage (GT) was from 22 million GT to 558 million GT (Figure 3.11). This growth was driven by increased demand for passenger and cargo transport, with 300 million tons (Mt) cargo transported in 1920 (Stopford, 1997) and 5 400 Mt in 2000 (Fearnleys, 2002). Up to around 1960, the world fleet still transported large numbers of passengers, and the passenger ships were the largest ship type in the fleet. It was not until 1958 that airplanes transported more transatlantic passengers than large passenger ships (Hansen, 2004). More efficient and specialised ships have also pushed their way into the market. The specialised ships have different operational

Figure 3.11. **Development of world fleet of ocean-going vessels and transport work**

Civil vessels, 100 GT or larger



Left: Development of size and tonnage (data from Lloyd's Register of Shipping). Right: The development of average size (including non-cargo ships) and transport work (billion tonne-miles) (Stopford, 1997; Fearnleys, 2002). No data is available for the World-War periods.

Source: Endresen *et al.* (2007).

and technological characteristics, which results in a particular logistic efficiency, with related energy and emission profiles. The world civil fleet in 2007 was mostly diesel-powered, and consisted of about 96 000 ships above 100 GT (LRF, 2007), of which cargo-carrying ships (including passenger ships) accounted for roughly 50%. The other half was employed in non-trading activities like offshore supply, fishing and general services (*e.g.* towage, surveying).

The ocean-going civil world fleet gradually shifted from sail around 1870 to a fully engine-powered fleet around 1940 (Figure 3.11) (Stopford, 1997; Lloyd's Register of Shipping [LR], 1961 and 1984). Steamships, burning coal, dominated up to around 1920. Coal was thereafter gradually replaced by marine oils due to a shift to diesel engines and oil-fired steam boilers (Table 3.1). The shift to modern marine diesel engines was a slow process, taking more than 100 years. In 1961, there were still over 10 000 steam-engine powered ships and 3 536 steam-turbine powered ships in operation (36% by number) (LR, 1961). As modern diesel engines have about half the daily fuel consumption compared to old, inefficient, steam engines with the same power outtake, the shift to diesel is important to consider when estimating historical fuel consumption (Endresen *et al.*, 2007).

Table 3.1. **World total merchant fleet by form of motive power**

Per cent, 1914-35

	Coal	Oil fuel under boilers	Internal combustion (diesel) engines
1914	96.6	2.9	0.5
1922	74.1	23.4	2.5
1924	68.9	27.9	3.2
1927	63.9	29.3	6.8
1929	60.8	29.2	10.0
1935	51.0	31.2	17.8

Source: Fletcher (1997).

The scrapping of inefficient steamers was economically and politically motivated. When the oil price was low, little attention was paid to fuel costs, and many large vessels were fitted with turbines, since the benefits of higher power output and lower maintenance cost appeared to far overweigh their high fuel consumption. During the period 1970 to 1985, the fuel price increased by 950% (Stopford, 1997). This was followed by the design of more fuel-efficient ships and adjustments of operational practices. The main focus areas for improvements were the main engine, the hull and the propeller. For instance, between 1979 and 1983, the efficiency of energy conversion in slow-speed diesel marine engines improved by nearly 30% (Stopford, 1997). As a result, tankers fitted with inefficient steam turbines were among the first to go to the scrap yards in the 1970s, when the fuel price was rising (Stopford, 1997; Wijnolst and Wergeland, 1997). By 1984, only 1 743 turbine-powered ships remained in service (LR, 1984). These vessels were normally the largest ships in the fleet, as turbine-propulsion commonly was used in the upper power range (SNAME, 1988).

The annual fuel consumption is also strongly affected by operational conditions, such as market situation and bunker prices. The depressions in the world economy in the 1930s and 1970s resulted in laid-up tonnage and lower productivity, due to lower demand for sea transport. For instance, 21% of the fleet tonnage was out of service in 1932 and 13% in 1983 (Stopford, 1997). In addition, crude oil tankers reached a peak in productivity in 1972 (measured in tonne-miles per deadweight [total carrying capacity]). By 1985, this had nearly halved, and a few years later, it had increased by 40% (Stopford, 1997). These operational changes had a significant impact on fuel consumption.

Operational speed significantly influences power requirements and fuel consumption, and it has also varied widely over time. Depending on the market situation and bunker prices, vessels operating in the spot market have the possibility to reduce operating speed. At low freight rates it pays to steam at low speed, because the fuel cost savings may be greater than the loss of revenue. A substantial increase in bunker price will for the same reason change the optimum operating speed. Thus, for any level of freight rates and bunker prices, there is an optimum speed that ship owners will seek. For example, very large crude oil carriers typically operated at 10 knots when freight rates were low in 1986, but this increased to 12 knots when the rates were higher in 1989 (Stopford, 1997). Changes in operational speed will have a large impact on fuel use. For instance, a reduction in average operating speed by 2-3 knots below design speed may halve the daily fuel consumption of the cargo fleet (Stopford, 1997; Wijnolst and Wergeland, 1997). Moreover, technical developments of antifouling systems have influenced fuel consumption over the past 100 years (Evans, 2000).

1870-1913

From 1870 to 1910, the world fleet doubled, from 16.7 million GT to 34.6 million GT. In this period, transport by steamers grew from 15% of the tonnage to 75% (Stopford, 1997), illustrating the shift from sail to steam ships. Estimated fuel consumption over the period is based on statistics reported by Fletcher (1997). At the turn of the century, more than 50% of the British coal exports (Table 3.2) were ultimately used for ship transport. The statistics do not include coal shipped to foreign stations within Great Britain. The amount of coal burned by ships exporting British coal was 21 Mt in 1913. About 270 000 tons of coal was consumed by transporting ships for every million tons of coal delivered abroad (Fletcher, 1997). These figures only include the total amount of British coal consumed by vessels refilling at UK ports, and not the total amount of British coal consumed by the world fleet. The United States Shipping Board has estimated annual bunker consumptions before the First World War (assumed here to be year 1913). Out of 80 Mt of bunker consumed annually for shipping purposes, 60 Mt were supplied by Britain and 5 Mt by British colonies (Annin, 1920). In other words, the British Empire supplied 81% (and Britain 75%) of the coal consumed as bunkers by all ships in the world fleet. This indicates that 64% of the British coal export (94.4 Mt for 1913) was used as bunker for ships (60 Mt). Table 3.2 shows the

Table 3.2. **Estimated global coal bunker sales and CO_2 emissions**

	Exported as cargo	Shipped as bunker fuel[1]	Total export	Estimated: UK parts of bunker sale[2]	Estimated: Total bunker sale[3]	Emissions CO_2 (Mt)
1870	10.2	3.2	13.4	8.6	11.4	30
1880	17.9	4.9	22.8	14.6	19.5	50
1890	28.7	8.1	36.8	23.6	31.4	81
1900	44.1	11.8	55.9	35.8	47.7	123
1913	*73.4*	*21.0*	*94.4*	*60*	*80*[4]	*206*

1. Engaged in foreign trade.
2. It is assumed that 64% of the annual British coal export was used by shipping.
3. Assuming that Britain supplied 75% of the coal consumed as bunkers by all ships in the world fleet.
4. Reported by Annin (1920), based on estimates presented by the United States Shipping Board.

Source: Fletcher (1997). Estimates based on the quantity of coal (Mt) leaving United Kingdom ports.

estimated coal sales (and CO_2 emissions) (SNAME, 1983; Endresen *et al.*, 2007). The sales to shipping increased by a factor of about 7 from 1870 to 1913. As the tonnage with steamers increased by a factor of 6 from 1870 to 1910 (see above), this estimate may be reasonable.

1925-2007

Estimates of the more recent activity level and fuel use in the shipping sector vary considerably (see Figure 3.13 for some examples). While some estimates are based on reported fuel sales, other estimates are based on attempts to calculate how much fuel ships of different categories and sizes would have used.

Transport vessels account for almost 60% of the ships of the internationally registered fleet (not including military ships). Including military ships, cargo ships accounted for 40% of the world fleet of vessels and 66% of world fleet fuel use in 2002 (see Table 3.3). The registered fleet had approximately 84 000 four-stroke engines, with total installed power of 109 000 MW and some 27 000 two-stroke engines with total installed power of 164 000 MW. Engines with "unknown" cycle types and turbines together made up about 2.5% of total installed power for main engines.

Table 3.3. **Profile of 2002 world fleet, number of main engines, and main engine power**

Ship type	Number of ships	Per cent of world fleet	Number of main engines	Per cent of main engines	Installed power (MW)	Per cent of total power	Per cent of energy demand[1]
Cargo fleet	43 852						
Container vessels	2 662	2	2 755	2	43 764	10	13
General cargo vessels	23 739	22	31 331	21	72 314	16	22
Tankers	9 098	8	10 258	7	48 386	11	15
Bulk/combined carriers	8 353	8	8 781	6	51 251	11	16
Non-cargo fleet	44 808						
Passenger	8 370	8	15 646	10	19 523	4	6
Fishing vessels	23 371	22	24 009	16	18 474	4	6
Tugboats	9 348	9	16 000	11	16 116	4	5
Other (research, supply)	3 719	3	7 500	5	10 265	2	3
Registered fleet total	88 660	82	116 280	77	280 093	62	86
Military vessels	19 646	18	34 633	23	172 478	38	14
World fleet total	**108 306**	**100**	**150 913**	**100**	**452 571**	**100**	**100**

1. Per cent of energy demand is not directly proportional to the installed power because military vessels typically use much less than their installed power except during battle. Average military deployment rate is 50% underway time per year (Navy, 1996); studies indicate that when underway, naval vessels operate below 50% power for 90% of the time (NAVSEA, 1994). Therefore, energy demand was adjusted in this table to reflect these facts. The data upon which military vessel power was based specified the number of engines aboard naval ships.

Sources: Corbett and Koehler (2003), and Corbett (2004).

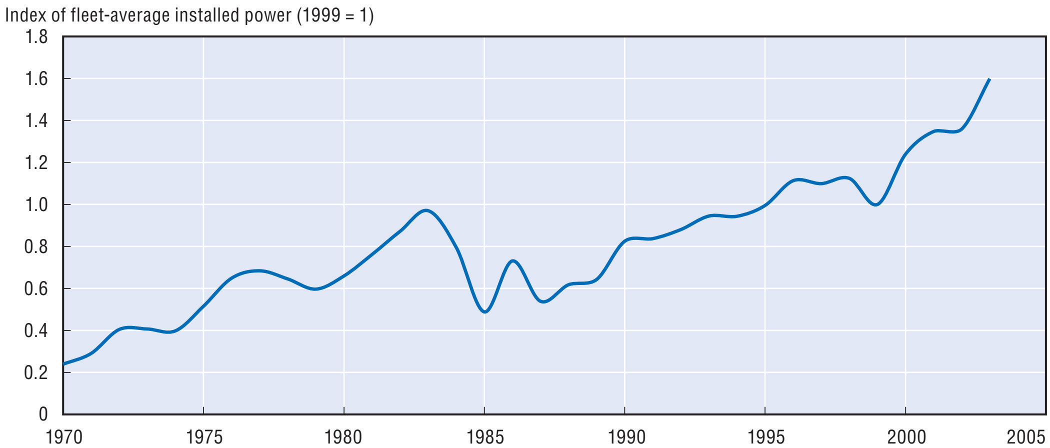
Fuel types used in marine transport are different from most transport fuels. Marine fuels, or bunkers, can be generally classified into two categories: residual fuels and other fuels. Residual fuels, also known as heavy fuel oil (HFO) or intermediate fuel oil (IFO), are a blend of various oils obtained from the highly viscous residue of distillation, or cracking, after the lighter (and more valuable) hydrocarbon fractions have been removed. Since the 1973 fuel crisis, refineries adopted secondary refining technologies (known as thermal cracking) to extract the maximum quantity of refined products (distillates) from crude oil. As a consequence, the concentration of contaminants such as sulphur, ash, asphaltenes and metals has increased in residual fuels.

To reduce operating expenses, marine engines have been designed to burn the least costly of petroleum products. Residual fuels are preferred if ship engines can accommodate their poorer quality, unless there are other reasons (such as environmental compliance) to use more expensive fuels. Of the two-stroke, low-speed engines, 95% use HFO and 5% are powered by marine diesel oil (MDO) (Corbett and Koehler, 2003). Some 70% of the four-stroke, medium-speed engines consume HFO, with the remainder burning either MDO or marine gasoil (MGO). Four-stroke, high-speed engines all operate on MDO or MGO. The remaining engine types are small, high-speed diesel engines, all operating on MDO or MGO, steam turbines powered by boilers fuelled by HFO or gas turbines powered by MGO.

The switch to more fuel-efficient engines over time has been counteracted by increased engine power requirements to meet rapidly expanding demand for more and faster global trade. This is illustrated in Figure 3.12, which depicts average installed power, indexed to 1999; estimated from vessels in service as reported in 2003 vessel registry data.

Figure 3.12. **Average installed power (kW) for worldwide vessel fleet**

1970-2003



Source: Lloyd's Register of Shipping (2006). Extracts from the World merchant fleet database for the years 2001 to 2006. Lloyd's register of Shipping, London.

Corbett and Kohler (2003) provided an activity-based, bottom-up estimate of world fleet fuel consumption, calculated for all main and auxiliary marine engines in the internationally registered ocean-going fleet, including military vessels, of about 289 million tons per year, more than twice the quantity reported as international fuel sales. In the estimation, the authors used ship registry data to define five main groups of engines onboard vessels: 1) two-stroke low-speed engines; 2) four-stroke medium-speed engines; 3) four-stroke high-speed engines; 4) turbines; and 5) others. Each main group was also split in several categories, resulting in more than 130 engine categories in all. Auxiliary engines were treated as a separate subgroup. The authors further assumed that typical maximum power in service is 80% of rated engine power and applied average fuel consumption rates for the different engine fuel combinations.

Endresen *et al.* (2003) developed an activity-based modelling approach, distinguishing between seven ship types and three size categories in the world cargo and passenger fleet. The model calculated consumption and emissions for the years 1996 and 2000. The fuel consumption estimate was based on the number of hours at sea (depending on ship size), statistical relations between size (in Dwt or GT) and engine power for the ship types (container, bulk, general cargo, etc.), distribution of engine types across ship types (slow, medium and high-speed engines), bunker fuel consumed per power unit (kW) (depending on engine type), and an assumed average engine load. Total fuel consumption was calculated to 145 Mt and 158 Mt for 1996 and 2000, respectively. If fuel consumption by 45 000 non-cargo ships is taken into account, this study estimated fuel consumption for the entire civilian world fleet above or equal 100 GT (ocean-going) to be of the order 200 Mt in 2000.

Eyring *et al.* (2005a) produced one of the first estimates for fuel usage over a historical period, from 1950 to 2001. They reported simplified activity-based inventories from 1950 up to 1995, using ship number statistics and average engine statistics, while the estimate for 2001 was based on detailed fleet modelling. Their results suggested fuel consumption of approximately 280 million tons in the year 2001.

Endresen *et al.* (2007) reported more detailed activity estimates for each year from 1970 to 2000. They suggested that activity-based estimates of past fuel consumption should take into account variations in the demand for sea transport and operational and technical changes over the years, to better represent the real fuel consumption. For instance, their model distinguishes between diesel and steam ships, as steam ships have significantly higher fuel consumption. Their results suggest that fleet growth is not necessarily followed by increased fuel consumption, as technical and operational characteristics changed over time. An important input to the modelling in Endresen *et al.* (2007) is the change in fleet productivity (measured in tonne-miles). For instance, the peak level of 1979 was not reached again before 1991 (Figure 3.11, right).

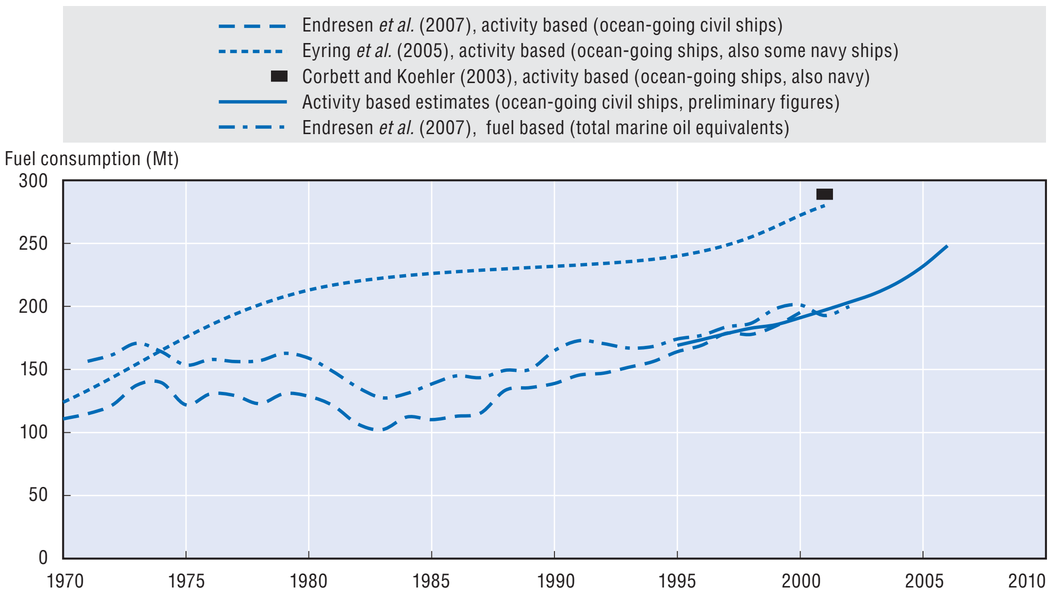
Endresen *et al.* (2007) also reported detailed estimates based on fuel sales from 1925 to 2000. The results indicated that ocean-going ships had a yearly fuel consumption of about 80 Mt of coal (corresponding to 56.5 Mt of heavy fuel oil) before the First World War. This increased to a sale of about 200 Mt of marine fuel oils in 2000 (including the fishing fleet), *i.e.* about a 3.5-fold increase in fuel consumption. Of this sale, international shipping accounts for some 70% to 80%.

Buhaug *et al.* (2008) produced a report of a group of experts tasked to work out a consensus-estimate of CO_2 emissions from international shipping in 2007 for IMO. Their findings on fuel use agree well with the result of Corbett and Kohler (2003), when military vessels are removed from their original figures. The 2008 estimate is higher than that of Endresen *et al.* (2007), and higher than what the fuel statistics indicate, but lower than forecasts based on Eyring *et al.* (2005a).

Dalsøren *et al.* (2009) used an even more detailed breakdown of the world fleet than the preceding studies, distinguishing among 15 ship types and 7 size categories. Global port arrival and departure data for more than 32 000 merchant ships were used to establish operational profiles for the ship segments. Further, the authors used more than 600 000 individual ship movement records from four months in 2003 (January, April, July and October) to calculate average times at sea and in port for the 7 size categories for each of the 15 ship types. The study estimated total fuel consumption in civil international shipping in 2004 to be 217 Mt, of which 11 Mt was consumed in in-port operations. Based on the growth in the shipping sector between 2004 and 2007, the authors estimated fuel consumption in 2007 to be 258 Mt. These estimates are in agreement with international sales statistics, and significantly lower than the estimates in most of the studies above.

Uncertainties in historic activity-based fuel consumption estimates arise from the fact that reliable input data, such as detailed shipping and engine as well as engine performance statistics, activity data and the detailed fleet structures before 1960 are not available. Also, the level of detail in the fleet-modelling approach is important. Endresen *et al.* (2007) estimated that fuel consumption in the period 1980-2000 was significantly lower than reported by other activity-based studies (Corbett and Koehler, 2003; Eyring *et al.*, 2005a) (Figure 3.13). A main reason for the large deviations among these activity-based fuel consumption estimates is the assumed number of days at sea (Figure 3.14). Endresen *et al.* (2007) based their estimates on an assumed average number of days at sea of 212 days. This assumption was based on yearly tracking of more than 3 400 ships in the *AMVER Database*,

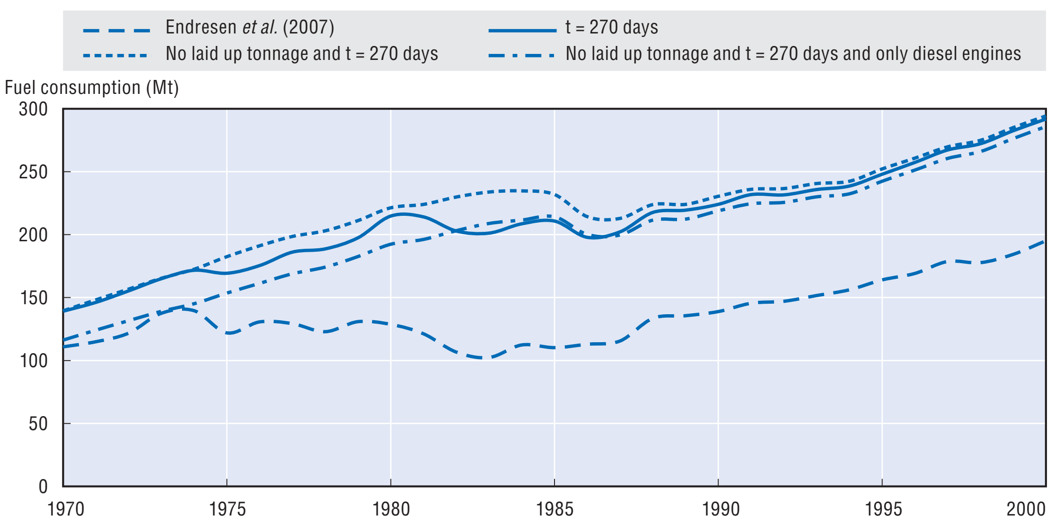
Figure 3.13. **Comparison of some estimates of ships' fuel consumption**



Source: Endresen et al. (2008).

Figure 3.14. **Sensitivity analysis of estimated fuel consumption in international shipping**

1970-2000



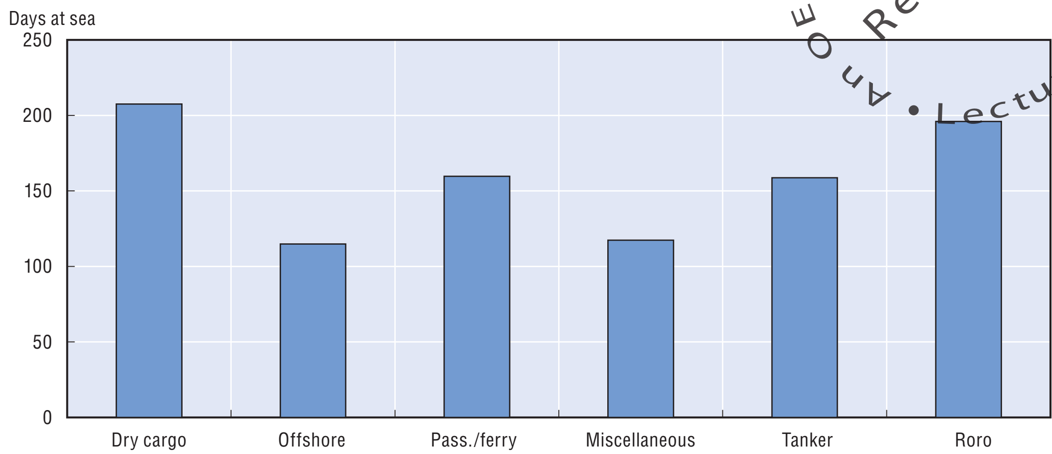
Comparison of alternative input data. The estimates cover all ocean-going civil ships 100 GT or larger.

Source: Endresen et al. (2007).

mainly medium and large cargo vessels. For smaller ships, the number of days at sea is lower (typically below 200 days), as indicated by AIS data shown in Figure 3.15.

Figure 3.15. **Calculated days at sea for different vessel categories**

Based on AIS data for 500 ships larger than 300 GT tracked in Norwegian waters, first six months of 2007



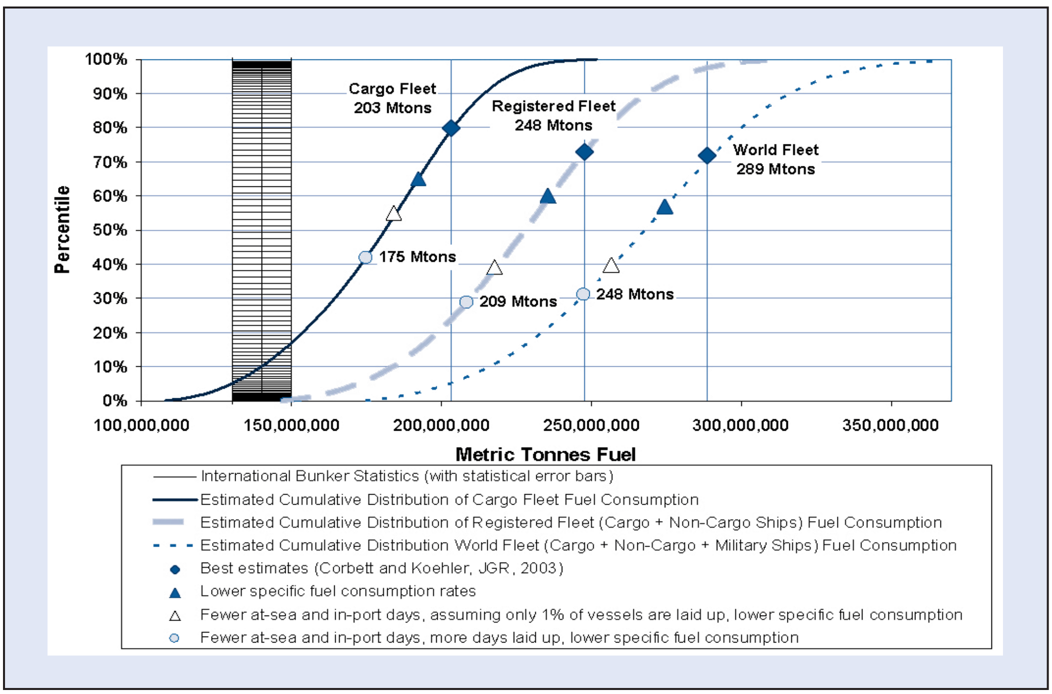
Offshore ships have low activity, as dynamic position operations are not included.

Source: Data from the Norwegian Coastal Administration.

Figure 3.16, from Corbett and Koehler (2003), provides additional illustrations of how estimates of fuel use in maritime shipping vary with the assumptions made.

Endresen *et al.* (2007) suggested that the actual days at sea and the service speed in the future could be estimated based on automatic identification systems (AIS) for individual

Figure 3.16. **Activity-based estimates of energy use and international marine sales**



Source: Corbett and Koehler (2003).

ocean-going ships. Such data will also make it possible to indirectly estimate the engine power utilisation per ship (and for fleet segments) by combining recorded service speed with installed main engine power for each individual ship (available from Lloyds' Fleet Databases). AIS is primarily an anticollision system, and is designed to automatically provide position and identification information about the ship to other ships and to coastal authorities (United States Coast Guard, 2002). The International Maritime Organization requires AIS to be fitted aboard all international ships above a certain size. A preliminary analysis based on AIS data and individual profiles for 500 small- and medium-sized ships (greater than 300 GT) sailing in Norwegian waters does not support the activity level of 225-270 days at sea assumed by recent activity-based studies (Figure 3.13). Buhaug *et al.* (2008) made a first attempt to establish global operational profiles using AIS data, but the reported profiles represent small vessels only crudely. This issue should be addressed in new studies, also considering larger ships. When the global identification and tracking of ships is implemented, using long-range identification and tracking (LRIT) technology, the potential for effective monitoring on an individual ship basis would increase further. LRIT is a satellite-based system with planned global coverage of maritime traffic (IMO, 2006).

Ships operate differently depending on type and size, but cargo ships mostly operate in a similar way, transporting cargo between ports (the length of the voyages will vary). Endresen *et al.* (2004a) reported the average number of days at sea for five size categories and six ship types, based on yearly tracking of cargo ships in the AMVER database. Number of days at sea was found to vary by about 50 days between the cargo ship types, for a given ship size category. Also, the difference between a small and a large ship can be 100 days for a defined ship type.

Dalsøren *et al.* (2009) studied the number of days at sea in greater detail and found that the number varies between 136 days for small bulk vessels to 280 days for large liquefied gas tankers. Ships of the same type show a variation as large as 120 days between size categories. For cargo ships of similar size, the variation was as large as 114 days between ship types. Non-cargo ships of similar size have a variation up to 98 days between ship types. Thus, ship type and size should be taken into account when modelling activity level in the shipping sector.

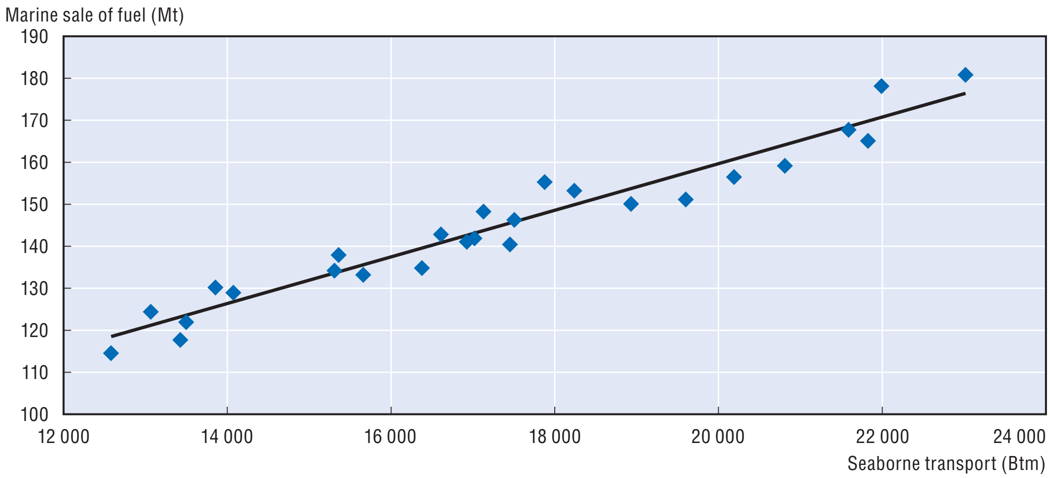
The engine load assumed for different types and sizes is also an important input. The cargo fleet, accounting for about 80% of the installed power in non-military vessels (Table 3.3 and Endresen *et al.*, 2007), will normally have a higher engine utilisation (load) and a higher number of sailing days compared to non-cargo ships (Endresen *et al.*, 2004a). The relative energy production (kWh) will then exceed 80%, and could be as high as 90%. Consequently, to reduce the uncertainty in activity modelling, it is important to apply pre-defined size and type categories (with mostly the same characteristic of the input variables) which resolve main characteristics. Alternatively, the non-linear effects have to be taken into account when simplified models are used. Yearly movement and tracking data (*e.g.* AIS data) available for individual ships can be used to increase the reliability of model results.

Several studies have indicated that significant under-reporting of bunker sales has occurred.[3] However, activity-based studies have reported fuel consumption excluding ocean-going ships less than 100 GT. The fuel consumption by these ships is not addressed in the literature, and could be significant. For instance, in 1998, there were about 1.3 million engine-powered fishing vessels globally (Food and Agriculture Organization, 2006), while only some 23 000 of these vessels were larger than 100 GT in year 2000

(LR, 2000). The fishing fleet of less than 100 GT represents nearly half of the installed power for the entire fishing fleet (Endresen *et al.*, 2007). Norway, for example, has approximately 3 000 cargo and service ships between 25 and 100 GT in coastal trade (Statistics Norway, 2000). Data for the rest of the world fleet of less than 100 GT operating mainly in national waters have not been identified, but this fleet (*e.g.* national fleet for the US and Japan) could account for a significant part of global fuel consumption. Detailed activity-based modelling, with the use of high-resolution time series as input data, gives estimates of fuel consumption that correspond relatively well to fuel sales numbers (Dalsøren *et al.*, 2009; and Figure 3.13). In addition, Endresen *et al.* (2007) found a strong correlation between sales to the world fleet and total seaborne trade in tonne miles (r = 0.97) (Figure 3.17). This result indicates that if under-reporting of fuel sales occurred over the period, the ratio is probably approximately constant.

Figure 3.17. **Correlation between IEA-reported sales of marine oil products and transport work**

1975-2000



Source: Endresen *et al.* (2007). Transport work data is based on Stopford (1997) and Fearnleys (2002). For the period 1975-2000, the correlation is 0.97.

Some debate continues about the best estimates of global fuel usage, but the major elements of activity-based inventories are widely accepted. Considering the range of current estimates using activity-based input parameters, ocean-going ships consume 2% to 3% (perhaps even 4%) of world fossil fuels.

3.5. Future developments

Two approaches are applied here to estimate future activity levels in maritime shipping and future emissions. The first is extrapolation of historical growth trends (*e.g.* via the number of ships in fleet or installed fleet power). The second is scenario-based estimates. In its simplest form, extrapolating the growth trend in total fleet installed power (LRF, 2007) in the period 1996-2006 gives a growth of 34% from 2006 to 2020. However, the growth from 1979 to 2006, or from 1986 to 2006, indicates a 4% and 16% increase from 2006 to 2020 respectively. In other words, using shorter regression periods leads to higher estimates, due to higher growth in the period 1996-2006. Assuming that all factors are kept constant, this growth in the installed power corresponds to growth in fuel use.

Another approach is to extrapolate the growth in transport work (tonne-miles) (Fearnleys, 2006). Transport work is linearly correlated with installed fleet power for historic data (LRF, 2007) (correlation coefficient higher than 0.95). If this linear correlation is assumed valid also for the future, the extrapolated values for transport work yields estimates for future fleet power by the same linear function. If the extrapolation is based on the growth trend in transport work from 1995 to 2005, the growth in installed fleet power to 2020 would be 33%. However, if the extrapolation is based on the trend from 2002 to 2005, the growth to 2020 will be 64%. Again, using shorter regression periods leads to higher estimates due to higher growth in transport activity in the years preceding the current severe economic recession.

Of course, the above growth trends (in installed power) do not directly translate into fuel use growth rates. Most studies on future scenarios, however, take historic trends for some recent period and extrapolate, with adjustments for expected changes in trends. Often these adjustments are the responses to economic and population drivers affecting global trade or consumption. The TREMOVE maritime model (Ceuster *et al.*, 2006; Zeebroeck *et al.*, 2006), is an example of such a model. It estimates fuel consumption (and emissions) trends derived from forecasted changes in ship voyage distances (maritime movements in km) and the number of port calls.

An IMO study on greenhouse gas emissions from ships (Skjølsvik *et al.*, 2000) forecasted a growth rate in seaborne trade (in terms of tonnage) of 1.5% to 3% annually. The study applied these growth rates in trade to represent growth in energy requirements.

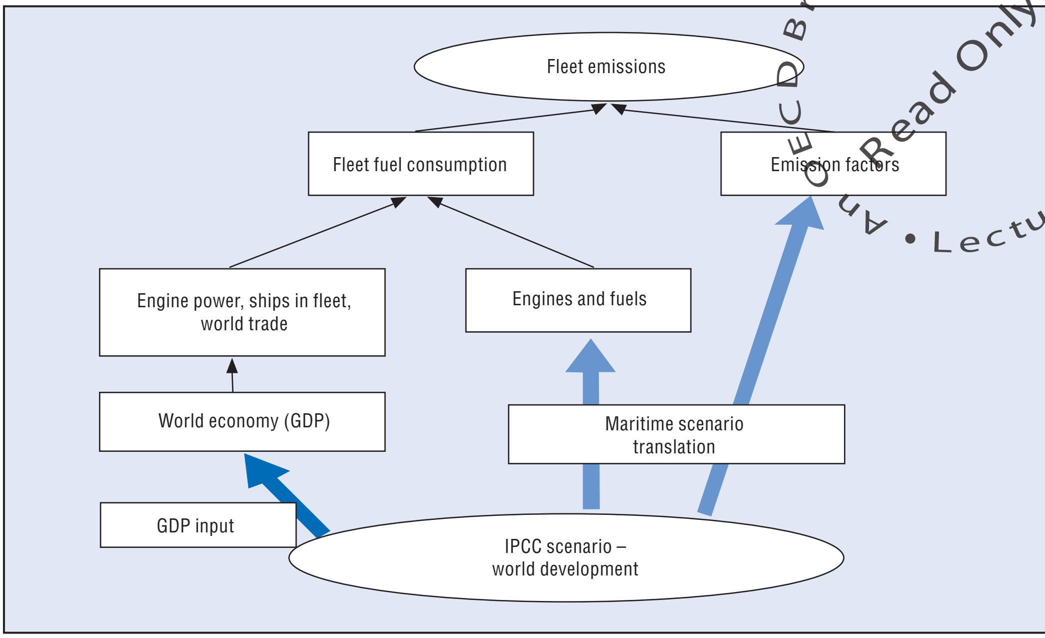
Eyring *et al.* (2005b) estimated future world seaborne trade in terms of volume in tons for a specific ship traffic scenario in a future year based on the historical correlation between the total seaborne trade and world gross domestic product (GDP) from 1985 to 2001. Following the annual growth rate in GDP for four Intergovernmental Panel on Climate Change (IPCC) storylines (varying between 2.3% and 3.6%) (IPCC, 2000), seaborne trade increased by 2.6% to 4.0% per year. According to this study, fuel consumption by the world fleet may increase from 280 Mt in 2001 to 409 Mt in 2020 and 725 Mt in 2050. It should be noted that the calculations done by Eyring *et al.* (2005b) starts in 2002 and does not include the unexpectedly high growth between 2002 and 2007.

Buhaug *et al.* (2008) reported scenarios for 2020 and 2050, with even higher projections, and an IMO working group estimated marine fuel consumption of 486 Mt in 2020 (IMO, 2007).

In the Quantify project,[4] future fuel consumption, emissions and geographical distribution of emissions for shipping in the years 2025, 2050 and 2100 were modelled based on four IPCC scenarios. The IPCC storylines were translated into maritime scenarios, exploring the major factors expected to determine the development in shipping, most notably GDP development, environmental policy development and pace of technology development. Separate models for fuel consumption, total emissions and geographical distribution of ship emissions were made for each scenario, taking into consideration future changes in world trading patterns. Cargo and non-cargo ships were modelled separately in this study. This allowed alternative input data per scenario (*e.g.* based on availability of fossil fuel and ship power supply). Two of these scenarios are presented below.

Primary input from the IPCC scenario descriptions are projections of growth in the world economy, expressed as gross domestic product (GDP). Using historical data, aggregated global GDP is linked to the size of the world fleet, through world seaborne trade volumes. Hence, future expectation of economic development stipulates the future world shipping fleet which, along with historical data for average installed engine power, gives an estimate of the future fleet's total installed engine power (Figure 3.18). The future fuel consumption

Figure 3.18. **Modelling future fuel use and emissions in shipping**



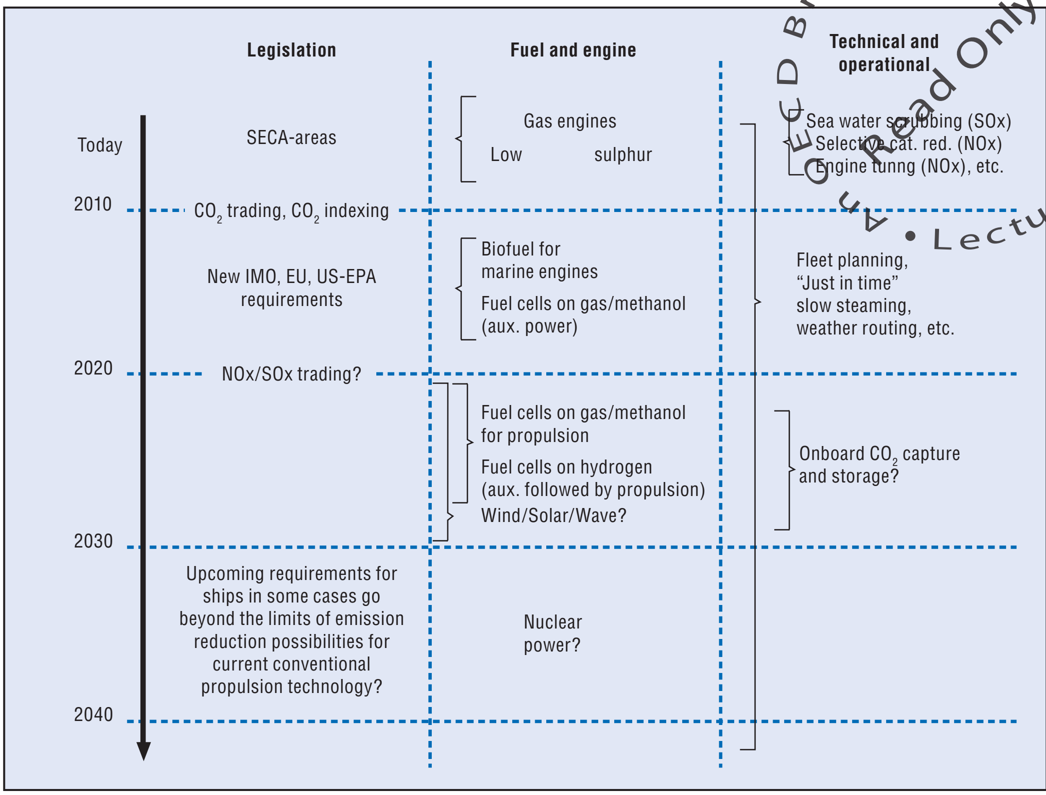
World GDP estimates from the IPCC scenarios are transformed into fleet installed engine power using regression. Interpretations of scenario storylines provide future engine and fuel distributions as well as future emission factors. Emission factors and fuel consumption combined results in fleet emissions.

Source: Eide *et al.* (2008).

for the fleet was estimated on an activity-based approach, taking into account (among other factors) future distribution of power and fuel types for the estimated installed power.[5]

In order to come up with estimates of future development for the fleet (*e.g.* related to powering, fuel types and plausible emission reduction factors), qualitative indications of technological and legislative development outlined in the IPCC scenarios were considered. Assumptions regarding future development were based on relevant information in the IPCC scenarios, and on current options and trends, experience and relevant industry insights (see Figure 3.19). The future use of biofuels is highly dependent on environmental focus and technological developments. The use of gas in shipping could increase significantly in the years to come, but with considerable variation, depending on the given scenario. For instance, supply ships (*e.g.* Viking Energy, built in 2003) and ferries (*e.g.* Glutra, built in 2000) operating in Norwegian waters have been fuelled by gas for several years. Fuel cells running on gas could come first in the small-ship segment (and auxiliary engines), but depending on the technology focus in the scenarios, more general use would come later. Wind and solar energy will not power ships alone, but may contribute alongside diesel engines with a few percentages for individual ships. Various sail arrangements, both fixed wing and soft cloth, have been tested out on merchant vessels over the years. Experiments conducted from 1979 to 1985 did show that sails represent an interesting supplementary propulsion system when the wind direction is favourable (*e.g.* tested on M/V Ususki Pioner) (Det Norske Veritas, 1984). Ongoing testing of kites on merchant ships has also been reported (*e.g.* MV Beluga SkySails[6]). Their usage could increase beyond 2025, depending on technology focus (and environmental focus). Nuclear propulsion has been used in military vessels for decades (also icebreakers). However, it has been used only in four vessels: Savannah (US), Otto Hahn (Germany), Mutsu (Japan) and Enrico Fermi (Italy). Due to the need for a special infrastructure and societal fears, it plays a minor role in all scenarios.

Figure 3.19. **Some possible developments for ships' fuel use and emissions**



This graph gives an indicative overview of possible future legislation initiatives, fuel and engine types available for shipping, and technical and operational measures available for emission reduction.

Source: Eide *et al.* (2008).

It is difficult to assess the impact these technologies will have in the future, but within a foreseeable timeframe, marine diesel engines will continue to dominate. In the scenarios presented here, both existing and emergent technologies and solutions are assumed to be phased-in gradually.

The Quantify project calculated fuel consumption in maritime shipping between 453 and 810 Mt in 2050, based on the storylines in the IPCC A1 and A2 scenarios (Eide *et al.*, 2008). A1 gives the highest estimate, while A2 gives the lowest.

3.6. Conclusions

Increasing globalisation has led to a strong increase in international shipping activity. Trade and shipping are closely linked, although some disagreement remains about the degree to which energy use in shipping is coupled with the movement of waterborne commerce. The estimates depend *inter alia* on the number of days at sea or in port that are assumed in the analysis. The available evidence largely indicates that world marine fleet energy demand is the sum of international fuel sales, plus domestically assigned fuel sales. Some debate continues about the best estimates of global fuel usage, but the major elements of activity-based inventories are widely accepted. Considering the range of current estimates using activity-based input parameters, ocean-going ships now have an activity level making them consume about 2% to 3% – and perhaps even as much as 4% – of world fossil fuels.

Future activity levels are obviously uncertain (not least given the current economic crisis) but a growth in fuel use in the sector of about one-third between 2006 and 2020 is conceivable.

Notes

1. This chapter is an edited version of two papers: *The Impact of Globalisation on International Maritime Transport Activity: Past Trends and Future Perspectives*, written by James J. Corbett and James Winebrake, Energy and Environmental Research Associates, the United States, for the OECD/ITF Global Forum on Transport and Environment in a Globalising World, held in Guadalajara, Mexico, 10-12 November 2008 (*www.oecd.org/dataoecd/10/61/41380820.pdf*) and *The Environmental Impacts of Increased International Maritime Shipping: Past Trends and Future Perspectives*, written by Øyvind Endresen and Magnus Eide, Det Norske Veritas, Høvik; Stig Dalsøren and Ivar S. Isaksen, University of Oslo; and Eirik Sørgård, Pronord AS, Bodø, Norway, for the same event (*www.oecd.org/dataoecd/52/30/41373767.pdf*).
2. A somewhat similar relationship could also hold in the current economic recession. While OECD (2009) foresees a 2.75% reduction in world GDP in 2009, a 13.2% reduction in world trade is expected.
3. See Corbett and Winebrake (2008) for further elaboration.
4. *www.pa.op.dlr.de/quantify/*.
5. Future emissions from shipping are then estimated based on the calculated fuel consumption and the assumed time-dependent technological factors.
6. *http://skysails.info/index.php?id=6&L=1*.

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Chapter 4

International Air Transport: The Impact of Globalisation on Activity Levels

by
Ken Button and Eric Pels[1]

This chapter describes the basic features of international air transport. It opens with a historical perspective from the 1930s to modern day. The modern air transport industry is one that increasingly operates within a liberal market context. While government controls over fares, market entry and capacity continue in many smaller countries, they are gradually and almost universally being removed or relaxed. The chapter explains why the air transport industry is now large – it accounts for about 1% of the GDP of both the EU and the United States. It is an important transporter of high-value, low-bulk cargoes. International aviation moves about 40% of world trade by value, although far less in physical terms.

The chapter explores the effects of globalisation on airlines, not just on the demand side – where the scale, nature and geography of demand in global markets has led to significant shifts – but also on the supply side, where government policies (e.g. regarding safety, security and the environment) require international co-ordination. It examines technological developments. Two major innovations in air transport were the introduction of jet engines, which considerably shortened travel times, and the introduction of wide-bodied aircraft, which gave airlines the opportunity to reduce the cost per seat. Both developments reduced the generalised cost of travel, so that they had a positive impact on demand. And in closing, the chapter explores changing industrial needs.

4.1. Introduction

Air transport is a major industry in its own right and it also provides important inputs into wider economic, political and social processes. The demand for its services, as with most transport, is a derived one that is driven by the needs and desires to attain some other, final objective. Air transport can facilitate, for example, the economic development of a region or of a particular industry such as tourism, but there has to be a latent demand for the goods and services offered by a region or by an industry. Lack of air transport, as with any other input into the economic system, can stymie efficient growth, but equally inappropriateness or excesses in supply are wasteful.

Economies, and the interactions between them, are in a continual state of flux. This dynamism has implications for industries such as air transport. But there are also feedback loops, because developments in air transport can shape the form and the speed at which globalisation and related processes take place. In effect, while the demand for air transport is a derived demand, the institutional context in which air transport services are delivered have knock-on effects on the economic system. These feedback loops may entail direct economic, political and social effects that, for example, accompany enhanced trade and personal mobility, but they may also be indirect, as for example through the impacts of air transport on the environment.

The analysis here focuses on one small sector, international commercial aviation, and on only one direction of causality, the implications of globalisation for this sector. Some related considerations are embraced where particularly important. For example, there is an increasing blurring of international and domestic air transport as airlines form alliances and invest in each other to form global networks. Indeed, the domestic and international air transport market within the European Union (EU) is *de facto* one market. Also, not all feedback loops are ignored, particularly when changes in air transport facilitate global trends that then, in turn, feed back on the air transport industries; migration of labour is one example of this.

4.2. Globalisation and internationalisation

The reasons for the contemporary globalisation processes from the latter part of the 20th century, and their larger implications, are much debated. Thomas Friedman (2005) for example, suggested the world is "flat", in the sense that globalisation has levelled the competitive playing fields between industrial and emerging market countries. The globalisation of trade, outsourcing, supply-chaining and political forces have changed the world permanently, for both better and worse. He also argued that the pace of globalisation is quickening and will continue to have a growing impact on business organisation and practice.This flattening is seen as a product of a convergence of the emergence of the personal computer and the fibre-optic micro cable, combined with the rise of work-flow software. He called this "Globalization 3.0", which is different from "Globalization 1.0" (when countries and governments were the main protagonists in globalisation) and "Globalization 2.0" (in which multinational companies led the way in driving global integration). Cairncross (1997) looked at it from only a slightly different perspective. The growing ease and speed of communication was seen as creating a world where distance has little to do with abilities to work or interact together. Much work that can be done on a computer may be done from anywhere; workers can code software in one part of the world and pass it to a company thousands of kilometres away that will assemble the code for marketing. With workers able to earn a living anywhere, countries will find themselves competing for citizens as individuals relocate for reasons ranging from lower taxes to nicer weather.

Much of these processes have been technology-driven, although facilitated by broad political shifts, such as the demise of the Soviet system, the gradual emergence of international free trade bodies, such as the EU and World Trade Organization, and reductions in global political tensions. Many of the technical changes have been in transport. In particular, there have been massive developments in the technologies used to transport information. While traditional transport analysts often see the "telecommunications revolution" as somehow different and outside their field of study, it is, in fact, the first major transport change since the widespread adoption of mechanised transport in mid-19th century. Air transport, although still a child of the mechanised age, has been closely linked with globalisation and the telecommunications revolution. It has been important in the opening up of labour markets, along the lines indicated by Cairncross, and in its role as a facilitator for the development of industry allowing the production and maintenance of cheap telecommunications hardware. It has also, in turn, benefited from the communications revolution in terms of air traffic control, navigation and safety enhancement, but also in making possible the logistics of bringing together the elements required in moving millions of people and tons of cargo across complex networks.

4.3. The basic features of international air transport

Historical perspective

Air transport has always been seen to have an inherently strategic role. It has obvious direct military applications, but it is also highly visible and, for a period, and in some countries still, was seen as a "flag carrier", a symbol of international commercial presence. From their earliest days, airlines were seen as having potential for providing high-speed mail services, and subsequently medium- and long-term passenger transport. Technology now allows the transportation of much larger cargo payloads in a more reliable way. These strategic functions were used to pursue internal national policies of social, political, and economic integration within large countries such as Canada, the US and Australia, but also took on international significance from the 1930s within the imperial geopolitical systems focused mainly on the UK, France, Germany and other European countries, when technology allowed for intercontinental services to be developed.

Air transport was highly regulated and protected in this environment, to be used as a lever for larger political and economic objectives. But even in these roles, its importance was small. British Imperial Airways, for example, only carried about 50 000 passengers to the colonies in the 1930s, a figure hidden in the public media coverage given to the importance of colonial air networks. Technology shifts as an offshoot of military developments in World War II changed this with the introduction of planes with far longer ranges, faster speeds, enhanced lift and increasing ability to cope with adverse weather conditions. Air traffic control, navigation, communications and airport facilities have also improved considerably, and more recently, the underlying management structure of the supplying industries has enhanced efficiency.

The Chicago Convention of 1944 confronted the new international potentials of civil aviation and initiated an institutional structure that laid common ground rules for bilateral air service agreements (ASAs) between nationals. The result, however, while providing a formal basis for negotiation, was essentially one of protectionism, with pairs of countries agreeing on which airlines could offer services between them, the fares to be changed and, often, how the revenues could be shared. Added to this, with the major exception of the United States, most international airlines were state-owned flag carriers that operated to fulfil often vague, national objectives of prestige, as well as linking colonies. Internal markets within countries were regulated in similar fashion, and it was not uncommon for wealthier countries to have one airline to provide primarily domestic and short-haul services, and one for long-haul, international markets.

The breakdown of the domestic regulatory structure within the United States from the late 1970s (Morrison, and Winston, 1995) provided a demonstration for other countries to follow in deregulating their own domestic regimes. It also led to the (initially unsuccessful) US initiative from 1979 to liberalise international services on a bilateral basis, based on a common "Open Skies" recipe to bring about wider reforms. This was coupled with more generic moves towards withdrawal of government in market-oriented countries such as New Zealand and the United Kingdom, that saw airports and air traffic control privatised, or at least operated on a more commercial footing. The move to a single European market within the EU from 1992 represented a broader trend, both in terms of the sectors and the geography involved, towards market liberalisation of air transport infrastructure, as did the collapse of the Soviet economic system. Not all countries moved completely in this direction; the United States for example, rather perversely, continued with its policy of air traffic control being a state-owned, tax-financed monopoly and airports, with few exceptions, being owned by local governments (Button and McDougall, 2006).

There has been almost universal tightening of regulations that run counter to market liberalisation in what the United States calls "social regulation" and Europe calls "quality regulation". This concerns such matters as the environment, safety, security, and consumer and labour protection. These are areas that have been traditionally dealt with at the international level by the International Civil Aviation Organization (ICAO) set up under the Chicago Convention, in accordance with international accords such as the Warsaw Convention, that dates back to 1929 and deals with liabilities in the case of accidents.[2] More recently, regional or national actions have also taken on international significance (*e.g.* the extension of carbon trading within the EU to embrace all air transport, and the US introduction of stricter security measures, such as the provision of passenger information for all flights into the country).

Modern aviation

The modern air transport industry is thus one that increasingly operates within a liberal market context. While government controls over fares, market entry and capacity continue in many smaller countries, they are gradually and almost universally being removed or relaxed. International controls under the bilateral ASA structure are increasingly moving towards broad Open Skies formulations, allowing free provision of services between countries. However, progress on an open market, where nationality of ownership of airlines is unrestricted, is coming more slowly. The EU area[3] has effectively been the largest international free market in air transport services in the world since 1997, and this has grown as the EU has expanded. The supply and operation of air transport infrastructure is also becoming more market driven with privatisation of airports and air traffic control systems, or the use of franchising mechanisms to involve private capital and expertise (Button, 2008). It is also becoming more co-ordinated.[4]

The air transport industry is now large – it accounts for about 1% of the GDP of both the EU and the United States – and is vital in many industries such as tourism, exotic plants and fruits, and high technology.[5] It is an important transporter of high-value, low-bulk cargoes. International aviation moves about 40% of world trade by value, although far less in physical terms. The market is served by a diversity of carriers, some specialising in long-haul international routes and others in short-haul markets.[6] Table 4.1 offers some indication of the scale of larger airlines involved. To handle the interface between land and air transport, the world's major airports have grown to handle millions of international passengers (Table 4.2) and tons of cargo[7] each year, and many have been significant catalysts facilitating

Table 4.1. **Top ten international airlines by scheduled passenger-kilometres**

2007

Airline	Scheduled passenger-kilometres (million)
Air France	112 689
British Airways	111 336
Lufthansa	109 384
Singapore Airlines	87 646
American Airlines	81 129
United Airlines	74 578
Emirates Airline	74 578
KLM	71 761
Cathay Pacific	71 124
Japan Airlines	59 913

Source: International Air Transport Association.

Table 4.2. **Top 20 international airports by passengers**

2007

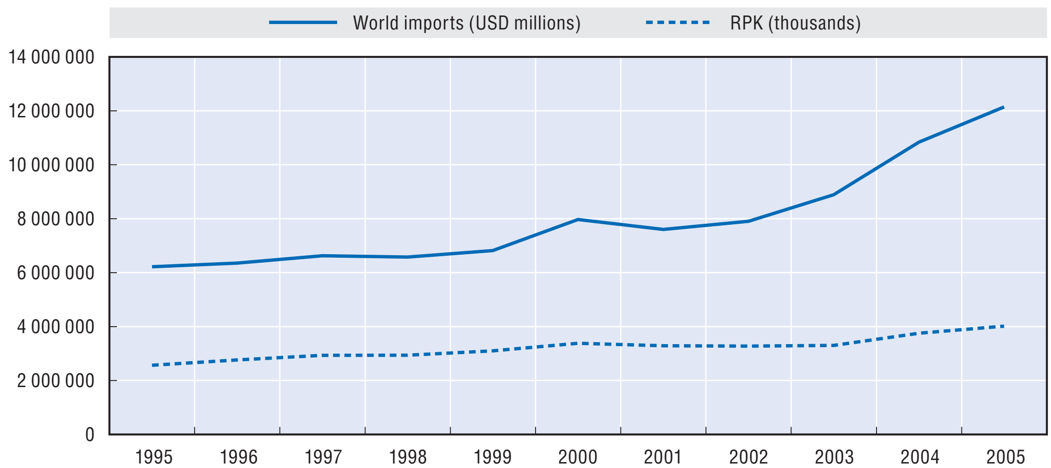
Airport	International passengers
London Heathrow Airport	62 099 530
Charles de Gaulle International Airport	54 901 564
Amsterdam Airport Schiphol	47 677 570
Frankfurt Airport	47 087 699
Hong Kong International Airport	46 281 000
Singapore Changi Airport	35 221 203
Narita International Airport	34 289 064
Dubai International Airport	33 481 257
Suvarnabhumi Airport	31 632 716
London Gatwick Airport	31 139 116
Incheon International Airport	30 753 225
Madrid Barajas International Airport	29 339 784
Kuala Lumpur International Airport	26 938 970
Chatrapati Shivaji International Airport	25 360 860
Munich Airport	23 988 612
Dublin Airport	22 339 673
John F. Kennedy International Airport	21 521 711
London Stansted Airport	21 201 543
Taiwan Taoyuan International Airport	20 855 186
Malpensa International Airport	20 627 846

Source: Airports Council International.

the growth of modern high technology industries and tourism. In 2008, passenger air services globally linked around 15 500 airports, with the fastest growth in air services over the past two decades being in the Europe-Asian Pacific markets.[8]

If one looks at the basic aggregate data, there is clear general link (although causality is another matter) between the growth in global GDP and international trade and air transport. Figure 4.1 provides aggregate information on the trends in world trade and international air transport from the mid-1990s. A similar picture emerges if one plots world GDP against air traffic. In each case, air volumes have risen albeit slightly less rapidly than GDP. Figure 4.2 gives details of the shorter-run trends in growth in world trade and air freight traffic volumes, and shows the common cyclical effects. While the ups and downs broadly coincide, little by way of a consistent lag structure emerges.

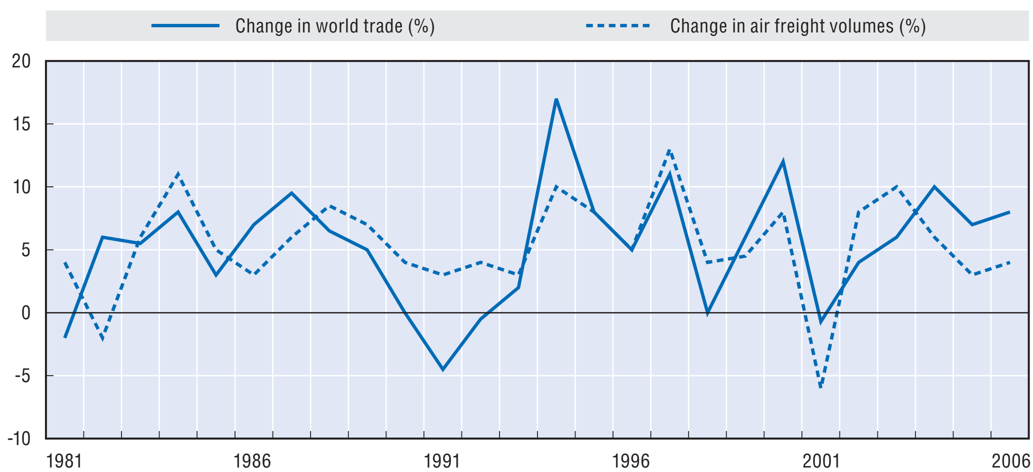
Figure 4.1. **World international trade and airline revenue passenger-kilometres**



Note: RPK are revenue passenger-kilometres.

Source: International Civil Aviation Organisation.

Figure 4.2. **Short-term links between world trade in manufactures and air freight volumes**



Source: International Civil Aviation Organisation.

4.4. Effect of globalisation on airline markets

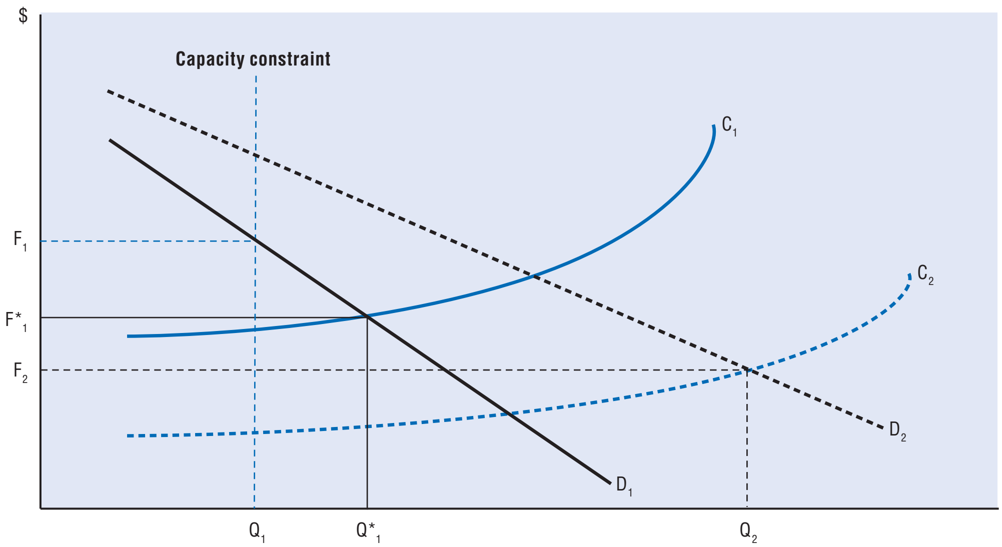
The implications of globalisation in its many manifestations have been profound for the international air transport industry, not just on the demand side – where the scale, nature and geography of demand in global markets has led to significant shifts – but also on the supply side, where implicit and explicit international co-ordination of policies by governments (*e.g.* regarding safety, security and the environment) and the private sector (*e.g.* the internationalisation of airframe and aero-engine production) have affected the institutional and technological environment in which air transport services are delivered. Some of the most important of these interactions are addressed below.

4.5. Institutional changes in airline regulation

Fares

The restrictive bilateral ASAs that typified the institutional structure of international airline markets before the advent of Open Skies had a number of adverse effects on the efficiency of supply and levels of benefits society could reap from air travel. These effects are not easy to isolate and to completely quantify in a simple way, but Figure 4.3 offers a general representation of the issues that are involved. In particular, it highlights the potential fare- and output-implications of the various types of regulatory regimes that have been common in the past and are gradually emerging as globalisation is taking place.[9]

Figure 4.3. **The simple economics of Open Skies policies**



Source: Based on Button (2009a).

The initial position of the demand curve for international services between two countries, **A** and **B**, under the pre-1980s regulatory regimes that typified international trade in air services is assumed linear and shown as D_1 in the figure, and the average cost curve per passenger, which for simplicity is assumed to rise more than linearly with quantity, as C_1.[10] Market forces, however, because of institutional interventions in place, did not determine fares and capacity in these regulated markets. Capacity under this system was limited (seen as the capacity constraint in the figure) and fares were regulated. If we assume that the terms reached under the bilateral agreement between **A** and **B** regarding fares allowed for at least cost recovery by the partners' airlines, this implies a fare level up to F_1.[11] The removal of both this capacity constraint and of negotiated pricing, as happens under a typical Open Skies arrangement, results in competition for air services, and a move toward cost-recovery pricing strategies by the carriers. This would reduce fares to F^*_1.

Open Skies policies, coupled with allowing strategic alliances, not only remove the capacity constraint, but also affects both the demand and supply curves for international air travel between **A** and **B**. The ability of airlines to more effectively feed their transatlantic routes and co-ordinate their activities, through the restructuring of their business and networks will reduce the average cost of carriage to C_2 in the figure. The effect is often reinforced due to downward pressures on costs because, although not strictly part of the Open Skies framework, the wider competitive environment within Europe, and the privatisation of many carriers, by heightening commercial pressures, reduces the amount of static and dynamic X-inefficiency in the airline industry. In other words, there is the combined pressure of both free airline markets across the Atlantic and within the two feeder markets at either end.

The Open Skies policy also has stimulation effects on the demand side. By allowing more effective feed to the long-haul stage of transatlantic services through the concentration of traffic at international hub airports, it increases the geographical market being serviced and also generates economies of scope and scale. The larger physical market demand, combined usually with the improved quality of the "product" that accompanies more integrated services, such as code sharing, interchangeable frequent flier programmes, common lounges and through baggage checking, pushes out the demand for international air services to D_2 in Figure 4.3.

The outcome of lowering costs and the outward shift in demand is that the number of passengers travelling increases to Q_2 and, because Open Skies allow price flexibility, the fare falls to F_2 in the way our example is drawn. It should be noted that fares might not actually fall; indeed, they may rise as the result of the freer market conditions. The reason for this is that the outward shift in demand reflects a better quality of service – *e.g.* more convenient flights, transferability of frequent flier miles and seamless ticketing – and that, on average, potential travellers are willing to pay more for this than the generic portfolio of features that were found under the old bilateral ASA structure. (In Figure 4.3, the shift out in demand may counteract the fall in costs resulting in $F^*_1 < F_2$.)[12]

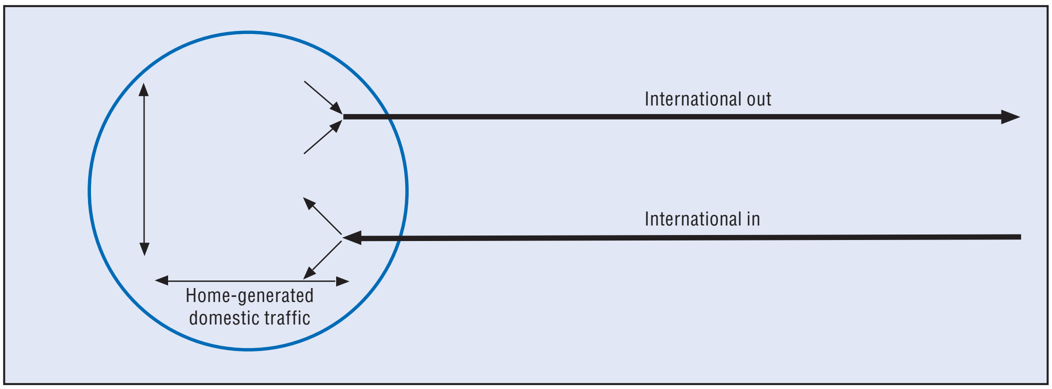
What does become pertinent, however, is the extent to which the fare structure is influenced by the market power of the airlines. The analysis presented in Figure 4.3 assumes that in the Open Skies environment, fares are set to recover costs; in other words, competition and mergers policy can effectively fulfil the role of regulation. This raises issues as to the nature of markets that are generally served by a relatively small number of large network carriers, often involving alliances. A degree of competition exists among the various alliances for the trunk hauls market, and there is also competition at either end of routes with many other (including low-cost) carriers competing for passengers in overlapping feeder and origin-destination traffic to international hub airports. There are also theoretical reasons derived from game theory suggesting that the outcome in a market with three players approaches that of competition. Nevertheless, each alliance by dint of product differentiation (*e.g.* they serve different airports) inevitably enjoys some degree of monopoly power. This could lead to fares higher than F_2 and a smaller output than Q_2, with consequential reductions in consumer surplus.[13]

The effects of a full open aviation area – a genuine open market involving capital mobility as well as simply the ability to sell final airline services in both **A** and **B**'s markets – can be seen as an extension of this framework. Free capital markets, together with the ability to have more flexible feeder networks owned by the truck carrier at both ends of transatlantic services, would further lower costs and may generate additional economies of market presence, although the latter effect is unlikely to be large. The ability to invest across national boundaries provides for short-term support in situations of local market fluctuations and more integrated long-term planning of infrastructure; it would in effect produce air networks akin to those enjoyed by US railroads that can move investment funds across states rather than have separate rail companies each with limited intra-state operations. In terms of Figure 4.3, it would mean lower fares and larger air traffic volumes with concomitant increases in society benefits.

Linkages between domestic and international air services

There is a further aspect to liberalising international services stemming from the interaction of domestic air transport with international markets. The growth of international trade in general that accompanies globalisation obviously leads to more demands for international air services, and changes in the air transport regulatory environment has added to this effect, but trade also increases demands for domestic transport, including air services, and especially so within larger countries. The economic structures required to produce the additional exports, and to distribute additional imports, also need supplementation by further layers of domestic economic structures to satisfy the new internal demands that come from a more prosperous economy. Figure 4.4 offers a stylised representation of the types of airline markets affected by an increase in globalisation.

Figure 4.4. **Implications of globalisation on air transport markets**



International markets

Globalisation inevitably means higher demands for the movement of people and goods among countries which, given the largely commercial orientation of modern air transport, will bring forth additional supply. Given the economies in air transport, most notably the decreasing costs involved in infrastructure use, this in turn can bring about further fare reductions. In addition, international trade increases global income that results in more international tourist travel and shipment of higher value goods, such as exotics, in which air transport often has a comparative advantage. Finally, globalisation entails greater factor mobility, with an increase in both temporary and permanent migration. Over longer distances, international air transport is normally the cheapest mode for this.

Domestic feeder services

International air transport enjoys significant economies of scale, scope and density. The main international airports, and their associated long-haul carriers, benefit from feeder services that take domestic traffic to and from more distant locations within a country. Increasingly, major international airlines operate "dog-bone" networks (Figure 4.5) with their trunk haul operations between international city hubs in countries **A** and **B** supplemented by local services at each main hub that the international carriers either provide for themselves or (and mainly in the non-home country) by partners of various kinds.[14] Increases in international air transport inevitably have implications on the demands for feeder air services as well as for the main international service. In some countries, these feeder services may involve collecting and distributing passengers from nearby countries as well as domestically.

Figure 4.5. **"Dog-bone" international air transport network**

Trade-generated domestic air services

Globalisation involves increased economic activity, and this in turn leads to the need for more domestic transport as part of the enlarged value chain. In countries with a small land mass, much of this additional transport is provided by surface modes that enjoy a comparative advantage over shorter distances, although adverse terrain may give a comparative advantage to air transport in some contexts. In larger countries, however, personnel and freight movements where speed is important will require more air transport as the globalisation process takes place. This is a purely domestic implication of increased globalisation, and may be quite remote from the international air transport market.

Income-generated domestic air services

Globalisation leads to higher income and consumption in each country (see again Figure 4.4), although the affluence is not spread evenly. Air transport facilitates some of this consumption. Again, in larger countries, as incomes rise, people spend more on domestic vacations and make more frequent visits to family and friends. Again, as with trade-generated domestic air movement, this internal activity may be remote economically and institutionally from international movements, but it is nevertheless a result of it.

From an analytical perspective, it is convenient to isolate these four distinct types of air transport influenced by globalisation trends, but from an empirical basis, it is virtually impossible to isolate their relative magnitudes from available data. There are two major problems. First, the air transport sector provides network services, and any shock to one link or node has implications throughout other parts of the network. This is not simply a matter of additional demands on an international route affecting the domestic feeder services of that airline, but rather it has ripple effects across the networks of all carriers in the domestic market because aircraft carrying feed traffic also carry purely domestic traffic. Thus, a change in international demand affects the basis of competition among all domestic services. Disentangling these effects even for a marginal change in the international market affecting one airline and one route is empirically impossible at present, let along larger changes involving numerous international routes.

Second, there are the problems in defining the counterfactual. At the simplest intellectual level there is the challenge of saying what would have happened if the new trades with their associated demands on air transport had not arisen; in other words, if past trends had continued or alternative background variables had changed. Technically one could compare a simple extrapolation of the past with actual events. Predicting economic growth is, however, a treacherous task. Where there have been partial attempts to look at the wider implications of growth in international air traffic as the result of some external change, the ripple effects through the network were frequently large. For example, the Brattle Group (2002) study of the effects of relaxing entry to the North Atlantic air traffic market suggested significant implications for demand on the internal European market, and this did not allow for any trade- or income-induced effects.

Hub-and-spoke networks

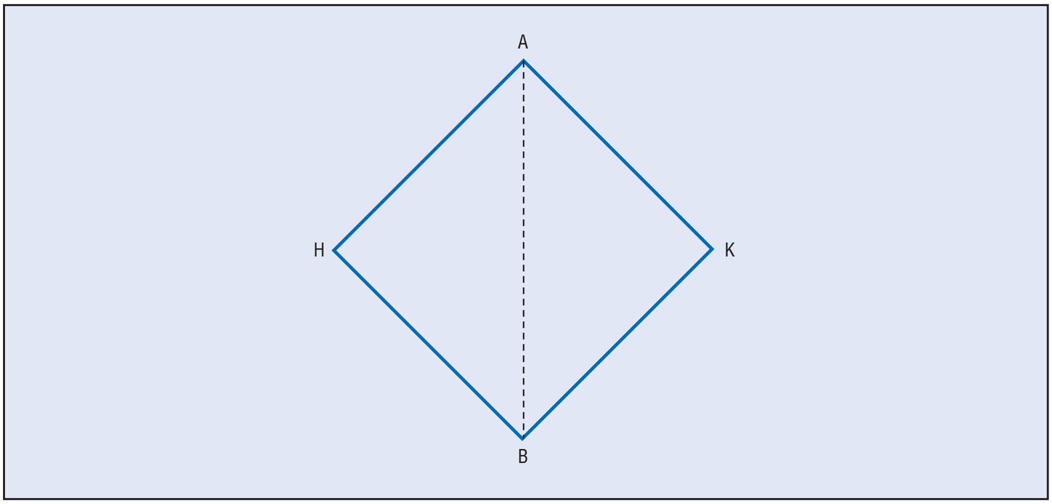
Following the adoption of the Chicago Convention, there was (as illustrated above) no market mechanism that led to economically efficient prices and frequencies. As a result, costs were high and prices did not reflect supply and demand. Customer preferences, frequencies and routes operated were a political issue rather than an outcome of market forces. Already in 1960, *The Economist* wrote: "The basic trouble remains that the world has too many airlines, most of them inefficient, undercapitalised and unprofitable."

Also within the United States markets were closed. The Civil Aeronautics Authority, later renamed as the Civil Aeronautics Board (CAB), determined routes and regulated fares in the US to protect the carriers from "destructive" competition and protect consumers, while allowing airlines to obtain a reasonable return on ticket sales. During the 1960s and 1970s it became more and more clear that government regulations were too restrictive for the airline industry. In 1978, the Airline Deregulation Act was passed. All restrictions on domestic routes, fares and schedules were to be removed. Increased airline operating efficiency and competition were expected to benefit both airlines and passengers.

Following this deregulation of the US aviation market, there was a large-scale entry of new carriers, followed by the rapid departure of almost all of them. Immediately after the deregulation, there were about 40 major carriers, while some 15 years later, there were 6 or 7. It thus appears that competition did not increase following the deregulation, albeit fares decreased in real terms since deregulation. The decline in fares from 1976 to 1985 represented a savings of USD 11 billion to passengers in 1986 (Kahn, 1988). The disciplining effect of competition was, however, geographically unevenly distributed. Airlines were free to operate their most efficient networks, and most airlines decided to operate a hub-and-spoke network, which allows for the exploitation of density economies and reduces fixed cost per link. The number of competitors may have actually decreased on routes starting or terminating at a hub. On routes between hubs and on long-haul, connecting flights, there may, however, be fierce competition. These developments meant that passengers in long-haul markets within the US, and in international markets, often had to make detours, *i.e.* use indirect flights with relatively long flight distances and two take-offs.

The hub-and-spoke systems allow for the creation of so-called fortress hubs. Zhang (1996) showed that airlines using hub-and-spoke networks may not have an incentive to invade each other's network, because this may lower profits in the "original" network. Zhang used the network depicted in Figure 4.6 to make this point, where Airline 1 uses H as a hub, serves AH and BH directly, and AB indirectly, while Airline 2 uses K as a hub, serves AK and BK directly, and serves AB indirectly. This network is not realistic since the market between hubs is missing, but similar results are obtained when this market is included.

Figure 4.6. **Network configuration**



When Airline 1 invades markets AK and BK, the price decreases because of increased competition. Airline 2 responds by increasing its output in the AB market and lowers average costs on the AK and BK links because of density economies. Airline 1 loses output in AB market (Airline 2 captures part of the AB market of Airline 1), so that average costs on the AH and BH links increase. As a result, flights in the AH and BH markets get more expensive, and the number of passengers in these markets decreases. Because output decreases in the original network (HAB), the additional profits of the new AK and BK markets have to be balanced against losses in the original network. When density economies are strong (effects mentioned above are strong) and willingness-to-pay is high, attacking the network of Airline 2 decreases profits for Airline 1. Therefore, entry in a competitor's network may lead to lower overall profits. Instead, more often than not, airlines choose to enter alliance agreements rather than to enter a competitive game. This means that in the 1980s and 1990s, there was a geographical concentration of airline networks around a limited number of hub airports. Goetz and Sutton (1997) found that from 514 locations with one or more regular connections in 1978, 167 locations lost these connections in the period until 1995. Only 26 new locations got regular connections, and connections to 77 locations were subsidised by the government. Again, this implies that many passengers on long-haul or international flights necessarily fly on indirect flights, resulting in relatively long flights.

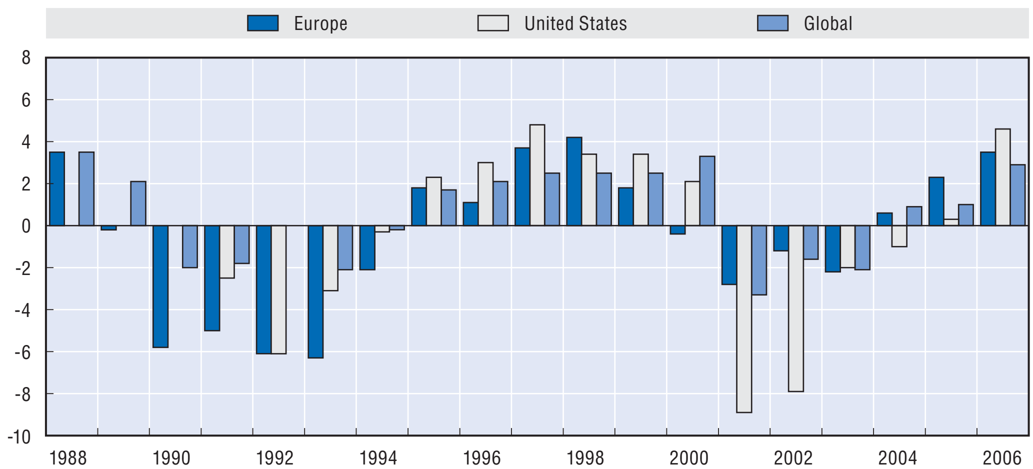
The deregulation of the EU aviation market was far more gradual compared to the US case. But the outcomes are similar. Many European airlines were state-owned companies with radial networks. The potential for transfer existed, but airlines did not fully exploit the possibilities offered by transfer traffic (Dennis, 1998). A shift from a radial network to a hub-and-spoke network by a better timing of flights to allow for more convenient transfers allows for the exploitation of density effects. Airlines with hub-and-spoke networks did not invade each other's networks, so in the EU there was also concentration: some airlines went bankrupt (Swissair, Sabena), while other airlines entered alliance agreements (the Air France-KLM merger being the most far reaching). In the most profitable international markets (between Europe and the US), concentration becomes apparent through the formation of various alliances. Airlines enter such agreements to exploit density effects and reduce competition. For international passengers, alliances can be beneficial. Before alliances were created, European airlines had restricted access to US destinations. Following an alliance agreement with a US partner, European airlines could offer far more destinations to its passengers within the US. Again, such international passengers more often than not fly indirectly. For instance, about 65% of KLM's passengers are international passengers transferring at KLM's hub (Amsterdam airport, Schiphol).[15] Thus, alliance agreements led to growth in international markets, measured in passengers and in passenger-kilometres due to longer distances.

Airline profits

That the financial conditions of airlines are strongly influenced by international economic trade-cycle effects is clearly seen in Figure 4.7, which shows net operating

Figure 4.7. **Operating margins of airlines**

1988-2006



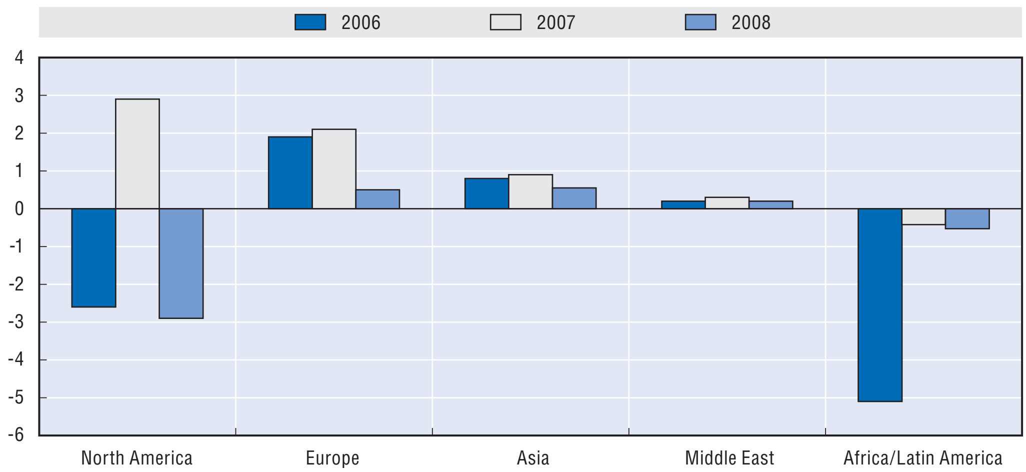
Note: A lack of a bar indicates a missing observation and not a zero operating margin. The data refer to members of the various associations that provide financial details of associated airlines. Memberships of the various reporting bodies vary over time and thus the reported margins reflect the associated carriers at the time of reporting.

Sources: Boeing Commercial Airplane, Association of European Airlines, Air Transport Association of America, International Air Transport Association.

margins, although other financial measures exhibit similar patterns. There have been demonstrable downturns in the past coinciding with international financial crises (the early 1990s) and major international incidents (the terrorist attacks on New York and Washington DC and the SARS epidemic). The figure illustrates the consistency with which these types of factors affect all air transport markets, albeit with different intensities. But, in addition, even during relatively good times, the returns earned do not compensate for the losses, even assuming a zero operating margin is viable, which is unlikely.

The financial situation of airlines as of July 2008, with serious macroeconomic problems in the US economy and slowing of many other economies, led IATA to forecast potential global losses of USD 6.1 billion for the airline industry in 2008 due to higher input prices and a downturn in the business cycle.[16] Within these global trends, however, there have also been significant variations in profitability across regional markets (Figure 4.8), which in part reflect the maturity of markets, but also the extent to which individual countries have liberalised their international ASAs.

Figure 4.8. **Airline profitability by region**



Note: 2008 data are from the IATA June 2008 provisional forecasts.

Source: IATA.

Elementary economic theory tells that, when there are no fixed costs, then bargaining between suppliers and customers will ensure that prices are kept to a minimal level that allows suppliers to recover all costs over the long term. When there are no fixed costs, the marginal cost of meeting customer demand represents the entire costs of production. The problems come when there *are* fixed costs.

The traditional view of fixed costs was developed when the bricks, steel and mortar of industrial plants had to be paid for. The world has changed, and with service industries, and especially those involving scheduled services, the fixed costs are somewhat different. While airlines do use expensive hardware, this is not their underlying fixed cost problem. Indeed, the largest costs of airlines has traditionally been their labour, although rising fuel prices has changed this somewhat.[17] These in the traditional sense are variable costs. Even aircraft are now seldom owned by the carriers, but are leased, sometimes (it is illegal in the United States) on a wet-least that includes crew. The result is that airlines are increasingly becoming "virtual carriers" that act to bring together packages of services owned by others and thus are encumbered with few fixed costs themselves in the traditional economic sense.

Fixed costs in a modern service industry, therefore, can take an entirely form. An airline is committed to a scheduled service some six months or so before the flight: it is committed to have a plane, crew, fuel, gates, landing and take-off slots, etc., available at a scheduled time and designated place. This does have the advantage that fares are often collected before the airlines has to provide the service, but in a highly competitive market, this is generally more than offset by the limited amount of revenue that is ultimately collected.

Airlines in deregulated markets engage in price discrimination and charge passengers different fares to try to extract as much revenue as possible. In generally, this means that lower fares are offered initially when a flight is some way off, because leisure travellers are willing to pay less for a seat and are more flexible in their scheduling and will seek lower fares if available. They are caught early by the airline. Towards the time of take-off, fares rise as last-minute travellers, often business travellers, seek seats. These people are less sensitive to fares, meeting a last-minute business deadline can make or break a deal, and tax deductions are normally allowed for the offsetting of higher fares. The problem is that with a fixed schedule in a competitive market, the various airlines set take-off times for each destination at about the same time. These leads to intense competition to fill seats and forces fares down to levels that do not allow all the costs of service to be met.[18] It is worth filling a seat once it is there with anyone willing to pay for the additional costs of handling.

The problem is exacerbated when taken over a business cycle, and when there is new entry to markets. In the longer term, it leads to instability in the market as airlines enter and leave. It also leads to sub-optimal levels of investment, despite excess capacity during peaks in the cycle. When full costs are not recovered, and an airline ultimately withdraws a service or goes out of business, is known as the "empty core problem" in economic analysis. It is neither a new concept (developed in the 1880s by a largely forgotten Oxford economist, Francis Edgeworth), nor is it one that has limited application. In the long term, as potential investors become aware of this problem, they will reduce or cease to put new capital into the industry. However, the complexity of the underlying economic model has hindered the communication of the issue to decision makers.[19] This situation also runs counter to some traditional views of competition policy that hold that there can "never be too much competition".

The current situation, with large parts of the airline industry haemorrhaging cash, while widespread, has impacted individual markets differently. The domestic US market, which is possibly the most competitive in the world, has been the hardest hit, and although low-cost domestic carriers, such as Southwest, has been adding some routes, the vast majority of airlines have been retracting, pulling services and some (such as ATA Airlines, Skybus, and the legacy airline, Aloha) have simply vanished from the market. European airlines (although some like Ryanair, British Airways and Air France have been recording profits) are also being badly hit financially by a rise in fuel cost, as are carriers elsewhere.

The airlines have historically reacted to the situation in a number of ways, essentially trying to glean a degree of short-term monopoly power wherever and whenever the opportunity has arisen. Many of the initiatives have been extensions or modifications to existing strategies that have been used in previous market downturns, but which, as has been seen, have not prevented long-term financial problems for the airlines. The measures that have been taken, and in turn influenced the international air transport market include:

Loyalty payments

Major international partners operate frequent-flier programmes that reward regular customers with free flights and bonuses, such as upgrades to higher classes of service and access to airport lounges. The "miles" earned on carriers within airline alliances are normally interchangeable, albeit not perfectly, providing passengers with an extensive range of services for redemption. More recently, it has been possible in many programmes to obtain miles with non-airline purchases such as credit card use, car rentals and dining. The airlines effectively sell their miles to other industries that then give them as rewards to their own customers – the value of this business to the airlines was about USD 3 billion in 2005. The long-term problem is that there is an inherent tendency for the "currency" to be debased, with ever-increasing numbers of miles being required to buy flights and the number of flights for sale shrinking. The impact has been that loyalty incentives have been weakened, reducing the incentive to make multiple trips by one carrier.

Cost cutting

To gain an advantage over competitors, many airlines have sought to reduce costs. If other carriers cannot match the lower costs, then either fares remain at the competitive level of the higher-cost airlines, allowing the low-cost carrier to earn a margin towards fixed costs, or the higher-cost airlines leave the market. This has been the strategy of low-cost international airlines like Ryanair in Europe. The low-cost carrier business model, with numerous variants, centres on the ability of an airline to undercut its rivals, and thus obtain market power. This generally entails standardisation in its operations (the use of a common family of aircraft and a homogeneous network of services), maximising the use of its labour force, serving less congested airports, providing a "no-frills" service on the plane and at the airport, limiting methods of booking to the web, charging for non-core services (such as refreshments) and offering only one class of service. Such measures can reduce costs by 30% or so compared to those of traditional airlines. Low-cost carriers have thus trimmed their costs considerably and the traditional carriers have been forced to follow (Morrison, 2001), often going through bankruptcy, by re-negotiating labour contracts, replacing older aircraft with fuel-efficient planes, increasing automation and unbundling some services. There are technical limits, however, to which viable and safe services can be offered and, in many cases, airlines may well be approaching these.

There are also more fundamental issues. The successful low-cost carriers have tended to be the first in the market and to enjoy a "first mover advantage". The list of failed low-cost airlines in Europe (Table 4.3) and elsewhere, however, is long. One problem is that as low-cost carriers have expanded, they have moved into increasingly thin and less suitable markets for their style of operations. Additionally, as more carriers have emerged, so competition between low-cost airlines has grown, hitting their bottom lines (Button and Vega, 2007). The traditional airlines have also become leaner and more skilled at resisting the challenges associated with low-cost carriers trying to enter their routes. While the low-cost model may continue to produce winners, it does not solve the problem of market stability. Even if all airlines were low-cost, competition among them would erode their revenue streams.

Subsidies

Subsidies have long been used to recover capital costs. One argument is that once an investment has been made, it becomes economically efficient to maximise its use subject to

Table 4.3. **European low-cost carriers that ceased to exist**

2003 to 2005

Aeris	BuzzAway	Hellas Jet
Agent	Dream Air	Hop
Air Bosnia	Duo	Jet Magic
Air Andalucia	Europe DutchBird	Jetgreen
Air Catalunya	EastJet	JetsSky
Europe Air Exel	EU Jet	JetX
Air Freedom	Europe Exel Aviation Group	Low Fare Jet
Europe Air	Fairline Austria	Maersk Air
Air Littoral	Fly Eco	Now
Air Luxor	Fly West	Silesian Air
Air Madrid	Flying Finn	Skynet Airlines
Air Polonia	Free Airways	Spirit Of Balkan
Air Wales	Fresh Aer	Swedline Express
Airlib Express	Germania Express	V Bird
BasiqAir	GetJet Poland	VolareWeb
BerlinJet	Go Fly	White Eagle
Bexx Air	Goodjet	Windjet

Note: Most of these airlines operated for a period and then went into bankruptcy. Some, such as Go Fly and BuzzAway, merged with successful low-cost airlines. In a few cases, the airline was registered but never offered actual services.
Source: www.discountairfares.com/lcostgra.htm.

the willingness of users to pay their incremental costs. The current trend to unbundle attributes of an airline service – such as charging for food and second checked bags by some airlines – attempts to separate the activities in which the fixed costs are concentrated and to charge explicitly for the incremental costs. The fixed costs in this sense can then be isolated, and the other attributes – the food and bag service – are sold in the market at competitive prices. Direct subsidies are then used to cover the fixed costs that cannot be recovered from customers. In the airlines case, however, where the fixed cost is that of a commitment to a schedule, it is difficult to isolate the fixed cost in the traditional sense. Further, there is the generic problem that subsidies reduce the incentive toward efficient production. If the recipient knows that losses are going to be covered by external sources, there is less incentive to restrain costs – a moral hazard issue. Further, there is less incentive to provide the goods and products that customers seek. These problems have led to considerable reductions in subsidies for international airlines services.

Institutional market power

Institutional market power is engendered either by government actions (as with the ASA that exist in non-Open Skies markets) or by suppliers erecting barriers to competition. Market power may also arise naturally when suppliers merge or a dominant player exists. In the context of airlines, the domination of certain hub airports by network carriers, such as Delta at Atlanta and Northwest at Detroit and Minneapolis airports in the US, has given them some degree of market power (US Department of Transportation, 2001). Airlines have sought to grow by mergers and through the formation of cartels or strategic alliances. While there are many alliances, often involving a single route and a pair of carriers, the major international traffics, about 60% of all passengers, are increasingly being carried by members of three global alliances: Oneworld, SkyTeam and Star Alliance (Table 4.4). Similar cartels are found in international air cargo, *e.g.* the WOW Alliance and SkyTeam Cargo.

Table 4.4. **Strategic Airline Alliances**

	Star Alliance	SkyTeam	Oneworld
Passengers per year	455.5 million	428 million	319.7 million
Destinations	975	841	692
Global market share	25.1%	20.8%	14.9%
Participants	Adria Airways	Aeroflot	American Airlines
	Air Canada	Aeroméxico	British Airways
	Air China	Air Europa	Cathay Pacific
	Air New Zealand	Air France	Finnair
	ANA	Alitalia	Iberia
	Asiana Airlines	China Southern	Japan Airlines
	Austrian Airlines	Continental	LAN
	Blue1	Copa Airlines	Malév
	BMI	Czech Airlines	Qantas
	Croatia Airlines	Delta	Royal Jordanian
	EgyptAir	Kenya Airways	
	LOT Polish Airlines	KLM	
	Lufthansa	Korean Air	
	SAS	Northwest	
	Shanghai Airlines		
	Singapore Airlines		
	South African Airways		
	Spanair		
	Swiss International Air Lines		
	TAP Portugal		
	Thai Airways International		
	Turkish Airlines		
	United Airlines		
	US Airways		
	American Airlines		

Source: Web-sites of the different airline alliances.

Monopoly power associated with airlines' own actions has traditionally been a concern of government, and, in particular, mergers and competition agencies. Regulation has been used to prevent an institutional monopoly from exerting excessive market power, *e.g.* by controlling fares as under the traditional ASA regimes, or by preventing mergers or cartelisation. At the extreme there has been state ownership. Given the state of the finances of many major international carriers, however, the amount of market power enjoyed as a result of alliances and mergers can seem rather limited, and is unlikely to increase significantly within liberalised markets.

Long-term contracts between supplier and customer

Negotiating a long-term cost recovery contract with a major customer, at the time capacity is introduced, can help ensure an airline a guaranteed revenue flow that will cover most of its capital outlay. Such arrangements, while relatively common in other industries, are not often pursued by passenger airlines, although they are more common in the freight sector. Scheduled passenger airlines find it difficult to do because they guarantee a service ahead of time and then effectively become common carriers of the traffic willing to pay for flights. In some US cities, groups of business people have, however, tried to ensure regular air services with guarantees of adequate patronage for an initial period. In Wichita, Kansas, some 400 businesses raised USD 7.2 million to attract carriers. Air Tran started operations in

May 2002 with services to Atlanta and Chicago's Midway airport. The agreement included up to USD 3 million to cover losses in its first year and USD 1.5 million in the second. Similarly, Pensacola, Florida, raised USD 2.1 million from 319 businesses to attract Air Tran while companies and individuals in Stockton, California, bought USD 800 000 of prepaid tickets to attract American West (Nolan *et al.*, 2005).[20] In a different context, the US's Civil Reserve Air Fleet programme may be seen as a long-term contract to buy military support from commercial airlines.

Vertical integration

If one link in the overall air transport value chain fails to recover its full long-run costs, but the chain in its entirety is viable, then one option is for the loss-making element to vertically integrate with profitable links, or to in some way be subsidised by them. Historically, airlines such as American initiated the computer reservation system (CRS), Sabre, that was subsequently separated but provided a revenue flow to the airline. There were historically strong ties between Boeing and Pan American, and between Lockheed and TWA in terms of aircraft development and use. Outside the US, airlines have a major stake in the UK's public-private air traffic control system – NATS – and airlines like Lufthansa have invested in catering and in railway services. While in some cases these activities produce direct revenue flows – American Airlines enjoyed considerable incomes when it owned a CRS system – such involvements up and down the chain offered an assurance of stable cost and other controls over inputs that potentially give a carrier a cost advantage over competitors. The problem is that airline management is often not adept at managing non-airline activities. United Airline's ownership of Hertz rental cars in the 1980s is a classic case of the problems encountered. This inevitably limits the extent to which airlines should become integrated with other elements in the supply chain.

Discriminate pricing

The US domestic air transport market developed and refined price discrimination (the charging of customers different fares according to their willingness to pay) that has now become almost universal. There are several forms of price discrimination deployed by airlines, but yield management – essentially dynamic temporal pricing – is the most potent (Dana, 1998). An airline revises the fare charged as seats are filled. The advent of sophisticated information systems allows an airline to offer seats at various prices, and to continue to vary these offers, as seats are purchased. Generally, leisure travellers are relatively sensitive to fares, but know in advance when they wish to travel and thus lower fares are offered well before a particular flight. As the departure date is approached, fewer cheap seats become available, as the focus is on attracting less price-sensitive business traffic that requires flexibility in its travel planning. The conditions pertaining to a seat can also differ; for example, the ticket may be refundable, it may be upgradeable, or it may be at a particular location on a plane (*e.g.* a seat at an emergency exit row) and prices are adjusted according to these quality factors.

Yield management is designed to extract as much revenue from customers as possible by levying prices that reflect the willingness of customers to pay. Consequently, customers who are less sensitive to price pay more, and contribute to the capital cost of the service, while those who are less willing to pay are charged lower prices that at least cover their marginal costs. While it can be used to generate large profits, and this has been done in many industries, its main purpose in air transport is to generate sufficient revenue to earn an acceptable return after all costs (including those of capital) have been covered.

However, to be able to practice discriminatory pricing, an airline has to enjoy a degree of monopoly power.[21] While the international airlines sold many of their tickets through their own retail outlets, and subsequently when they developed their own CRS systems used by travel agents, they enjoyed control over fares; it was time-consuming for potential customers to search for the cheapest ticket. Travel agents are now a dying breed in the United States (National Commission to Ensure Consumer Information and Choice in the Airline Industry, 2002) and in many other countries, and online booking on global distribution systems has largely removed the asymmetric information advantage that the airlines enjoyed. Customers can easily get details of fares and the associated services and restrictions that go with them from sites such as Priceline, Orbitz, Opodo and Travelocity. This makes it much harder for any airline to differentiate among customers and to extract the highest possible fares from them.

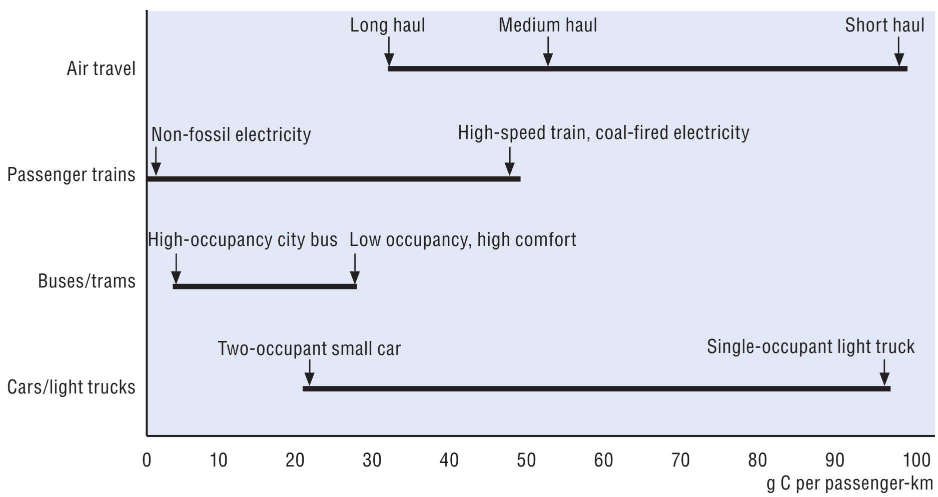
4.6. Technological developments

Two major innovations in air transport were the introduction of jet engines, which considerably shortened travel times, and the introduction of wide-bodied aircraft, which gave airlines the opportunity to reduce the cost per seat. Both developments reduced the generalised cost of travel, so that they had a positive impact on demand.

Jet engines allowed for much faster travel, although fuel consumption increased. When we only consider the jet engines, the energy efficiency improved in recent decades (piston engines were more fuel efficient compared to the early jet engines). IATA states that fuel burn and CO_2 emissions were reduced by 70% per passenger-kilometre compared to 1970s (*www.iata.org*). The sector's goal for a 10% improvement in fuel efficiency (and relative CO_2 emissions) between 2000 and 2010 will likely be met, while IATA forecasts a 25% reduction in fuel consumption per RTK between 2005 and 2020.

Figure 4.9 shows that air transport may be as fuel efficient *per kilometre* as road traffic, as suggested by IATA. Two remarks are in order, though. First, aircraft emit CO_2 and NO_x at cruising altitude, which is close to the tropopause (the transition between the troposphere and stratosphere). Depending on the cruising altitude, emitted NO_x can contribute to the

Figure 4.9. **CO_2-intensity of passenger transport**



Source: Penner *et al.* (1999).

production of the greenhouse gas ozone (troposphere) or the destruction of ozone levels, which leads to increased UV radiation exposure (stratosphere) (Royal Commission on Environmental Pollution, 2007). IPCC reported that ozone increased at cruising altitudes for sub-sonic aircraft, while predicted changes in UV-radiation are minimal (Royal Commission on Environmental Pollution, 2007).

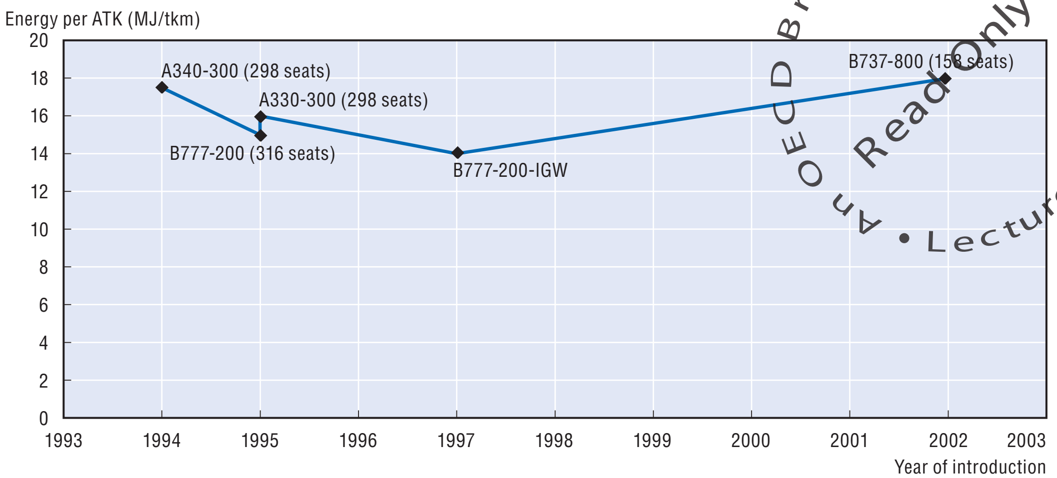
Second, air travel in most cases covers far longer distances than road travel. Although one can argue that because of these longer distances, the environmental impact of aviation is bigger, one needs to look at total passenger-kilometres. According to IATA, all modes of transport together account for 23% of global CO_2 emissions (*www.iata.org*). Road traffic accounts for the vast majority, 74%, of the transport sector's CO_2 emissions because of the sheer magnitude of road use worldwide. Air transport accounts for 12% of the transport sector's CO_2 emissions, or about 3% to 4% of global carbon emissions (Penner *et al.*, 1999). Even though the availability of international air travel at low prices (*i.e.* low-cost travel and indirect flights) can cause an increase in CO_2 emissions, the increasing demand for short-haul car trips (*e.g.* for commuting) could cause an even higher increase in CO_2 emissions. Finally, as mentioned above, the concentration in the aviation markets caused an increase in flight distance and the need for two landing and take-off cycles for many passengers, which have different fuel burn rates (Pejovic *et al.*, 2008). Fuel burn during the take-off and landing cycle is much higher than during the climb, cruise and descent cycle, so that network configurations with indirect travel have relatively large environmental impacts.

The environmental effects of the growth in aviation may be mitigated by technological developments, such as more efficient engines. In the literature, an increase in fuel efficiency of 70% between 1960 and 2000 is often mentioned. Peeters *et al.* (2005) argued that the often-cited 70% improvement in fuel efficiency as reported by the IPCC (Penner *et al.*, 1999) is somewhat optimistic because it uses a De Havilland Comet 4 as the reference aircraft, while this aircraft was only used for a brief period and gained little market share. If, instead, the successful Boeing 707 is used as the reference, fuel efficiency improved by 55% rather than 70% over the same period. Although the analysis of Peeters *et al.* (2005) confirms that jet aircraft fuel efficiency increased over time, the authors also conclude that the target for 2020 as mentioned by ATAG (2005), and based on an annual reduction of fuel consumption per ASK of 3%, is probably too optimistic. Peeters *et al.* (2001) pointed out that technological developments in the last decades were mostly made for small and medium-sized aircraft. Under the simple assumption that these aircraft are used in short to medium-haul markets, it appears that in long-haul (international) markets, there were relatively few gains. But newer aircraft (the latest B777 and A380) now allow for gains to be made in international markets.

If considering the fuel burn per available tonne-kilometre of a number of popular aircraft (Figure 4.10), it appears that smaller aircraft (in terms of passengers carried) have higher energy use, although the number of observations is too small to find a reliable statistical relation.

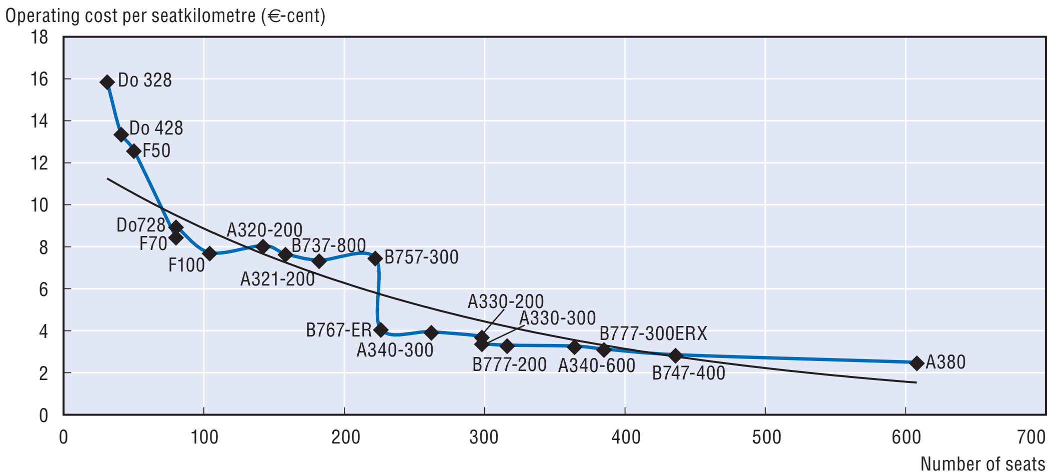
The adoption of hub-and-spoke networks meant that an increasing number of passengers are concentrated on a relatively small number of links. Because larger aircraft are cheaper to operate per seat (see Figure 4.11), airlines could reduce their cost. Moreover, if there are economies of scale in environmental terms (see *e.g.* Schipper, 2004), meaning that an aircraft with 300 seats emits less noise or CO_2 per seat than two aircraft with 150 seats, larger aircraft also provide environmental benefits.

Figure 4.10. **Fuel use per available tonne-kilometre**



Source: Adapted from Peeters *et al.* (2005).

Figure 4.11. **Operating cost per seat**



Source: Adapted from Connekt (2001).

Interestingly, the average plane size in the transatlantic markets peaked at about 320 seats in 1985, after which it rapidly decreased to about 260 seats in 1995. After 1995, there was a steady increase, with an expected size of about 300 in 2010 (Penner *et al.*, 1999). Brueckner and Zhang (1999) indicated that the frequency of service in hub-and-spoke networks may be increased to attract additional traffic in the face of competition. When a number of competitors offer a high frequency, this may create over-capacity in the market. Airlines can counter this by using smaller aircraft.

To summarise, the introduction of jet engines meant faster travel, but also a decrease in fuel efficiency. The fuel efficiency of jet aircraft increased over the last decades, although one can wonder whether the 70% estimate improvement compared to the De Havilland Comet 4 provides useful information. If more successful early jet aircraft are used as the base for the comparison, the efficiency improvement is less. The introduction of wide-bodied aircraft meant that the cost per seat decreased due to density economies, and that the environmental cost per seat could be reduced due to economies of scale in environmental terms. The formation of hub-and-spoke networks concentrates large passenger flows on a limited number of links, allowing the use of relatively large aircraft. Hub-and-spoke networks thus offer potential reductions in environmental damage per seat because of the possibility to use larger aircraft. On the other hand, hub-and-spoke networks are centred on large airports, which are often congested, while passengers travelling indirectly cause a relatively large amount of pollution because of the detour, and more importantly, the double take-off and landing.

4.7. The shifting situation

The difficulty with trying to look into the future of international air transport is that it is going to be influenced not only by ongoing trends, but also by trend breaks and new trends. While current trends can be generally extrapolated, economists and others sink when it comes to projecting trend breaks or the implications of new trends. Thus, here the focus is mainly on emerging trends and the way they are shaping the international air transport as globalisation takes place, and is assumed to continue. Initially, some forecasts in the public arena are reproduced. In doing so, one very important factor is emitted: the role of public policy, and in particular that which relates to environment policy. This is emerging as a key area of global concern, particularly with regard to global warming gases. Related to these environmental concerns, albeit at a local level, is the provision of infrastructure, and particularly airports. Additional capacity will be needed to cope with growing demands for international air transport services, but providing this generally meets with considerable local opposition. The discussion of environmental topics is left to Chapter 7.

Traffic forecasts

Air transport requires forecast: airlines have to plan their commercial strategies; suppliers of hardware, such as airframe and aero engine manufacturers, need to plan investment and production schedules; those responsible for stationary hardware such as airports and air traffic control need to develop their capacity; and surface land-use/transport planners need to construct roads and railroads to service airports. Government policy makers need forecasts to allow for the development of overall institutional and regulatory structures. International forecasts are largely based on trends in economic drivers, most notably growth in world GDP and emerging patterns of trade and tourism. Their accuracy in the short term, because of unexpected shocks to the aviation market, is not high, but the main concern of many of the users of forecasts is the longer-term magnitudes and patterns of air travel. Like much transport forecasting, there is often little attempt to embrace feedback effects, such as capacity constraints or changing input prices, making them *de facto* extrapolations of experiences.[22]

What the current forecasts, which normally have a 20-year time horizon, suggest is that air travel will continue to grow, albeit at different rates in different geographical markets, and for different types of service (*e.g.* for passengers and cargo). Below are some examples of recent forecasts.

Boeing updates its forecasts annually. The 2007 predictions from Boeing were that passenger traffic (RPK) will grow over the next 20 years at 5% and cargo at 6.1% per year (Boeing Commercial Airplane, 2007). (This contrasts, for example, with the 4.8% average annual passenger traffic growth of the previous two decades, although the prediction for cargo broadly follows the historic pattern.) Since it was forecast by Boeing that passenger numbers would increase by 4% per annum, this implies a larger increase in longer-distance traffic. In terms of the global commercial aircraft fleet, Boeing predicted an increase from 18 230 in 2007 to 36 420 airplanes in 2026. In terms of geographic markets, Boeing predicted Europe's passenger demand will grow at 4.2% per year, North America at 4% and Asia-Pacific at 6.7% a year (including China at 8%).

The aggregate Airbus (2007) forecasts were similar. World passenger traffic was expected to grow at 4.9% per annum for the period 2007 to 2026 with service frequencies doubling. This would imply the world's commercial aircraft fleet, including passenger (from 100 seats to very large aircraft) and freighter aircraft, will grow from 14 980 at the end of 2006 to nearly 33 000 by 2026.[23] While passenger traffic demand will nearly triple, airlines will more than double their fleets of passenger aircraft (with more than 100 seats) from 13 284 in 2006 to 28 534 in 2026. In terms of geographic markets, Airbus predicted Europe will receive 24% of new aircraft, with North America and Asia-Pacific taking 27% and 31% respectively.

Regarding infrastructure, Airbus estimated 93 major airports around the world are stretched to capacity, representing 63% of passenger traffic. A key airport on the list is London's Heathrow Airport, which is operating at about 99% of its permitted runway capacity. Its forecasts implicitly assume capacity expansion, either through physical construction or making better use of what is already available.

IATA's short-term forecasts made in 2007, based upon a survey of the airline industry, suggested that passenger and freight demand growth would continue to provide a positive boost to airline revenues over the five years to 2011, although the profile of growth would differ. Compared to 2006, international passenger growth was expected to slow slightly, domestic passenger growth to improve slightly and international freight growth to remain at a similar level. International passenger volume growth was expected to remain strong and passenger numbers were expected to grow at 5.1% annually between 2007 and 2011, lower than the average rate of 7.4% seen between 2002 and 2006. Demand was expected to be weakened by slightly slower global economic growth, but also to be boosted by the liberalisation of markets and the emergence of new routes and services. Domestic passenger growth was expected to pick up slightly, growing at an annual rate of 5.3% between 2007 and 2011, led by strong growth in the Chinese and Indian domestic markets. International air freight traffic was forecast to increase at 4.8% a year, lower than that seen between 2002 and 2006, but similar to its 2006 growth level of 5.0%.

Globalised labour markets, migration and international air transport

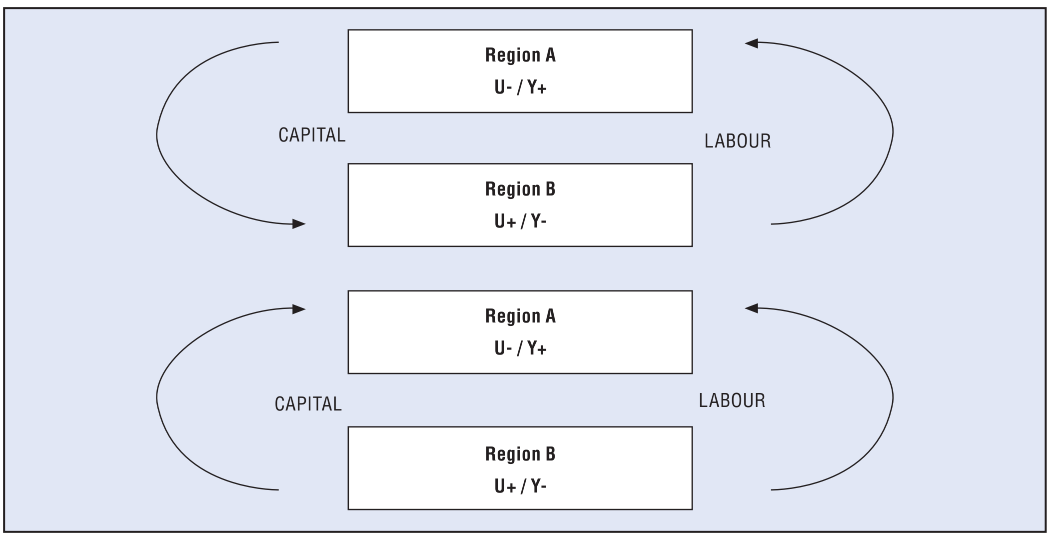
The role of international air transport has continually been changing since the early days when it was seen as a sort of "Pony Express of the skies", carrying express mail. It then became a mode for the wealthy and for governments to reach the extremes of their spheres of influence. It subsequently became the mode of choice for long-distance business travel as trade expanded after World War II, and then as a mass mode for leisure and personal travel, as technology advances and regulatory reform reduced its costs and increased leisure time, while higher disposable income stimulated tourism. While all these demands for international air services remain, there has been an added one that may be important in the future, namely the demand for air transport to facilitate labour migration (Button and Vega, 2008).

Labour migration is growing, and about 3% of the world's population lives outside their country of birth for one year or more. The role of transport in carrying these migrants depends on a variety of factors, but distance and the income of the migrants are critical factors. Much of the migration today involves developing countries: the World Bank estimated that in 2005, two in every five migrants reside in a developing country, and most have come from developing countries.[24] Most of this is relatively short distance and between countries with contiguous borders. It, therefore, seems that air transport plays an insignificant role for this large group. In cases of movement between developing and higher-income countries, there may be more scope for migration by air. While the two largest single corridors for migration – Mexico to the United States and Bangladesh to India – are mainly served by surface modes, geography means that the next three largest corridors – Turkey to Germany, India to the United Arab Emirates, and the Philippines to the United States – have significant flows by airlines.

The pattern of labour migration has also varied over time and can differ among corridors. Migration of workers from Asian countries, for example, shifted from a predominantly Middle East bound flow to an intra-Asian flow in the 1990s. Labour migration in Asia is mostly on fixed-term contracts representing temporary migration, although permanent or settled migration still takes place on a limited scale to Australia and New Zealand. Most Asian migrant workers are unskilled or semi-skilled, such as construction workers and female domestic workers.

There are two broad theories of migration illustrated in Figure 4.12 (Hart, 1975a; b).[25] We assume two regions, **A** and **B**. **A** has high income (Y+) and low unemployment (U–) whilst **B** is the mirror image of this. The classical model assumes that with zero costs of migration, labour will move from **B** to **A** seeking work and higher pay, and that capital will move from **A** to **B**, where it can be combined with abundant, cheap labour to maximise returns. The process continues until labour costs and employment levels are equalised.[26]

Figure 4.12. **Alternative views of the implications of migration**



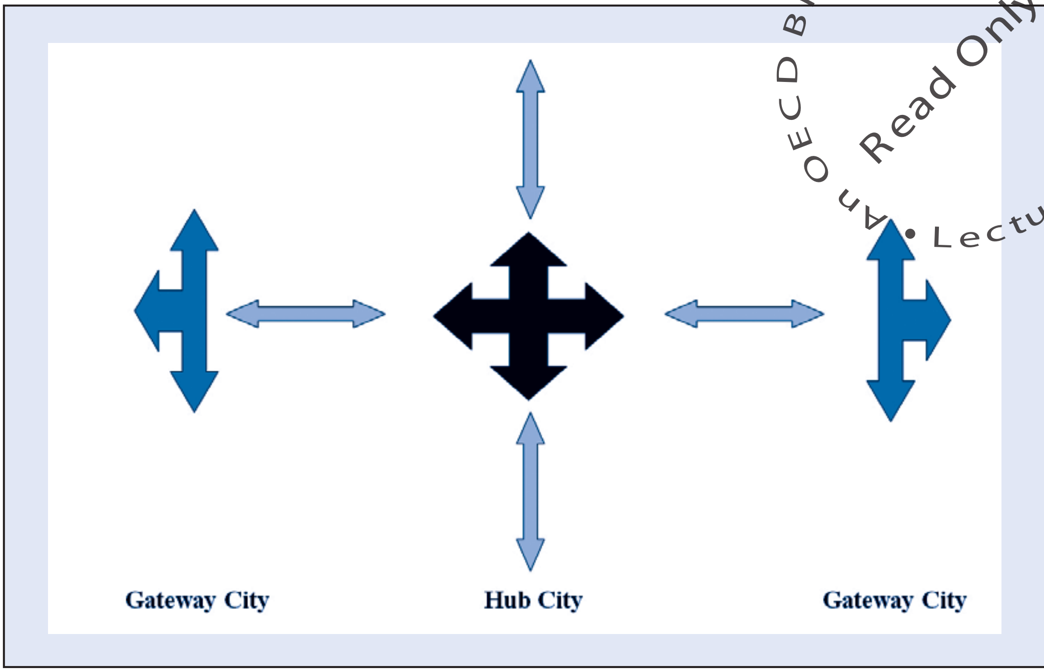
The alternative approach is essentially Keynesian in its orientation, and in its modern form is linked to the New Growth Theory. Taking the initial starting positions for our two regions, this approach argues that not only will equalisation of real wages and employment levels not be attained, but that there may be cases where they diverge further. Labour mobility may be impeded by the various costs of migration – embracing social and search costs, as well as simple financial costs – and heterogeneity in the labour market – the jobs available in region **A** not being compatible with the skills of labour in region **B**. Equally, capital does not move from region **A** to **B** because of the higher returns that are to be found in regions that already have a high level of prosperity. The original formulation of this type of model in the 1960s put emphasis on the scale economies enjoyed by prosperous regions with a larger capital base, but, as the nature of industry has evolved, it switched the ability of advanced, knowledge-based economies to continually push forward the technology envelope and forge ahead of other regions (Button, 2009b).

The role of transport in these models is different. In the classic framework it is considered, as in classic trade theory, to be ubiquitous and free. In the Keynesian style model, it is seen as a major transactions cost that affects clearing in the labour markets; transport costs are considered important in the labour mobility decision, but the labour market *per se* is largely seen as clearing in most other respects. There is an underlying assumption that in the short term, there are potential mismatches between available pools of labour skills and the demand for different types of labour, but in the long term, this is resolved both through migration and natural adjustments to the endogenous labour bases of each labour market.

Traditionally, migrants may do one of three things: stay in the same host country forever (permanent settlers), go somewhere else (remigration) or go back to their country of origin after a period.[27] But these definitions raise some problems in a more globalised world and one where mobility is easier. In the past, migrants to countries had little choice but to become permanent settlers, as transport was extremely expensive. More recently many migrants have been seen as guest workers and, for example in Germany in the 1970s, were often not highly skilled workers on short-term contracts. This has now changed in many places.[28] Globally, there has also been some attempt to liberalise the temporary movement of service workers under the General Agreement on Trade and Services, but implementation has been piecemeal. It has focused largely on high-level personnel who are more likely to use air transport if they become temporary migrants.

Until the mid-1900s, the traditional flow of migrants passed through some form of geographical "gateway" or institution such as Ellis Island in the United States (Button, 2007). These gateways have gradually moved farther apart, as it has become easier for migrants to pass through them and, as transport systems have evolved, to cover the distance between them. Figure 4.13 represents the traditional view of gateways (Burghardt, 1971). In the US context, for example, the two traditional gateway cities of the mid-1880s may be seen as New York on one coast and San Francisco on the other. Once into the country, migrants would move into the hinterland, often through a hub such as Chicago. Railroads largely facilitated this movement. The nature of maritime transport at the time, as well as institutional controls, led to this pattern of behaviour. The gateways proved challenging barriers to cross and, while migration was extensive, it was not easy and reverse migration, or visits to family left behind, proved almost impossible for the vast majority of individuals even if they did succeed in their new land.

Figure 4.13. **The notion of gateways**

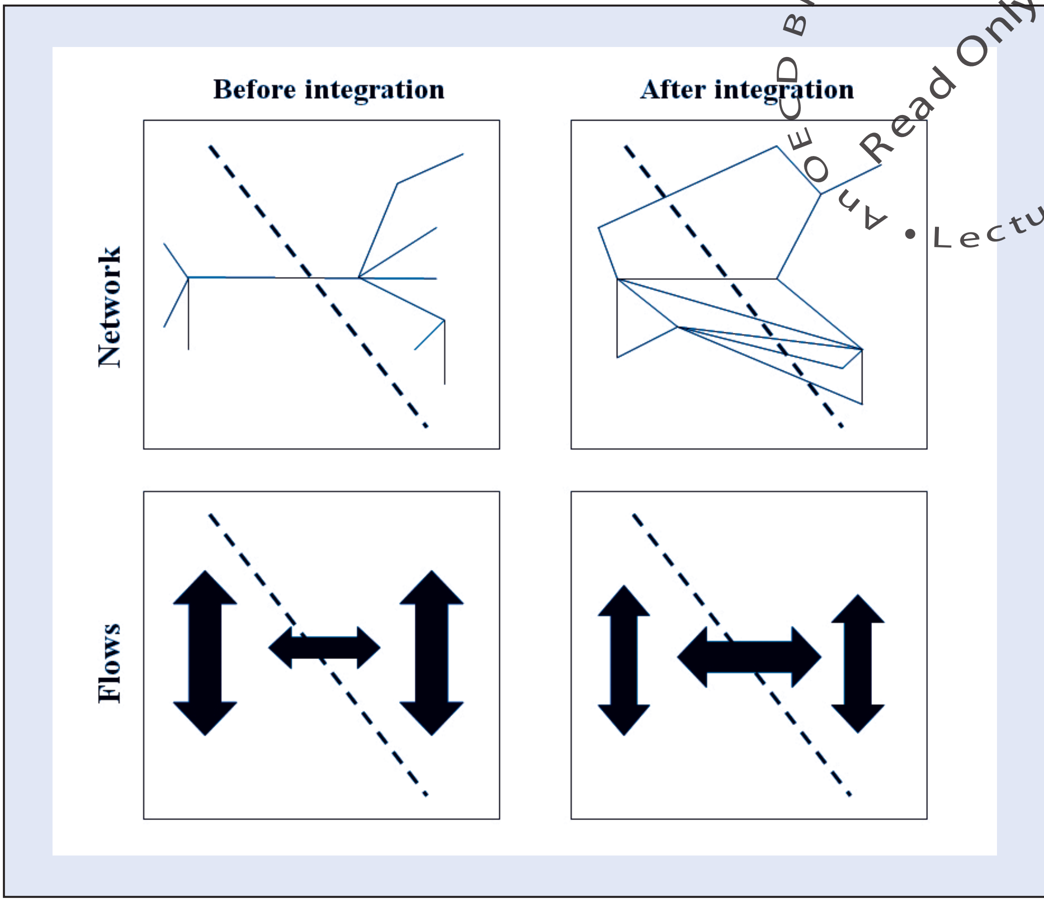


The institutional and technical changes that have taken place, particularly over the past three decades, have changed this picture dramatically (Rodrigue, 2006). The speed and flexibility of air transport have both effectively shortened the "distance" between recipient countries (such as the United States) and those sending immigrants, and between settling locations within the recipient country. Open Skies has also provided more gateways into the country. Figure 4.14 offers a simplified picture of the types of effects that this has had on air traffic flows. The left side of the diagramme shows the limited gateways between countries **A** and **B** (the line crossing the "dashed" international border) that existed prior to the emergence of more air transport services and the types of internal movements that took place. The upper part of this side of the figure shows that the bulk of labour migration was internal to the countries involved, with only limited international mobility.

The advent of domestic aviation reforms in both **A** and **B** stimulated more domestic labour mobility of various types, including long-distance commuting, as airfares fell with the advent of low-cost carriers and more services came on line. Internationally, labour movements crossed more border points that, in turn, further affected the nature and pattern of internal migration. These cross-border flows have themselves also changed in nature, with more movement of temporary migrants and also more back-and-forth movements, as migrants take advantage of low fares to revisit their homelands. The result of has been a relative growth in international migration (conceptualised in the lower elements of Figure 4.14).

In many cases, including large parts of the EU, freer global labour markets have allowed workers to select their place of work. Even where labour mobility is still restricted, the high demands for particular types of labour have led governments to open gateways to those with the required skills. The result is that the nature of labour migration has changed in recent decades, including a shift from longer-term to more temporary migration,

Figure 4.14. **Impacts of gateways on air transport networks and flows**



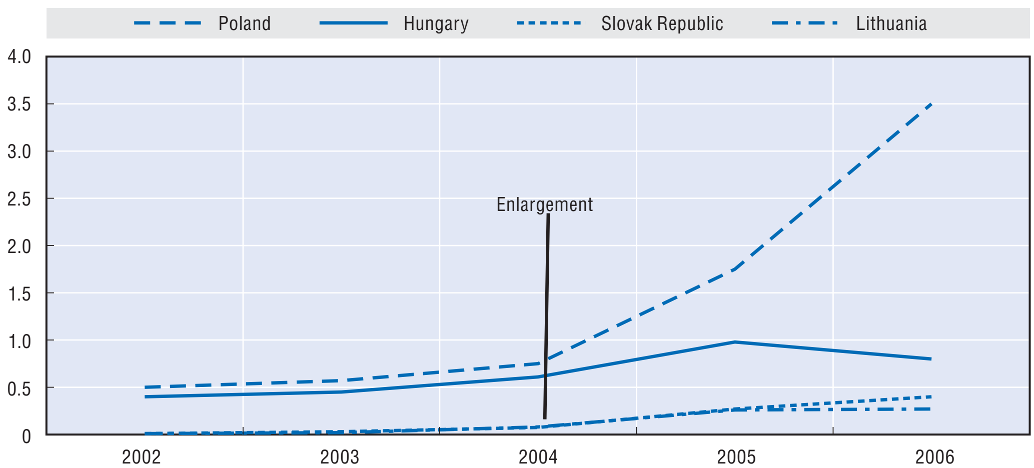
sequential migration and cycles of migration. There has also been an increase in long-distance commuting, involving regular return trips home, whether weekly or at some longer interval. Air transport seems to be in many cases a facilitator of these changes. Labour migration, both in its volume of flows and its changing composition (including greater emphasis on circulation and temporary migration), has in many cases been shaped by changes in the availability, frequency and costs of air travel. It makes the initial migration itself more viable and, by facilitating cheap return trips, reduces the longer-term social costs of being away from family.[29]

The reforms in air transport regulation have overcome many of the previous limitations of air transport as a significant form of mass mobility; costs were a significant barrier to air travel, as were the frequency and convenience attributes. Low-cost airlines, and their knock-on effects on the legacy carriers, have changed this. As a result, they have impacted labour markets in several ways, but mainly through reducing travel costs and increasing accessibility. Effectively, they reduce the transaction costs of international labour migration; by shifting the balance between the costs and returns of migration, they have contributed to the increase in factor mobility. For individuals, the cost of being away from home is high (mental and physical stress, the cost of separation, etc.), for others, the cost of travelling may be more important. For all, air transport lowers migration costs. Some can visit relatives more often. Others can at least afford to get to their destination. There is also the induced demand for migration that is made possible by lower air transport costs.

Airlines have changed to meet the challenges of the new demands posed by freer international labour markets. Low-fare services from local airports have changed consumer perceptions about flying generally and consequently are having an effect on travel patterns. In many cases, as with Ryanair in Europe that serves numerous small airports with radial structures of routes, it is not simply about vacations and visiting a second home, but also seems to stimulate people to apply for jobs abroad and may facilitate working far from home. Wizz Air, the Hungarian air carrier, is a leader among several low-cost airlines in transporting planeloads of Poles, Hungarians and others to western Europe with one-way fares starting at less than EUR 20, including taxes. Nearly 1 million East Europeans moved to Britain, Ireland, Sweden, Germany and other countries between 2004 and 2008, after the EU expanded from 15 to 25 nations.

Figure 4.15 provides an indication of the increased air traffic between several of the countries with significant migrant flows into the UK on routes where there had been expansions of low-cost carrier activity: not only Wizz, but also Centralwings (a subsidiary of Lot Polish Airlines), the former Slovakian carrier SkyEurope Airlines and others. For example, in 2000 there were five scheduled services between Poland and the UK; by 2006 this had grown to 27 scheduled services linking 12 Polish cities and 12 UK airports (UK Civil Aviation Authority, 2006).

Figure 4.15. **Air travel between the UK and selected transition economies**



Source: UK Civil Aviation Authority (2006).

The causality between changes in the airline market and labour migration patterns is not all unidirectional. Workers are increasingly participating in labour markets far from home and airlines have responded by creating an informal new travel category alongside the traditional business, leisure and "visiting friends and relatives" traffic breakdown. Airlines often call this "ethnic traffic", to reflect the cultural diversity of this type of traffic. Many carriers have even adapted their business models to cater for these "ethnic travellers" because of the relative reliability and predictability pattern of their demands that offset the relatively cheap fares paid. "Ethnic travellers" are, for instance, highly regarded by low-cost airlines like Wizz.

While official statistics do not capture this particular sub-class of traveller, one can glean some indication of the growth in this "ethnic" traffic, at least in Europe, by looking at the conventional "visiting friends and relatives" (VFR) category, most of the growth being migrants making visits to their homeland. Comparing the number of inbound passengers for 2000 and 2005 at the two primarily low-cost UK airports, Stansted and Luton, VFR traffic grew by 198% over the period to become the largest single component of inbound traffic. At the national level, a similar picture emerges with VFR traffic growing from less than 2.5% of EU passengers in 1997 (when there were 15 member countries) to about 15% by 2005 (albeit with 25 members).

Business models of airlines

There are considerable economies of scale density and scope on the cost side, and of market presence on the demand side, in the provision of airlines services. These features have led many of the major airlines to adopt hub-and-spoke styles of operations, and particularly when there is a focus on long-haul operations. In the short-haul market, the growth of low-cost, or "no-frills" carriers, such as Southwest Airlines in the United States and Ryanair in Europe, operating either point-to-point services akin to a bus service (with scope and scale economies coming from generating high load factors, by combining a series of short segments) or radial services (with the airline operating a set of routes from an airport but not providing online connections) has impacted adversely the viability of hub-and-spoke operators.

While the airline industry has, as a whole, proved itself remarkably robust and flexible over previous decades, there would seem to be a need to redefine the existing models further as globalisation progresses. There is already some indication that airlines are looking to deploy different business models. What the exact outcome will be over the next decades is difficult to say, but some indications may be found in current trends.

There has been a demonstrable switch by the traditional network carriers away from short-haul markets to long-haul international routes, and as the forecasts of Boeing, Airbus and others suggest, this is likely to be ongoing in the future. For US airlines, for example, even in the short term, international passenger traffic grew by 5.7% between January-May 2007 and January-May 2008, compared to a decline of 1.9% in domestic passengers[30] (see Figure 4.14). One possibility is that as traffic grows, the patterns of routes will remain unaltered (as in the top left quadrant), with increasing volumes of traffic being pushed through the existing major hubs. Congestion being handled through the use of very much larger aircraft, improved operations and ground investments at these hubs, with short-haul feeder services providing egress and access for domestic traffic. The alternative view, essentially that of Boeing, is that there will be more long-haul routes developed to carry traffic between **A** and **B**, with ground capacity coming from the utilisation of smaller airports and air service being provided by large, but not super-jumbo, fuel-efficient planes. Which will prove the correct prediction has yet to emerge.

A second modification of the business model is a further, and clearer, demarcation of service quality. The initiation of low-cost services effectively moved away from passengers seeking on-board service attributes to a separation of those seeking low fares. More recent premium services, initiated by Lufthansa on the North Atlantic, have been introduced to separate passengers where the on-plane environment is important. The aim is to segregate the business market niche where long-distance travellers want to arrive to work and where in many cases, there is a principle-agent distinction (the employer pays the fare and the employee selects the flight). To date, this has not proved a successful model and some of the early actors such as MAXjet, Silverjet, and EOS have left the market. The traditional carriers competed heavily by reducing the business-class fares on their multi-class planes, and the all-business airlines could not provide the level of frequency that business travellers seek. Whether large carriers moving into this market will be more successful remains to be seen, but they do have the advantages of substantial financial reserves, good airport access, capacity to offer a high service frequency and control over the fares they offer on their own competing multi-configuration services.

At the other extreme, long-haul, low-cost services are only just beginning to be developed. The availability of longer-range, smaller aircraft is one technical factor for this, but also the increased movement of labour and growing levels of long-distance tourism provided an impetus on the demand side. Progress has been slow, but the economics of the industry may change with the arrival of the Airbus A-380 superjumbo.

Historically, Freddie Laker's Laker Airways, that operated its "Skytrain" service between London and New York City during the late 1970s was a pioneer in this type of travel, but failed financially. In 2004, Aer Lingus started offering no-frills transatlantic flights for just over EUR 100, and the Canadian airline Zoom Airlines started selling transatlantic flights between Glasgow UK or Manchester UK and Canada for GBP 89.[31] On 26 October 2006, Oasis Hong Kong Airlines started flying from Hong Kong, China to London Gatwick Airport (delayed by one day because the Russian Federation suspended fly-over rights for that flight an hour before the flight's scheduled departure). Economy tickets for flights between Hong Kong, China and London could be as low at GBP 75 per leg excluding taxes and other charges, and business class GBP 470 per leg. The company stopped its flights in 2008, after running up HKD 1 billion of losses. In 2007, AirAsia X, a subsidiary of AirAsia and Virgin Group, initiated services from Kuala Lumpur to the Gold Coast, Australia, claiming it was the first true, low-cost, long-haul carrier of the modern era.

Developing a viable low-cost business model is difficult because of the need to have sufficient feeder traffic. While connecting flights can generate this, this adds significantly to operating costs and means that a mixed fleet of aircraft is needed. Additionally, low costs on short-haul routes come, in part, from rapid turnaround time for hardware and crew, but this is not relevant for long-distance flights that also often encounter problems of co-ordination across time zones and in meeting the scheduling limitations imposed by airport curfews. Additionally, very long flights are fuel intensive, as the plane has to carry additional fuel to carry the extra fuel needed. This makes saving costs difficult.

Changing industrial needs

The demand for air cargo movement has historically been correlated with economic growth, but is also influenced by the types of consignment to be moved and the logistic needs of the associated supply chain. The move to higher-value manufacturers, demands for exotics and the need to replace damaged or worn-out industrial components has been instrumental in increasing the demands for international freight transport.[32] In addition, with the growth of such activities as "teleshopping", with its associated physical supply chain, there have been additional demands for fast and reliable movement of goods across borders where there are free trade agreements, such as within the EU. Air cargo also has an advantage of needing less fixed infrastructure than surface transport, making it a viable mode in many locations where there are major physical constraints to trucking or sea transport; thus it has found an increasing role in developing countries with poor infrastructure and difficult terrain for the export and import of capital equipment (Vega, 2009).

According to the ICAO, aircraft, while only carrying around 2% of international trade by volume, carry about 40% by value. Air cargo, because road and rail offer alternatives over short distances, is also predominantly an international activity; about 85% of freight tonne-kilometres (FTK) done are intercontinental. A large part of the global market for airfreight services is provided by a limited number of large carriers (Table 4.5) that often, and particularly for wealthier countries with large land masses, provide seamless domestic and international collection and delivery; about 59% of the worlds FTKs involve the United States. Further, much of the longer-distance air freight is carried in the belly-holds of scheduled passenger aircraft because of the costs savings from economies of scale that this can create.[33] Short-distance movements, because there are fewer synergies between passenger and freight traffic, are usually done on dedicated aircraft. Not only does the carriage of freight slow the turnaround times of passenger planes, the peak times for its movement often do not coincide with passenger schedules, and freight hubs, such as Memphis for FedEx, are not large passenger airports.

Table 4.5. **Scheduled freight tonne-kilometres flown**

Airline	2007 (millions)	2006 (millions)	2005 (millions)
FedEx Express	15 710	15 145	14 408
UPS Airlines	10 968	9 341	9 075
Korean Air Cargo	9 568	8 764	8 072
Lufthansa Cargo	8 348	8 091	7 680
Cathay Pacific	8 225	6 914	6 458
Singapore Airlines Cargo	7 945	7 991	7 603
China Airlines	6 301	6 099	6 037
Air France	6 126	5 868	5 532

Source: International Air Transport Association, *www.iata.org/ps/publications/wats-freight-km.htm.*

Air freight transport has also become an integrated part of the modern supply chain. In some sectors, such as the movement of exotics (largely flowers and fruits with a short market life) this is essential because of a lack of durability in the product, while in others it is because of the need for reliable and rapid delivery (industrial components and legal documents). Unlike passenger transport, where the passengers deliver themselves to airports and then disperse themselves to final destinations, a single commercial carrier often handles air cargo from origin to destination. The integrated carriers that provide these services, such as FedEx Express, DHL, UPS, etc., are multimodal companies that, for example, also have extensive fleets of trucks for pick-up and delivery, and flow a large part of their business through one or more major hubs. In addition, packages and cargo are insensitive to the quality of the on-board service that they receive, other than temperature control in some cases, and routing is unimportant to them. This offers more opportunity for flexibility in the supply chain and for the air transport component to avoid some of the constraints on passenger movements. It is, therefore, easier to develop mega-hubs away from environmentally sensitive locations.

In the past, the growth in international air cargo has been heavily influenced by the availability of suitable planes. The advent of the wide-bodied jet in the late 1960s offered belly-hold capacity and the lift required to take significant amounts of freight. Later these planes were converted into dedicated freighters. These freighters have both a significant carrying capacity and range: *e.g.* a Boeing 747-400ERF freighter aircraft has a payload of 112 760 kg and a range of some 18 000 km. Technology does allow for larger planes, although Airbus is not immediately planning to produce a freighter version of its A380 plane,[34] and limits on wing technology, airport capacity issues and other factors may result in short-term constraints.

Developments in emerging markets

There are a number of markets that seem likely candidates to replace the lead of more traditional ones of North America and western Europe as these reach full maturity. Some regions, such as Africa, seem unlikely to develop significant air traffic flows over the next 20 years, in part because the base incomes levels are low, but also because their economic growth rate seems uncertain. Some South American international air transport markets have been growing, and if political stability is maintained, these may grow at an accelerated rate; the uncertainty, however, is high. The focus here is, therefore, on two types of emerging markets, those associated with the European transition countries and those with the mega-developing economies.

Transition economies

The collapse of the Soviet bloc from the late 1980s resulted in large increases of trade between the transition economies[35] and the more traditional market economies to the extent that some have joined the European Union. Figure 4.15 provides some indication of the growth of air transport in one segment of the European air transport market as transition economies became integrated within the EU.

The former communist states had relatively undeveloped international air transport networks prior to 1989, often served by poor quality hardware and not managed to maximise either social or commercial efficiency. Since that time, many of the countries have upgraded their fleets and restructured their route networks to integrate into the western European short-haul markets. A number of successful low-cost carriers did emerge to carry migrant workers and to offer leisure services as incomes rose. There was until recently a clear shortage of capacity due to limited investment availability which has been a constraint on expansion. In the longer term, with the liberalised EU market, the industry will confront competition from low-cost and traditional carriers from western European states. How many of the carriers from the transition economies will survive in this type environment, despite higher traffic levels, is uncertain.

Emerging mega-economies: China and India

China and India are large exporters and importers. They both have large and growing domestic airline markets to facilitate their production of goods to sell in the international market, and also have rapidly growing flows of international air traffic. Certainly, from the projections of the main airframe manufacturers, there is a sense that they will provide continuing and expanding markets for their products.

China has the second largest economy in the world and grew at an average rate of 10% per year during the period 1990 to 2004. Its international trade in 2006 surpassed USD 1.76 trillion, making it the world's third-largest trading nation. Accessibility to air transport improved significantly over the past 20 years as China expanded its air transport system and, in particular, its airport capacity (Table 4.6) to meet growing economic demands. The dominance of major airports has declined as the system has expanded to medium and small cities. The heart of passenger traffic migrated southeast, consistent with the expansion of economic growth in that region's coastal areas. Distance decay in air traffic became more pronounced in China after 1998, as the country's air transport system became more commercially driven. The east region has a high proportion of air passengers given its population and GDP, followed by the west and the central regions. By 1998, a hub-and-spoke air transport system was clearly in place in China.

Table 4.6. **Selected indices of China's civil air transport system**

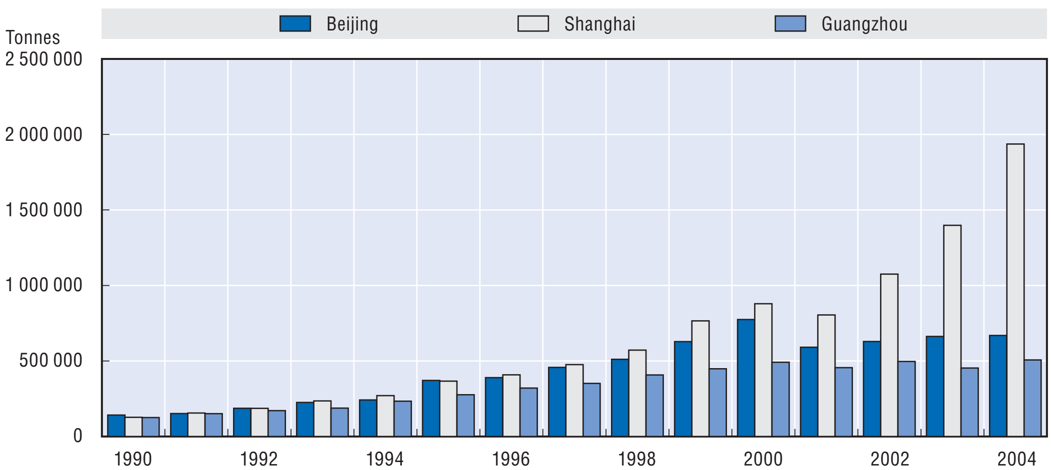
1980-2005

	1980	1985	1990	1995	2000	2005
Number of airports	77	80	92	116	139	142
Passenger traffic (million persons)	3.4	7.5	16.6	51.2	67.2	138.3
Passenger traffic turnover (million person-km)	39.6	116.7	230.5	681.3	970.5	2 044.9
Freight traffic (thousand tons)	90	200	370	1 010	1 970	3 070
Freight traffic turnover (million tonne-km)	140.6	415.1	818.2	2 229.8	5 026.8	7 889.5

Source: Wang and Jin (2007).

China's rapid industrialisation, and in particular the development of its manufacturing industries, has also led to a massive growth in its use of air cargo to export commodities and to bring into the country components, etc., that are needed to keep its factories working (see Table 4.6).[36] Much of this traffic has come in through three major gateways: Shanghai, Beijing and Guangzhou (Figure 4.16). The airports at these cities have become focal points in the country's domestic and international freight network. Beijing, for example, offered 57 freight

Figure 4.16. **Throughput of freight at major Chinese cargo hub airports**



Source: Statistical Data on Civil Aviation of China, various years.

connection cities in 1990, of which 13 were international; by 2003 this had grown to 126 connections with 65 destinations. The comparable figures for international connections for Shanghai were 13 in 1990, rising to 65 in 2003.

China's international air transport has, until recently, been heavily protected, and many hard (largely infrastructure) and soft (institutional protection) barriers remain. This protection has been exercised through a number of channels, including protecting uncompetitive carriers, restrictions on its citizens' travelling abroad, limited infrastructure (particularly airport capacity) and a lack of skilled labour and management (Zhang and Chen, 2003). In the context of cargo traffic, these have not only limited market access, but also made the development of fully integrated logistics system difficult (Fung *et al.*, 2005). These constraints have begun to be less binding and many bilateral ASAs have been signed, although Open Skies in major markets remains distant. It seems inevitable that China's international air markets will be further liberalised, stimulating traffic.

The geography and size of the domestic market in China suggests that its air transport sector will gradually move to a structure akin to that in the United States. Its domestic airline industry, while initially very fragmented after deregulations of the late 1980s, is now consolidating and alliances are being formed to provide seamless international services; for example, China Southern Airlines became a member of SkyTeam in 2007. The perceived strategic nature of the air cargo market, however, suggests that government involvement will remain a feature. Given the institutional structures within China, which is largely modal based with no single agency covering freight transport, this government involvement is likely to impair the growth of multi-modal logistics. This is despite the fact that China's accession to the World Trade Organization allows part or full ownership of air-cargo related companies.

Although its economic growth has not been so pronounced as China's, the Indian economy has expanded considerably – its growth rate in 2007 was 9%, compared to China's 13%[37] – and with this has come an expansion of its domestic and international air transport networks. The Indian air transport market was traditionally highly regulated with the flag carrier, Air India, enjoying considerable monopoly rights. In 1994, however, the Air Corporation Act of 1953 was repealed with a view to removing monopoly of air corporations on scheduled services, enabling private airlines to operate scheduled service, converting Indian Airlines and Air India to limited company status, and enabling private participation in the national carriers. However, beginning 1990, private airline companies were allowed to operate air taxi services, resulting in the establishment of Jet Airways and Air Sahara. These changes in the Indian aviation policies resulted in an increase in the share of private airline operators in domestic passenger carriage to 68.5% in 2005 from 0.4% in 1991. More recently, numerous low-cost carriers have entered the Indian domestic market, including Air Deccan, Kingfisher Airlines, SpiceJet, GoAir, Paramount Airways and IndiGo Airlines since 2004 (O'Connell and Williams, 2006). Externally, India has liberalised many of its bilateral agreements, including signing an Open Skies agreement with the United States in 2005 which has stimulated traffic – a trend that will probably continue as India's GDP increases.

4.8. Conclusions

The beginning of the 21st century saw a continued internationalisation and globalisation of the world's economy. There is also evidence of deeper globalisation of cultures and politics. Air transport played a part in fostering these developments, but airlines, and to a greater degree, air transport infrastructure, have had to respond to changing demands for their services. Air transport is a facilitator and, as such, the demands for its services are derived from the requirements for high-quality, speedy and reliable international transport. Globalisation, almost by definition, means demands for greater mobility and access, but these demands are for different types of passengers and cargoes, to different places and over different distances than was the previous norm.

International air transport is less than a century old, but is now a major contributor to globalisation and is continually reshaping to meet the demands of the economic and social integration that globalisation engenders. Economically, in static terms, globalisation occurs to facilitate the greater division of labour and allows countries to exploit their comparative advantage more completely. Perhaps more importantly in the longer term, globalisation stimulates technology and labour transfers, and allows the dynamism that accompanies entrepreneurial activities to stimulate the development of new technologies and processes that enhance global welfare. To allow the flows of ideas, goods and persons that facilitate both static and dynamic efficiency on a global scale, air transport has played a role in the past, and it seems inevitable that this role will continue in the future.

Notes

1. This chapter is an edited version of two papers: *The Impact of Globalisation on International Air Transport Activity: Past Trends and Future Perspectives*, written by Ken Button, George Mason School of Public Policy, United States, for the OECD/ITF Global Forum on Transport and Environment in a Globalising World, held in Guadalajara, Mexico, 10-12 November 2008 (*www.oecd.org/dataoecd/51/53/41373470.pdf*) and *The Environmental Impacts of Increased International Air Transport: Past Trends and Future Perspectives*, written by Eric Pels, VU University, the Netherlands, for the same event (*www.oecd.org/dataoecd/44/18/41508474.pdf*).
2. The air transport industry itself has established international bodies to interact with national governments and institutions such as the ICAO. The International Air Transport Association (IATA) was established to assist airline companies to achieve lawful competition and uniformity in prices.
3. Norway and Switzerland are also included in most of these agreements.
4. In October 2001, the European Commission also adopted proposals for a Single European Sky, to create a community regulator for air traffic management within the EU, Norway and Switzerland.
5. One US survey has shown that high technology personnel fly about 60% more than their counterparts in traditional industries. A broader econometric analysis indicates that the location of a city with a hub airport in the US in the 1990s enjoyed some 12 000 more high technology jobs than a comparable city without a hub (Button *et al.*, 1999). Analysis of transatlantic routes shows that enhanced numbers of links and service frequencies lead, albeit at a declining rate, to more high technology employment (Button and Taylor, 2002).
6. In terms of total passengers, because length of trips not included in the ranking of airlines is somewhat different; *e.g.* according to IATA, Ryanair carried 40 532 000 passengers in 2006; Lufthansa, 38 236 000; Air France, 30 417 000; British Airways, 29 498 000; and KLM, 22 322 000.
7. For example, Airports Council International data shows Memphis International Airport handled 3 840 491 metric tons of cargo in 2007; Hong Kong International Airport New Territories, 3 773 964 tons; Shanghai Pudong International Airport, 2 559 310 tons; Incheon International Airport, 2 555 580 tons.
8. The current economic recession has halted the previous growth. According to Airports Council International (2009), airport passenger traffic in January-September 2009 was 4% lower than in January-September 2008. Total air freight traffic had declined 14% over the same period, with international freight declining 17%.
9. The treatments of elements in the figure are static in the sense that technology is held constant. Modern economic theory holds that at least part of technical change is endogenous and thus a function of market and institutional structures.

10. This particular approach to examining the implications of international deregulation of air transport markets was developed in the specific context of transatlantic routes, but the arguments are general (Button, 2009a). That paper also assesses the quantitative analysis that has been done on the implications of a US-EU Open Skies agreement.

11. In practice, fares tended to reflect the bargaining power of the parties and the objectives of the countries' overall approaches to the airlines market. Continental European countries have had a long tradition of supporting their flag carriers for a variety of reasons that are linked to their perceptions of their national interest. In some cases, the fares may have been below the level required for cost recovery, whilst in others they may have been higher if, for example, one partner sought to cross-subsidise domestic services.

12. If there are economies of scope or density from offering air services in this market, as is often the case, the cost curve would be downward sloping and in this case the outward shift in demand reinforces the cost curve more and fares will always fall.

13. If there are declining costs, however, this monopoly power may be needed to allow for the recovery of the fixed costs of providing a scheduled service.

14. In some cases, these feeder flights may actually be by another mode. For example, Lufthansa has rail feeder services and most feeder movements for cargo to Heathrow in London are, despite having a flight number associated with them, carried out by truck.

15. *Source: www.klm.com.*

16. While airlines have, as a whole, found it difficult to recover their full economic costs, other actors in the air transport value chain have generally earned a reasonable return. International airlines can be seen as "till" at the end of this chain and as collectors of the revenues that finance the chain (Button, 2004).

17. There was unprecedented rapid rises in costs of aviation fuel (kerosene) between 2001 and 2008. Jet fuel rose from USD 30.5 a barrel in 2001 to USD 81.9 in 2006, to USD 113.4 in December 2007 and to over USD 140 in July, 2008. The result was that for international airlines, fuel costs that constituted 13% of operating costs in the US in 2001 rose to 26% by 2006 and to between 30% and 50% in 2008. The cost of kerosene has, however, decreased significantly from 2008 to 2009.

18. Even where there is not actual competition, potential market entry for at least a period prior to take-off is possible. This is weak competition due to contestability (Button, 2006).

19. For a largely accessible general survey of the theory, see Telser (1987). The academic literature applying the theory to airlines is thin, but includes Button *et al.* (2007) and Button (1996).

20. In the EU, efforts by Ryanair to pursue similar strategies for inter-European international services fell foul of legislation covering the use of any public funds to support services.

21. Levine (2002) argues that you can have price discrimination without market power and that this is a natural way to recover costs. However, while price discrimination, as practiced by airlines in the form of yield management, may be needed for cost recovery, it seems difficult to see how its use is possible without an airline having some market power. The issue is more the extent to which market power is necessary for optimal price discrimination for cost recovery and when this changes to become a tool of rent seeking.

22. From the mid-1990s, there was some effort to adopt scenario-driven analysis for forecasting, although simple extrapolations still dominate – *e.g.* see British Airways (1995). One attempt to look at the future of international air travel using a softer approach is to be found in OECD (1997).

23. The differing futures seen by Boeing and Airbus are in part due to the fact that Boeing believes that growth in long-haul traffic will be catered for by point-to-point services, whereas Airbus believes there will be a significant demand for its A380 super-jumbo plane to link up large hub airports.

24. This is often called "South-South migration" as opposed to "South-North migration" that traditionally describes movements from developing to developed countries. Of the South-South migration, 80% is between countries with contiguous borders and 65% of the remainder is between countries with the 40th percentile of countries ranked by distance.

25. These theories only relate to the narrow economic motivations for migration and do not include socio-political theories, covering such things as military disruptions and forced migration.

26. Strictly with full market clearing, there is no unemployment in this type of model, labour movements being determined by real relative wages. The unemployment effect is added to indicate possible imperfections in the short-term labour markets in the two regions.

27. These are often "target workers", who return home once a certain amount of money has been saved or skills attained.
28. There are still significant flows of unskilled temporary migrants that have become institutionalised in some cases. Canada, for example has the Seasonal Agricultural Worker Program that in 2006 allowed 13 000 workers to come from Mexico. These workers all had to travel by air transportation.
29. Improvements in telecommunications have added to the ability to retain close ties with the homeland and are closely linked to the effects of air transportation.
30. For a more detailed assessment of this type of strategy in the context of TAP, the Portuguese airline, see Button *et al.* (2005).
31. Zoom filed for bankruptcy protection in August 2008, due to its deteriorating financial position, see *http://en.wikipedia.org/wiki/Zoom_Airlines*.
32. About 19% of FTKs involve capital equipment, 13.5% computers, 12.4% intermediate materials and 7.4% perishables.
33. In terms of purely international freight tonne-kilometres done, Korean Air Cargo did 8 680 in 2006; Lufthansa Cargo, 8 077; Singapore Airlines Cargo, 7 991; Cathay Pacific, 6 914; and FedEx Express, 6 136.
34. Originally a freighter version was planned, but was abandoned after only one order was received.
35. "Transition economies" is now a somewhat dated term, but it is useful shorthand for this group of countries. It should, nevertheless, be taken into account that a number of these countries have been hit particularly hard by the current economic crisis.
36. In terms of tonnage, this has risen from some 157 000 in 1980 to 4.5 million in 2003.
37. See OECD (2009). In 2008, the growth rates were 6% and 9%, and the OECD estimates GDP to grow 4.3% and 6.3% in 2009 in India and China, respectively.

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Globalisation, Transport and the Environment

Chapter 5

International Road and Rail Freight Transport: The Impact of Globalisation on Activity Levels

by

Allan Woodburn, Julian Allen, Michael Browne, Jacques Leonardi and Huib van Essen[1]

This chapter establishes the recent trends in international trade volumes. It then aims to identify the main ways in which this trade growth has affected road and rail freight transport activity at the international level, and finally considers the likely future direction of international land-based transport movement. Road and rail are currently carrying relatively small quantities of products traded internationally compared with maritime shipping. However, likely increases in the total quantity of international trade (as a result of manufacture continuing to grow in distant locations, facilitated by more reliable, and faster transport services, supported by improvements in technology) will increase the amount of goods that need to be transported internationally.

The chapter looks at recent trends in international trade activity. It discusses international trade and transport from a policy and economic perspective, before describing the importance of customs clearance and border crossings together with the increased concerns about security in international transport. The chapter provides a more detailed discussion of road and then rail within which aspects such as infrastructure issues, policy and regulation, operations and technology are reviewed. The chapter closes with a look at future perspectives. New developments to remove bottlenecks, combined with operational improvements, provide scope for considerable increases in the efficiency of international road and rail freight in many regions.

5.1. Introduction

In this chapter, the international focus is on cross-border road and rail transport, rather than on comparisons of trends and prospects across a range of different countries. However, there is huge variation in the types of trips that make up international freight in terms of their frequency, complexity, distance travelled and vehicle types used. For instance, international road freight trips between the Netherlands and Belgium take place on a very regular basis, are relatively simple (due to the lack of border controls in the EU), are very short distance (sometimes shorter than the average domestic trip) and do not necessarily use maximum weight articulated vehicles. However, by comparison, trips from Asia to Europe can be occasional, extremely long distance (thousands of kilometres), very complex (due to numerous border crossings), and typically use maximum weight fully laden articulated vehicles in order to minimise unit costs of transport. Therefore, in talking about international freight transport it is important to be aware of the diversity of trip types included, and the impact that the attributes of the trips described above can have on its organisation and cost.

As far as possible, experiences from around the world are identified and discussed, although the main focus is on cross-border flows between countries in Europe, Asia and North America since these three regions are where the majority of land-based international transport takes place, and for which there is considerable published information. While the assessment is evidence-led where possible, there are limitations relating to differing definitions and measurement units, both spatially and temporally, and inadequate data relating specifically to cross-border freight transport activity.

5.2. Recent trends in international trade activity

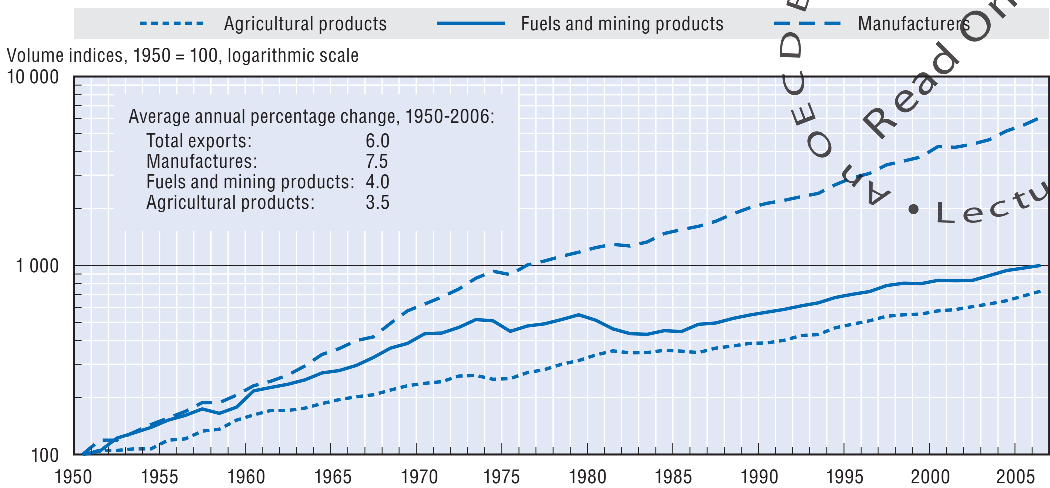
The World Trade Organization (WTO) provides the most comprehensive data on trade volumes and trends. This section highlights some of the main aspects of world trade that affect freight transport activity and mode choice. Figure 5.1 reveals the long-term growth in international trade volumes in all product categories, but most notably in manufactures.

In general, trade growth has exceeded the increase in GDP over this time period: between 2000 and 2006, trade growth was approximately twice the GDP increase (WTO, 2007). Table 5.1 shows the key international trade flows between world regions, and within these main regions, in 2006, in terms of the value of products. The top six flows involve just three regions, Europe, Asia and North America, with trade within and between these regions accounting for three-quarters of world trade value. Internal European flows alone make up almost one-third of all international trade. Six of the top 10 countries involved in international trade are European, with two each from North America and Asia.

Table 5.2 shows the average annual growth in trade to and from each of the world regions for the 2000-06 period. Globally, the value of goods traded increased by an average of 11% per annum. North America recorded lower than average growth, and those regions less involved in international trade experienced higher than average growth rates, but remain relatively insignificant in comparison to Europe, Asia and North America.

Figure 5.1. **World merchandise trade volume by major product group**

1950-2006



Source: WTO (2007).

Table 5.1. **Intra- and inter-regional merchandise trade flows, 2006**

Trade flow	Trade value (2006 USD bn)	% of 2006 trade value
Intra-Europe	3 651	31.4
Intra-Asia	1 638	14.1
Asia – North America	1 022	8.8
Asia – Europe	970	8.3
Intra-North America	905	7.8
Europe – North America	709	6.1
Asia – Middle East	451	3.9
CIS – Europe	388	3.3
Africa – Europe	268	2.3
Central/South America – North America	242	2.1

Source: WTO (2007).

Table 5.2. **Annual percentage change of value of goods in world merchandise trade by region**

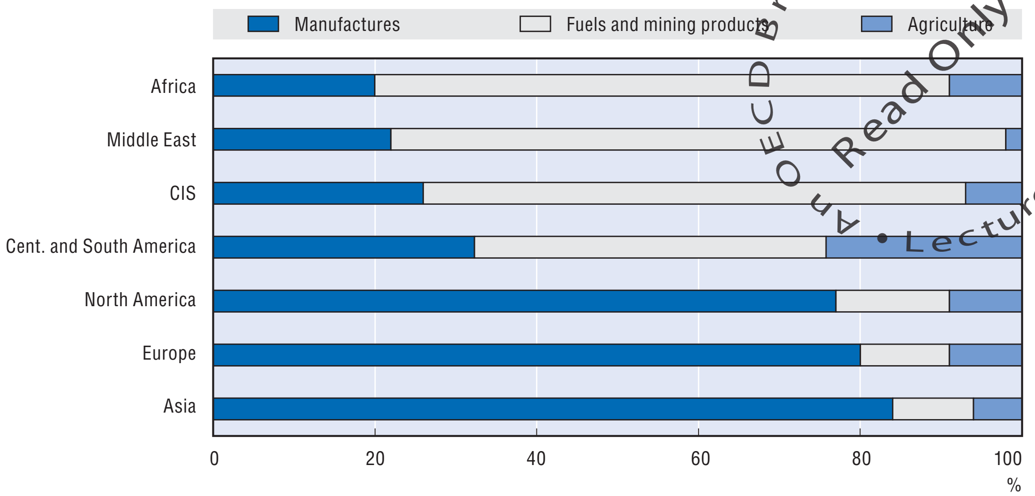
2000-06

Region	Exports	Imports
CIS	20	23
Middle East	16	15
Africa	16	14
South and central America	14	10
Asia	12	12
Europe	11	11
World	**11**	**11**
North America	5	7

Source: Adapted from WTO (2007).

Figure 5.2 reveals regional differences in the composition of trade flows. For Africa, the Middle East and CIS, exports are dominated by fuels and mining products, while for Asia, Europe and North America, manufactured products make up the overwhelming majority of

Figure 5.2. **Sectoral structure of merchandise exports by region, 2006**



Source: Adapted from WTO (2007).

exports. In central and South America, there is a broadly equal distribution among the three product categories, giving this region by far the highest share of exports for agriculture products. Manufactures have been increasing their share of total trade value and now account for approximately 70% of the total, reflecting the dominance of the three main regions where manufactured goods represent the majority of trade value.

The introduction, and subsequent increased scope and/or geographical coverage, of regional trading blocs have been an important factor influencing international road and rail transport movements. Table 5.3 shows the major trading blocs involved in merchandise trade, with the two most significant by far being the European Union (EU) and the North American Free Trade Agreement (NAFTA). The EU has expanded geographically over time, taking in 27 countries by 2007, and has removed internal trade barriers while developing unified trade agreements for extra-EU trade. EU countries were involved in 38% of global merchandise trade by value in 2006. Of this, two-thirds was traded internally between EU countries (WTO, 2007). By contrast, trade among the three NAFTA countries (Canada, Mexico and the United States) comprised just over 40% of the total merchandise trade involving those countries, and in many of the other trading blocs, the internal trade was a smaller proportion of the total involving member countries. In addition to Europe's role in global trade (shown in Table 5.1), the

Table 5.3. **Involvement of major trading blocs in world merchandise trade**

% of total world merchandise trade value, 2006

Trading bloc	Exports	Imports
European Union (EU)	37.5	38.3
North American Free Trade Agreement (NAFTA)	13.9	20.5
Association of Southeast Asian Nations (ASEAN)	6.4	5.5
Gulf Cooperation Council (GCC)	3.9	1.7
European Free Trade Association (EFTA)	2.3	1.7
Southern Common Market (Mercosur)	1.6	1.1
South Asian Preferential Trade Arrangement (SAPTA)	1.3	1.9
Southern African Development Community (SADC)	1.0	1.0
Common Market for Eastern and Southern Africa (COMESA)	1.0	1.0

Source: Adapted from WTO (2007).

significance of the EU to trade within Europe is clearly very great, reflecting the large number of small countries that are now able to trade freely with each other.

Road and rail modes are mainly dealing with intra-regional flows, given that two of the three main inter-regional flows (Asia-North America and Europe-North America) are not possible by land-based routes, so maritime transport dominates. For the third (Asia-Europe), land transport is possible, though currently very limited, with the majority of goods again being moved by sea. Considerable use is made of road and rail as feeder modes for these inter-regional maritime services, connecting with inland flow origins and destinations and, in some cases, acting as land-bridges.

At the intra-regional level, road and rail are more often used as the main transport modes in their own right, although shipping is also significant in some locations. As a consequence of the geographical distribution of this trade, much of the discussion in this paper relates to the three regions with significant intra-regional trade, these being Europe, Asia and North America.

5.3. International trade and transport: Policy and economics

As noted by Kopp (2006), "there is widespread agreement that the reduction in long-distance transport and communications costs has been an important determinant of today's globalisation". For a long time it was believed that trade costs were of little importance for the structure and quantity of global trade; however it is now acknowledged that these costs are significant (Kopp, 2006).

Trade costs can be influenced by time and duration, or not (Deardorff, 2005). These are mainly:

- Non-time related costs:
  - resource cost of transport (the cost of transporting goods from one international location to another);
  - insurance;
  - financial costs of exchange;
  - other (legal costs, charges for transit procedures, legal or illegal facilitation payments, etc.).
- Time-related costs:
  - interest;
  - storage;
  - depreciation.

Trade costs (especially transport costs) can reduce the amount of international trade by making it unprofitable. In such a situation, countries rely more on their own resources and this deprives them of the gains that flow from international trade.

This is a problem that is often faced by landlocked, developing countries, which as a result of their geographical disadvantage face "specific challenges in their attempts to integrate into the global trading system, mainly because goods coming from or going to a landlocked country are subject to additional trade barriers such as lengthy border-crossing procedures. In addition, many landlocked developing countries suffer from weak legal and institutional arrangements, poor infrastructure, a lack of information technology, an underdeveloped logistics sector and a lack of cooperation with neighbouring transit countries. Finally, the distance to markets, as compared to countries with direct access to seaports, can also be a disadvantage in some cases" (UNCTAD, 2007). The economic growth of landlocked countries in the period 1992-2002 was 25% lower than that of their transit neighbouring countries (UNCTAD, 2007).

The costs of transporting goods from one international location to another (the resource cost of transport) is probably the most important cost of trade for most products. This cost varies with distance, weight and bulk density of the product, and its handling requirements in transit. Other costs of international trade include insurance (which is related to size and value), financing (which varies depending on the elapsed time between production and receipt of payment), and financial fees (resulting from trading across national borders and often using more than one currency) (Deardorff, 2005).

Time is a crucial factor in the cost of international trade (Deardorff, 2005). Time is required to transport the good from its origin to its destination, as well as to load and unload it, and to process the goods and the vehicle through customs clearance and border crossings. Given that it takes time to carry out international transport of goods, it is necessary for companies to hold stock. This stockholding incurs several costs in terms of warehousing costs, interest payments and depreciation costs associated with physical deterioration or change in consumer tastes. These time-related costs will vary depending on the product in question, but make it important to minimise the time-to-market if one wants to minimise these costs. Therefore, in trying to minimise these time-related costs, it is important to choose the fastest possible means of transport (obviously taking into account the resource cost of each mode).

It has been noted that time delays and the variability of transit times are of greater concern to shippers than direct transport costs, as they affect companies' ability to meet agreed delivery schedules and therefore necessitate large stockholding. Hummels (2001) has used the costs of different modes of transport to infer the costs of time from the amount that firms are prepared to pay to reduce it. His results suggest that a one-day delay in shipping leads to an average cost equivalent to a 0.8% tariff.

Trade costs are high. Broadly defined trade costs include all costs incurred in getting a good to a final user, other than the marginal cost of producing the good itself. A rough estimate of the representative tax equivalent of trade costs for industrialised countries is 170% of the original value. This estimate includes 74% international trade and transport costs (which include 21% transport costs, and 44% border-related trade barriers) and 55% local distribution costs. The international transport costs comprise direct freight transport costs as well as a 9% tax equivalent of the time value of goods (Anderson and Wincoop, 2004).

International manufacture is becoming increasingly common over time as companies seek out low wages and land costs to achieve low production costs (Rodrigue and Hesse, 2007). However, this results in the need for long-distance international transport. At the same time, consumer tastes are changing ever more rapidly, especially in relation to high value and technology products. In such products it is therefore becoming increasingly important for producers and retailers to get products to market as quickly as possible.

Technological innovations in transport and ICT are reducing the time-to-market for products. This is making it possible to manufacture products in distant locations from market and is also making trade in products possible where it had not been previously (*e.g.* air-freighted cut flowers). High-quality, fast and reliable international freight transport systems, that have resource costs that are sufficiently low to ensure profitability, are essential in achieving this.

This is opening up new opportunities for international land (road and rail) transport. Traditionally for international goods movement, air transport has been used for products that are time sensitive and valuable, and sea has been used for lower-value products that are less time sensitive. However, ever-longer international road and rail transport options are becoming viable as a result of infrastructure improvements and international agreements, resulting in expanding land-based international transport volumes. These land-based modes are likely to increase their modal share of international goods movements as they offer services that are cheaper (but slower) than air freight and faster (but more expensive) than sea.

However, the quantity of goods transported internationally by land modes is still very small in comparison with domestic road and rail freight movements.

5.4. Other considerations in international trade of physical goods

Customs clearance and border crossings

Time-consuming and complex customs-clearance and border-crossing procedures can cause significant journey time delays and poor journey time reliability on international road movements. They can also impose additional costs, both in terms of actual fees and charges for services provided, unofficial payments (*i.e.* bribes), and as a result of time delays and unreliability in delivery. At worst, several days can be lost at these border points. As discussed in Section 5.3, these costs increase the total costs of traded goods and can have a negative impact on competitiveness. One study mentions that the direct and indirect costs associated with border crossings can be as much as one quarter of total transport costs (Chamber of Commerce of the United States, 2006). These problems are particularly acute in some central Asian countries, with suggestions that road freight trips to these countries can be up to three times as expensive, and take up to twice as long, as in an ideal situation (*i.e.* with straightforward border crossings, low fees for border services, no visa difficulties and no unofficial payments) (Chamber of Commerce of the United States, 2006).

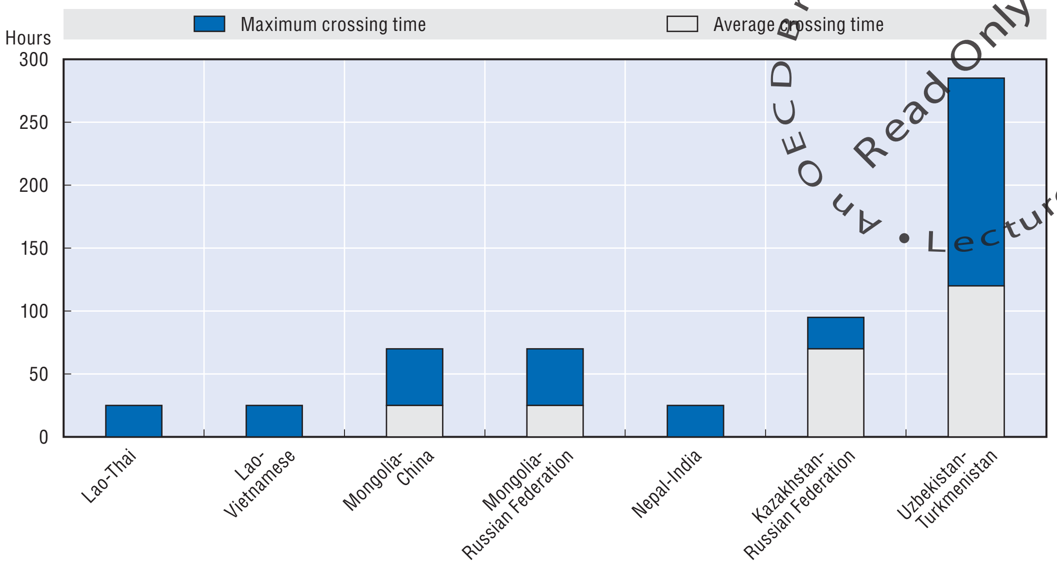
Landlocked countries face particular difficulties in relation to border-crossing delays and costs. The ESCAP region (Asia and the Pacific) contains 12 of the world's 30 landlocked developing countries. For most countries in this region, transit transport is

> "most heavily constrained by excessive delays and costs incurred at border crossings. Time-consuming border crossing and customs procedures, complicated non-standard documentation, poor organisation and a lack of skills in the transport sector are some of the major contributory factors. Overlapping obligations brought about by several bilateral, trilateral and subregional agreements, the need for multiple bilateral agreements and the lack of a harmonised legal regime for transit transport, including arrangements for transit fees, further compound the complexity of the transit transport process" (UNESCAP, 2003).

UNESCAP carried out a series of case studies in 2003 "to identify the common issues and concerns related to physical and non-physical barriers that characterise the transit transport systems of landlocked and transit developing countries in the ESCAP region" (UNESCAP, 2003).

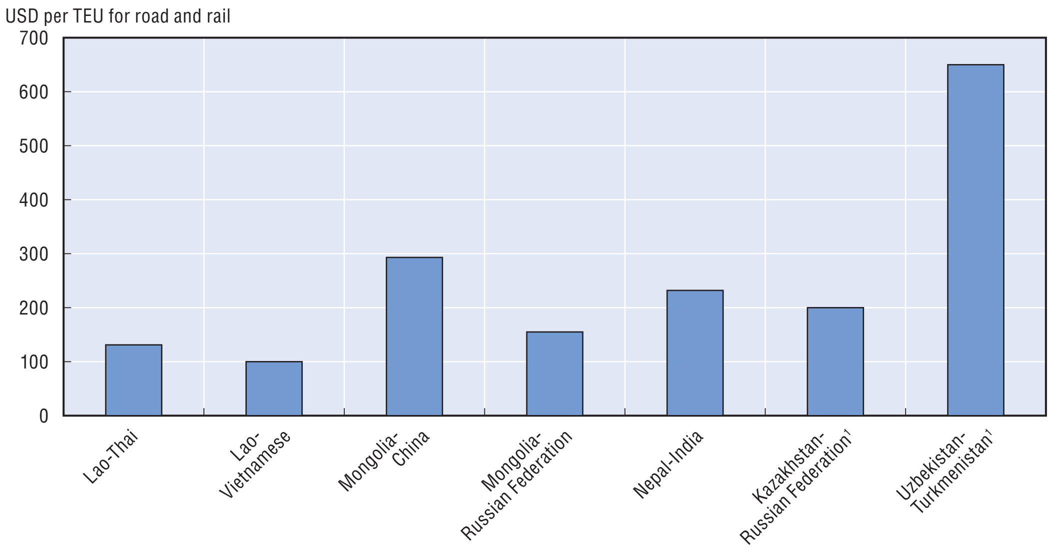
The case study countries represented least developed countries and economies in transition. Figure 5.3 shows a comparison of border crossing times and Figure 5.4 a comparison of border crossing costs in these case studies. The results showed that time and costs associated with border crossings ranged between 3 hours and 120 hours, and between USD 100 to around USD 650.[2]

Figure 5.3. **Selected border crossing times for road and rail**



Note: The results include border delays for road and rail crossings.
Source: UNESCAP (2003).

Figure 5.4. **Selected border crossing costs for road and rail**
Per twenty-foot-equivalent unit (TEU)



1. Border-crossing costs per 12-metre truck.
Source: UNESCAP (2003).

Despite the reforms that have taken place in some countries, and the growing use of international conventions to help reduce or overcome border crossing delays, it is still the case that clearing customs and border checking points is a cumbersome process in many countries, see Box 5.1. It can involve the following types of checks and controls (ECMT, 2000):

- Customs controls on the goods carried (which can involve checking relevant documentation and sometimes the product origin and destination).

- Inspections of goods (this can include sampling and testing).
- Vehicle checks (which can involve safety and environmental standards, and licensing).
- Immigration controls (including passport and visa checks, and possible vehicle searches for illegal immigrants).
- The collection of taxes, fees and duties associated with the above checks and controls.

Box 5.1. **Border problems**

The lack of a unified procedure in customs procedures and of a single document explaining all the necessary steps and payments required can worsen the problems experienced and increase the potential for the extortion of unofficial payments. Limited use of ICT in customs clearance can also cause delays at borders, as can visa policies. Recent examples include:

- The Former Yugoslav Republic of Macedonia imposes a EUR 100 payment for each tariff line inserted in the certificate of import for all imports of agricultural goods that benefit from tariff preferences.
- Local authorities in Romania have discretion to impose additional taxes, *e.g.* for environmental reasons. Such taxes are highly variable and non-transparent.
- In Uzbekistan, ten different documents, issued by various departments and ministries, are required for customs clearance, prolonging custom procedures for up to two to three months.
- In the Republic of Moldova, several government agencies are present at the border, each of them representing a different ministry and collecting fees.
- Truck drivers cannot obtain a visa for Bulgaria at the border.
- Strict visa requirements for business visitors including transport operators can cause significant delays for exports to Serbia.
- Insufficient information technology equipment combined with inadequate training of custom staff delays customs clearance and traffic, throughout the region but especially in the Republic of Montenegro, Albania, Bosnia and Herzegovina.

The *Logistics Performance Index (LPI) Survey* has highlighted that "the rating for transparency of border processes consistently declines along with LPI scores: … poor performers in the LPI were also poor performers on transparency of border processes". Only 10% of responses stated that solicitation of informal payments was common in high-income countries, whereas more than 50% of responses indicated that such informal payments were common in low-income countries.

Sources: UNECE (2006); Arvis *et al.* (2007).

Security considerations

As UNECE (2008) noted, transport systems are vulnerable to being used for, or being the target of, terrorism because they have not been designed to cope with security threats, and traditionally the focus has been on smooth, fast and reliable flows, while achieving certain safety rather than security standards. In addition, road transport infrastructure is easily accessible and often lacking surveillance (such as major roads, bridges and tunnels), and road goods vehicles are readily available and can be used as either a means of conveying weapons or as weapons themselves. Also, complexity presents major problems. Supply chains involving international road freight consist of thousands of companies and national regulations often differ widely. Harmonising national security standards across borders could help to prevent terrorists using roads and road freight, but is difficult to achieve.

UNECE's Inland Transport Committee has reviewed issues that could benefit from further security considerations. In the field of land-based freight transport, these include (UNECE, 2008):

- Vehicle regulations (concerning vehicle alarm and immobilisation systems, agreements on provisions for immobilising vehicles after unauthorised use, and the installation of positioning systems in vehicles to identify their location).
- Dangerous goods and special cargoes (the need for security recommendations for transport of dangerous goods, and updating training requirements for drivers and other personnel involved in the transport of dangerous goods to include security issues).

This Committee identified that, unlike the protective measures that exist in ports and airports, inland transport would seem to be relatively under-protected and "appears to be the weakest link in today's supply chain". They have argued that vulnerable pieces of infrastructure (such as roads tunnels and bridges) are difficult to protect due to their public access and that therefore it is important to support research into new infrastructure protection technologies (such as control and detection systems, including vetting of the personnel working close to such critical infrastructure). They have also identified that there is no international body for land transport security (for goods and passengers), that is equivalent to bodies in maritime and air security. The existence of such organisations would make it easier to introduce international standards (UNECE, 2008).

5.5. Recent trends in international freight transport volumes by road and rail

In the previous sections, the discussion of the growth in international trade was in terms of the *value* of the goods being traded, since this relates to the main purpose of the WTO. When considering modal trends, it is more common for the statistics to be *weight*-related, and as a consequence most of the discussion in this section is tonnage-based.

Azar *et al.* (2003) made an assessment of the growth in freight transport worldwide between 1990 and 2100. The same study also gives estimates for energy use in 2100. The results of this assessment are depicted in Table 5.4.

Worldwide, the share of road and rail transport are currently roughly the same (Azar *et al.*, 2003; IRF, 2007). Also within the OECD, the share of road and rail is comparable (OECD, 2007).

Table 5.4. **Growth in global freight transport volumes**

	Transport volume in tkm per year		Energy demand (EJ per year)	
	1990	2100	1990	2100
Road	6.4	40	23	72
Rail	6.1	13	3.1	4.3
Domestic water	2.6	5.0	1.2	1.6
Ocean	29	126	5.8	16
Air	0.07	0.28	0.32	0.62
Total	**44**	**184**	**33**	**95**

Source: Azar *et al.* (2003).

Table 5.4 shows that whereas the growth in freight transport volume is expected to be strongest in road transport, the growth in rail transport is expected to be much lower than the average. Despite an expected improvement in fuel efficiency, the global energy use of freight transport is expected to triple.

European Union (EU)

Assessments of the EEA indicate that freight transport volumes in Europe are growing strongly, outpacing economic growth (EEA, 2008a). This growth in transport volume, mainly in road freight, is the main driver behind the increasing energy demand of freight transport. Road freight transport volume in the European Union is expected to grow 78% between 2000 and 2030. This means an even stronger growth than in the past 20 years (Smokers *et al.*, 2007).

For the 11 EU member states with consistent data, the proportion of tonne kilometres for international road haulage increased slightly from 22% in 1995 to 26% in 2005 (Eurostat, 2004, 2007a). This represented an increase of 52% in absolute terms, given the overall growth in road activity during this period. Of the cross-border volume for this group of member countries, 90% in 2005 was between adjacent countries, so the incidence of cross-trade (*i.e.* transiting one or more intermediate countries) was low. For the EU25 countries (excluding Greece and Malta), 30% of road freight volumes in 2005 were cross-border in nature, with 15% of the cross-border volume being cross-trade, representing the greater incidence of transit traffic in certain eastern European countries (Eurostat, 2007a). Of the cross-border flows, 94% of the volume in 2005 was between EU members and, of the remaining amount, most was to/from Switzerland, Norway and the Russian Federation. International road freight transport in the European Union grows twice as fast as national transport volumes: 25% against 12% growth between 2000 and 2005 (European Commission, 2007b).

By contrast, international flows are more significant in the rail market. Some 51% of rail freight volumes in the 25 EU countries in 2005 were cross-border in nature (Eurostat, 2007b). As with road, the vast majority of this volume was between adjacent countries, with just 20% of the total international volume transiting intermediate countries. While no consistent statistics over time exist at the European level, analysis of trends in individual countries reveals the growing share of international flows for national rail systems. For example, international rail freight increased from 37% of all rail freight in Germany in 1995 to 47% in 2005; in the Netherlands, the increase was from 76% to 79%; and in France, the share went up from 30% to 33% (Eurostat, 2003, 2007b).

North America

Given its central position between Canada and Mexico, the United States is involved in all intra-North American trade flows. The *North American Transport Statistics Database* (NATSD) does not contain detailed and consistent time series data relating to intra-North American trade by transport mode; these data have been published only since 2004 (NATSD, 2007). Table 5.5 summarises the road and rail freight flows between the United States and Canada and Mexico in 2006. These two modes are more dominant for exports from the US, where 60% to 65% of tonnage is by road or rail, whereas water transport and, in the case of Canada, pipeline, are important modes for imports to the US.

In North America, the share of international transport in total road freight transport is much smaller: about 8% (US Department of Transportation, 2006; IRF, 2007). The share of international rail transport in total freight rail transport in North America is only 5%. These

Table 5.5. **US trade with Canada and Mexico by road and rail, 2006**

	Exports from US		Imports to US	
	Mode share (%)	tons (m)	tons (m)	Mode share (%)
Canada				
Road	42	59	62	21
Rail	21	30	76	26
Mexico				
Road	38	31	28	20
Rail	26	21	11	8

Source: Adapted from NATSD (2007).

small shares can be explained by the small number of (very large) countries involved: international surface transport in North America is limited to transport between Canada, the United States and Mexico.

In 2002, international road freight accounted for just 2% of total road freight lifted to, from and within the United States. The corresponding figure for international rail was 6% (measured in tons lifted). In combination, road and rail represented 32% of international tons lifted to and from the United States (imports and exports combined) (Office of Freight Management and Operations, 2007).[3]

Europe to and from Asia

The modal split differs a lot among countries. In the Russian Federation, the rail freight transport volume is several times larger than the road freight transport volume, and also in China, the share of rail is much higher than that of road.[4]

Travel distances between Europe and Asia are generally far shorter by land than they are by sea. This is especially true if the origin and/or destination are inland. Rail services from China to Europe via central Asia that take approximately 20 days could be provided, whereas this takes approximately 6 weeks by sea. It has been estimated that travelling from Europe to Asia by road would take approximately two weeks (ECMT, 2006).

At present, the major trans-Asia land routes are rail routes, including the Trans-Siberian, the TRACECA corridor, and the southern route via Turkey and Iran. Road routes can be preferable to rail routes in Asia in terms of the denser coverage they provide to larger towns. In addition, the physical terrain in the south of the continent is often better suited to road than rail.

China is currently developing a countrywide network of road and rail infrastructure, that will link up with connections to Kazakhstan, Mongolia and the Russian Federation.

Land transport between Europe and Asia is one of the oldest trade routes in the world (the Silk Route). However, over time long distance freight flows on this route were largely replaced by maritime transport. The re-opening of the border between China and Kazakhstan for commercial trade has resulted in the recommencing of long distance freight flows by (road and rail) land between the two continents. However, volumes of intercontinental freight flows remain relatively small at present. These land routes are mostly used at present for the transport of commodities such as coal, agricultural products, iron and oil, and bulk goods. Only very limited quantities of containerised cargo is transported on these land routes. Table 5.6 shows the estimated modal split for containers between Europe and China. This reflects that maritime transport still dominates these container flows at present. Rail transport (especially

Table 5.6. **Estimated transport of full-load containers between Europe and China**

2005, million full-load TEUs

	Westbound	Eastbound	Total
Sea transport	4.5	2.5	7.0
Rail	< 0.2	< 0.1	< 0.3
Road (truck)	< 0.03	< 0.03	< 0.06

Source: Chamber of Commerce of the United States (2006).

the Trans-Siberian Railway) was estimated to account for approximately 3% to 4% of these containerised freight flows in 2005, and road freight was estimated to represent less than 1% of these containerised flows (Chamber of Commerce of the United States, 2006).

It has been estimated by industry sources that in 2005, approximately 0.2 million tons of cargo (12 000 trips) crossed the China-Kazakhstan border on trucks. Freight volumes transported by road between China and the Russian Federation were estimated at 1.8 million tons (0.2 million truck trips) in 2005 (which represents an 80% increase over five years) (Chamber of Commerce of the United States, 2006). These freight flows by road are likely to increase in the coming years as a result of infrastructure improvements, including improvements to roads, freight terminals and customs facilities.

5.6. Factors influencing recent trends in international road freight transport

Infrastructure

The basic infrastructure for international road transport is available, but "missing links" constrain route choice. In addition, insufficient capacity on some international transport corridors and the poor quality of infrastructure add to the cost and time of international road transport. There is a general lack of infrastructure facilities, such as inland container depots, particularly at border crossings, to support the consolidation and distribution of goods and trans-shipment between road and rail services (UNESCAP, 2003). Examples of international road infrastructure issues are highlighted below.

Figure 5.5 shows the latest version of the International E-road Network in Europe (a European road numbering system). It provides a map of the road routes followed by the traffic arteries defined in Annex I to the European Agreement on Main International Traffic Arteries (AGR) signed at Geneva in November 1975 (UNECE, 2007). The AGR was extended in 2000 to include the E-road Network for the new UNECE member countries in the Caucasus and central Asia. This resulted in the international road network in these countries, which extend right up to the borders with China, also being ascribed "E" numbers. As well as establishing a coherent road network, the AGR sets in place minimum technical requirements to which E-roads should be constructed.

Asia also has a dense road network which links major cities, especially in the southern part of the continent (including India, Pakistan and the South-East Asian peninsula). Some of these road routes run parallel to East-West rail lines in the north of the continent. The Asian Highway (see Figure 5.6) provides road transport infrastructure linkages to and through the region. It is a network of 141 000 km of standardised roadways joining 32 Asian countries with linkages to Europe.

Whilst the construction and improvement of road infrastructure is important in the development of international road freight, there are additional factors necessary in order to create a successful and efficient road network. This includes standardisation and

Figure 5.5. **International E-road Network**

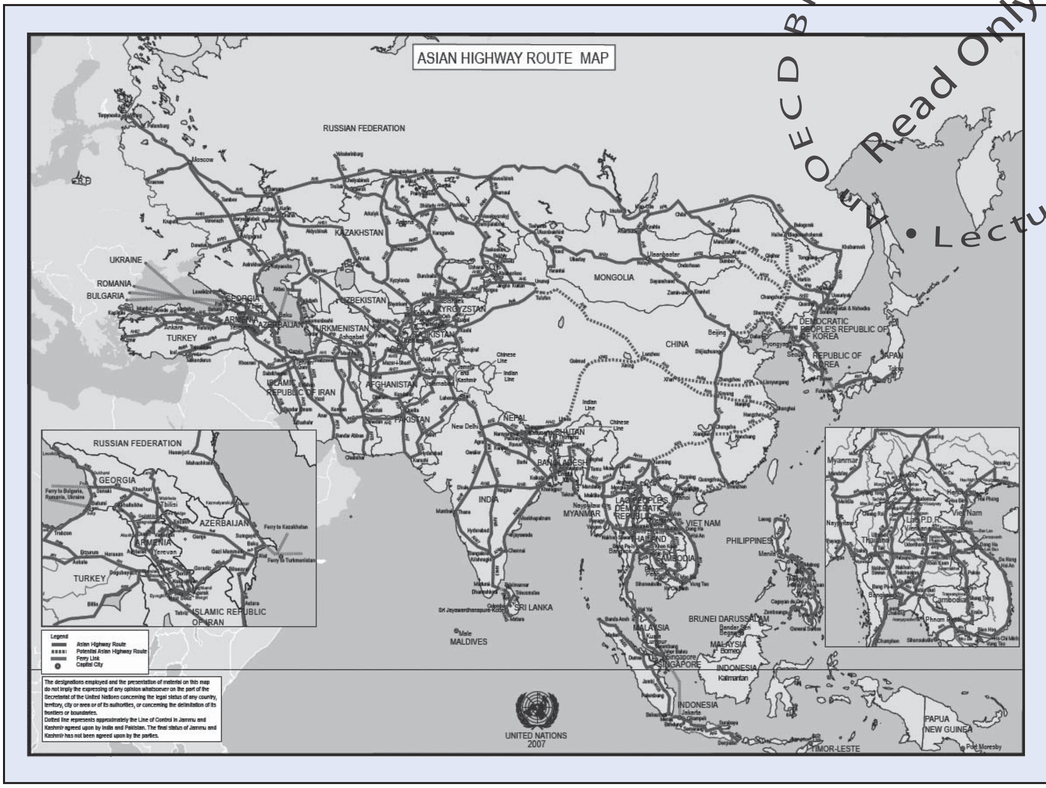
Source: http://en.wikipedia.org/wiki/File:International_E_Road_Network_green.png.

harmonisation of many other factors besides the quality of the road construction, such as traffic regulations, vehicle regulations and traffic technologies. Specific factors that need to be taken into account in standardising and harmonising the road network include:

- the systems adopted for traffic management (including the policies and technology used);
- border crossing arrangements and dwell time caused by customs and transport policies at these locations;
- road signage and information, including traffic conditions and road works;
- emergency operations (calling a single number, minimum guarantee response time, etc.);
- truck-stop facilities (including eating and resting locations and services for drivers);
- emergency vehicle services (in case of vehicle breakdowns or other unexpected incidents); and
- repair, maintenance and disaster management systems (including emergency service response to traffic accidents and adverse weather conditions, such as floods and earthquakes that may damage the road or make driving unsafe).

Several conventions concerning international road transport can help in the standardisation and harmonisation of international road networks. These include the Convention on Road Traffic that helps to harmonise road traffic rules, the Convention on Road Signs and Signals which has produced a large set of common signs and signals to use, and the TIR Convention that allows trucks loaded with goods to cross several borders without customs controls and without payment of duties or taxes.

Figure 5.6. **Asian highway network project**



Source: UNESCAP (2008), *www.unescap.org/TTDW/common/TIS/AH/maps/ah_map_2007.jpg.*

Box 5.2. **The Trans-European Transport Network "TEN-T"**

The Trans-European Transport Network (TEN-T) was first established in 1993. It involves transport infrastructure projects to help put in place high quality trans-European transport networks (unimodal, intermodal and multimodal) that contribute to the smooth functioning of the EU internal market, ensuring the sustainable mobility of persons and goods under the best possible social, environmental and safety conditions. It is intended to overcome problems associated with missing transport links and existing bottlenecks. Fourteen priority projects were established in the EU15 in 1996, this was extended to 30 priority transnational axes in 2004, following the accession of new member states (EU27). In 2007, discussions began on modifications to the major TENs axes to neighbouring countries. This involves TEN-T being redefined to include the EU's neighbours, towards the CIS and central Asian countries, along key transport corridors (as has previously been carried out for central Europe and Mediterranean countries).

Road projects carried out as part of the priority infrastructure projects include: *i)* the Igoumenitsa/Patras – Athens – Sofia – Budapest motorway axis; *ii)* the United Kingdom/Ireland/Benelux road axis; and *iii)* the Gdansk – Brno/Bratislava – Vienna motorway axis.

In addition to these priority infrastructure projects, the TEN-T Network also involves horizontal measures to help:

- Speed up border crossing procedures.
- Simplify and harmonise trade and transport related documentation (including the language regimes).

Box 5.2. **The Trans-European Transport Network "TEN-T"** *(cont.)*

- Implement compatible new technologies.
- Put in place measures to improve safety and security in all transport modes.
- Enhance technical and administrative interoperability.

Specific horizontal measures for roads include: designing and implementing measures to improve road safety by addressing driver behaviour, vehicle safety and road infrastructure safety; and gradually upgrading the road network along the major axes to take goods vehicles of up to 11.5 tonne axle-weight and up to four metres high.

Sources: ECMT (2006), Fontaine (2007), European Commission (2005).

Policy/regulation

Agreements between countries

International road freight operations by definition involve goods vehicles moving between two or more countries as part of a delivery or collection. Some international trips can involve the goods passing through (*i.e.* transiting) many different countries in order to get from the point of collection to the point of delivery. Different countries tend to have developed varying national rules governing goods vehicles, goods movement and driver regulations, and have typically had differing views and approaches to international road freight. Over time, this has resulted in the establishment of conventions that govern international road freight operations, thereby allowing vehicles to pass between and through countries in carrying out their work.

The international community has, over the years, adopted several international legal instruments that contain provisions intended to assist international road freight operations, including gaining access to seaports via transit traffic through neighbouring countries. The four main legal instruments addressing transit traffic and customs transit are (UNCTAD, 2007):

- Convention and Statute on Freedom of Transit, 1921 (entry into force 31 October 1922; 50 parties).
- General Agreement on Tariffs and Trade (GATT), 1947, now part of GATT 1994 (provisional entry into force 1 January 1948; 150 members of the World Trade Organization [WTO]).
- Convention on Transit Trade of Land-Locked States, 1965 (entry into force 9 June 1967; 38 states parties).
- United Nations Convention on the Law of the Sea, 1982 (entry into force 16 November 1994; 155 states parties).

In addition, the General Agreement on Trade in Services (GATS) extends the GATT's principles of freer and fairer trade in goods to services as well, which includes freight companies looking to do business abroad (Latrille, 2007).

Each of the above instruments is intended to address different issues concerning transit traffic and customs transit. Thus there are different definitions of transit used in each. GATT, in its Article V, and the Convention on Transit Trade of Land-Locked States only include goods (including baggage) in the definitions of transit. However, the Convention and Statute on Freedom of Transit and the United Nations Convention on the Law of the Sea also include passengers. These latter two agreements also include the concept of trans-shipment as a type of transit.

In addition, there are many other international legal conventions and agreements that have been established by various intergovernmental bodies which aim to facilitate international road transport and transit traffic. Each of these conventions cover different themes in international transport operations, such as the transport of dangerous goods, the facilitation of crossing of borders, or the contract of carriage for road or rail transport. There are also other legal conventions that are mode-specific, addressing issues such as the harmonisation of road signs and signals, or the transport of goods by rail.

International legal instruments are complementary to regional, corridor and bilateral transport and transit agreements, and are often referred to in such agreements on transport as well as in those on infrastructure, storage and general trade terms (UNCTAD, 2007). Several regional co-operation organisations have established transit and/or transport agreements. Many countries have traditionally entered into bilateral agreements on particular aspects of co-operation. In road transport, such agreements have often been needed to allow a transport-operator in one country to carry out bilateral transport operations, third-country transport operations or transit transport operations through another country. A transit corridor agreement is an agreement concerning a designated route between two or more countries along which the corridor countries have agreed to apply specified procedures. These agreements tend to be very focused on the corridor and transit issues, such as infrastructure, customs, border crossings and vehicles. An example of this type of arrangement is the Walvis Bay Corridor Group which was established in 2000. It brings together public and private stakeholders along four transport corridors in southern Africa, all connecting with the port of Walvis Bay in Namibia.

One of the main issues for land-based transport systems that need to cross borders is clearly the complexity of international agreements and the time taken to achieve these agreements. This has the effect of inhibiting some of the potential initiatives that could be taken from a commercial and operational perspective. As the following section notes, when transport regimes are liberalised, there are many more opportunities to provide services and the operations themselves can become more efficient.

Liberalisation of international road freight transport

The European Union provides an example of the total liberalisation of international road freight transport movements between member states. The origin of the liberalisation of trade and freight transport movements in the European Union was in the Treaty of Rome and the formation of the European Economic Community. This treaty provided for the establishment of a common transport policy, based on principles of free market economics, which was intended to remove obstacles to free competition between transport operators from different countries. Multilateral Community authorisations were introduced in 1969, which gradually replaced bilateral agreements between countries. The establishment of the Single European Market was the catalyst for full liberalisation in international road freight, with the removal of these multilateral authorisations and the introduction of European Community licences. Full liberalisation of international road freight was completed by 1998. Operators based in a member state only need to comply with two requirements to be able to carry goods between any EU countries: *i)* to be recognised as a professional road transport operator; and *ii)* to hold a European Community licence. To be recognised as a professional operator it is necessary to meet three criteria: good repute, financial standing and professional competence. Any operator who meets these requirements, and who meets any other national market access regulations, obtains a Community licence. This then allows the operator to carry out international transport operations in the entire geographical area of the EU (ECMT, 2005).

The European Commission has put in place harmonised social regulations to ensure that full liberalisation does not lead to competition distortions brought about by national differences in factors such as labour rates. These regulations cover issues such as working hours, driving time and rest periods for drivers, periodic technical inspection of motor vehicles and their trailers.

Operations

Growth in world trade together with road and rail infrastructure improvements have made the possibility of land-based international freight solutions better over time. In the case of the EU, deregulation, the abolition of internal frontiers and harmonisation of fiscal and technical standards, together with the introduction of the euro, have also helped to boost internal international trade. In other countries and regions, better organised and faster border controls, together with trade and transport agreements, have facilitated growth in land-based international freight movements, albeit to a lesser extent. These changes have made it simpler for logistics service providers to participate in international road and rail solutions.

Logistics service providers can enter into foreign markets by establishing operating centres in other countries and gradually increasing their networks. However, rather than follow this evolutionary and somewhat slow route to growth in foreign markets, some firms prefer the prospect of mergers, takeovers or strategic trading alliances with operators based in other European countries.

The growing internationalisation of business has forced companies providing logistics services to consider their own strategies to meet these new needs. Service providers need to determine the extent to which they can meet all the service requirements of a European business or whether they can realistically only meet part of those needs. In many cases, there remains at present a potential mismatch between the logistics demands of European companies and the ability of any single service provider to meet these demands. This often results in disappointment when a manufacturer decides to rationalise its logistics network and reduce the number of service providers it deals with at a European level. In many cases, the manufacturer finds that there are few logistics service providers that wish to take on the commitment of handling all their European activities.

Providers of logistics services need to be concerned with two dimensions to their activities in the first instance: geographical scope and range of services. These two dimensions highlight how challenging it really is for the logistics service company to be able to provide one-stop shopping for a customer. Some companies already provide what can be described as European services, providing the long-distance links in a network used by manufacturing companies. This provision of services is evident in the case of airlines, shipping lines, freight forwarders and integrators. It is clearly at the level of local and national distribution that internationalisation of service provision has been slowest to develop.

A broad range of logistics activities can be provided by logistics service providers. Freight transport and warehousing services have been widely available for many decades, together with documentation services to support the flow of these products (*e.g.* delivery and customs documentation). However, in recent years, logistics service providers have begun to offer an ever-expanding range of services, such as final assembly of products, inventory management, product and package labelling, product tracking and tracing along the supply chain, order planning and processing, and reverse logistics systems (which tackle the collection and recovery of end-of-life products and used packaging in the supply chain).

Despite a period of uncertainty about the benefits of scale for logistics service providers, there have been some important developments in the last few years. Larger logistics service providers have grown mainly through merger and acquisition, and appear to be committed to developing more global capabilities.

The very different nature of global markets means that logistics providers wishing to meet growing demand for international services adopt suitable and appropriate approaches for different markets. International transport companies engaged in cross-border work already understand that strategies may need to be tailored to the particular country of operation.

In deciding how to take advantage of the new global opportunities, logistics service providers need to be clear about which of the following strategies they wish to adopt:

- Strategy A (Global) – providing a worldwide service, offering distribution both within and between a number of countries.
- Strategy B (Multi-domestics) – providing national services in several countries.
- Strategy C (Global-linkers) – providing a network (or part of a network) of mainly international services between major global markets.

Clearly the most ambitious strategy is the first – to provide a truly global service. Several major logistics service providers are working towards this, but it is a challenge. The foundations for the multi-domestic strategy appear to lie in the successful duplication of domestic services in other countries. The original services are, of course, adapted as required.

Crimes against road freight

International road freight drivers are prone to criminal attacks on their vehicles, the goods they carry and themselves. The fact that such operations are taking place in foreign countries, and sometimes in isolated locations, makes drivers more prone to such attacks than in domestic operations.

The IRU and ITF (formerly ECMT) carried out a study into attacks on international road freight drivers in 2005/6 (IRU, 2008). This research, involving a survey of drivers, transport companies and transport authorities in 35 European and central-Asian countries, documented the type and scale of attacks on international good vehicle drivers operating across Europe and how governments are addressing this problem. The work included 1 300 face-to-face interviews and 700 replies to a web questionnaire. Respondents were asked about their experiences over the period 2000 to 2005. The main findings included (IRU, 2008; Crass, 2007):

- 17% of all drivers interviewed have suffered an attack during the five-year period;
- 30% of attacked drivers have been attacked more than once;
- 21% of drivers were physically assaulted;
- 60% of the attacks targeted the vehicle and its load, whilst the remaining 40% were related to the theft of the driver's personal belongings.

Box 5.3. **The Beijing-Brussels international truck caravan**

A 12 000 km caravan by goods vehicles took place in 2005. It started at the International Road Transport Union (IRU) Euro-Asian Road Transport Conference on 27 September and arrived in Brussels on 17 October. Road transport carriers from several countries participated in the project.

The project set out to demonstrate that road transport is an effective means of shipping cargo by land between Europe and the countries of the Asia-Pacific region. It was initiated by KAZATO, IRU's member association in Kazakhstan, and supported by governments, international institutions as well as road transport associations.

The caravan started from Horgos in China (with loaded containers delivered by Chinese carriers). The containers (under TIR carnets) then commenced their journeys on Kazakh, Latvian, Lithuanian, Polish and Russian trucks.

IRU President Paul Laeremans said that the caravan had "proven that freight can be efficiently transported from China to CIS countries and further to the EU within just one-third of the time it would take by sea. This caravan demonstrates that road transport, in an increasingly competitive globalised world economy, is no longer just a means of carriage, but rather an irreplaceable production tool for all companies and economies".

Peter-Hans Keilbach, Senior Representative of the US Chamber of Commerce said that "trade between the Asia-Pacific region and Europe exceeds USD 300 billion per year. American companies invested over USD 4 billion in China in 2004 and this number grows every year. Total US assets in Europe are worth nearly USD 3.3 trillion. Currently, trade between Asia and Europe primarily involves sea transport as well as expensive freight handling ports. Road transport will significantly reduce transit time to less than 3 weeks, reduce costs, and allow for door-to-door delivery".

At the roundtable discussion on using Russian transit potential in road freight transport by road, held on the same day the truck caravan arrived in Moscow, Mr. Rounov, IRU General Delegate to the CIS, emphasised the competitive advantages of road transport in terms of delivery speed and possibility of door-to-door delivery. Mr. Sukhin, President of the Russian Association of International Carriers, stated that the average speed of freight delivery by road (16 km per hour) outperformed that of sea (4 km per hour) and rail (8 km per hour).

Source: IRU (2005).

Technology

This section discusses two aspects of technology that influence international road transport. It explores issues relating to vehicle technologies and the rapid developments in information and communication technologies. Clearly these latter developments have major implications for the efficiency and commercial possibilities of longer-distance international road freight operations.

Vehicle technology

The UNECE has developed two key agreements that relate to vehicle technology for international road freight trips; these are open to all UN member countries (Ferrer, 2005):

- The "Agreement Concerning the Adoption of Uniform Technical Prescriptions for Wheeled Vehicles, Equipment, and Parts which can be Fitted and/or be used on Wheeled Vehicles and Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these Prescriptions" (referred to as the "1958 Agreement").

- The "Agreement Concerning the Establishment of Global Technical Regulations for Wheeled Vehicles, Equipment, and Parts which can be Fitted and/or be used on Wheeled Vehicles" (referred to as the "1998 Agreement"). This provides the legal framework for the establishment of global technical regulations for road vehicles. This Agreement was introduced largely to meet US concerns about the type-certification system included in the 1958 Agreement and a perceived loss of sovereignty.

These UNECE agreements provide the legal framework for the development of technical regulations to improve the safety and environmental performance of road vehicles, including goods vehicles. They help to remove non-tariff barriers caused by incompatible vehicle standards, and provide an easier process than countries attempting to harmonise their different domestic standards.

Within the EU, rules exist governing engine emission standards (Euro standards) for new goods vehicles, aiming at limiting the amount of pollutants in the road freight sector. The introduction of this standard was leading to substantial improvement in air quality over Europe, mainly reducing air pollutants and particulates. In addition, member states have to accept goods vehicles within agreed maximum weight (gross weight and axle weight) and vehicle dimensions (length and height) limits from other member states. The maximum weight for road-trains and for articulated vehicles with 2-3 axle trailers is 40 tons, and 44 tons for three-axle motor vehicles with 2- or 3-axle semi-trailer carrying a 40 foot ISO container. Member states may allow heavier and larger goods vehicles on their national roads if they wish.

Information and communications technology (ICT)

A wide range of ICT solutions are now commonly used in logistics and freight transport operations, and which have made international road freight operations more efficient, more secure and safer. These include:

- vehicle and trailer tracking systems;
- on-board communication systems;
- computerised vehicle routing and scheduling (CVRS);
- satellite navigation systems;
- track and trace systems;
- paperless documentation and customs clearance.

Vehicle and trailer tracking systems. Systems that can track a goods vehicle's movements have been available for many years. They can be used for tracking loads as well as vehicles and trailers. The hardware usually involves an on-board computer, a satellite signal (GPS) receiver and a communications module. These systems can help to deter and detect vehicle and load theft, and thereby improve driver safety. Typical security applications can include: *i)* panic buttons that allow the driver to raise a security alert so that the company can alert the police and the vehicle can be tracked; *ii)* remote vehicle immobilisation that can be accompanied by door locking, flashing lights and horn sounding; *iii)* several vehicle-tracking system providers offer vehicle-tracking bureaux that can detect when a vehicle or trailer has moved outside a specified location or is operating outside its normal operating period.

On-board communication systems. Such systems can range from mobile and satellite telephones, to on-board text messaging and computing systems. These allow drivers to keep in touch with their company and other companies they are collecting from and delivering to in the course of their operations. Drivers can be alerted of changes in their schedules and warned of problems in advance. In addition, drivers can contact supply chain partners, vehicle recovery services and the police in case of emergency.

Computerised vehicle routing and scheduling (CVRS). CVRS can be used to plan suitable vehicle routes and schedules to fulfil orders using digital maps and user-set parameters. The use of CVRS can help to improve customer service, planning time, reduce journey times and distances, and thereby reduce fuel costs.

Satellite navigation systems. Satellite navigation systems (SatNav) is used to provide drivers with instructions and mapping to reach their intended destination. This can be especially useful when the driver is making international deliveries in unfamiliar countries and cities, saving time spent deciding on a route and in selecting the wrong road. However, there can also be problems associated with using such technology. Such systems are capable of misrouting, resulting in a driver being directed a longer way when a shorter suitable route was available. In addition, drivers of heavy goods vehicles have frequently reported routing problems caused by unsuitable routings when the computerised mapping software did not contain constraints such as bridge heights, road widths and weights restrictions (Freight Best Practice, 2006). There are frequently news reports in Europe of foreign goods vehicle drivers using satellite navigation systems that direct them onto inappropriate roads where they are stuck for several days, and block the road in the process.

Track and trace systems. Track and trace systems can be used to track products throughout the supply chain. Such systems can provide visibility of the product at all stages and at all times. They are widely used in the parcels sector for worldwide operations. They help companies to ensure safe, reliable and on-time delivery, and allow for improved planning. Such systems are also of great importance in locating products that have gone missing en route. Electronic seals and RFID[5] technologies are being increasingly used to track containers and other loads moved by road internationally.

Paperless documentation and customs clearance. Paperless documentation systems can be used to load manifest information electronically into a driver terminal at the beginning of the working day or throughout the day for greater working flexibility. Electronic proof of delivery can reduce delivery time and provide immediate proof of safe delivery and receipt of goods. Benefits of paperless systems can include reduced paperwork and administration costs, reduced delivery and invoicing errors, improved order status information and consignment tracking. This can result in lower operating costs and improved customer service.

Many customs authorities now use ICT applications in their work to help speed up processes and make them increasingly reliable, secure and resistant to fraud and corruption. ICT can also help to process customs revenue collection. It can also significantly reduce the number of physical inspections of goods required, and allow for pre-arrival clearance and risk analysis. It can be used to better plan the timing and location of physical inspections, thereby reducing the waiting times for trucks and containers. An example of such a system is the UNCTAD Automated System for Customs Data (ASYCUDA) used to manage customs transit systems (UNCTAD, 2006). There are also plans to make some international road transport documentation electronic in future, such as TIR Carnets.

5.7. Factors influencing recent trends in international rail freight transport

Rail systems tend to be more heavily regulated than road operations and, in many cases, governments are directly involved in service provision, in addition to their infrastructure-related responsibilities. The discussion that follows has been divided in four sections (infrastructure, policy/regulation, operations and technology), but there are many inter-relationships between the issues raised.

Infrastructure

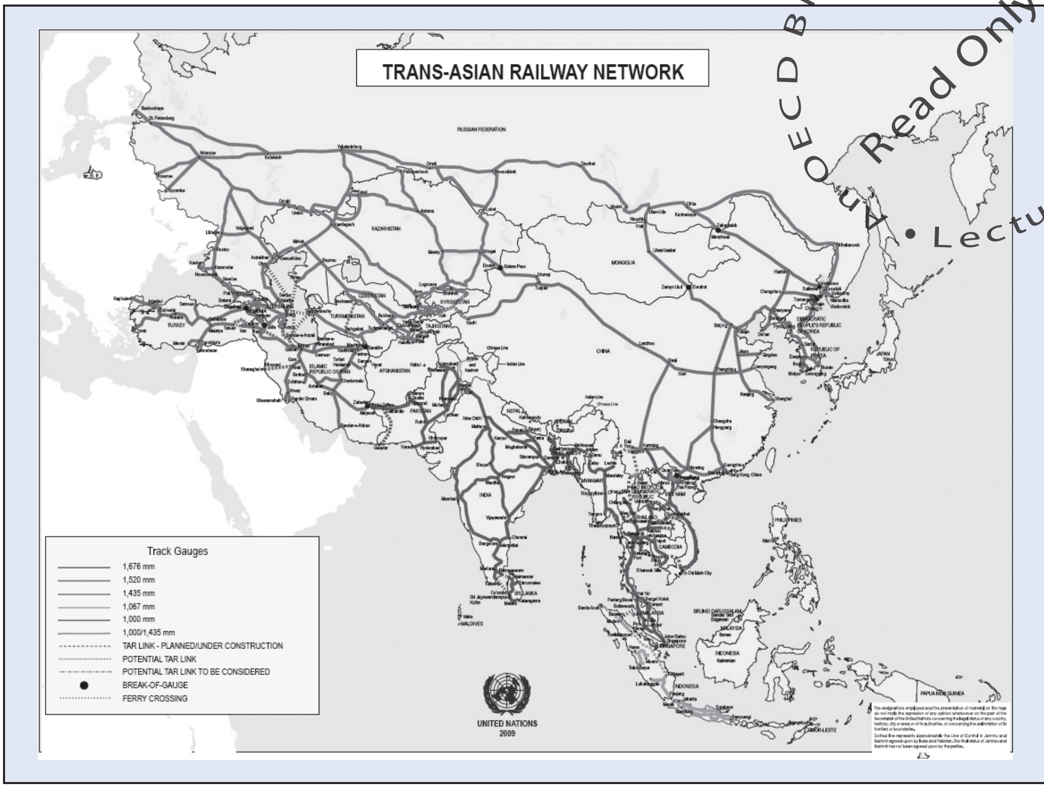
The most critical physical requirement to allow cross-border rail freight traffic is an active network connection. In some countries, rail networks are domestic in nature, and cross-border links have either never been constructed or have ceased operation. For example, in Latin America, links that previously existed between Colombia and Venezuela, and between Guatemala and El Salvador, are no longer present (ECLAC, 2003). In Europe, the various national railway networks are relatively well interconnected, although the quality of the international links can often be sub-standard compared to domestic corridors. Where a physical cross-border connection does exist, one of the biggest infrastructure constraints for international rail flows is the historical decision made by different countries to adopt a different track gauge (*i.e.* the distance between the two rails) when constructing their rail system. This is a problem that persists within some countries, but is more particularly an issue at international borders. Two main gauges exist, metric (1 000 mm) and standard (1 435 mm), but there are others in certain parts of the world. Where different gauges are found, time and cost are added to the rail cross-border transfer since the goods themselves need to be transferred between rail wagons, or the wagons need to have their axles changed for onward transport on the other gauge.

Examples where gauge differences exist at international borders include:

- Southern Brazil is metric gauge whereas Uruguay and Argentina have standard gauge networks; only the link to Bolivia is compatible with Brazil (ECLAC, 2003).
- France has standard gauge track, but traditional routes in Spain and Portugal have different gauges, 1.672 mm in Spain and 1.664 mm in Portugal; new high-speed lines on the Iberian peninsula are being constructed to the standard gauge (European Commission, 2005), but freight will have to continue using the traditional routes where the difference in gauge will persist for the foreseeable future.
- In Asia, at least 5 different track gauges exist, ranging from metric in much of South-East Asia up to 1.676 mm in the Indian sub-continent; China has generally adopted standard gauge track, while the Russian Federation has a broader 1.520 mm gauge (see Figure 5.7).

Another infrastructure-related issue is that of differing voltages on electrified lines, which has traditionally required a change of locomotive at border crossings where electric locomotives are used. This tends not to be as significant an obstacle as track gauge differences, though, since a locomotive change can be completed in a shorter period of time than regauging the wagons on an entire train. In many cases, diesel locomotives are used for cross-border services (even where systems are electrified) and, as identified below, multi-voltage electric locomotives have been introduced to operate internationally.

Figure 5.7. **Trans-Asian railway network**



Source: UNESCAP (2006), *www.unescap.org/ttdw/Publications/TIS_pubs/pub_2434/integrated_2434_full.pdf*.

A number of initiatives have been developed to try to better integrate domestic rail networks to provide higher quality long-distance corridors, notably in Europe, where countries tend to be smaller and international rail freight activity more significant than elsewhere. RailNetEurope is one such initiative – see Box 5.4. Elsewhere, political alliances and/or disputes have had an influence on the continued use of existing cross-border infrastructure or the provision of new routes. For example, the break-up of the Soviet Union and subsequent unrest in much of the Caucasus region led to many of the rail routes linking the Russian Federation, Armenia, Georgia and Azerbaijan being abandoned and international rail freight volumes declining (Jackson, 2008). New links within this region are now proposed, together with external routes to Turkey and Iran which may eventually form part of strategic long-distance international corridors planned for the Asian continent. New routes are also planned within South-East Asia, linking China to Thailand, Singapore and the Indian sub-continent (Briginshaw, 2007). Should the range of schemes currently proposed or under construction come to fruition, rail network connectivity across Asia will be significantly enhanced, opening up an array of new international journey opportunities.

Policy/regulation

In many parts of the world, railways are viewed as a responsibility of the public sector. Over time, though, many countries have initiated a process of liberalisation. Most noticeably, this occurred first in North America, but has also now taken place elsewhere, including Australasia, South America and Europe. There has been no standard method of liberalisation, but competition among rail freight companies is now prevalent in many

Box 5.4. **RailNetEurope**

RailNetEurope (RNE) was established in 2004 and now has 31 rail infrastructure manager members from across the European Union. These members are responsible for a network covering approximately 230 000 km, and aim to develop a consistent European approach to cross-border rail traffic through greater harmonisation of systems and the removal of barriers.

RNE is designed to:

- Develop traffic on the European rail network.
- Facilitate European rail infrastructure access.
- Improve rail service quality.
- Increase performance of the associated scheduling and operational procedures.

An example of an initiative developed by RNE is the one-stop-shop concept, which brings together the disparate rail networks along an international corridor and offers a single point of contact for potential service providers who are keen to operate services using two or more infrastructure providers' networks. This should help reduce the barriers associated with national borders and simplify the process of establishing new international rail freight flows.

Source: RailNetEurope (2008).

Table 5.7. **Institutional differences between North America and Europe**

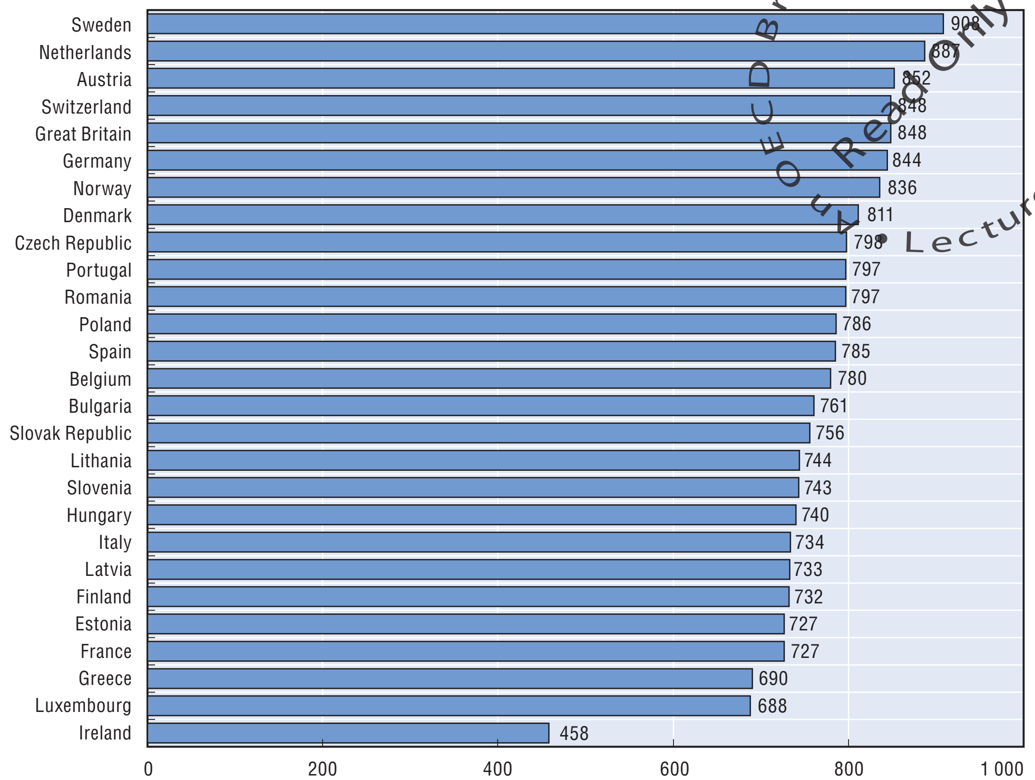
	North America	Europe
Rail policy	Competition	Regulation
Rail competition	Parallel rail	On-rail
Infrastructure control	Operator	Regulator
Infrastructure funding	Private	Public

Source: Posner (2008).

countries. As Table 5.7 reveals, there are considerable differences in the processes implemented in North America and Europe. As a consequence, there remains a much greater role for the public sector in European rail provision. This may also result from the fragmented nature of the European market, compared to the more integrated North American situation, where there are only three countries in a large land mass. Public policy remains an important issue regardless of the nature of the market.

The European Union sees growth of international rail freight activity as a political objective, for economic, environmental and social reasons. Over the last decade, it has agreed to a series of packages aimed at liberalising the rail freight market, particularly concerning cross-border traffic. Figure 5.8 shows that the extent to which specific European Union countries have liberalised their rail freight activity varies so far. Quite clearly there are differing experiences along the spectrum, with eight countries identified as being at an advanced stage. Just one, Ireland, falls in to the "delayed" category. Under European law, international rail freight must now be liberalised, although certain countries have been less enthusiastic than others in allowing competitive service provision to develop.

Figure 5.8. **Liberalisation of rail freight transport in Europe**



Key: 1 000-800 – Advanced; 799-600 – On schedule; 599-300 – Delayed.

Source: IBM Global Business Services (2007).

Operations

There are various ways in which rail freight operations are being influenced by the internationalisation of transport activity. This section will highlight three of these to show the range of effects:

- Geographical expansion of operators.
- New international services provided by co-operation between operators.
- Land-bridge corridors.

With the liberalisation of access to provide services over rail networks in different parts of the world, formerly domestic rail freight operators have started to become more international in nature. An early example in the 1990s was the expansion of Wisconsin Central, a US railroad company that is now part of Canadian National, in to New Zealand, Canada, United Kingdom and Australia, often through the purchase of rail freight operations being privatised by governments (Canadian National, 2008). America Latina Logistica (ALL), a private Brazilian operator, has expanded its operations across the border into northern Argentina (Kolodziejski, 2005). More recently, Railion Logistics has begun expanding rapidly across Europe – see Box 5.5 for details.

In addition to rail operators expanding their own territorial coverage, there have been developments in international services provided through co-operation between infrastructure and/or service operators, where two or more rail freight companies are responsible for the transit from origin to destination. For example, RZD, the Russian public rail company has developed partnerships with a number of neighbouring countries, and has set up the Eurasia

Box 5.5. **European expansion of Railion Logistics**

Railion is a division of Deutsche Bahn AG, the German national rail organisation which holds the majority of shares, with small percentages owned by the Dutch and Danish state railway organisations. In addition to its core German operations, Railion Deutschland, the company has direct rail operations in its established subsidiaries in the Netherlands, Denmark, Italy and Switzerland. Expansion is occurring through acquisitions and partnerships. As examples, during 2007:

- Joint venture established between Railion and Green Cargo, a Swedish operator, to improve service provision between Scandinavia and central Europe.
- Acquisition of EWS, Britain's largest rail freight operator, that has also developed open access operations in France.
- Purchase of the majority of shares in Transfesa, a Spanish logistics company with significant rail interests.

As a consequence of this geographical expansion, which occurred soon after the liberalisation of the European rail freight market, Railion is rapidly becoming a Europe-wide rail freight operator

Source: Railion (2007, 2008).

Rail Logistics joint venture, which also includes Germany, Poland and Belarus (Lukov, 2008). A number of partnerships have developed in the European Union since the liberalisation process began, and service quality initiatives have subsequently been developed, building on the CER-UIC-CIT[6] Freight Quality Charter that was implemented in 2003 (CER, 2005). The charter focuses mainly on train punctuality and the implementation of quality-contracts between railways and customers. CER claims considerable success in improving service punctuality on international corridors, with steady improvement from 50% of trains arriving within one hour of schedule in 2001 to 72% in 2004. The impact of the charter, which is being rapidly adopted to cover more and more services, is expected to lead to further improvement.

The third example can develop either as a result of one operator's expansion or the co-operation among a number of operators, demonstrating rail's abilities in providing a land-based link in international supply chains dominated by shipping, primarily for containers. The US land-bridge, where containers shipped across the Pacific from Asia are moved across to the East Coast is well established, with international containers accounting for the majority of some 15 million intermodal units moved by rail from the west to east of the US (Briginshaw, 2007). The growth in traffic between Asia and North America has led to rapid land-bridge growth for North American operators, such as Union Pacific, BNSF Railway, Canadian Pacific and Canadian National (Lustig, 2006). In South-East Asia, there has been growth on the land-bridge route between Malaysia and Thailand, in competition with feeder ships (Abdullah, 2006). A similar land-bridge proposal is now being developed in Saudi Arabia, linking the Red Sea and the Gulf, which will allow traffic from the key Jeddah Islamic Port on the Red Sea to move more directly to the Gulf region (Jackson, 2005).

More innovatively, plans are emerging for new long-distance services taking advantage of the network improvements and regulatory freedoms outlined earlier. For example, Box 5.6 describes a trial container train service from China to Europe in early 2008, possibly marking the start of a concerted effort by rail companies to gain a share of the rapidly expanding market for freight transport between the Far East and the European Union.

Box 5.6. **China-Germany container train trial**

Responding to the increasing trade volumes between China and the European Union, a trial container train operated in January 2008 between Beijing and Hamburg conveying a range of consumer goods. The 10 000 kilometre journey through six countries (China, Mongolian Republic, the Russian Federation, Belarus, Poland and Germany) took 15 days, which is approximately half the duration by sea between the two cities. As a consequence of the successful trial, plans are being developed to commence regular operations on this corridor.

Source: Deutsche Bahn AG (2008).

Technology

Despite the greater potential benefits from adopting new technologies in a more fragmented continental market, European countries have tended to lag behind North America in their adoption of new technologies that assist in making rail freight more competitive. In general, the rail freight sector has typically not been very quick to develop and adopt new technologies. The combination of generally low-technology operations and, where technological solutions have been adopted, incompatibility among different national systems, poses considerable challenges for cross-border rail movements.

The United States has progressively modernised its systems, for example with the introduction of higher axle-loads, automatic wagon tracking and wagon auto-couplers, while European systems have tended to be slow to introduce new methods (Anon, 2008). This may reflect the commercial imperative of North American operators, who have seen the benefits

Box 5.7. **Technologies to enhance interoperability in the European Union**

Examples of technologies being implemented include:

- Multi-voltage electric locomotives: a number of new locomotive designs are being introduced that allow locomotives to work across international borders; for example, the Traxx locomotive has modules that allow it to operate on most of the electrified networks across Europe.
- Signalling systems: a key component of European Rail Traffic Management System (ERTMS) is a new interoperable signalling system that is intended to reduce operating costs and enhance rail's competitiveness through the implementation of continent-wide standards that incorporate modern technology.
- Gauge transfer: pending the full standardisation of track gauge across the European Union, new rapid gauge-changing technologies have been developed to regauge wagons, reducing the length of time required at borders where track gauges differ on either side.
- Train payloads: technological solutions to allow freight trains to be longer, larger and/or heavier, thus benefiting from economies-of-scale and reducing the unit cost of rail transport.
- Information technology (*e.g.* consignment tracking): a technical specification for interoperability (TSI) has been developed relating to the adoption of standardised telematics applications, which will feed in to ERTMS.

While some of these initiatives are starting to have an impact on reducing delays at border crossings and improving the performance of international freight services, overall progress is relatively slow and full implementation of some measures (*e.g.* ERTMS) is likely to take many more years.

Sources: CER (2007a), CER (2007b) and Vitins (2008).

of investment to improve rail's market position, compared to the state-controlled or state-influenced operations in Europe, where innovation has been much slower. The European Railway Agency sees as one of its main objectives the development and introduction of new, standardised technologies and working practices to make rail freight more competitive with road, particularly for cross-border flows where interoperability is currently a significant obstacle (ERA, 2007). Box 5.7 identifies a number of technologies that are being adopted, or are under development, in the European Union to help to overcome infrastructure differences and enhance the quality of cross-border rail freight services.

5.8. Future perspectives

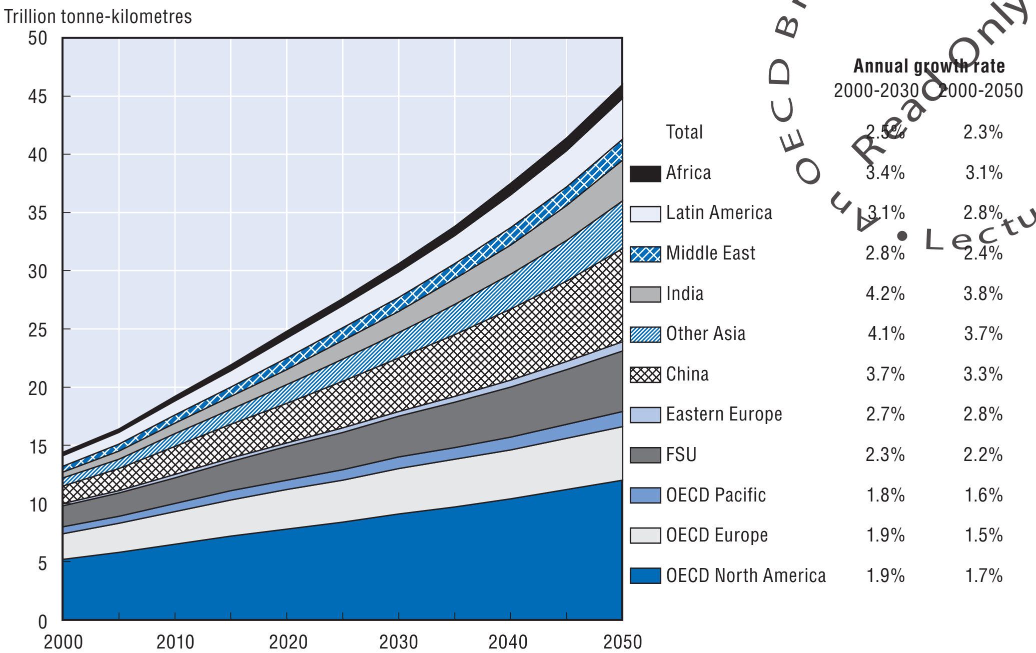
Projections of total road and rail freight activity (*i.e.* domestic and international) were produced as part of the Sustainable Mobility Project in 2004 (WBCSD, 2004). These projections indicated that road and rail freight transport activity will grow significantly over the period to 2050. Figure 5.9 shows the projections by region and Figure 5.10 shows the projections by mode (road – divided into medium and heavy trucks – and rail). In the United States, international freight was forecast to grow by 111% between 2002 and 2035, while domestic freight was expected to grow by 91%. International road and rail freight were expected to grow by 188% and 112% respectively over the same time period (Office of Freight Management and Operations, 2007).

Growth in international movements are not shown separately – but if the broad trends above also occur in international road and rail transport, then there would be some dramatic consequences in terms of the need for improved infrastructure and the removal of bottlenecks.

However, it is not simply a question of infrastructure. Recent work to develop a logistics performance index (LPI) suggests "that policymakers should look beyond the traditional 'trade facilitation' agenda that focuses on road infrastructure and information technology in customs to also reform logistics services markets and reduce coordination failures, especially those of public agencies active in border control" (Arvis *et al.*, 2007). The LPI is a benchmarking tool developed by the World Bank that measures performance along the logistics supply chain within a country. It is based on a worldwide survey of global freight forwarders and express carriers, and allows comparisons across 150 countries. The index is intended to help countries identify challenges and opportunities and improve their logistics performance, in moving goods internationally rapidly, reliably and cheaply (Arvis *et al.*, 2007).

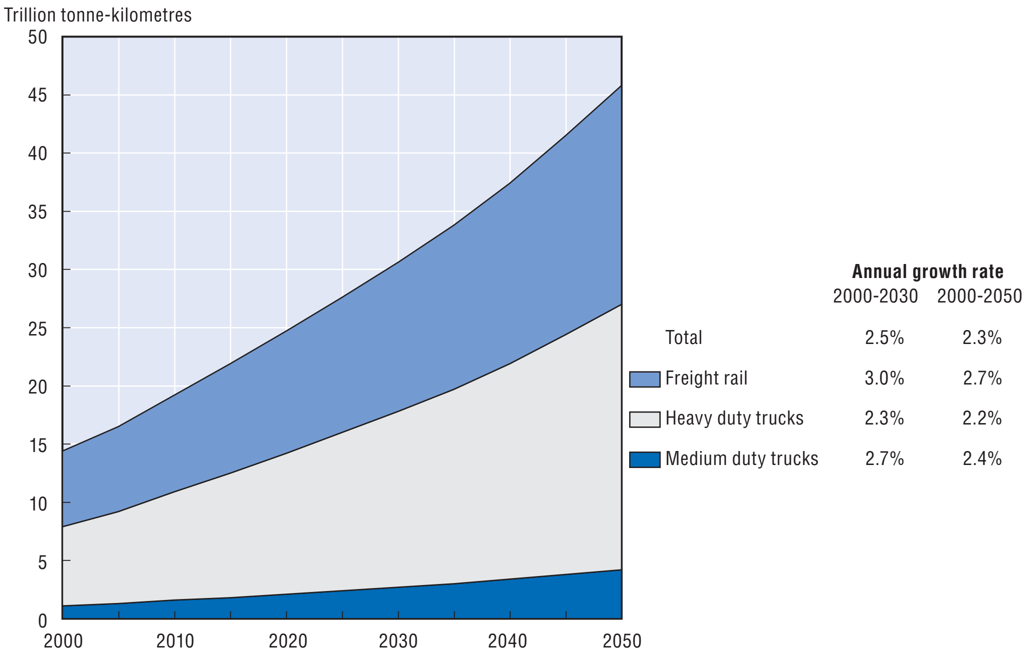
It is evident that many multinationals are rationalising the number of logistics service providers they deal with – in much the same way as they have rationalised their production and warehousing operations (there is, of course, a link between these developments). This, together with the growth in intra-regional trade, is leading to greater demand for transport and logistics services. Political changes have opened up new geographical markets, both for production and consumption. Devising and implementing the right logistics strategies lies at the heart of successfully capitalising on these commercial opportunities. Many of these changes are of significance to logistics service providers, especially those concerned with international markets.

Figure 5.9. **Projected road and rail freight transport activity by region to 2050**



Source: WBCSD (2004).

Figure 5.10. **Projected road and rail freight transport activity by mode to 2050**



Source: WBCSD (2004).

Road and rail are currently carrying relatively small quantities of products traded internationally compared with maritime shipping, especially in terms of products moving among economic regions. However, likely increases in the total quantity of international trade (as a result of manufacture continuing to grow in distant locations, facilitated by more reliable, and faster transport services, supported by improvements in technology) will increase the amount of goods that need to be transported internationally. In addition, the relative cost and speed advantages of land-based transport compared to water and air are likely to increase demand for international movements by these modes.

However, in order for international land-based transport to grow in this way, continued efforts must be made by governments to put in place measures and initiatives to enhance its efficiency. In many developing and landlocked countries and regions, major improvements must be achieved to further reduce the costs and increase the speed of road and rail systems if they are to enjoy the benefits in trade growth resulting from globalisation. In countries already participating in large international trade flows, efforts will need to continue to reduce physical and non-physical barriers in order to maintain their competitive position. This will involve taking a range of initiatives, which include:

- Improving road and rail infrastructure to reduce bottlenecks and fill missing links.
- Harmonising road and rail networks internationally.
- Reducing time spent obtaining customs clearance and crossing borders.
- Reducing crime against drivers and loads in land-based transport.
- Reducing the level of corruption at border points.

In order to achieve these improvements, countries will need to enter into international trade and transport agreements with neighbouring states. Greater use of international agreements will be more beneficial than bilateral and regional agreements. Where bilateral and regional agreements are chosen, these should make use of existing international conventions.

Manufacturers, retailers and logistics companies are becoming increasingly aware of the importance of time in the supply chain. It can result in additional costs due to the need for expensive stockholding. Also, shortening product life-cycles are making it increasingly important for producers and retailers to get products to market as quickly as possible. For land-based transport to play a growing role in international supply chains it must therefore be able to provide sufficiently rapid and reliable service levels to meet this demand.

ICT can help to bring about time-compression in land-based transport services and in customs and border services. ICT also has an important role in making customs and border systems more transparent and increasing the reliability and efficiency of transport services. It also improves safety and security for drivers on international freight trips. Both the public and private sectors have important roles to play in ensuring that these technologies are embedded and used to their capacity.

Terrorism poses a particular threat to international road and rail transport. The infrastructure used by these modes is easily accessible and often lacks surveillance (such as major roads, bridges and tunnels). In addition, road goods vehicles are readily available and difficult to monitor for such use. It is therefore important that efforts are made at an international level to harmonise national security standards across borders, to help prevent the risk of terrorist-related activity using road and rail.

The logistics performance index (Arvis *et al.*, 2007) suggests major differences in logistics performance across countries and regions, including differences among developing countries at similar levels of development. Those developing countries with relatively poor indices, and especially those that are landlocked, need to focus on the service level (in terms of cost, speed and reliability) provided by the road and rail services if they are to enjoy the benefits of trade-related globalisation in coming years. Their focus should not necessarily be on building road and rail infrastructure. Key factors are likely to include reducing land-based transport costs (domestically and in transit countries), and negotiations with transit countries to put in place suitable transport agreements and to work jointly to speed up customs and border processing. As Grigoriou (2007) noted, "transit corridors are regional public goods and should be managed as such through international cooperation. International financial institutions can, and do, play a key role in this regard by providing assistance and coordination, as well as participating in policy dialogue".

If land-based transport services can achieve these efficiencies, it is likely that they will increase their share of international freight traffic over time.

Projects to improve international freight transport

This section contains some examples of projects that are aiming to improve trade and international freight transport operations in specific regions. Box 5.8 presents some examples from Southeast Europe.

Box 5.8. **Trade and Transport Facilitation in Southeast Europe Program**

The World Bank, with the bilateral aid agencies of countries including the United States, the Netherlands, France and Austria, has supported a regional Programme on Trade and Transport Facilitation in Southeast Europe (TTFSE). The programme, which started in 2001, includes Albania, Bosnia and Herzegovina, Bulgaria, Croatia, FYR Macedonia, Moldova, Romania, Serbia and Montenegro.

The programme was designed to encourage trade in the region by promoting more efficient and less costly trade flows across these countries, and improve customs operations to European Union standards. The programme has sought to reduce non-tariff costs to trade and transport, to reduce smuggling and corruption at border crossings, and to strengthen and modernise the customs administrations and other border control agencies. The primary emphasis in the early years of the programme was on road transport, but the focus has now been broadened to include other modes, primarily rail.

An important element in the programme has been the use of benchmarks and monitoring systems to track improved performance over the life of the programme. Specific performance indicators were established on the basis of consultation with border crossing agencies, and local project teams were established at border crossing points to analyse the results and solve problems through inter-agency interaction at the local level. Validation of the progress, as well as the status of corruption, was also obtained through surveys of users.

The programme has achieved some notable success, with significant reductions of up to 87% in clearance times reported for a number of the most important border-crossing points, and at inland terminals. In addition, there has been an increase in trade volumes and in the revenue collected by customs from duty and VAT.

Box 5.8. **Trade and Transport Facilitation in Southeast Europe Program** *(cont.)*

Communications between the public and private sectors were formalised and improved with the establishment of public-private "Pro-Committees", which assisted with the dialogue between the parties and identified pragmatic solutions to the problems faced by forwarders and traders in the region.

TTFSE II has broader aims than TTFSE: embracing further aspects of trade facilitation by ensuring effective collaboration among all agencies active at border crossings (customs, road administration, border police, phyto-sanitary and veterinary controls), all modes of transport in the region (road, rail, inland waterway, and multimodal transport), and all border crossings on the main TEN-T Corridors running through Southeast Europe and connecting the region with its neighbours.

Sources: World Bank (2005) and TTFSE (2008).

The European Union is continuing to focus on international rail freight, with a policy document from late 2007 aimed at identifying a Europe-wide network of corridors where priority is to be given to freight flows (European Commission, 2007a) (see Box 5.9).

Box 5.9. **Priority Rail Freight Network**

Figure 5.11 shows the initial proposal for a Priority Rail Freight Network across the European Union. On this network, it is the intention that infrastructure and operations issues will be brought together to improve service quality to make rail more competitive against road haulage. Journey times, reliability and capacity are the key elements that will be addressed by this initiative. Specific actions that are proposed include:

- Determining the legal definition, and associated operating rules, of a priority freight corridor.
- Encouraging infrastructure managers to co-ordinate their activities to promote corridors.
- Identifying funds for corridor development.
- Developing legislation to publish quality measures.
- Examining steps taken by rail operators to improve service quality.
- Co-ordinating technical improvements to make the most of capacity and to remove bottlenecks.
- Improving international train paths through better co-ordination and priority for international trains (building on the RailNetEurope concept).
- Specifically, giving priority to international services at times of network disruption.
- Ensuring that sufficient, good quality rail terminals and marshalling yards are provided.

Source: European Commission (2007a).

Box 5.10 describes a potential new land-bridge freight corridor across Asia and Scandinavia. Table 5.8 shows the distance savings that are offered by the two key rail routes across Asia when compared to the sea corridor; the land route is typically about half of the sea distance.

Figure 5.11. **Indicative scope for a rail freight-oriented network**

Source: European Commission (2007a), *http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0608:FIN:EN:PDF*.

Box 5.10. **The proposed Northern East West Sea-Rail Freight Corridor**

UIC (International Union of Railways) has proposed the development of a sea-rail corridor between China, the Russian Federation, the Nordic countries and North America. The rail-leg would run from China to Norway, with a sea-leg from there to North America. One of the key objectives of the proposed corridor is the provision of an alternative east-west route that would avoid major existing bottlenecks on the traditional more southerly routes. The rail link between China and Norway already exists, passing through Kazakhstan, the Russian Federation, Finland and Sweden, although it has a mix of broad and standard gauge tracks. Despite the technical and political obstacles associated with gauge changes and border crossings, UIR estimates that the journey time from Urumchi (west China) to Halifax (Canada) by rail and sea could be as little as 15-16 days, representing a considerable time saving over current routings. However, major improvements would be required in the organisation of the railway operations, with far greater international co-operation and a streamlining of procedures.

Source: UIC (2004).

Table 5.8. **Sea and rail distances between China and Rostock, Germany (km)**

From	To	Rostock		
		By sea	By rail	
			Trans-Siberian	Euro-Asian
China port:	Tianjin	22 500	9 900	10 400
	Lianyungang	21 800	10 700	10 200
	Shanghai	21 200	11 100	10 600
Japan		22 800	13 300	12 700
Hong Kong, China		19 700	–	11 200

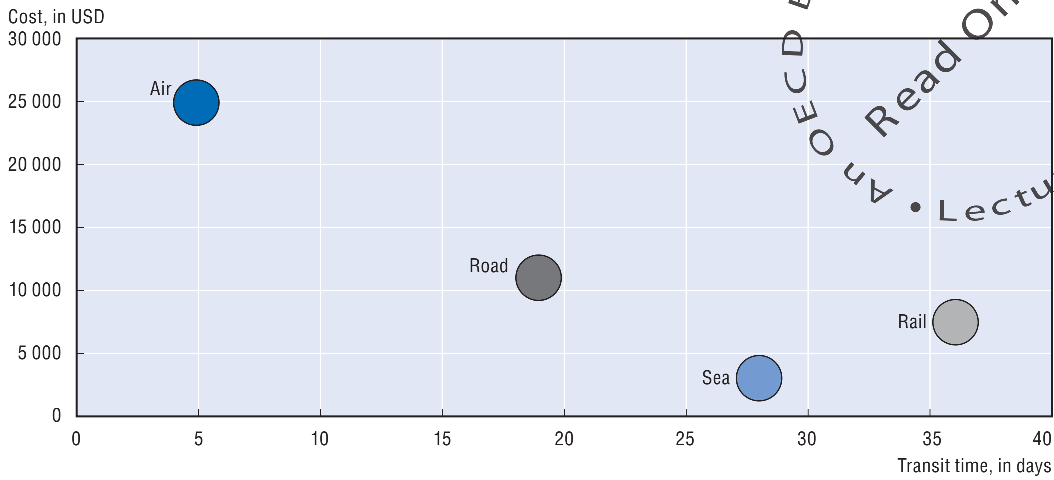
Source: UNESCAP (1995).

5.9. Conclusions

The above sections clearly show that with developments to remove bottlenecks, combined with operational improvements, there is scope for considerable increases in the efficiency of international road and rail freight in many regions. Of course, it is not simply a question of transit time and reliability (although both these are highly important), it is also a question of cost. Figure 5.12 illustrates total door-to-door transport costs and journey times for a range of available transport solutions carrying containerised cargo from Asia to Europe. In the study, quotes were obtained from freight forwarders and transport operators for a specified list of transport services and destinations, in order to produce these results.

The results indicate that air transport has the highest cost, but a very short transit time. Sea transport provides the lowest cost, but has a long transit time. Road freight results fall between air and sea both in terms of cost and transit time. The rail transport results had a very wide range of costs (USD 4 000-USD 10 000) and transit times (14 to 45 days). The rail data showed major differences between the officially scheduled transit times and the transit times quoted by freight forwarders for complete door-to-door solutions (as did the rail freight rates quoted, which were 30%-60% higher than the listed rates). Transit times for rail transport between western China and western Europe are quoted as 15-20 days in other studies, so the rail results should be treated with caution.

Figure 5.12. **Freight costs and transit times for containerised freight between Asia and Europe**



Note: The freight rate quotations on which these results are based were for a single 40' container loaded with 20 tons of cargo. The quotations include 100 km of trucking at both origin and destination. Insurance cost and other payments related to liabilities were not included. Transit times were provided by the freight forwarders/operators. The study was based on a relatively small sample size for each of the analysed transport legs.

Source: Chamber of Commerce of the United States (2006).

Clearly, there are many developments that are difficult to predict with accuracy and certainty. Many past forecasts of improvements in transport technology and operations have been overtaken by events and in some cases, rather than transport becoming easier and faster, it has become more complex and occasionally slower. Further consideration of Figure 5.12 highlights the way in which developments in the performance of one mode can have major implications for the use of the mode. Within the next 15 years, there seems to be limited opportunity to dramatically increase the speed of either ships or aircraft. Indeed, increased concern about CO_2 emissions could lead to changes in the view of the role of air freight within the supply chain. During the same period, there may be calls for sea freight transport to operate at slower speeds (thereby lengthening transit times) in order to save fuel. Given these uncertainties, it is interesting to note the potential for rail movement, in particular to offer opportunities for shorter transit times and possibly reduced costs. Road freight times may not have the scope to be reduced to the same extent as rail freight, but there are still many opportunities to improve road operations and thereby improve both the economic and environmental performance of road freight transport over long distances.

As noted in the introduction, international road and rail freight transport is extremely diverse. Thus, the developments that have implications for short-distance road freight are very different from those that affect long-distance rail. It is evident from this review that there remain many opportunities to improve the efficiency and to reduce the environmental impact of both international road and rail freight transport. Many of these developments require government intervention in the form of changes in policy and regulation or improvements to infrastructure. This is a complex area when considered within one country – when it concerns international developments it is, of course, even more complicated. However, it is important when considering the developments that will happen in the next 15 years to note the growing role played in international transport of the major logistics companies. The consolidation that is evident means that single companies are now able to provide truly integrated services in a way that was not possible a few years ago. At the same time, an increased business focus on applying a supply-chain approach is also evident – it is vital for policy makers and regulators to take note of these developments, in order to maximise the opportunities for more efficient international road and rail freight transport, and in order to ensure that developments meet the much more demanding environmental constraints that the transport sector faces.

Notes

1. This chapter is an edited version of the paper *The Impact of Globalisation on International Road and Rail Freight Transport Activity: Past Trends and Future Perspectives*, written by Allan Woodburn, Julian Allen, Michael Browne and Jacques Leonardi, Transport Studies Department, University of Westminster, London, UK, for the OECD/ITF Global Forum on Transport and Environment in a Globalising World, held in Guadalajara, Mexico, 10-12 November 2008 (*www.oecd.org/dataoecd/52/29/41373591.pdf*). Some paragraphs are also taken from the paper *The Environmental Impacts of Increased International Road and Rail Freight Transport: Past Trends and Future Perspectives*, written by Huib van Essen, CE Delft, the Netherlands, for the same event (*www.oecd.org/dataoecd/10/62/41380980.pdf*).
2. Some regional trade agreements have had additional environmental effects, such as the building of new infrastructure for customs facilities, sometimes at huge scale, devouring hectares of land around major crossing points and increasing air pollution.
3. These figures should be interpreted with caution, as rail or road transport of imported goods arriving to the country by boat is registered as *domestic*, rather than *international*, freight transport. There are, for example, more than 15 000 truck trips departing every day from the Los Angeles and Long Beach harbours in California, all counted as domestic transport.
4. Nikomborirak and Sumano (2008) found a rapidly increasing share of road transport in international transport in Thailand between 2000 and 2007, due to increased regional trade, facilitated by a rapidly developing road network. The increase in road transport, however, took place from a very low base. Sea transport was boosted by containerisation, but rail transport remained negligible.
5. Radio-frequency identification.
6. Community of European Railway and Infrastructure Companies (CER), Union Internationale des Chemins de Fer – International Union of Railways (UIC), Comité International du Transport Ferroviaire – International Railway Transport Committee (CIT).

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Chapter 6

International Maritime Shipping: Environmental Impacts of Increased Activity Levels

by
Øyvind Endresen, Magnus Eide, Stig Dalsøren, Ivar S. Isaksen Eirik Sørgård, James J. Corbett and James Winebrake[1]

It is estimated that 80% of the maritime traffic is in the northern hemisphere, with 32% in the Atlantic, 29% in the Pacific, 14% in the Indian and 5% in the Mediterranean Oceans. The remaining 20% of the traffic in the southern hemisphere is approximately equally distributed among the Atlantic, the Pacific and the Indian Oceans. This chapter addresses the environmental impacts of the shipping activity. It explores the ongoing scientific debate regarding both the historic and the current fuel use in the sector, which has a direct relevance for the environmental impacts of the sector.

The chapter describes modelling of air emissions from shipping and the geographically resolved emission inventory. It examines atmospheric impacts. Emission of pollutants to the air from a ship is often chemically transformed to secondary species and mixes with ambient air. The chapter explores the impact on pollution levels and climate; for example, the effect on surface ozone shows a profound seasonality at northern latitudes. In closing, it looks at future impacts. Most scenarios for the near future, the next 10-20 years, indicate that regulations and measures to abate emissions will be outweighed by an increase in traffic, resulting in a global increase in emissions.

6.1. Introduction

Building on the discussion of the activity level in international maritime shipping in Chapter 3, this chapter addresses the environmental impacts of the shipping activity. As highlighted in Chapter 3, there is an ongoing scientific debate regarding both the historic and the current fuel use in the sector, which has a direct relevance for the environmental impacts of the sector.

Global warming, acidification and degradation of air quality are environmental impacts high on the international agenda. Consequently, several studies have focused on anthropogenic emissions of compounds leading to such environmental impacts: carbon dioxide (CO_2), nitrogen oxides (NO_x) and sulphur dioxide (SO_2) emissions. Recent studies indicate that the emission of CO_2, NO_x and SO_2 by ships corresponds to about 2% to 3% (perhaps even 4%), 10% to 15%, and 4% to 9% of the global anthropogenic emissions, respectively (Buhaug *et al.*, 2008; Corbett and Köhler, 2003; Dalsøren *et al.*, 2009; Endresen *et al.*, 2003; 2007; Eyring *et al.*, 2005a).

Regulations and incentives to control pollution sources are often directly aimed at reducing total emissions, typically on a source-by-source basis. Focus is either on sources causing the greatest impact or on the most cost-efficient sources to control (Corbett and Koehler, 2003). Ship emissions have not previously been regulated, but the International Maritime Organization (IMO) and EU have recently implemented some requirements for ships. A new set of regulations is in process by IMO, EU and US EPA (Dalsøren *et al.*, 2007; Eyring *et al.*, 2005b). The focus so far is mainly on NO_x and SO_2 emissions, but strategies for CO_2 reductions are also being considered (IMO, 2005).

Exhaust emissions from a marine diesel engine, the predominant form of power unit in the world fleet, largely comprise excess carbon dioxide and water vapour with smaller quantities of carbon monoxide, oxides of sulphur and nitrogen, partially reacted and non-combusted hydrocarbons and particulate material (Lloyd's Register of Shipping [LR], 1995). The exhaust gases are emitted into the atmosphere from the ship stacks and diluted through interaction with ambient air. During the dilution process in the ship plume, the active chemical compounds are partly transformed and deposited on ground and water surfaces. Furthermore, during oil transport and cargo handling, evaporation leads to VOC (volatile organic compounds) emissions (Endresen *et al.*, 2003). Shipping also emits other compounds (*e.g.* refrigerants and fire fighting agents), contributes to the spread of invasive species and has other negative impacts on biodiversity (*e.g.* collision with whales).

In order to reduce exhaust emissions, measures can be taken either before the combustion process (fuel oil treatment and fuel oil modifications), during the combustion process (reduce formation of air pollutants in the combustion process) or through after-treatment of exhaust gases. Fuel consumption and emissions may also be reduced by improved technical conditions (*e.g.* antifouling systems, engine efficiency), operational means (*e.g.* reduced speed, weather routing), alternative fuels (*e.g.* LNG) and alternative propulsion systems (*e.g.* fuel cells, sails) (Eyring *et al.*, 2005b; Tronstad and Endresen, 2006).

Different operational and technical alternatives for reducing cargo VOC emissions (*e.g.* recovery systems) are available.

A number of emissions control technologies and operational strategies are in use or currently being evaluated, especially for pollutants such as NO_x and PM. These emissions controls have been categorised as either pre-combustion, in-engine or post-combustion controls (Corbett and Fischbeck, 2002). A list of technologies for selected pollutant reductions is shown in Table 6.1. Many of these technologies would, however, require increased energy use, and therefore increases in CO_2 emissions. This suggests that technology alone may not solve environmental issues, and that alternative energy sources or more sustainable freight logistics or operations may play a role.

Table 6.1. **Examples of air pollution control-technologies for maritime shipping**

Stage	Control-technology	Target pollutant
Pre-combustion	Fuel water emulsification	NO_x
	Humid air motor	NO_x
	Combustion air saturation system	NO_x
In-engine	Aftercooler upgrades	NO_x
	Engine derating	NO_x
	Injection timing delay	NO_x
	Engine efficiency improvements	NO_x, SO_x, PM, CO_2
Post-engine	Selective catalytic reduction	NO_x
	Seawater scrubbing	SO_x
	Diesel particulate filters	PM
	Diesel oxidation catalysts	PM
Vessel designs	Hull form	CO_2, energy ratio pollutants
	Propeller	CO_2, energy ratio pollutants

Source: Corbett and Winebrake (2008).

The main fraction of sulphur dioxide emitted from ships will oxidise in the atmosphere to form sulphate, and nitrogen compounds will form nitric acid and nitrate, and thus contribute to acidification. Sulphate and nitrate aerosols, together with directly emitted particles like organic and black carbon, might have impacts on both health and climate. Emissions of nitrogen oxides, carbon monoxide and VOCs will affect pollution levels, especially through enhanced surface ozone formation. Ozone is also an important greenhouse gas, and emissions of ozone precursors impact on the oxidation of methane (CH_4), another important greenhouse gas. Direct emissions of greenhouse gases (CO_2 and small amounts of N_2O and CH_4) change the radiative balance of the atmosphere. There is a significant delay in the build-up of the concentrations of some of the greenhouse gases (*e.g.* CO_2) and thereby in the climate impact. Knowledge of how ship emissions have developed over time is required to quantify climate effects and trends. Since the response time of the climate compounds is very different, ranging from days to centuries, and the chemical interactions between pollutants are highly non-linear, integrated studies estimating more than the impact of one single pollutant will give a better basis to assess the effect of different emission control options.

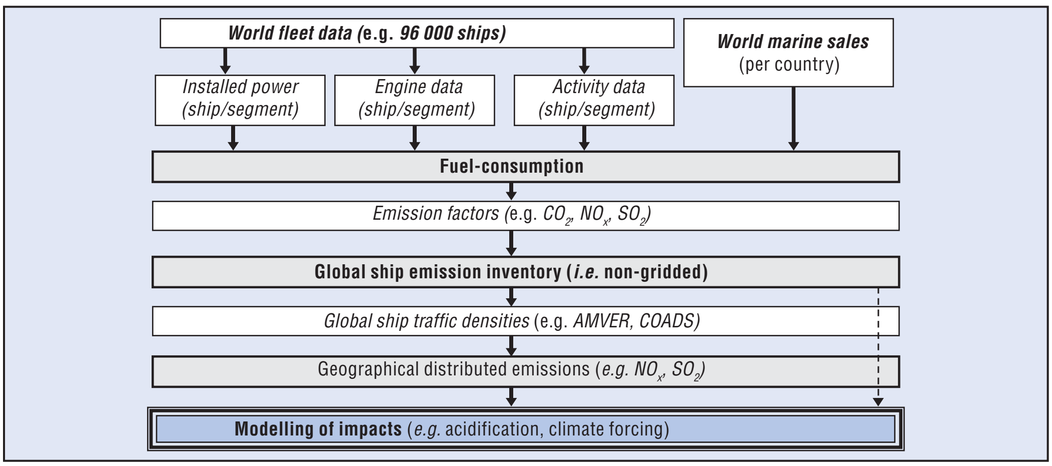
A reliable and up-to-date ship emission inventory is essential when evaluating impacts, but also when assessing the effects of different emission control options. Shipping activity has increased considerably over the last century (Eyring *et al.*, 2005a; Endresen *et al.*, 2007), and currently represents a significant contribution to the global emissions of greenhouse gases and pollutants, in particularly NO_x and SO_2 (Corbett *et al.*, 1999; Corbett and Koehler, 2003; Endresen *et al.*, 2003; 2007; Eyring *et al.*, 2005a). Despite this, information about the historical development of fuel consumption and emissions is in general limited, with little data published prior to 1950. There are in addition large deviations in the estimates covering the last three decades and present-day fuel consumption (see the discussion in Chapter 3). It is for this reason challenging to evaluate and quantify the environmental impacts of ship emissions.

6.2. Modelling of air emissions from shipping

In general, ship emissions are calculated by quantifying the fuel consumption from power production first and then multiplying the consumption by emission factors. (VOC emissions from oil cargo handling are exempt from this general approach.)

The calculated emissions can be distributed geographically based on global traffic data (*e.g.* Corbett *et al.*, 1999; Endresen *et al.*, 2003). Alternatively, geographically resolved emission inventories can be developed directly by calculating emissions for individual ship movements on defined trades (*e.g.* Whall *et al.*, 2002; Endresen *et al.*, 2003; Dalsøren *et al.*, 2007). The geographically resolved emission inventories can then be used to assess regional and global impacts of ship emissions (*e.g.* Capaldo *et al.*, 1999; Lawrence and Crutzen, 1999; Endresen *et al.*, 2003; Dalsøren *et al.*, 2007). Figure 6.1 illustrates an integrated approach, where ship emissions and impacts are calculated based on activity-based fleet modelling or by marine sales.

Figure 6.1. **Integrated modelling of fuel consumption, emissions and impacts from shipping**

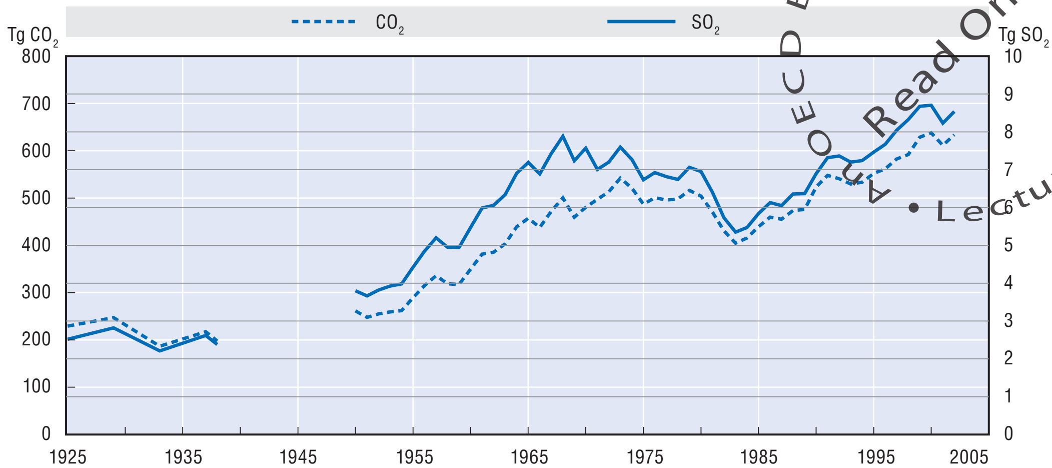


Source: Endresen *et al.* (2008).

Figure 6.2, taken from Endresen *et al.* (2007), illustrates historical, total emissions of CO_2 and SO_2 from ships, including the fishing and military fleet. Emissions generated from the shipping industry are an important contributor to global emissions, and scenarios for future activities indicate a significant increase in energy consumption and emissions (Eyring *et al.*, 2005b; Dalsøren *et al.*, 2006; Skjølsvik *et al.*, 2000; Eide *et al.*, 2008). The future development of ship emissions to the atmosphere, *versus* other transport and industry segments, is essential to quantify climate effects and trends, and to implement adequate

Figure 6.2. **Estimates of CO_2 and SO_2 emissions from ships**

Including the fishing and military fleet, 1925-2002



Note that no data is available for the World War II period. Based on estimated sales of marine fuel.

Source: Endresen *et al.* (2007).

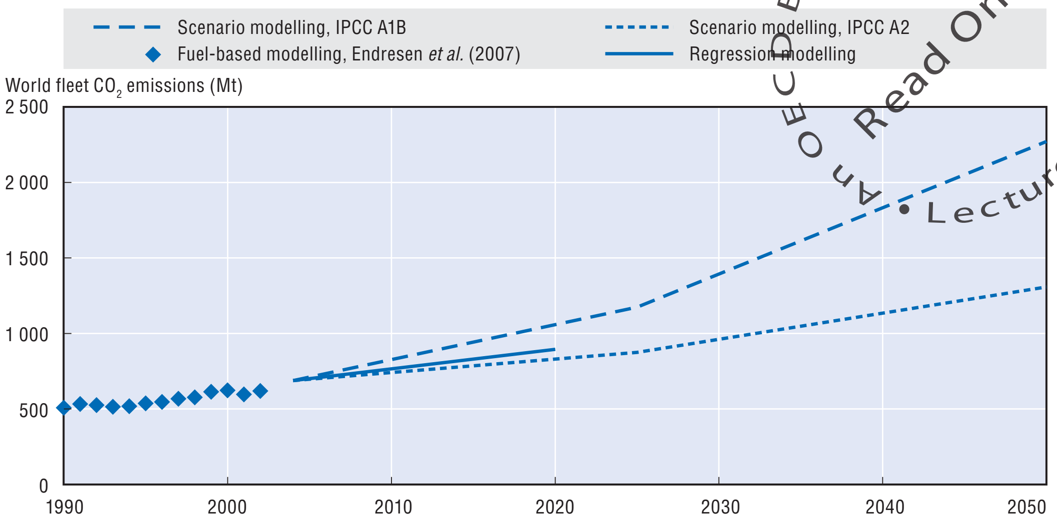
regulations and incentives. Developments in energy prices, regulatory regimes, sea transport demand, technical and operational improvements, and the introduction of alternative fuels and propulsion systems will probably explain most of the development in fuel consumption and emissions by the fleet during the next 100 years.

There is an increased pressure on industry and businesses, including the various transport modes, to contribute to sustainable development. In combination with the expected higher energy prices, this will increase the focus on development of more energy-efficient and environmentally friendly systems for ships. For example, the *FellowSHIP* project (*www.fuelcellship.com/*) seeks to develop ultra-clean and highly efficient power packs for the maritime power industry, in synergy with state-of-the-art fuel cell technology. The prototype power pack will be tested 2008-10 on board a supply ship, with no emissions of NO_x, SO_2 or particles expected, and up to 50% reduction in CO_2 emissions compared to diesel engines run on oil.

Based on some of the fuel-use projections presented in Chapter 3, Figure 6.3 illustrates a possible range for total CO_2 emissions from maritime shipping for the period up to 2050. Based on estimates for fuel consumption in 2050 between 453 and 810 Mt, appurtenant emissions from the maritime fleet were found to range from 1308 to 2271 Tg (CO_2), 17 to 28 Tg (NO_x) and 2 to 12 Tg (SO_2) (Endresen *et al.*, 2008). Scenario A1B gives the highest CO_2 estimates, while Scenario A2 gives the lowest estimates. This is in line with the results for fuel consumption, for which A1 gives the highest estimate, while A2 gives the lowest. These results suggest that ships in 2050 will account for a significantly higher share of world anthropogenic CO_2 emissions, compared to the 2% to 3% today. While CO_2 emission reduction in the scenarios mainly depends on improved technical and operational conditions, alternative fuels and propulsion systems, reduction of NO_x and SO_2 emissions (and other exhaust compounds) can be achieved via specific emission reduction measures (*e.g.* after-treatment of exhaust gases).

Figure 6.3. **Estimates of world fleet CO_2 emissions**

1990-2050



Source: Endresen *et al.* (2008).

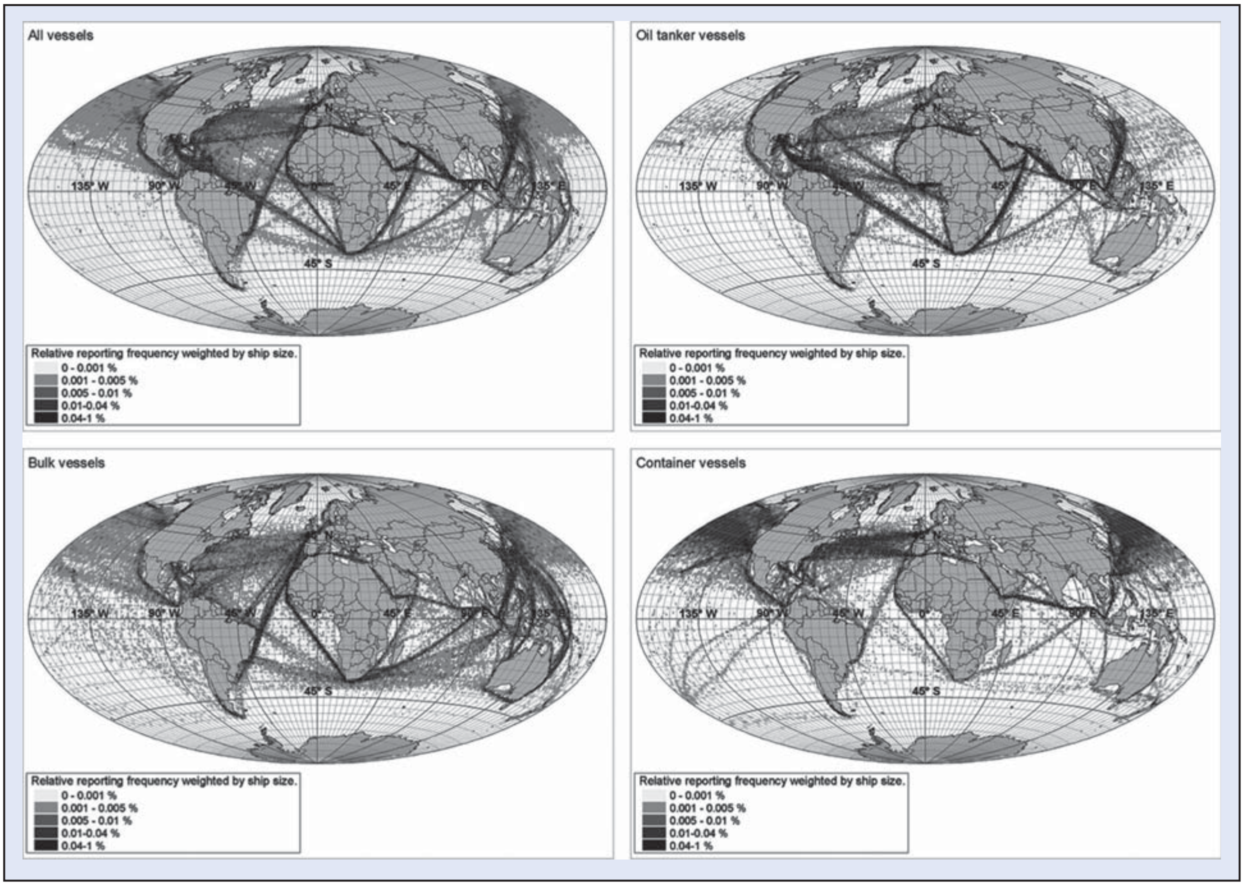
6.3. Geographically resolved emission inventory

Corbett *et al.* (1999) developed the first global spatial representations of ship emissions using a shipping traffic intensity proxy derived from the Comprehensive Ocean-Atmosphere Data Set (COADS). Endresen *et al.* (2003) collected and presented alternative global data and methods for the geographical distribution of emissions. The modelled exhaust gas emissions were distributed according to a calculated emission indicator per grid cell referring to the relative ship reporting-frequency or relative ship reporting-frequency weighted by the ship size. The indicator was based on global ship reporting-frequencies collected by COADS, PurpleFinder and AMVER (automated mutual-assistance vessel rescue system). The reporting-frequency weighted by the ship size was only available from the AMVER data. Recently, Wang *et al.* (2007) demonstrate a method to improve global-proxy representativity. Endresen *et al.* (2003) also developed a separate global oil cargo VOC vapour inventory.

It is estimated that 80% of the maritime traffic is in the northern hemisphere, with 32% in the Atlantic, 29% in the Pacific, 14% in the Indian and 5% in the Mediterranean Oceans. The remaining 20% of the traffic in the southern hemisphere is approximately equally distributed between the Atlantic, the Pacific and the Indian Oceans (Endresen *et al.*, 2003). Considering the number and type/size of vessels reporting and reference year, Endresen *et al.* (2007) found the AMVER data set most suitable for the distribution of emissions from international cargo traffic. The relative reporting frequency weighted by ship size may be applied to take into account large variation in emission between small and large vessels (only available for the AMVER data). The COADS data set was recommended when considering the entire world fleet (also non-cargo ships). However, national inventories covering coastal shipping should be added, as outlined by Dalsøren *et al.* (2006). The inventories developed by Endresen *et al.* (2003) have been applied in several studies (*e.g.* Dalsøren *et al.*, 2007; Eyring *et al.*, 2005b; Beirle *et al.*, 2004). This is important, as ships of less than 100 GT typically in coastal operations are not included (*e.g.* today some 1.3 million fishing vessels). The coastal fleet could account for an important part of the total fuel consumption. Also, it should be noted that recent changes to the world's trading patterns, in particular in Asian waters over the last years, need be covered by future updates in the global inventories.

Endresen *et al.* (2004b) presented a ship-type dependent geographical distribution of the traffic, based on AMVER data (bulk ships, oil tankers and container vessels) (Figure 6.4).[2] These data were also applied by Eyring *et al.* (2005b), and illustrate large variations in traffic patterns (and emissions) for different ship types.

Figure 6.4. **Vessel traffic densities for year 2000, based on the AMVER data**



Upper left: All cargo and passenger ships in the AMVER merchant fleet. Upper right: Oil tankers. Lower left: Bulk carriers. Lower right: Container vessels.

Source: Endresen *et al.* (2004b).

6.4. Atmospheric impacts

Emission of pollutants to the air from a ship is often chemically transformed to secondary species. Mixing with ambient air takes place and dry deposition or rainout occurs. The meteorological state of the atmosphere and insolation are also decisive for the chemical reactions taking place. These factors make the interaction between chemically active gases highly nonlinear and atmospheric perturbations may deviate substantially from perturbations in emissions. Ship emissions might affect the levels of ozone (climate, health effects), sulphate (acidification, climate, health effects), nitrate (acidification, eutrophication), NO_2 (pollution, precursor ozone and nitrate), NMVOCs (pollution, precursors ozone), SO_2 (pollution, precursor sulphate), OH and its effect on methane (climate), and aerosols (pollution, climate). Computer models are often used to quantify the impacts. Global and regional chemical transport models (CTMs) contain comprehensive chemical packages, including the calculation of some or all the above-mentioned compounds. Meteorological data (winds, temperature, precipitation, clouds, etc.) used as input for the CTM calculations are provided by weather prediction models or climate models.

Satellite observations indicate high NO_x concentrations along major shipping lanes (Beirle *et al.*, 2004; Richter *et al.*, 2004). Regional emission estimates based on these observed concentrations are in good agreement with global emission inventories. Ship plume processes are generally not resolved by global models with a resolution (grid-box sizes) from hundred to several hundreds of kilometres. These models therefore distribute emissions over larger areas. Detailed chemical box-model studies and measurements increase our understanding of subgrid-scale processes taking place within fresh, undiluted, plumes and during the first stages of dilution. Studies and measurements indicate that plume chemistry have to be better taken into account in the impact modelling (Kasibhatla *et al.*, 2000; Chen *et al.*, 2005; Song *et al.*, 2003; von Glasow *et al.*, 2003). These studies suggest enhanced NO_x destruction within the ship plumes. It is possible that some models might overestimate the effect of ship emissions on the NO_x, OH and ozone budget, and one way to overcome this is to multiply with a reduction factor (effective emission) or introduce plume chemistry in the global models. However, the amount of observations from ship plumes is limited and more data and studies are needed. This was also the conclusion in comparisons between global models and observations over oceanic and coastal areas (Dalsøren *et al.*, 2007; Eyring *et al.*, 2007).

Impacts on pollution levels and climate

Primary components, like particles NO_2, CO, NMVOCs and SO_2, may cause problems in coastal areas and harbours with heavy traffic because of their impact on human health at high concentrations (Saxe *et al.*, 2004; EPA, 2003). Secondary species formed from the effluents in the ship emissions have longer chemical lifetimes and are transported in the atmosphere over several hundreds of kilometres. Thereby they can contribute to air quality problems on land. This is relevant for ozone and the deposition of sulphur and nitrogen compounds, which cause acidification of natural ecosystems and freshwater bodies and threaten biodiversity through excessive nitrogen input (eutrophication) (Vitousek *et al.*, 1997; Galloway *et al.*, 2004; Bouwman *et al.*, 2002).

The highest surface increases in short-lived pollutants like NO_2 are found close to the regions with heavy traffic around the North Sea and the English Channel. Model studies in general find NO_2 to be more than doubled along the major world shipping lanes (Endresen *et al.*, 2003; Lawrence and Crutzen, 1999; Dalsøren *et al.*, 2007; Eyring *et al.*, 2007).

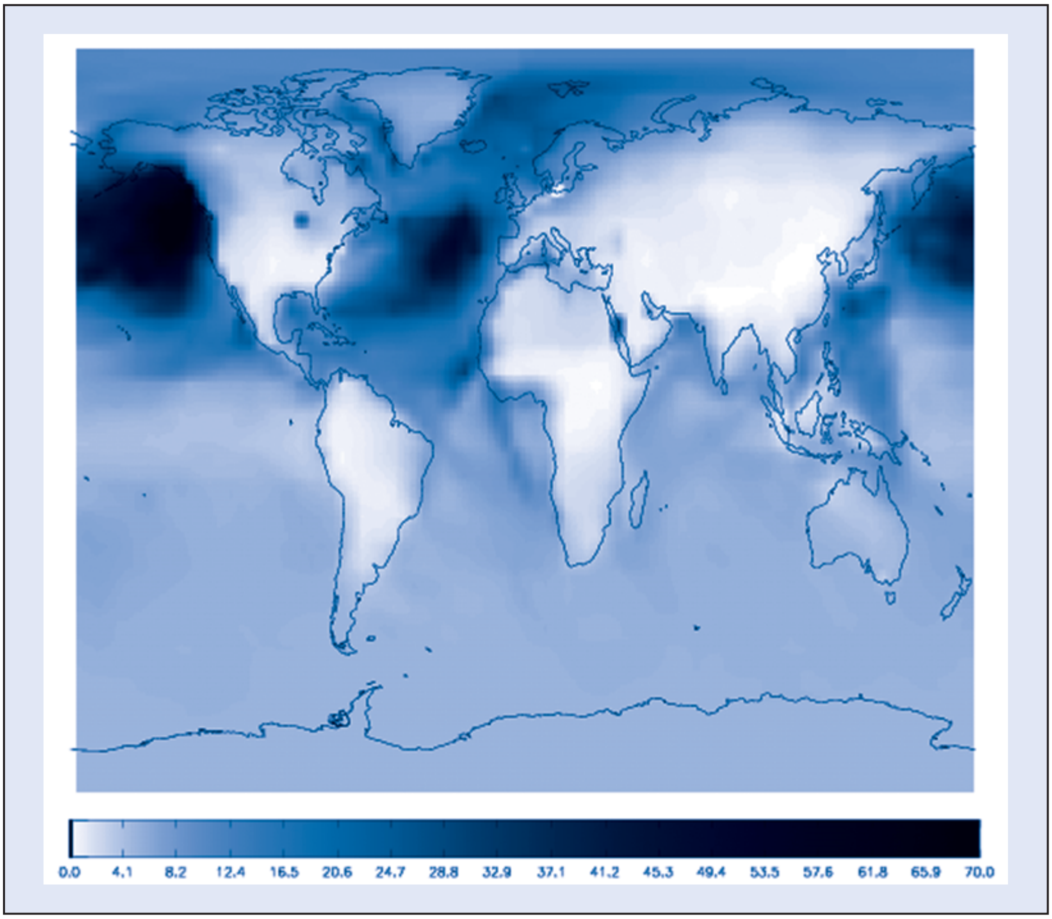
The ozone levels in the lower atmosphere are dependent on competitive reactions between formation and sink cycles. The abundance of NO_x ($NO + NO_2$) is crucial for ozone formation, but the number of ozone molecules formed is also dependent on the presence of CO and NMVOCs. In general, an emission perturbation is most effective in increasing ozone in regions with low background pollution. Ozone is also a major greenhouse gas. Ozone is estimated to be the third most important of the greenhouse gases contributing to warming since the pre-industrial era (Ramaswamy *et al.*, 2001). Exposure to high ozone levels is linked to aggravation of existing respiratory problems like asthma, increased susceptibility (infections, allergens and pollutants), inflammation, chest pain and coughing (Mauzerall and

Wang, 2001; EPA, 2003; WHO, 2003; HEI, 2004). Some of these studies have strengthened indications of short-term effects on mortality, but evidences of long-term health effects are limited. Repeated long-term exposure could possibly lead to premature lung aging and chronic respiratory illnesses, like emphysema and chronic bronchitis. Elevated ozone levels during the growing season may result in reductions in agricultural crops and commercial forest yields, reduced growth, increased susceptibility for disease and visible leaf damage on vegetation (Emberson *et al.*, 2001; Mauzerall and Wang, 2001). Ozone might also damage polymeric materials such as paints, plastics and rubber.

The effect on surface ozone shows a profound seasonality at northern latitudes. Absolute increases in ozone due to ship emissions are largest in July when sufficient sunlight results in an active photochemistry and a significant ozone production in the northern hemisphere over large regions including coastal areas. Major increases are found in regions with large traffic (the North Sea, fishing docks west of Greenland, the English Channel, the western Mediterranean, the Suez Channel, the Persian Bay) (Dalsøren *et al.*, 2007). Some of these regions already suffer from high summer ozone levels due to pollution from nearby land sources. Figure 6.5 shows that the relative contribution from international

Figure 6.5. **Relative contribution to ozone concentrations at the surface due to emissions from ships**

Per cent, July 2004



Source: Dalsøren *et al.* (2007) – which presents a graph with higher resolution.

shipping to surface ozone is even larger over mid-oceans where, as earlier mentioned, ozone production is relatively more efficient due to low background pollution levels. The relative contribution is also significant over coastal areas on the west coast of North America and western Europe. Similar contributions to ozone are found by Cofala *et al.* (2007), Derwent *et al.* (2005), Collins *et al.* (2007), and Eyring *et al.* (2007) and Cofala *et al.* (2007) discuss the European health impacts related to ground level ozone and the contribution from shipping both for current (year 2000) and future scenarios (year 2020).

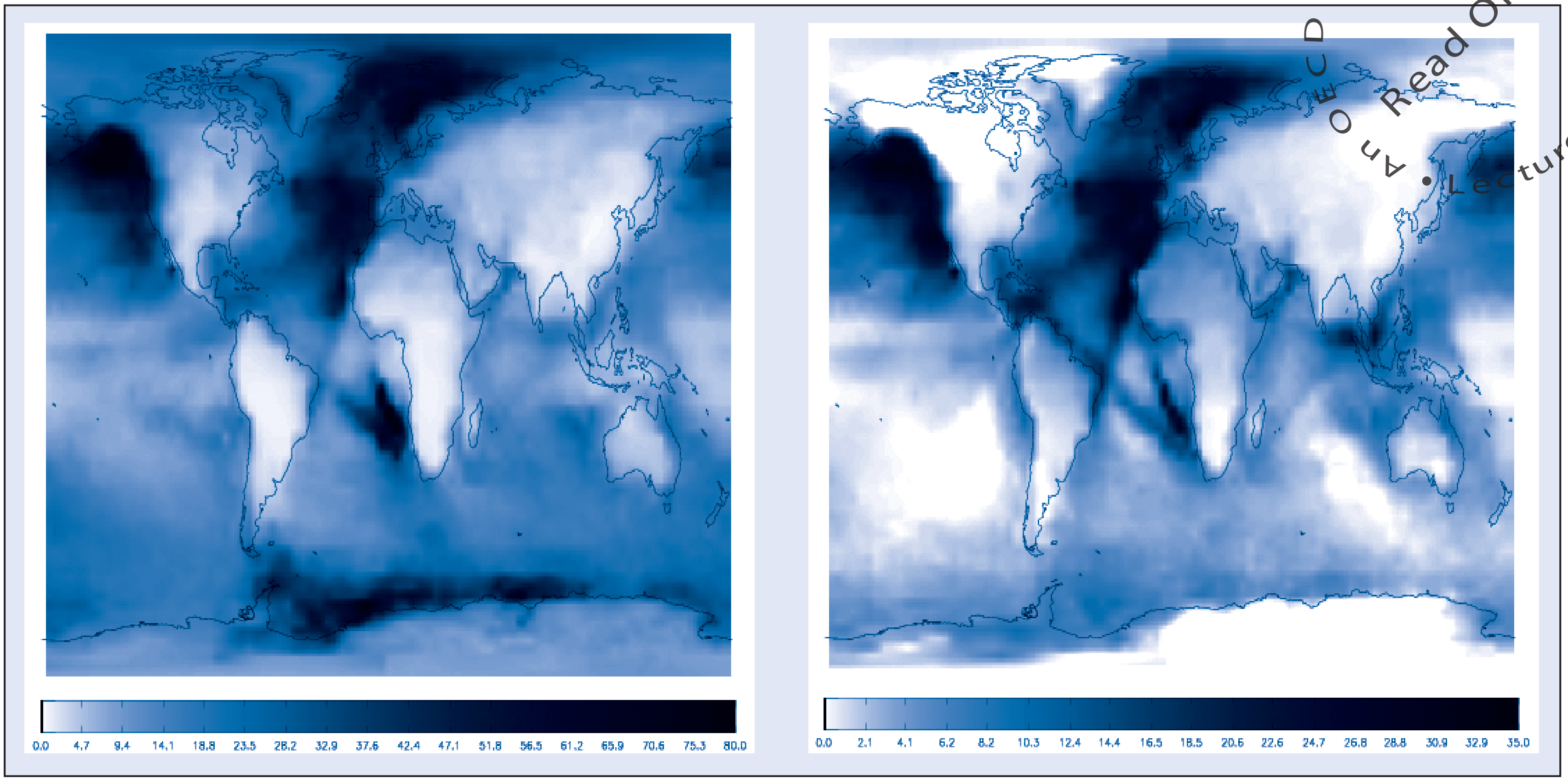
With regard to climate effects, the ozone perturbations at high altitudes are important. Ozone produced near the emission sources or produced during the transport process is lifted by convection and frontal systems to higher altitudes where the lifetime is longer and transport faster. Typical relative tropospheric column increases due to ship traffic (not shown) are 7% to 14% in the northern hemisphere, and 2% to 7% in the southern hemisphere (Dalsøren *et al.*, 2007).

Hydroxyl (OH) is the main oxidant in the troposphere (Levy, 1971). This radical reacts with and removes several pollutants and greenhouse gases; one of them is methane (CH_4). The OH abundance itself is in turn highly dependent on some of these pollutants, in particular CH_4, NO_x, O_3 and CO (Dalsøren and Isaksen, 2006; Wang and Jacob, 1998; Lelieveld *et al.*, 2002). Whereas CO and CH_4 emissions tend to reduce current global averaged OH levels, the overall effect of NO_x emissions is to increase OH (Dalsøren and Isaksen, 2006). Due to the large NO_x emissions from shipping, shipping leads to quite large increases in OH concentrations. Since reaction with OH is the major loss of methane from the atmosphere, ship emissions (for current atmospheric conditions) *decrease* the concentration of the greenhouse gas methane. Reductions in methane lifetime due to shipping NO_x vary between 1.5% and 5% in different calculations (Lawrence and Crutzen, 1999; Endresen *et al.*, 2003; Dalsøren *et al.*, 2007 and 2009; Eyring *et al.*, 2007).

NO_x oxidation by OH leads to formation of nitric acid and nitrate. When nitric acid and nitrate undergo dry deposition or rainout it may contribute to eutrophication or acidification in vulnerable ecosystems (Vitousek *et al.*, 1997; Galloway *et al.*, 2004). Sulphur emissions might reduce air quality over land *e.g.* by contributing to sulphate particles and sulphate deposition. SO_2 emissions from shipping are oxidised to sulphate primarily in the aqueous phase (in cloud droplets and sea salt particles) and also in the gas phase by the OH radical. The largest impact of shipping on sulphate chemistry is through the direct emissions of SO_2. However, increases in the OH radical due to NO_x emissions will enhance the gaseous oxidation pathway. This pathway is also important since it leads to new particle generation whereas aqueous oxidation adds mass to existing particles. Currently shipping increases the global sulphate loading with about 3% (Endresen *et al.*, 2003; Eyring *et al.*, 2007). But the relative load in some coastal areas is much higher. Figure 6.6, taken from Dalsøren *et al.* (2008), shows the impact of ship emissions on wet deposition of nitrate and sulphur. These are major components of acid rain. The largest contributions can be seen in seasons with much rainfall on the west coast of the continents where westerly winds often prevail. Parts of Scandinavia are particularly vulnerable to acid precipitation due to slowly weathering bedrock. The impact of shipping emissions on this region is large, with a contribution above 30% in nitrate wet deposition and 10% to 25% in sulphate wet deposition. Coastal countries in western Europe, North-western America and partly eastern America are also substantially impacted, with relative contributions between 5% and 20%. Similar numbers were found by Endresen *et al.* (2003), Collins *et al.* (2007),

Figure 6.6. **Yearly average contribution from ship traffic to wet disposition**

Per cent



Left: Nitrate. Right: Sulphur.

Source: Dalsøren *et al.* (2008).

Dalsøren *et al.* (2007) and Lauer *et al.* (2007). Marmer and Langmann (2005) found large increases in sulphate in the Mediterranean Sea due to shipping.

For other particles than sulphate (Black carbon [soot], organic carbon, etc.), the contribution from shipping seems to be moderate, a few per cent in the most impacted areas (Lauer *et al.*, 2007; Dalsøren *et al.*, 2007; Dalsøren *et al.*, 2008). But it should be noted that the uncertainty regarding the amounts emitted of these components is large. There is much concern about a number of health impacts of the fine and ultra-fine aerosols in polluted areas (Martuzzi *et al.*, 2003; Nel, 2005). Severe short- and long-term influences on illness and mortality due to effects on the cardiovascular system and lungs (for example lung cancer) occur with current pollution episodes and average levels in large cities (HEI, 2004; WHO, 2003). A non-threshold linear relationship with mortality and hospital admissions has been observed in several settings. Particles like soot may also lead to soiling of materials. Corbett *et al.* (2007) estimates 20 000 to 104 000 premature deaths each year globally related to particles caused by shipping.

Aerosols also have a direct effect on climate and visibility by scattering and/or absorbing solar radiation, thereby influencing the radiative balance (Penner *et al.*, 2001; Ramanathan *et al.*, 2001). Whether this leads to an overall cooling or heating of the surface depends on several factors, like the ratio of scattering and absorption (aerosols composition/properties), cloud fraction and surface albedo (Ramanathan *et al.*, 2001). Aerosols can act as condensation nuclei, modify cloud properties and precipitation rates, and through that have indirect climate effects. Aerosols may increase the number of cloud drops, and thereby increase reflected solar radiation to space which lead to a cooling (called 1st indirect effect [Twomey, 1974]). When the number of cloud droplets increases, this may decrease precipitation efficiency. This could also result in an increase in cloud lifetime and amount (Kaufman and Koren, 2006), which increases the reflection of solar radiation (2nd indirect effect [Rosenfeld *et al.*, 2000]). Reactions on aerosol surfaces may also modify the chemical composition of both the aerosol and gas phases (Tie *et al.*, 2005). The effects of aerosols emissions from ships on clouds are visible as so called ship-tracks in satellite images. Narrow stripes shows up downwind of the ships as bright features in the images (Schreier *et al.*, 2007). Airborne measurements in a cloud-free environment above a cargo ship showed that approximately 12% of exhaust particles act as nuclei where clouds could form (Hobbs *et al.*, 2000). Several studies show that the droplet concentration in the ship-tracks was enhanced significantly compared to ambient clouds and that the effective radius was reduced (Durkee *et al.*, 2000; Ferek *et al.*, 2000; Schreier *et al.*, 2006). The smaller water droplets are then less likely to grow into larger drops of precipitation size, extending the lifetime of the cloud and increasing reflectivity. A satellite study of clouds forming in the region of the English Channel showed a trend of increasing cloud reflectivity and decreasing cloud top temperature (Devasthale *et al.*, 2006), which may be related to increased ship emissions. Nearby polluted land regions showed opposite trends, probably due to reductions in particle emissions from land sources.

Radiative forcing (RF) calculations quantify the radiation balance at the top of the atmosphere due to components affecting the radiation budget. RF is a metric to quantify climate impacts from different sources in units of W per m^2, since there is an approximately linear relationship between global mean radiative forcing and change in global mean surface temperature (Forster *et al.*, 2007). Ship emissions impact the concentrations of greenhouse gases (mainly CO_2, CH_4 and O_3) and aerosols, causing both positive and negative contributions to direct RF. In addition, ship-derived aerosols cause a significant indirect RF, through changes in cloud microphysics (see previous paragraph). Table 6.2 summarises estimates of the

Table 6.2. **Radiative forcing for year 2000 of different components**

mW per m^2

Components	CO_2	SO_4	CH_4	O_3	BC	OC	Indirect
Range	*+ 26-43*	**÷12-47**	**÷11-56**	*+8-41*	*+1.1-2.9*	**÷0.1-0.5**	**÷38-600**

Text in *italics* denotes positive forcing (warming) and the **bold** denotes negative forcing (cooling).
Sources: Capaldo *et al.* (1999); Endresen *et al.* (2003); Eyring *et al.* (2007); Lee *et al.* (2007); Lauer *et al.* (2007); Dalsøren *et al.* (2007) and Fuglestvedt *et al.* (2008).

present-day contribution of ship emissions to RF from several studies (Capaldo *et al.*, 1999; Endresen *et al.*, 2003; Eyring *et al.*, 2007; Lee *et al.*, 2007; Lauer *et al.*, 2007; Dalsøren *et al.*, 2007; Fuglestvedt *et al.*, 2008). The range of values are wide, some of the uncertainties are related to use of different emission distributions and totals. Much of the rest is connected to uncertain historical evolution of long-lived components like CO_2 and CH_4, uncertainties in chemical calculations for reactive components (nonlinear chemistry), and the complexity and limited understanding of indirect effects. In summary, the studies indicate that ship emissions lead to a net global cooling.[3] This is different from other transport sectors (Fuglestvedt *et al.*, 2008).

However, it should be stressed that the uncertainties are large, in particular for indirect effects, and RF is only a first measure of climate changes. It is also important to have in mind that the forcing from different components act on different temporal and spatial scales. A long-lived, well-mixed component like CO_2 has global effects that last for centuries. Shorter-lived species, like ozone and aerosols, might have effects that are strongly regionally confined, lasting over a few weeks. The regional aspects are important as weather systems tend to be driven by regional gradients in temperature.

It should also be kept in mind that the net cooling effect that so far has been found primarily affects *ocean areas*, and thus does not help alleviate negative impacts of global warming for human habitats.

Future impacts

Model studies of future impacts from ship emissions are dependent on the projections used as baseline for the emission calculations. Most scenarios for the near future, the next 10-20 years, indicate that regulations and measures to abate emissions will be outweighed by an increase in traffic, resulting in a global increase in emissions. Assuming no changes in non-shipping emissions, Dalsøren *et al.* (2007) found that the scenarios for shipping activities lead to more than 20% increase in NO_2 emissions from 2000 to 2015 in some coastal areas. Ozone increases are in general small. Wet deposition of acidic species was found to increase up to 10% in areas where current critical loads are exceeded. Regulations limiting the sulphur-content in fuels in the North Sea and English Channel will reduce sulphate deposition in nearby coastal regions. Expected increased oil and gas transport by ships from Norway and Northwest Russian Federation, sea transport along the northern Sea Route will have a significant regional effect by increases of acid deposition in the North Scandinavia and the Kola Peninsula. Augmented levels of particles in the Arctic were found, and thus the contribution from ship traffic to phenomena like Arctic haze could be increasing. With sea ice expected to recede in the Arctic during the 21st century as a result of projected climate warming, global shipping patterns could change considerably in the decades ahead. Granier *et al.* (2006) uses one of the upper-end emission estimates for 2050 from Eyring *et al.* (2005b) and introduce some of the traffic into Arctic waters. During the summer months, surface ozone concentrations in the Arctic could be enhanced by a factor of 2-3 as a consequence of ship operations through the northern passages. Projected ozone concentrations from July to September are comparable to summertime values currently observed in many industrialised regions in the northern hemisphere.

Cofala *et al.* (2007) found that at present ships are responsible for 10% to 20% of sulphur deposition in European coastal areas. The contribution was expected to increase to more than 30% in large areas by 2020, and up to 50% in coastal areas. Technologies exist to reduce emissions from ships beyond what is currently legally required. Cofala *et al.* (2007) performed cost-effectiveness analysis for several possible sets of measures. Eyring *et al.* (2007) used results from ten state-of-the-art atmospheric chemistry models to analyse present-day conditions (year 2000) and two future ship emission scenarios. In one scenario, ship emissions stabilise at 2000 levels; in the other, ship emissions increase with a constant annual growth rate of 2.2% up to 2030. Most other anthropogenic emissions follow the IPCC A2 scenario, while biomass burning and natural emissions remain at year 2000 levels. Maximum contribution from shipping to annual mean near-surface O_3 was found over the North Atlantic. Tropospheric O_3 forcings due to shipping were 9.8 ± 2.0 mW per m^2 in 2000 and 13.6 ± 2.3 mW per m^2 in 2030 for the increasing ship emissions scenario. Increasing NO_x simultaneously enhances hydroxyl radicals over the remote ocean, reducing the global methane lifetime by 0.13 year in 2000, and by up to 0.17 year in 2030, introducing a negative radiative forcing. Increasing emissions from shipping would significantly counteract the benefits derived from reducing SO_2 emissions from all other anthropogenic sources under the A2 scenario over the continents, for example in Europe. Globally, shipping was found to contribute 3% to increases in O_3 burden between 2000 and 2030, and 4.5% to increases in sulphate. However, if future non-ship emissions follow a more stringent scenario, the relative importance of ship emissions would increase.

6.5. Other environmental impacts from shipping[4]

Environmental impacts of ocean shipping can be categorised as either *episodic* or *routine*. Examples of environmental impacts are listed in Table 6.3. Some pollution related to ocean shipping is not directly from the ships, but from efforts to serve the ocean shipping sector through port infrastructure maintenance and fleet modernisation.

Table 6.3. **Overview of types of ocean-shipping pollution**

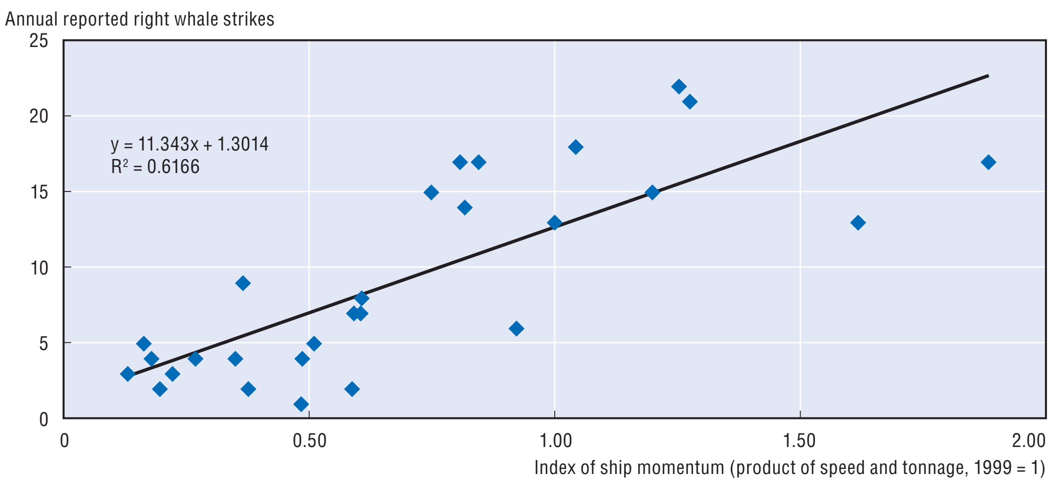
Episodic environmental events	Routine environmental events
Vessel-based	
Oil spills	Engine air emissions
Ocean dumping	Invasive species introductions (ballast water/hull fouling)
Sewage discharges	Hull coating toxics releases
Oily wastewater	Underwater noise
Vessel collisions	
Ship-strikes with marine life	
Port-based	
Dredging	Storm-water runoff
Port expansion	Vessel wake erosion
Ship construction, breaking	Cargo-handling air emissions

Episodic pollution discharges are among those best understood by the commercial industry and policy makers, as evidenced by the international conventions and national regulations addressing them. The dominant mitigation approach is to prohibit pollution episodes from occurring (such as ocean dumping), to design systems that are safer (as in double-hulls to prevent oil spills or traffic separation schemes to avoid collisions), to confine activities that produce untreated discharges to safer times or locations (*e.g.* environmental windows for dredging), to require onboard treatment before discharge (*e.g.* oily water separators), and/or to provide segregated holding and transfer to reception facilities at port (as in sewage handling).

Routine pollution releases are different than episodic discharges because they represent activities necessary for the safe operation of the vessel, whether at sea or in port. Regulation of routine releases has lagged in policy action to address episodic discharges, partly because these impacts were not as well understood in the past, and partly because operational behaviour must change and/or new technology is required.

Shipping's shift to larger and faster ships is also associated with increased lethality to marine mammals and other animals that may be struck by vessels (Vanderlaan and Taggart, 2007). The reported number of vessels striking large whales worldwide has increased three-fold since the 1970s, as has the number, sizes, and speeds of vessels in the world fleet (Corbett *et al.*, under review). Figure 6.7 shows the relationship between annual reported North Atlantic right whale strikes and average global ship momentum. North Atlantic right whales (*Eubalaena glacialis*) are critically endangered throughout their range along the eastern coast of North America (NOAA, 2003). The primary risk right whales face within this area, along with several other species of large whales, is being struck by large vessels transiting between ports along the eastern seaboard of the United States (Laist *et al.*, 2001). Approximately 35% of all right whale deaths documented between 1970 and 1989 have been attributed to ship strikes; while data from the period 1991-98 attribute 47% of right whale deaths to ship strikes (Knowlton and Kraus, 2001; Laist *et al.*, 2001). The

Figure 6.7. **Relationship between right whale strikes and global average ship momentum**



Source: Whale data from Kenedy, R.D. (2001), "the North Atlantic Right Whale Consortium Databases", *Maritimes* 43:3-5; Ship data derived from Lloyd's Register of Shipping (2006). Extracts from the World merchant fleet database for 2001 to 2006, Lloyd's Register of Shipping, London.

relationship illustrated in Figure 6.8 implies that if ships become larger and increase their speeds (in order to meet the demands of a globalised economy), an increase in mammal strikes will likely occur.

Another important environmental problem due to globalisation is the introduction of invasive species (Bright, 1999). Some species are introduced intentionally and subsequently escape, while others are introduced accidentally. Invasive species are implicated in 458 of the 900 species currently listed as either threatened or endangered in the United States. Research consistently identifies shipping (hull fouling, solid and water ballast) as a major invasion pathway since the 1500s when global maritime trade established routine intercontinental waterborne routes (Ricciardi, 2006; Ruiz *et al.*, 2000a; Ruiz *et al.*, 2000b; Wonham and Carlton, 2005). Native species can be transported by ships many thousands of kilometres and then released into non-native waters. These non-native species sometimes have the capacity to become "invasive", *i.e.* they can reproduce rapidly and tip the sensitive species balance that often exists in a given ecosystem.

Trends in non-native species invasions have tended to be correlated with increased seaborne trade and ship tonnage. However, recent research has also suggested that species invasions may be more related to increased diversity of global transport routes and cargoes traded than to the volume of shipping or trade activity. One recent study suggests that exponential trends in cumulative species invasions from ship ballast could result from constant introduction rates and species survivability (Endresen *et al.*, 2004b; Wonham and Pachepsky, 2006). The significant costs associated with aquatic invasive species (Lovell *et al.*, 2006; Pimentel *et al.*, 2005)[5] have motivated efforts to establish a global, integrated technology policy framework to prevent non-native species introductions by ships (Firestone and Corbett, 2005; IMO, 2004; Theis *et al.*, 2004). New technologies and operational approaches are now being developed to remove and destroy non-native species in ship ballast waters.

Levine and D'Antonio (2003) show that, although the number of non-native species is positively correlated with trade, because the number of potential invaders is finite, invasions will attenuate with time, rendering the relationship between invasions and trade concave. Moreover, Costello and Solow (2003) pointed out that there is a lag in the discovery process, so that the number of exotic species observed at any point in time underestimates the number actually present. Costello *et al.* (2007) estimated the rate at which new introductions arise as a result of trade. They used data on invasions in San Francisco Bay to calculate the marginal invasion risk (MIR) from imports from different regions. They find that imports from historic trade partners – specifically those in the Atlantic and Mediterranean (ATM) and West Pacific (WPC) regions – have been responsible for the lion's share of exotic species in San Francisco Bay, with invasions from ATM nearly double those from the WPC (74 and 43 respectively). However, the MIR from *future* WPC imports (0.38 additional introductions per additional million short tons imported) are triple that from future ATM imports (0.11). They projected that business-as-usual imports from ATM and WPC will lead to 1.4 and 52.4 introductions of new exotic species into San Francisco Bay by 2020; they offer no forecasts of introductions into other ports.

In a related vein, Kasperski (2008) used cross-sectional data and instruments for trade intensity and income levels to test whether the generally beneficial effect of openness on environmental indicators extends to biotic resources. While he found no statistically significant impact of trade intensity on the number of endemic species, he found a positive and statistically significant effect on the number of non-endemic species; he calculates elasticities of non-endemic species counts with respect to trade intensity of –1.045, –0.830, –1.080 and –1.071 for birds, mammals, plants and total biodiversity respectively. Although some might view this result as positive, given that exotic species are included in counts of non-endemic species, this result is consistent with the presumption that trade facilitates introduction of invasive species.

6.6. Conclusions

Shipping activity has increased significantly over the last century, and currently represents a notable contribution to the global emissions of pollutants and greenhouse gases. Despite this, information about the historical development of energy consumption and emissions is limited, with little data published before 1950 and large deviations in estimates covering the last three decades. Endresen *et al.* (2008) indicated global ship CO_2 emissions in 1870 to be 30 Tg (CO_2), growing to be about 206 Tg (CO_2) in 1913. The main development during this period was the transition from sail to steam-powered ships. Based on sales of bunker, global ship CO_2 emissions were estimated to be 229 Tg (CO_2) in 1925, growing to about 634 Tg (CO_2) in 2002. The corresponding SO_2 emissions were estimated to be approximately 2.5 Tg (as SO_2) in 1925 and 8.5 Tg (as SO_2) in 2002. The main developments during this period were that oil replaced coal, and the transition to a diesel-powered fleet.

The majority of today's ship emissions occur in the northern hemisphere within a well-defined system of international sea routes. The most accurate geographical representations of the emissions are obtained using a method based on the relative reporting frequency weighted by the ship size. When global identification and tracking of ships is implemented, using LRIT technology, the potential for effective monitoring and reliable emission modelling will increase significantly.

Activity-based modelling for the period 1970-2000 indicates that the size and the degree of utilisation of the fleet, combined with the shift to diesel engines, have been the major factors determining yearly energy consumption. Interestingly, modelling suggests that from around 1973 – when bunker prices started to rise rapidly – growth in the fleet is not necessarily followed by increased energy consumption.

The main reason for the large deviations among different activity-based estimates of fuel use and emissions is the assumed number of days at sea. Vessel type and size dependency should be further analysed and described, to improve the accuracy of detailed activity-based estimates. Available operational data indicate that the number of days at sea depend strongly on ship type and size.

Recent studies indicate that the emissions of CO_2, NO_x and SO_2 by ship corresponds to about 2% to 3% (perhaps even 4%), 10% to 15%, and 4% to 9% of the global anthropogenic emissions, respectively. Ship emissions of NO_2, CO, NMVOCs and SO_2 and primary particles cause problems in coastal areas and harbours with heavy traffic and high pollution levels because of their impacts on human health and materials. Particularly high surface increases of short-lived pollutants like NO_2 are found close to the regions with heavy traffic around the North Sea and the English Channel. Absolute increases in surface ozone (O_3) due to ship emissions are pronounced during summer months, with large increases found in regions with heavy traffic. Some of these regions already suffer from high ozone levels due to pollution from nearby land sources.

Formation of sulphate and nitrate resulting from nitrogen and sulphur emissions causes acidification that can be harmful to ecosystems in regions with low buffering capacity, and have harmful health effects. Relative ship-induced increases are estimated to be in the range 5%-35% in wet deposition of sulphate and nitrate. Nitrate and sulphate aerosols and directly emitted organic and black carbon (soot) affect the climate due to scattering/absorption of radiation (direct effect) and impact on clouds (indirect effect). NO_x emissions from ship traffic lead to significant increases in OH. Since reaction with OH is the major loss of methane from the atmosphere, ship emissions decrease methane concentrations. Reductions in methane lifetime due to shipping NO_x vary between 1.5% and 5% in different calculations. The effect on concentrations of greenhouse gases (CO_2, CH_4 and O_3) and aerosols have different impacts on the radiation balance of the earth-atmosphere system. In summary, most studies so far indicate that ship emissions lead to a net global cooling. This is different from other transport sectors.

However, it should be stressed that the uncertainties are large, in particular for indirect effects, and global temperature is only a first measure of climate changes. It is also important to have in mind that the forcing from different components act on different temporal and spatial scales.

Projections up to year 2020 indicate a growth in emissions in the range of 30%. For year 2050, one study has estimated emissions ranging from 1308 to 2271 Tg CO_2, 17 to 28 Tg NO_x, and 2 to 12 Tg SO_2.

Model studies of future impacts from ship emissions are dependent on the projections used as baseline for the emission calculations. Most scenarios for the next 10-20 years indicate that an increase in traffic will lead to a significant global increase in emissions from shipping. The relative contribution to pollutants (ozone, NO_2, particles) from shipping could increase, especially in regions like the Arctic and South-East Asia.

Notes

1. This chapter is an edited version of two papers *The Environmental Impacts of Increased International Maritime Shipping – Past Trends and Future Perspectives*, written by Øyvind Endresen and Magnus Eide, Det Norske Veritas, Høvik; Stig Dalsøren and Ivar S. Isaksen, University of Oslo; and Eirik Sørgård, Pronord AS, Bodø, Norway, for the OECD/ITF Global Forum on Transport and Environment in a Globalising World, held in Guadalajara, Mexico, 10-12 November 2008 (*www.oecd.org/dataoecd/52/30/41373767.pdf*), and *The Impact of Globalisation on International Maritime Transport Activity: Past Trends and Future Perspectives*, written by James J. Corbett and James Winebrake, Energy and Environmental Research Associates, United States, for the same event (*www.oecd.org/dataoecd/10/61/41380820.pdf*).
2. Dalsøren *et al.* (2009) presents vessel traffic densities for year 2001/02 for the same vessel categories.
3. This is also the finding of Hoor *et al.* (2009).
4. Part of this discussion is taken from Corbett and Winebrake (2008), adapted or excerpted from Houghton *et al.* (1997), ICF Consulting (2005) and Thomas *et al.* (2002), part is taken from McAusland (2008).
5. Pimentel *et al.* (2005) estimated that the annual cost of dealing with invasive species present in the United States was USD 120 billion per year. Of course some of the 50 000 alien species present in the United States are beneficial, including corn, wheat, rice, cattle and poultry (Pimentel *et al.*, 2005; USBC, 2001).

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Chapter 7

International Air Transport: Environmental Impacts of Increased Activity Levels

by
Eric Pels[1]

This chapter reviews the literature on the environmental impacts of aviation, discusses trends in emission patterns and comments upon how the external cost of aviation is estimated in various studies. The purpose of the chapter is to assess how developments in the aviation sector in the last few decades have impacted on the environment, and what this means for transport and environmental policy.

The chapter explores how hub-and-spoke networks can lead to environmental benefits because of economies-of-scale in environmental terms. Passengers are concentrated on a few routes, so that larger aircraft may be used. But transfer passengers fly longer distances, and take off and land twice, so that they have a relatively large environmental impact. The chapter explores policy instruments, such as compensation regulation. A number of factors are examined: noise (people are asked what they are willing to pay to experience less aviation noise); emissions (damage to human health, damage to buildings, reduced visibility, damage to forests, crops and fisheries); and accidents.

7.1. Introduction

The environmental impact of air travel attracts much attention, both in the media in the policy debates. Air travel contributes to climate change, and causes environmental and economic damage by its CO_2, NO_x, noise and other emissions. In economic terms, air travel causes external effects, which somehow need to be accounted for in the price of air travel. A number of countries (*e.g.* the United Kingdom, France and the Netherlands) have therefore implemented departure or ticket taxes. But whether such taxes cover the environmental cost of air travel, not included in the ticket price, is a difficult question. This leads to heated debates about, for instance, ticket taxes. Opponents of such taxes argue that they are harmful for the economy, while the effect on the CO_2 emissions is questionable, if passengers can easily switch to an airport in a nearby country which does not levy such taxes.

7.2. Aviation growth and the environment

It is expected that demand for aviation services will continue to grow faster than GDP. De Haan (2007) looked at GDP growth, speed of maturation of aviation markets and network development to predict that in the most pessimistic economic scenario, air travel in 2050 will have increased by a factor of 2.5 in 2050, compared to 2004. In the most optimistic economic scenario, air travel in 2050 had increased 9 times compared to 2004. De Haan (2008) discussed potential reductions in CO_2 emissions per km travelled due to technological developments. However, reductions of 15% to 25% per, or even 50% for radically new designs, would not be enough to compensate for the increased demand.

Table 7.1 shows past and expected trends in emissions of CO_2 and NO_x, as reported by Penner *et al.* (1999). According to NASA's calculations, NO_x emissions from aviation grew by 46% between 1976 and 1984, and 41% between 1984 and 1992. NO_x emissions were expected to grow by 174% between 1992 and 2015. ANCAT and DLR presented somewhat more moderate expectations, with NO_x emissions growing by 111% and 113% between 1992 and 2015. The expected growth in CO_2 emissions reported by NASA is similar to the growth reported by ANCAT and DLR: 121%, 118% and 120% respectively. These numbers show that the growth in international aviation lead to increased environmental damage.

Table 7.2 shows the expected growth in CO_2 emissions between 2002 and 2030 in various scenarios (Horton, 2006). Horton (2006) assessed the growth of CO_2 emissions from civil aircraft to 2030. An important aspect in this analysis is the effect of a carbon tax. The same growth in traffic was applied to all cases, implying that the only effect of a carbon tax is an efficiency improvement. The study therefore, importantly, does not include the airlines' option of passing a carbon tax on to the passengers, so that demand is influenced (reduced).

Total distance covered by civil aviation aircraft is predicted to increase by 149% from 2002 to 2030, while the number of available seat-kilometres is predicted to increase by 229% over the same period. These numbers imply that aircraft size is expected to increase. In the scenario which is best for the environment (Case 5), CO_2 emissions in 2030 are 22% less than in the scenario which does not have incentives for technological development (Case 3). But even in

Table 7.1*a*. **Calculated NO_x emissions from aviation**

Tg, calculated as NO_2

	NASA 1976	NASA 1984	NASA 1992	ANCAT 1992	DLR 1992	NASA 2015	ANCAT 2015	DLR 2015
Civil	0.70	1.02	1.44	1.60	1.60	3.95	3.37	3.41
Military	0.28	0.25	0.23	0.20	0.20	0.18	0.16	0.16
Total	**0.98**	**1.28**	**1.67**	**1.81**	**1.80**	**4.12**	**3.53**	**3.57**

Source: Penner *et al.* (1999).

Table 7.1*b*. **Calculated CO_2 emissions from aviation**

Tg carbon

	NASA 1976	NASA 1984	NASA 1992	ANCAT 1992	DLR 1992	NASA 2015	ANCAT 2015	DLR 2015
Civil	55.36	74.44	97.91	98.22	96.52	247.72	234.21	232.63
Military	30.67	25.59	21.98	14.68	14.71	17.71	12.50	12.47
Total	**86.03**	**100.03**	**119.89**	**112.92**	**111.23**	**265.43**	**246.71**	**245.10**

Source: Penner *et al.* (1999).

Table 7.2. **CO_2 emissions from aviation under different assumptions**

2002 and 2030

	CO_2 emissions 2002 (Tg)	CO_2 emissions 2030 (Tg)	Ratio of CO_2 emissions to 2002
Case 1	489.3	1 609.7	3.290
Case 2	489.3	1 395.1	2.851
Case 3	489.3	1 247.0	2.549
Case 4	489.3	1 100.2	2.248
Case 5	489.3	970.0	1.982

Case 1: No technology improvements to fuel efficiency.
Case 2: 2005 and 2008 best available technology – Boeing 787/Airbus 350/Airbus 380 technology levels.
Case 3: Fuel efficiency improvements (1.3% per annum to 2010, 1.0% per annum to 2020, 0.5% per annum beyond).
Case 4: Fuel efficiency improvements as in 3, with additional efficiency improvements driven by a USD 50 per tonne CO_2 cost.
Case 5: Fuel efficiency improvements as in 3, with additional efficiency improvements driven by a USD 100 per tonne CO_2 cost.
Source: Horton (2006).

this environmentally favourable scenario, CO_2 emissions are almost twice as high in 2030 compared to 2002. This supports the claim by de Haan (2008) that technological developments are not enough to compensate for the increased demand. Because technological development is not enough to reduce the environmental impact of aviation, additional measures are necessary, such as environmental taxes or emission trading, which to some extent can limit demand for air travel. In any case, aviation will continue to cause environmental damage.

Long-term predictions of traffic demand and emissions are highly uncertain because of unpredictable changes in demand patterns and technological innovations. For instance, some of the assumptions used for IPCC scenarios (Leggett *et al.*, 1992) are that: *i)* fuel prices will not increase significantly relative to other costs; *ii)* infrastructure can accommodate all demand; and *iii)* there are no significant impacts from other modes, such as high-speed rail. Recent evidence shows that these assumptions are not met: fuel prices have risen, airports are becoming more and more congested, and high-speed rail may become a substitute for aviation in short-haul markets.[2] The debate over the use of market exchange rates or purchasing power parities in the IPCC scenarios also illustrates the difficulties in forming scenarios. However, to formulate long-term policy goals, it is necessary to use all currently available information to predict future demand and emissions. Long-term studies which are often cited are from ICAO's Forecasting and Economic Support Group (FESG), the UK Department of Trade and Industry (DTI) and the Environmental Defense Fund (EDF). The results are summarised in Table 7.3.

Table 7.3. **Estimates of emissions from aviation over the long term**

Tg, excluding military

	FESG FC1 2050	FESG FE2 2050	DTI 2050	EDF IS92c 1990	EDF IS92c 2050	EDF IS92e 1990	EDF IS92e 2050
Fuel use	253.8	757.7	633.2	179	837	179	2 297
CO_2	218.2	651.6		154	720	154	1 975
NO_x	3.9	8.7	4.45	1.96	5.77	1.96	15.84

Source: Penner *et al.* (1999).

FESG used high (FE) and low (FC) economic scenarios, combined with two different technology scenarios. The FE and FC scenarios were based on the IPCC scenarios IS92e and IS92c used by EDF (Penner *et al.*, 1992). The technology scenarios assumed: that NO_x reductions in aircraft emissions result from current design philosophies (Scenario 1); or that a more aggressive approach to NO_x reductions result in smaller fuel efficiency gains (Scenario 2). DTI used its own forecast models for traffic predictions, and extrapolated Greene (1992) to obtain forecasts for fuel efficiency. The results reflected the strong assumptions on reductions in NO_x-emissions (assumed to be the result of technological developments induced by regulations). EDF specifically accounted for demand growth in developing countries, and used IPCC scenarios for developments in economic indicators and emissions. Base level and high demand scenarios were used. Fuel efficiency was extrapolated from Greene (1992), while NO_x-emissions were extrapolated from NASA numbers. Penner *et al.* (1999) reported that the emission index for NO_x indicates that emissions reflect an ultra-low technology regime. Roughly speaking, DTI and EDF seem to have comparable expectations on trends in NO_x emissions. The differences in emission levels are then mainly caused by differences in assumed fuel use levels.

Table 7.4 shows the average external costs of transport in the EU17 countries, as reported by INFRAS (Schreyer *et al.*, 2004). Scheyer *et al.* (2004) provided an extensive report about external costs (total, average and marginal) of transport: road (passenger and freight), rail (passenger and freight), air (passenger and freight), and waterborne (freight) transport. In this report, almost all cost categories were discussed: accidents, noise, air pollution, climate change, costs for nature and landscape, additional costs in urban areas, upstream and downstream processes, and congestion costs. For the accident costs, a value (EUR 1.5 million) of a statistical life approach was used, using *ICAO Database* to determine fatalities per passenger-kilometre. For noise costs, a willingness-to-pay procedure (for those disturbed by the noise only) was used, using a database from OECD (OECD, 1993). These costs also include the valuation of health risks and medical costs. For road and rail, advanced models exist to accurately predict noise emissions. For aviation, such models do not exist, so Scheyer *et al.* (2004) used insights from road and rail models to determine the marginal cost of aviation.

Table 7.4. **Average external costs of transport in the EU17 countries**

2000, EUR per 1 000 pkm for passengers and EUR per 1 000 tkm for freight

	Road passengers	Rail passengers	Aviation passengers	Road freight	Rail freight	Aviation freight
Accidents	32.4	0.8	0.4	7.6	0.0	0.0
Noise	5.1	3.9	1.8	7.4	3.2	8.9
Air pollution	13.2	6.9	2.4	42.8	8.3	15.6
Climate change high	16.5	6.2	46.2	16.9	3.2	235.7
(Climate change low)	*(2.4)*	*(0.9)*	*(6.6)*	*(2.4)*	*(0.5)*	*(33.7)*
Nature and landscape	2.6	0.6	0.8	2.9	0.3	3.8
Up- and downstream	5.0	3.4	1.0	8.8	2.4	7.4
Urban effects	1.5	1.3	0.0	1.5	0.5	0.0

Source: INFRAS/IWW (Schreyer *et al.*, 2004).

The costs of air pollution were determined using a top-down approach, based on willingness-to-pay surveys. In this approach, existing estimates were used, and transferred to other countries (correcting for various indicators). Climate change costs were determined as follows: greenhouse gas emissions at global scale were included. Costs of CO_2 emissions were calculated by multiplying the amount emitted by a cost factor. This cost factor is the shadow price in currency per tonne CO_2. Scheyer *et al.* (2004) used, based on literature review, EUR 140 per tonne as upper value, and EUR 20 per tonne as a lower value. Costs for nature and landscape use were based on an expert valuation approach. The state of nature in 1950 was seen as sustainable by the experts; any damage since then needs to be compensated. To determine the compensation for aviation, Schreyer *et al.* (2004) looked at airport surface. The surface of the airport (aviation infrastructure) is the main cost component in this category.

The average external cost per passenger-kilometre using the high climatic impact scenario was about EUR 0.05. With the low climatic impact scenario, the average external cost per passenger-kilometre is less than EUR 0.02.

Dings *et al.* (2003) quantified "the external costs of air transport, and in particular the costs of climate change, air pollution and noise", aiming "to provide insight into the principal factors determining these external costs". No policy recommendations were provided. Apart from environmental costs which are not directly paid by airports, airlines or passengers, aviation also may cause accident costs, for instance due to fatalities. These costs were not included by Dings *et al.* (2003). The report estimated shadow-prices based on damage and abatement costs (direct costs approach, WTA approach, WTP approach and prevention costs approach). It defined the costs at the level of airplane type (number of passengers and flight distance). It used existing databases to come up with these numbers. Table 7.5 reports the average external costs (per passenger-kilometre) for different aircraft types, distances and climatic impacts. These numbers are of the same order of magnitude as the numbers reported by INFRAS.

The empirical studies mentioned above estimate the environmental cost of aviation. More theoretical (simulation) studies are also available in the literature. The deregulation of aviation markets led to lower real fares (see *e.g.* Kahn, 1988). Lower fares cause an increase in demand, so deregulation may lead to increased environmental damage. In this case, the welfare gains of deregulation have to be balanced against the welfare (environmental) damage of increased demand. Schipper *et al.* (2007) conducted an equilibrium analysis in a spatial competition model. In the equilibrium analysis, the external environmental costs

Table 7.5. **Average external costs of aviation**

	Shadow-price for climatic impact of per tonne CO_2-equivalent		
	EUR 10	EUR 30	EUR 50
Fleet – average technology, in EUR-ct per passenger-kilometre			
50 seats, 200 km	5.7	6.4	7.0
100 seats, 500 km	1.8	3.0	4.2
200 seats, 1 500 km	0.7	1.5	2.2
400 seats, 6 000 km	0.3	0.7	1.1
State-of-the-art technology, in EUR-ct per passenger-kilometre			
50 seats, 200 km	2.8	3.3	3.9
100 seats, 500 km	1.2	2.2	3.3
200 seats, 1 500 km	0.5	1.1	1.8
400 seats, 6 000 km	0.2	0.5	0.9

Source: Based on Dings *et al.* (2003).

were dependent only on total flight frequency in the total market. Given a constant marginal environmental flight cost, aggregate environmental costs could be determined in the analysis.[3] Using empirically calibrated parameters, Schipper *et al.* (2007) showed that the liberalisation of the European airline markets resulted in:

- Frequency increases (welfare +).
- Fare decreases (welfare +).
- Lower profits (welfare –).
- Increase environmental costs (welfare –).

According to Schipper *et al.* (2007), consumer welfare gains exceed environmental welfare losses. Because welfare increased, but at the expense of airline profits and the environment, part of the increase in welfare can in principle be used to compensate airlines and the population for their losses. Compensation regulation in a liberated market can therefore be a useful policy instrument, particularly around airports in densely populated areas. For instance, noise surcharges can be used to compensate home owners for noise damage. The simulation exercise used empirical inputs from Schipper (2004), which estimated the environmental costs in the European airline markets in 1990. The following costs were included:

- Noise (hedonic pricing and contingent valuation methods were used to determine noise annoyance). In hedonic pricing methods, the price of, for instance, a dwelling is related to all kinds of neighbourhood characteristics, including aviation noise. In contingent valuation methods, people are asked what they are willing to pay to experience less aviation noise. Both methods were used to put a price on aviation noise.
- Emissions (marginal damage functions for global warming and value-of-statistical-life [VSL] for local emissions [mortality]). Several methods can be used to determine the cost of local air pollution, *e.g.* damage to human health, damage to buildings, reduced visibility, damage to forests, crops and fisheries, etc. Schipper (2004) valued air pollution emissions using the health damage pathway, which is identified as a dominant cost effect of air pollution. Using available information on how emissions may lead to increased fatalities, and an estimated statistical value of life of 3.1 millions ECU, the cost of emissions was determined.
- Accident risks (again VSL).

It appears from this study that environmental costs are only a small fraction of total internal costs as measured by the ticket price (2.5%). Because prices have decreased since 1990, this may currently be an underestimate. Noise was found to be the dominant external effect (75% of the total external cost). This is probably due to the fact that noise damage is experienced directly by the surrounding population, while the cost of emissions, calculated using the marginal damage functions for global warming and value of statistical life, is only experienced indirectly. This shows the difficulty of combining different effects. The value of statistical life should reflect all costs that are incurred to avoid a fatality. But difficulties in estimating this value can make the comparison difficult. There are environmental economies of scale at the route level; environmental costs are decreasing in aircraft size, and size is related to distances: large aircraft may be used on short distances, but it is not always possible to use smaller aircraft on longer distances.

Scheelhaase and Grimme (2007) analysed the predicted growth of international air transport in relation to internationally coordinated instruments for the reduction of greenhouse gas emissions. Global (Kyoto) and European emission trading schemes were mentioned. Scheelhaase and Grimme (2007) calculated the economic impacts for low-cost carriers (Ryanair), full service (Lufthansa), holiday (Condor) and regional airlines (Air Dolomiti), using the EU-ETS emissions trading scheme. Different scenarios were analysed, in which airlines needed to hold allowances to emit CO_2. Scenarios were favourable for airlines (EUR 15 per allowance, allowances only needed for intra-EU flights), or less favourable (EUR 30 per allowance, allowances needed for all flights departing from or arriving at EU airports). Following an initial allocation based on grandfathering, airlines needed to purchase allowances. It was concluded that the introduction of such a scheme would generate competitive effects: the financial impact for low-cost carriers and regional carriers (without hub-and-spoke networks) was larger than for network carriers, because airlines with hub-and-spoke networks have better opportunities to pass the cost on to the passengers. The cost per passenger of an allowance was a relatively small proportion of the ticket price on a long-haul flight, so that given the price-elasticity of demand, which is relatively low in absolute value on long-haul flights, airlines with large networks suffered less. The impact on intercontinental traffic was therefore found to be relatively low. The financial impacts for airlines would be marginal: costs would increase approximately 1% to 3%. Depending on the level of the tax rate applied, the impacts of a tax on aviation fuels could have been higher.

7.3. Hub-and-spoke networks

The concentration in aviation markets means that airline networks are centred on major hubs, which handle a relatively large share of all flights. Hub-and-spoke networks can lead to environmental benefits because of economies-of-scale in environmental terms. Passengers are concentrated on a few routes, so that larger aircraft may be used. But transfer passengers fly longer distances, and take off and land twice, so that they have a relatively large environmental impact. Intercontinental passengers can fly relatively cheaply using indirect tickets, so that this may stimulate demand, while these passengers often have a short-haul flight, with relatively high environmental costs, included in their long-haul route. Moreover, the environmental damage of aviation at the ground level is concentrated on a few airports and the surrounding areas.

Peeters *et al.* (2001) found that point-to-point networks have the lowest environmental impacts, even though larger aircraft may be used in hub-and-spoke networks. Furthermore, hubs have larger environmental impacts than non-hub airports, and the number of hubs (in Europe) and their geographical distribution has a strong influence on the environmental impacts of the total network. It should be pointed out that hubs are important for international traffic. Passengers from different origins in Europe are collected at hubs, and then transported to their final international or intercontinental destination (and *vice versa*). Collecting passengers from different origins on a single intercontinental flight may be beneficial for the environment compared to different intercontinental flights, but the short-haul flights are relatively damaging. Interestingly, Peeters *et al.* (2001) found no environmental economies-of-scale (contrary to Schipper, 2004). They pointed out that technological developments in the last decades were mostly made for small- and medium-sized aircraft. Combining passenger flows from different origins may lead to financial benefits for airlines, but if the fuel efficiency of such aircraft per passenger-kilometre does not really improve compared to smaller or medium sized aircraft, there may be little gain for the environment. Peeters *et al.* (2001) mentioned that the results may change if technological progress is made with large aircraft. Recently, new large aircraft have emerged (such as the Airbus A380), which will probably offer environmental economies-of-scale. But such aircraft can only be used between very large airports (intercontinental hubs), so demand will be relatively low compared to smaller aircraft. Interestingly, Boeing chose not to develop such a large aircraft, focusing instead on a smaller aircraft, to be used primarily in point-to-point flights, rather than in a hub-and-spoke structure.

Morell and Lu (2007) examined noise disturbance and engine emissions in two network structures: hub-and-spoke networks and hub-bypass structures (*i.e.* networks in which passengers do not transfer at a hub). The noise social cost model was based on hedonic pricing methods; total aggregate noise disturbance was allocated to individual flights based on real impact of noise nuisance (aircraft type, etc.). The input for the engine emissions social cost model was based on a literature review. Given the analysed networks – using the airports London Heathrow, Glasgow, Frankfurt, Hamburg, Chicago O'Hara, San Diego, Dallas and Tokyo – it was concluded that the hub-bypass routes generate considerable savings in both noise and engine emissions costs. This confirmed the result of Peeters *et al.* (2001) that hub-and-spoke networks have a relatively high environmental impact, compared to point-to-point networks. This means that also in long-haul, international markets, it may be better for the environment if direct flights are used, rather than the indirect flights used by many passengers. Indirect flights may be cheap, because airlines use them to exploit density economies, but they are, relatively speaking, harmful for the environment.

Nero and Black (1998) also found that hubbing increases external costs (congestion, aircraft noise and emissions). The paper analysed the effects of introducing environmental costs on airport charges to hubbing airlines by formulating a model based on Schmalensee's model, but adapted to allow for monopolistic firms. After formulating that model, they performed a simulation exercise to show the optimal level of environmental taxes from a welfare perspective. From this exercise, the authors concluded that the hub-and-spoke network could be abandoned in favour of a fully connected network if the environmental tax were relatively high. No real empirical evidence was present, but the "polluter pays" principle suggests that taxes for indirect flights or for international passengers transferring at hubs should be relatively high, given the observations made above. The results of Nero and Black (1998) suggested that airlines then will no longer use such a network. Interestingly, the ticket taxes implemented by a few European countries are only for origin-destination passengers. Transfer passengers pay nothing, to safeguard the competitive position of the hub airports as a transfer airport in international or intercontinental markets. But this is bad for the environment. Carlsson (2002) extended the analysis by Nero and Black (1998) by relaxing symmetry restrictions. An optimal charge was defined for two types of networks (fully connected and hub-and-spoke) and for both a monopolistic and a duopolistic market situation. In this model, the environmental effects were solely dependent on the number of flights offered in the equilibrium outcome of each market. Again, no empirical estimations were present.

7.4. Effect of aviation on house prices

It was already mentioned above that hub-and-spoke networks lead to relatively large noise (and other) emissions around hub airports. Various authors have tried to determine the impact of airports on the surrounding region by looking at property prices. Such studies do usually not consider CO_2 and other emissions, but only focus on the relation between property prices and noise levels.

Schipper *et al.* (1998) considered noise nuisance around airports. A comparison of hedonic pricing (HP) and contingent valuation methods (CVM) to determine the cost of aviation noise showed that CVM noise cost estimates were significantly higher than HP noise cost estimates. An explanation might be that HP methods report only "use values", while CVM methods also uncover other value categories. Moreover, HP methods do not use information on consumers *not* willing to consider properties because of noise nuisance. Nineteen HP studies (related to property values), resulting in 30 noise depreciation indices (NDI), were analysed using meta-analytical techniques. The NDI gives the percentage change in property value due to a decibel change in noise exposure. Wealth and other neighbourhood characteristics, such as accessibility, had a positive impact on the NDI.

Morell and Lu (2000) provided an empirical case study about the implicit social costs of aircraft noise (via decline in property values) in the Amsterdam Schiphol area. Using a social cost of noise function, based on hedonic pricing methods and the property values, and the related parameters for the Amsterdam area (number of houses in noise contours, etc.), the average social noise cost in 1999 was calculated as EUR 326.8 per landing. From this estimate, the marginal social cost function was obtained. The authors claimed that the figures are in line with previous related studies. It was concluded that the current noise charges (EUR 157.3 per landing) were too low to "internalise" the social noise costs.

Morrison *et al.* (1999) provided an economic assessment of the benefits (higher property values for homeowners) and costs (airplane's reduced economical life) of the 1990 ANCA (Airport Noise and Capacity Act). Under noise regulation, the fleet of an airline operator has to be renewed faster than without such regulation. According to the authors, this accelerated (non-optimal) deprecation of the fleet was the source of the costs of regulation. Benefits of the regulation were taken as the increase in housing values (based on WTP). At the end, they came up with these figures: USD 5 billion benefits and USD 10 billion costs (1995 dollars); therefore they were wondering if airplane noise regulation was justified from an efficiency perspective.

7.5. Conclusions

Aviation demand grew rapidly in the past decades, and it is expected that this growth will continue (Boeing, 2007; de Haan, 2008; Horton, 2006). Technological innovations are not expected to prevent an increase in CO_2 emissions from aviation due to this increase in demand (de Haan, 2007) – but the rate of technological progress will likely depend on the extent to which the sector faces a price on the CO_2 it emits. Depending on the technology and scenario used, the average external cost of air travel is about EUR 0.01 to EUR 0.05 per passenger-kilometre.

The deregulation of the aviation markets had profound effects on network developments. Major airlines now use hub-and-spoke networks, which means that selected airports receive a relatively large share of all take-offs and landings in the network. As a result, noise pollution in the surrounding areas is relatively high, and passengers travelling indirectly have to make a detour. But hub-and-spoke networks might also have environmental benefits because of environmental economies-of-scale: larger aircraft, with lower emissions per seat, can be used because passenger flows are concentrated on a few links. The literature indicates that negative environmental effects of hub-and-spoke networks exceed the positive effects. Concentration therefore tends to be bad for the environment. It is expected that the trend of concentration will continue. For instance, when Ryanair celebrated the fact that it had flown 1 million passengers to Bratislava (early November 2007), its CEO, Michael O'Leary claimed that within five years there will be four major airlines left in Europe: British Airways, Air France, Lufthansa and Ryanair. If British Airways, Air France and Lufthansa and their alliance partners will focus their networks on a few intercontinental hubs, traffic levels will increase at these hubs due to the expected general increase in demand, but also because more people need to make transfers.

The increasing consolidation of aviation markets, together with growth in aviation activity, means that the environmental damage caused by aviation will continue to grow. As mentioned above, technological developments are not expected to prevent this. Therefore, new alternative policy measures are necessary. A number of countries in Europe have introduced ticket taxes. If such a ticket tax would approximate the marginal external cost, this would be a sensible strategy. In this case, one tries to influence the individual passenger's travel behaviour. As long as passengers do not face the full cost of travel (*i.e.* including external cost), demand will be too high. If the tax rate is too low or too high, improper incentives are given. For instance, if transfer passengers do not pay the tax, the ticket price is relatively low, and demand relatively high. As a result, the environmental damage can also be relatively high. Moreover, other countries have not introduced such a tax, and in most cases, passengers travelling indirectly (and thus causing relatively high external cost) are exempt from the tax.

A disadvantage with a ticket tax is that it does not give airline companies any incentive to reduce CO_2 emissions per ticket sold. A tax on aviation fuels, or inclusion of aviation in emission trading systems, would do that.

The EU will include aviation in their CO_2 emissions trading scheme. Scheelhaase and Grimme (2007) found that this will have only marginal effects on airline cost. The effect of a kerosene tax could be higher, depending on the tax rate applied.

Air travel connects regions to the world economy, and gives individual travellers the opportunity to explore the world. But as long as the full external cost is not covered by the ticket price, environmental damage caused by aviation will continue to grow.

Notes

1. This chapter is an edited version of the paper *The Environmental Impacts of Increased International Air Transport: Past Trends and Future Perspectives*, written by Eric Pels, VU University, the Netherlands, for the OECD/ITF Global Forum on Transport and Environment in a Globalising World, held in Guadalajara, Mexico, 10-12 November 2008 (*www.oecd.org/dataoecd/44/18/41508474.pdf*).
2. High-speed rail captured a significant proportion of the London-Paris market, while airlines may also substitute high-speed rail for flights in short-haul markets to avoid the relatively high cost of such short flights.
3. One may expect the external cost per flight to increase with the number of flights; *e.g.* a large number of flights with small aircraft may result in higher environmental costs than a relatively small number of flights with large aircraft. This makes the effects discussed below only stronger.

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Globalisation, Transport and the Environment

Chapter 8

International Road and Rail Freight Transport: Environmental Impacts of Increased Activity Levels

by
Huib van Essen[1]

This chapter assesses the environmental impacts of increased international road and rail freight transport – focussing on air emissions and noise. It gives an overview of major trends and of the main drivers behind them. In addition, this chapter briefly discusses the main technical and non-technical measures for tackling the increasing environmental impacts.

The chapter explores the developments in emission factors of road and rail vehicles, particularly the standards for reducing pollutant emissions and the differences among the emissions of the various modes. In the last decades, there has been increasing evidence that emissions of greenhouse gas contributes to the effect of global warming; the emissions of carbon dioxide (CO_2) from the burning of fossil fuels is a major contributor. For the transport sector, greenhouse gas emissions are dominated by the CO_2 emissions from burning fossil fuels. The CO_2 emissions of international road freight transport are increasing all over the world, and there is not yet a sign that this trend is to be curbed soon. The chapter looks at impacts from pollutant emissions on various problems related to air quality (health, building and material damages, crops and ecosystems), and at health and nuisance impacts from noise. A mix of measures, like increased motor fuel taxes, stricter fuel efficiency standards for vehicles, promotion of alternative fuels and logistical improvements, is needed.

8.1. Introduction

Background

Road transport has several impacts on the environment. Emissions contribute to air pollution and climate change, noise causes nuisance and health risks and infrastructure have serious impacts on landscape and ecosystems. In addition to these impacts on the environment, transport has also other severe impacts on society. Every year hundreds of thousands of people are killed and injured in accidents, and in many densely populated areas, high congestion levels result in time losses.

The impacts of the transport sector as a whole are the sum of the impacts of the various transport modes, both freight and passenger transport. The freight transport market consists of various submarkets that interact, but often do not really compete with each other. At a regional level, distribution of goods takes place, mainly by small and medium-sized trucks. At the other end of the spectrum, there are the long-distance global flows between the various continents, in which maritime shipping is the main mode of transport (in particular, as regards volume). Somewhere in between is the international haulage market, which can be characterised as the transport chain between shipping of goods between the continents and the regional distribution networks. In this intra-continental international freight transport market, road and rail transport are the most important modes, but inland shipping and short-sea shipping also play an important role in some parts of the world.

Environmental impacts from transport

Box 8.1. **Trends in transport accidents**

The WHO estimated the number of road fatalities at 1.2 million in 1999. Further research showed that this is probably an overestimation (Jacobs and Aeron-Thomas, 2000). They estimated the number of fatalities worldwide at 750 000 to 880 000 in 1999, and the number of people injured by road accidents at 23 to 34 million per year.

It is very difficult to make forecasts for these global figures. In Europe, the number of fatalities is rapidly decreasing (from about 71 000 in 1990 to 41 000 in 2005). However, in other parts of the world, transport growth may well exceed the effect of vehicle and traffic safety improvements.

The number of victims from rail transport accidents is much smaller than for road. In the European Union, 105 people were killed in rail accidents in 2004, which was about 0.2% of the number of fatalities in road accidents.

Climate change

Climate change is one of the great challenges of current society. In the last decades, there has been increasing evidence that emissions of greenhouse gas contributes to the effect of global warming. The emission of carbon dioxide (CO_2) from the burning of fossil fuels is a major contributor. For the transport sector, greenhouse gas emissions are dominated by the CO_2 emissions from burning fossil fuels. These are strongly related to transport energy use.

The Intergovernmental Panel on Climate Change (IPCC) has examined a range of future climate change scenarios and found that the globally average *surface air temperature is projected by models* to warm 1.1 °C to 6.4 °C by 2100 relative to 2000, and global average sea level is projected by models to rise 18 cm to 59 cm by 2100. The warming is expected to vary by region, and to be accompanied by changes in precipitation, in the variability of climate, and in the frequency and intensity of some extreme climate phenomena (drought, flooding) as well as impacts on ecosystems, and diseases (*IPCC, 2007*a).

Air pollution

Transport-related air pollution causes damages to humans, biosphere, soil, water, buildings and materials. The most important pollutants are the following:

- Particulate matter (PM_{10}, $PM_{2.5}$).
- Nitrogen oxides (NO_x).
- Sulphur oxide (SO_2).
- Ozone (O_3).
- Volatile organic compounds (VOC).

The emissions of pollutants give rise to negative health impacts, building and material damages, crop losses and damages to the ecosystem (biosphere, soil, water). Each impact is related to one or more type of pollutants (Maibach *et al.*, 2008):

- *Health impacts* – Impacts on human health due to the aspiration of fine particles ($PM_{2.5}$/ PM_{10}, other air pollutants). Exhaust emission particles are here considered as the most important pollutant. In addition, ozone (O_3) has impacts on human health. The main health impacts are increased problems for people who suffer respiratory diseases and a higher risk of these diseases.
- *Building and material damages* – Mainly two effects are of importance: First, soiling of building surfaces/facades primarily through particles and dust. The second, more important, impact is the degradation through corrosive processes, due to acid air pollutants like NO_x and SO_2.
- *Crop losses in agriculture and impacts on the biosphere* – Crops as well as forests and other ecosystems are damaged by acid deposition, ozone exposition and SO_2.
- *Impacts on biodiversity and ecosystems (soil and water/groundwater)* – The impacts on soil and groundwater are mainly caused by eutrophication and acidification, due to the deposition of nitrogen oxides, as well as contamination with heavy metals (from tire wear and tear).

The main impacts are the health impacts mainly caused by particulate matter (PM) from exhaust emissions or transformation of other pollutants. There is increasing evidence that ultrafine particular particles pose severe health risks.

The World Health Organization (WHO) estimated the number of people who die from outdoor air pollution at 865 000 per year worldwide (WHO, 2007), less than 10% of these in the European Union. Other estimates are even much higher. The European Commission estimated the number of premature deaths in Europe alone at 370 000 per year (EC, 2005). This is in line with an estimate from Pimental, who estimated the number of deaths globally from outdoor air pollution at about 3 million per year (Cornell Chronicle, 2007).

Unlike the climate impacts of CO_2, the impacts from air pollutant emissions depend on location. Air pollutants that are emitted in densely populated areas cause considerably more harm than pollutants emitted in remote areas.

Noise impacts

Traffic noise has a variety of adverse impacts on human health. WHO has recognised community noise, including traffic noise, as a serious public health problem.

Traffic noise has various adverse effects. The most widespread effect is simply annoyance. In addition, there is substantial evidence of serious health problems caused by traffic noise. The main problem is that sleep patterns are disturbed, which affects cognitive functioning (especially in children) and contributes to certain cardiovascular diseases. There is also increasing evidence of an impact of noise raising blood pressure (Den Boer and Schroten, 2007).

The number of people in the European Union who are affected by cardiovascular diseases that can be traced to traffic noise has been estimated at over 245 000 people per year (Den Boer and Schroten, 2007). About 20% of these people (almost 50 000) suffer a lethal heart attack, thereby dying prematurely. There are no such estimates known for other parts of the world, but there is no reason *not* to assume that also elsewhere a considerable share of the population is seriously affected by traffic noise.

8.2. Trends in environmental impacts from transport

This section gives an overview of the main trends in the environmental impacts of the transport sector as a whole, and road and rail freight transport in particular.

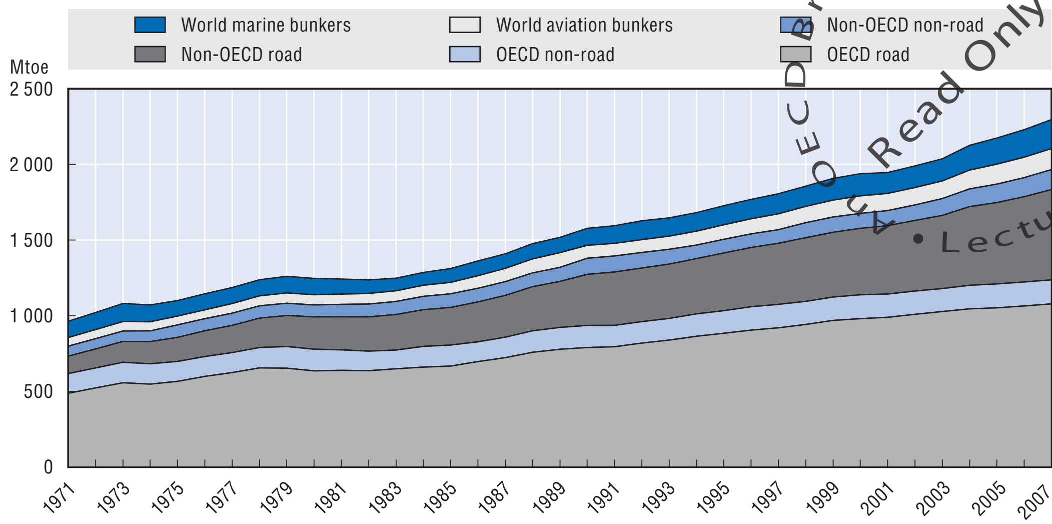
Energy use in the transport sector

The trends in energy use from transport over the last decades are depicted in Figure 8.1. Energy consumption in transport almost doubled over this period. The growth in non-OECD countries was even higher: energy use almost tripled over this period. Both for OECD and non-OECD countries, road transport had by far the largest share: about three quarters, and this share is steadily increasing.

Projections for energy use until 2050 are shown in Figure 8.2. This graph shows that the energy use of transport is expected to keep on growing at a similar rate as in the last decades, doubling between 2000 and 2040. The growth rates in road freight transport and rail transport are roughly the same as these general growth rates.

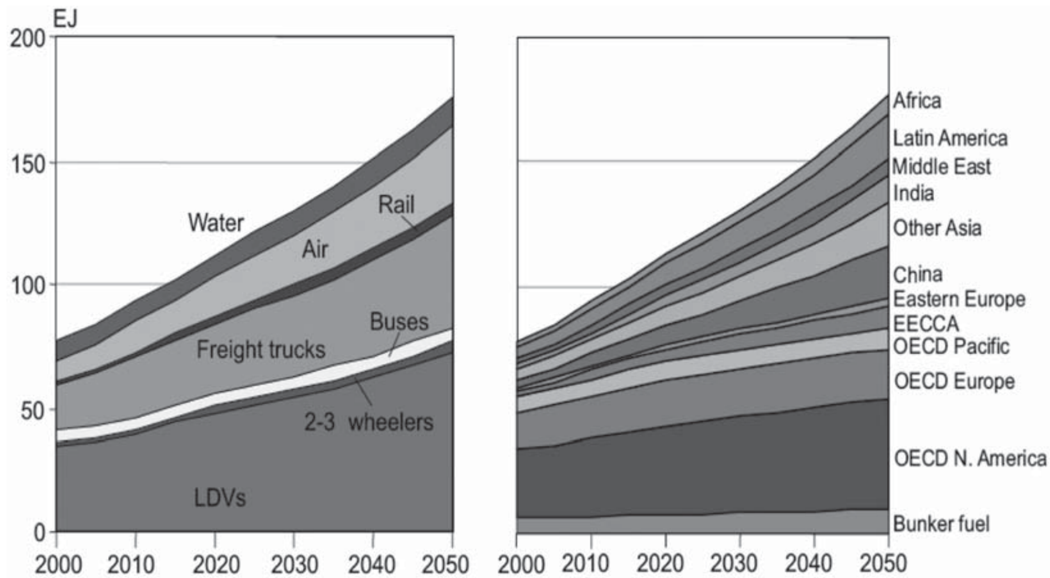
Just as happened in the past decades, the energy use of the transport sector is expected to grow much faster in non-OECD countries than in OECD countries. Where non-OECD countries currently account for about 36% of the worldwide transport-related CO_2 emissions, their share is expected to equal that of the OECD countries somewhere around 2040. Particularly in Asia and Latin America, energy use of transport is expected to grow strongly.

Figure 8.1. **Energy-use in the transport sector**



Source: IEA (2009a) and (2009b).

Figure 8.2. **Projections of transport energy consumption by mode and region**



Source: IPCC (2007b).

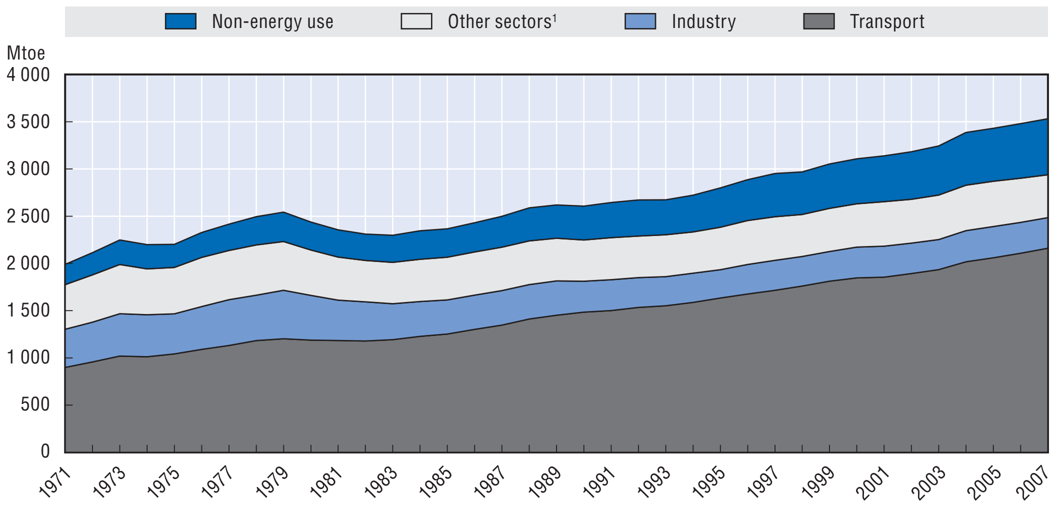
The expected growth is highest in China, where road energy consumption is expected to grow by a factor of five between 2000 and 2030 (He *et al.*, 2005). In China, freight transport has grown much faster than passenger transport (almost twice as fast) and is expected to do so in the future. The energy use of heavy duty trucks in China tripled between 1997 and 2002 (He *et al.*, 2005).

This trend makes clear that reducing energy consumption of transport, and the related greenhouse gas emissions, is becoming more and more a global challenge.

The main energy source for transport is fossil fuels. Road transport, shipping and aviation almost entirely rely on oil. The only exception to this is electric rail transport, which uses for a considerable share other energy sources, like hydro or nuclear power, depending on the energy mix in electricity generation.

The share of the transport sector in world oil consumption is much higher than the share in the world energy consumption. As can be seen in Figure 8.3, also this share is steadily increasing. Currently, more than half of the world oil production is consumed in the transport sector.

Figure 8.3. **Evolution of oil consumption per sector in Mtoe**



1. Includes agriculture, commercial and public services, residential and non-specified other sectors.

Source: IEA (2009c).

Data from IPCC (2007b) show that currently, road freight transport accounts for about 25% of the total energy use of transport, 16 % by heavy trucks and 9% by medium trucks. From the perspective of international road transport, particularly the heavy trucks (including truck-trailer combinations) are important, since these are the vehicles mostly used within the international haulage market.

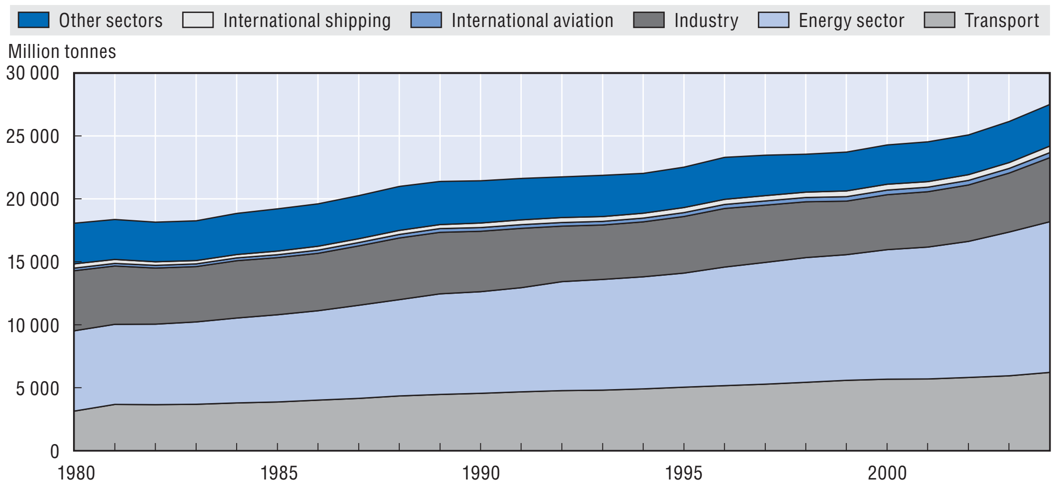
Rail transport accounts for only 1.5% of global transport energy use. Light duty vehicles (including passenger cars) have the highest share with 44%. The other main energy users within the transport sector are: aviation (12%), maritime shipping (10%) and buses (6%).

There are no worldwide statistics on the share of international road and rail freight transport in the energy use of total freight transport. However, data on the share of international freight transport in transport volume can give a good indication. As elaborated in Chapter 5, international transport generally constitutes a minor share in road transport. In rail transport, the share of international transport varies greatly.

Greenhouse gas emissions in transport

The worldwide greenhouse emissions of all sectors together show a steady growth. Despite policy interventions like the Kyoto Protocol, this growth is continuing. However, there are major differences among sectors. While greenhouse gas emissions of many other sectors stabilised, or even decreased, over the last decades, the CO_2 emissions of the transport sector keep on growing. Together with the energy sector, transport is the only sector with still strongly increasing CO_2 emissions. Figure 8.4 shows the trend in worldwide CO_2 emissions and the share of the various sectors. The share of transport increases from about one sixth in the early 1980s to now almost one quarter (23%). In OECD countries, this share is even higher (about 29%, ECMT, 2007).

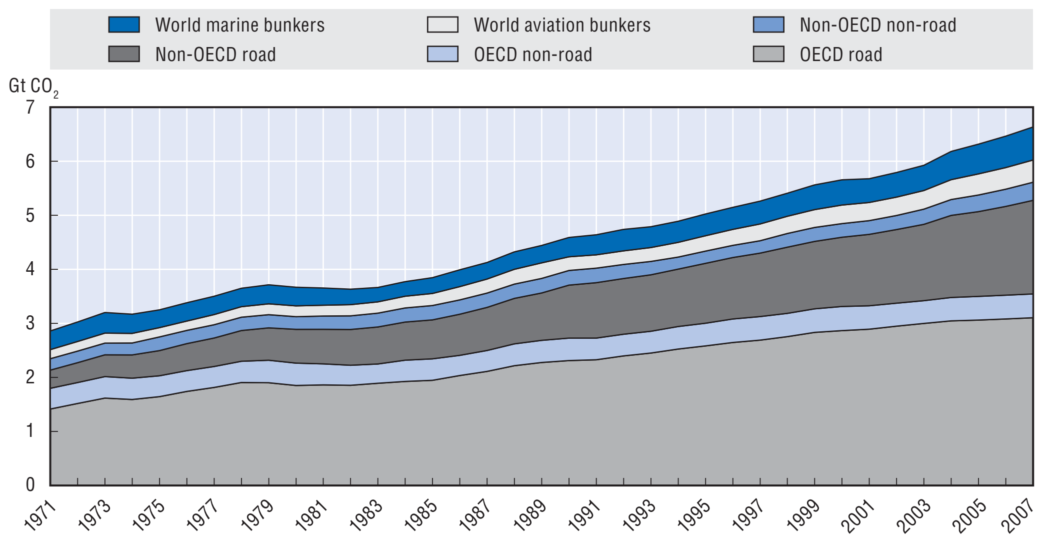
Figure 8.4. **Energy-related CO_2 emissions of various sectors worldwide**



Source: Based on IEA (2006).

Within the transport sector, the shares and trends in CO_2 emissions of the various transport modes are comparable to the shares and trends in energy use (see Figure 8.1). As depicted in Figure 8.5, road transport has the highest share in transport CO_2 emissions. As for energy use, growth in non-OECD countries is higher than in OECD countries, particularly for road transport.

Figure 8.5. **CO_2 emissions of the transport sector worldwide**

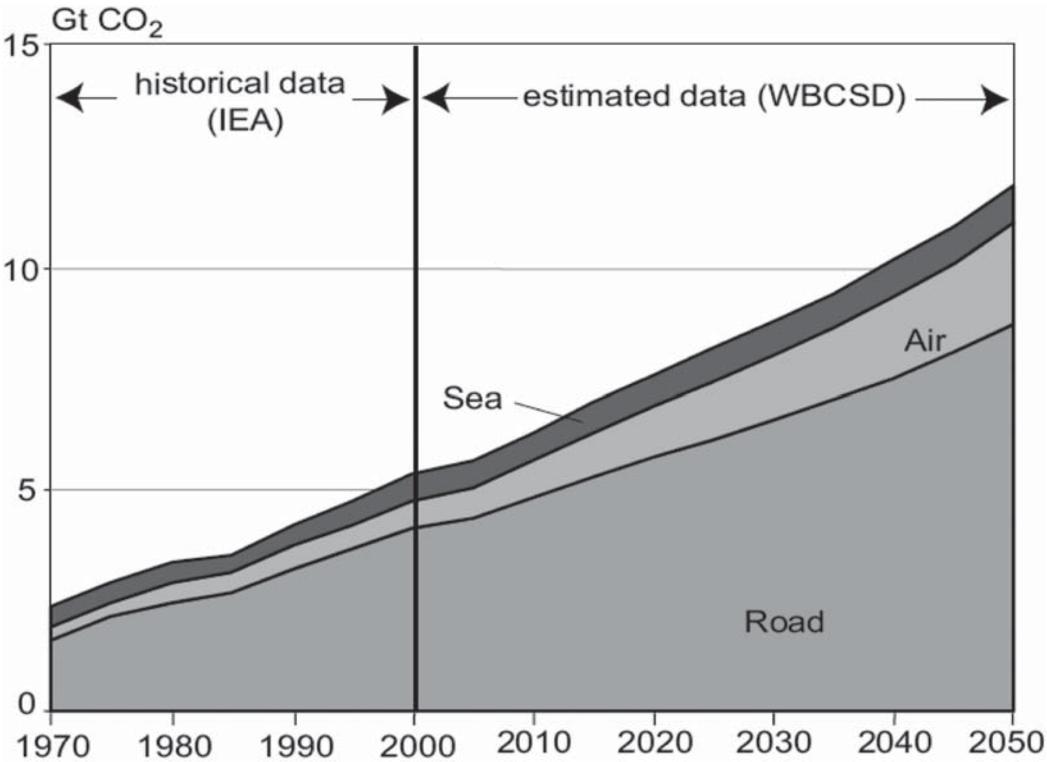


Source: IEA (2009a) and (2009b).

In Europe, aviation shows the highest increase in CO_2 emissions. In the European Union, CO_2 emissions of land transport increased by 26% between 1990 and 2005, while CO_2 emissions of international aviation and maritime shipping rose by as much as 66% (EEA, 2008b).

Without policy intervention, the current growth in transport CO_2 emissions is expected to continue. Figure 8.6 shows projections for the global transport emissions by mode from 1970 to 2050. Between 2000 and 2050, transport CO_2 emissions are expected to double, with most growth in road transport and aviation. Freight transport has been growing even more rapidly than passenger transport and is expected to continue to do so in the future (IPCC, 2007b).

Figure 8.6. **Historical and projected CO_2 emissions from transport by mode worldwide**



Source: IPCC (2007b).

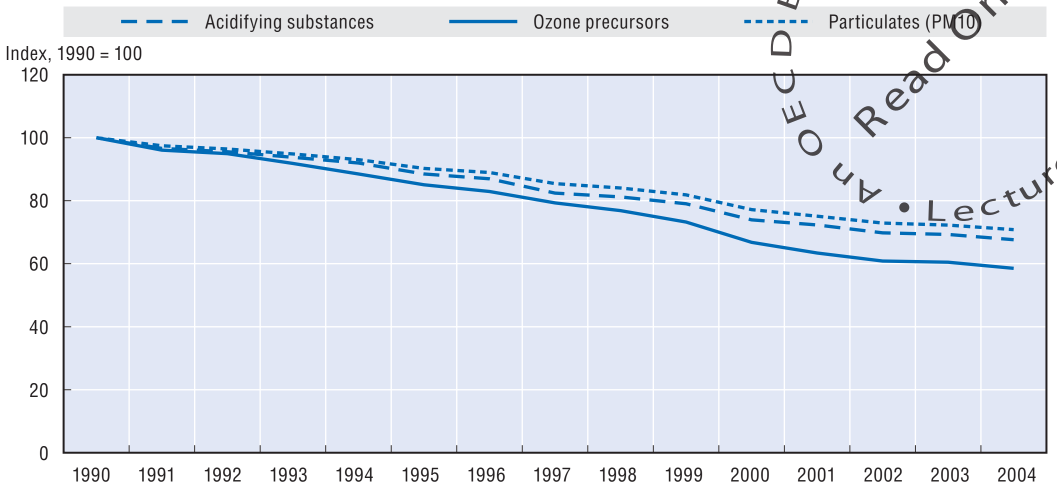
Trends in pollutant emissions

Pollutant emissions from transport have considerable effect on human health. While energy use and climate change emissions show a steady growth, the emission of pollutants have been curbed to a decreasing trend, thanks to emissions regulations in most countries (see also Section 8.4).

Figure 8.7 shows trends in air pollutant emissions from transport in Europe. Despite growing energy use in the transport sector, pollutant emissions are dropping steadily. This is the case for particulates, acidifying substances (NO_x and SO_x) and ozone precursors (NO_x and VOC). However, despite the decrease in air pollutant emissions, many European cities still

Figure 8.7. **Transport emissions of air pollutants in EEA countries**

1990-2004



Source: EEA (2006a).

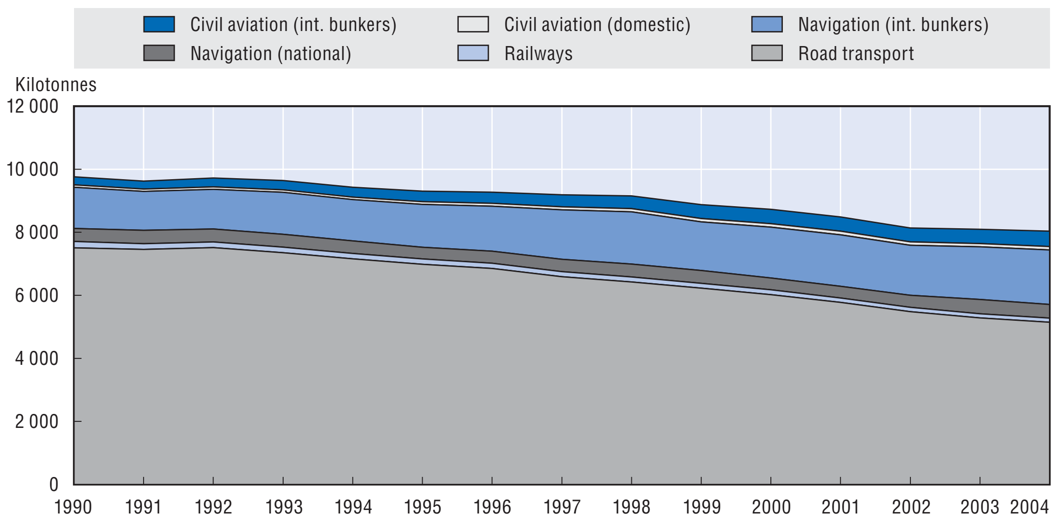
have problems meeting the current air quality standards, which might be further tightened from 2010. On the other hand, given the further tightening of emissions standards and natural renewal of the fleet, emission levels are expected to continue decreasing.

Also in most other parts of the world, stricter vehicle emission standards are resulting in an overall reduction of pollutant emissions. Only in regions with an extremely strong growth of transport volumes, particularly road (*e.g.* China), emission reduction per vehicle-kilometre may not be strong enough to result in an overall decrease in pollutant transport emissions.

A further breakdown of the NO_x emissions to the various transport modes makes clear that the decrease in pollutant emissions can in large part be explained by a reduction in road transport pollutants (see Figure 8.8). The decrease in pollutant emissions from road

Figure 8.8. **Transport emissions of air pollutants in EEA countries**

1990-2004



Source: EEA (2006a).

vehicles results in an increase of the relative share of the non-road modes. However, since emission standards have been or will soon be applied also for these modes (see Section 8.4), these emissions will start to decrease.

Trends in noise emissions

Unlike greenhouse gas and pollutant emissions, there is little data on trends in traffic noise levels and the number of people exposed.

The European Environment Agency (EEA) reviewed the number of people in Europe exposed to traffic noise levels above 55 dB, which is regarded as harmful. They concluded the following:

> "About 120 million people in the EU (more than 30% of the total population) are exposed to road traffic noise levels above 55 Ldn dB. More than 50 million people are exposed to noise levels above 65 Ldn dB. It is estimated that 10% of the EU population are exposed to rail noise above 55 LAeq dB. The data on noise nuisance by aircraft are the most uncertain, but studies indicate that 10% of the total EU population may be highly annoyed by air transport noise" (EEA, 2001).

Data for other parts of the world does not seem to be available, but it can be expected that a considerable share of the population is exposed to traffic noise.

8.3. Developments in emission factors of road and rail vehicles

Transport emissions are driven by transport volumes, which were discussed in Chapter 5, but also by the emissions per vehicle-kilometre and the shares of various modes. In this section, the emission factors of road and rail transport are discussed: first, the emission standards for pollutants; second, the emissions levels per kilometre for both long distance road and rail transport.

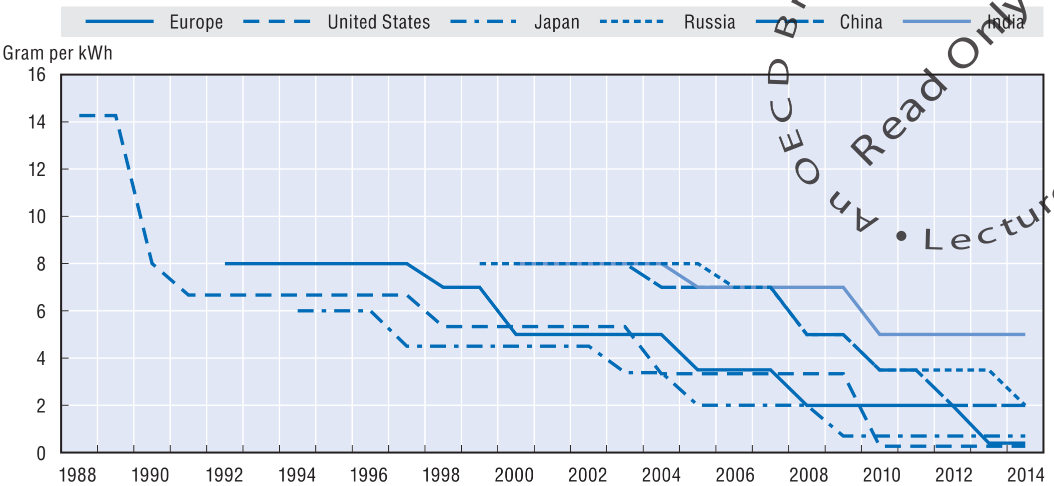
Emission standards for diesel engines of heavy duty vehicles

All over the world, countries have regulated the pollutant emission levels of new vehicles, both passenger cars and heavy duty vehicles. At type-approval, every vehicle needs to meet certain emission standards at a prescribed test-cycle. However, both the emissions levels that new vehicles should meet and the test cycles that are applied vary among countries. The three main streams are the European, Japanese and American standards. Countries like the Russian Federation, China and India tend to apply the European standards, but at a later year.

Figure 8.9 and Figure 8.10 give an overview of the NOx and PM10 emission standards for heavy duty vehicles in various parts of the world. In some cases, multiple standards apply, depending on for example engine power. In those cases, a typical engine for a large truck has been selected. Because of other differences in definition and test cycle used, standards are not completely comparable. However, these graphs give a rough overall picture of the worldwide developments in emission standards.

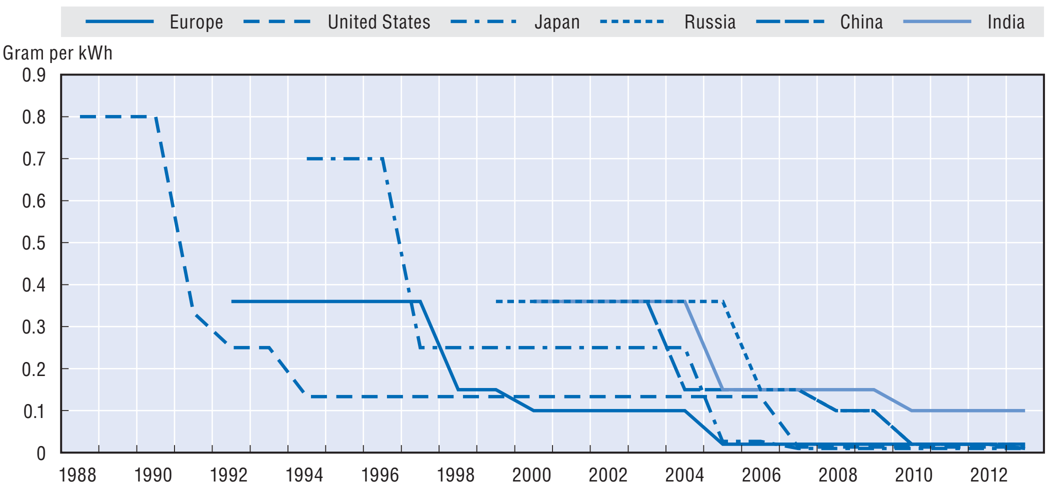
Various technologies have been developed and implemented in order to meet the various standards, *e.g.* various types of catalysts and, more recently, diesel particulate filters. Together with technological improvements, the knowledge on the impacts of air pollution has developed. Recently there is increasing attention to the health impacts of ultrafine particles ($PM_{2.5}$).

Figure 8.9. **NO_x emission standards for heavy duty vehicles in selected countries**



Source: Compiled with data from *www.dieselnet.com/standards*.

Figure 8.10. **PM_{10} emission standards for heavy duty vehicles in selected countries**



Source: Compiled with data from *www.dieselnet.com/standards*.

It should be noted that the emissions of vehicles on the road differ from emission levels in test cycles. Real-life emissions are generally considerably higher, because manufacturers tune engines to the test cycle conditions. Despite this so-called test-cycle by-passing, real-life emissions are still reduced by stricter emissions standards, but at a lower speed than one might conclude from the emissions standards themselves.

Overall, the pollutant emissions from heavy goods vehicles have effectively been reduced, but total emissions are not yet at a desired level. Further tightening of emission standards in the coming decade is expected to contribute to a further reduction of pollutant emissions.

Emission standards for non-road diesel engines

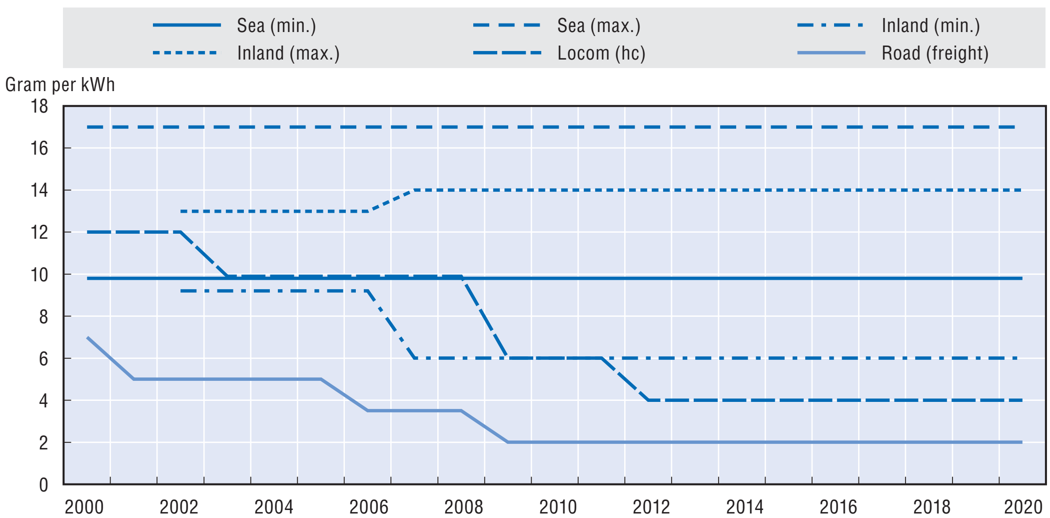
Emission regulation first tended to be focused on road transport. The reason for this is the large share of road transport in pollutant emissions. However, with the significant improvements made in road transport, attention has shifted to reduction of pollutant emissions from non-road modes, particularly diesel engines of trains and ships.

In the European Union, since about 2000, emission standards for non-road modes are being introduced. In the Non-Road Mobile Machinery Directive (2004/26/EC), emission standards (HC, CO, NO_x and PM_{10}) and deadlines are set for rail and inland navigation, distinguishing among types and engine sizes. The Directive introduces progressively lower emission standards until 2015. For rail and inland navigation, the first standards were introduced in 2006. Earlier standards for rail (diesel engines) were set by the UIC. For inland navigation, the Central Commission for Navigation on the Rhine (CCNR) set standards, starting from 2002.

Figure 8.11 (NOx) and Figure 8.12 (PM10) present an overview of European emissions standards coming into force until 2015. For each mode, both the highest and lowest standards are shown. In practice, those different standards apply to e.g. different power classes for the same mode. For comparison, the standards for road freight transport (since 2000) are shown as well. The standards are given in gram per kWh (mechanical energy delivered by the engine).

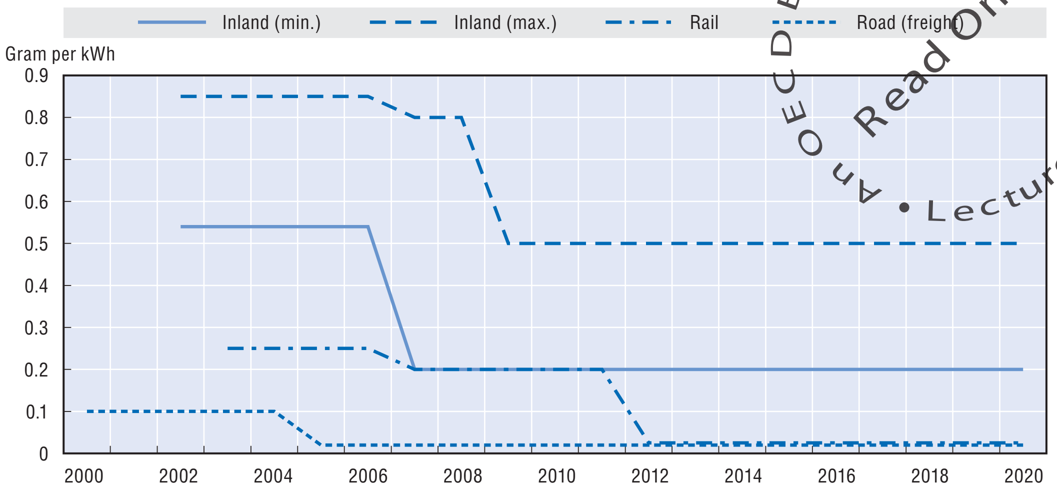
For NO_x, permitted emissions are clearly higher for maritime transport than for other modes of transport. Standards for road transport will remain stricter than for other modes for quite some time. For particulate emissions, no standards exist for sea-going engines. For rail, the standard for PM will coincide with that for road freight from 2012. Standards for inland navigation vessels are considerably more lenient.

Figure 8.11. **Standards for NO_x emissions for diesel vehicles in the European Union**



Note: Standards data are taken from 2004/26/EC, Marpol Annex VI, CCNR.
hc: Indicates combined standard for hydrocarbon and NO_x emissions.
Source: Van Essen *et al.* (2005).

Figure 8.12. **Standards for PM_{10} emissions for diesel vehicles in the European Union**



Note: Standards data are taken from 2004/26/EC, Marpol Annex VI, CCNR.

Source: Van Essen *et al.* (2005).

It should be noted that emission standards do not offer a direct comparison of modes in terms of environmental effect. The specific test cycles vary a lot, and the same standard may be very strict for one mode but easy to achieve for another mode, due to technological differences. Moreover, these emission standards are set per kWh. This cannot be directly translated to the actual effects of the sector and its efficiency, in terms of, for instance, tonne-km. It is fair to say, however, that for non-road modes, standards have been set much later than for road transport. Also, standards generally take longer to show actual effects on fleet emissions: non-road modes typically deal with smaller markets and fewer vehicles with a much slower turnover of the fleet than road modes.

In March 2008, the United States introduced emission standards for diesel locomotive engines and ship engines. When fully implemented, these new standards will cut PM_{10} emission factors by 90% and NO_x emission factors by 80% (Sustainable Business, 2008).

Box 8.2. **Sulphur content of fuels**

In addition to engine emission standards, the sulphur content of fuels is increasingly subject to standards. Reducing the sulphur content of fuels has a large impact on exhaust emissions as it enables the introduction of more sophisticated after-treatment systems. There is a huge range in sulphur content in fuels. For 2009, for road transport, the European standard is 10 ppm: a factor of 100 lower than for diesel trains. For comparison, the sulphur content in marine fuel is on average 7 times higher than for diesel trains.

Emissions levels per kilometre for long-distance road and rail transport

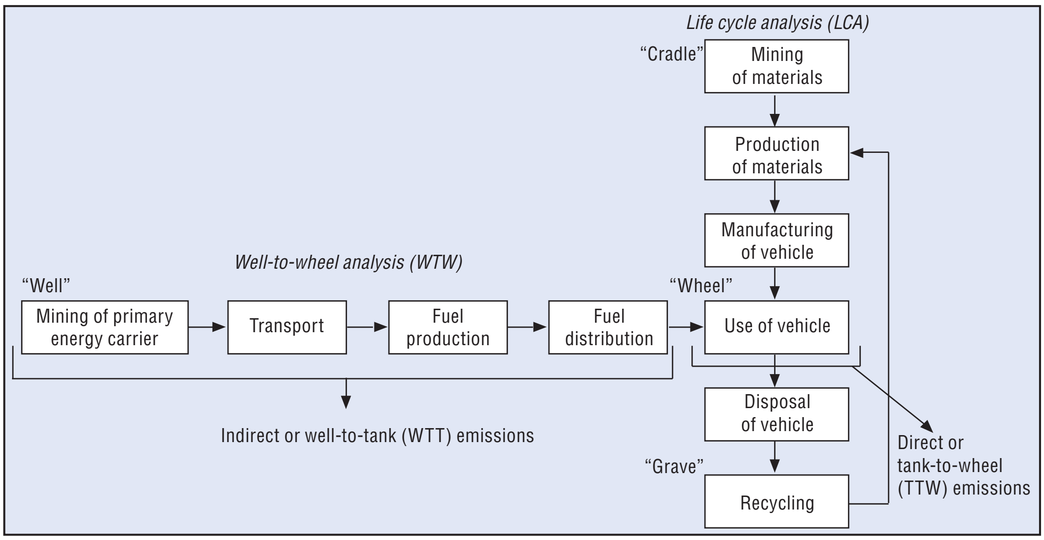
Transport causes emissions in various ways:

- Vehicle usage: burning of fuels.
- Fuel production.
- Vehicle production, maintenance and disposal.
- Infrastructure building, maintenance and adjustments.

The first type of emission is generally regarded as the most important source of transport-related emissions. In order to be able to compare various modes, emissions along the whole energy chain (both the production and burning of fuel) are usually taken into account. In the case of electric trains, this includes the electricity production. This approach is called "well-to-wheel". The well-to-wheel emissions of various freight transport modes can be compared by expressing them in gram per tonne-kilometre.

The emissions from the production, maintenance and disposal of vehicles can be analysed by life-cycle analysis (LCA). Both the well-to-wheel and LCA approaches are depicted in Figure 8.13.

Figure 8.13. **"Well-to-wheel" analysis of energy chains and "life-cycle analysis" of products**



Source: van Essen (2008).

For passenger cars, the emissions of vehicle use are about 80% of the total emissions; the other 20% are emissions related to infrastructure provisioning and the production, maintenance and disposal of vehicles (CE Delft, 2008). For passenger transport by rail, the estimates of these shares vary a lot, probably because of differences in the energy mix. There are no estimates available for road or rail freight transport.

For a sound comparison of the well-to-wheel emissions, competing modes should be compared within market segments. Differences in logistical parameters, like load-factors, empty rides and detours should be taken into account. In addition, it is important to compare whole transport chains. Transport by non-road modes usually needs some road transport to and from loading points.

Rail transport relies both on diesel and on electricity. The environmental performance of electric trains is generally better than that of diesel trains. The actual difference depends on the electricity mix and the applied diesel technology. An important difference is that electric transport offers the possibility to use sustainably generated electricity. In that case, the environmental performance of electric trains is much better than that of diesel trains. However, in an integrated electricity market, the marginal environmental impact from electric energy will be determined by the marginal supplier of electricity. It is difficult to determine from which source any particular electricity stems.

Emissions per tonne-kilometre depend on the emission factors (in g per kWh), the energy use and the vehicle utilisation. These factors vary a lot among countries and specific situations as:

- There is a wide bandwidth in emission factors, particularly for pollutant emissions.
- There is huge variation in logistical parameters, particularly load-factors.
- Differences exist in the energy mix of electricity used for electric trains.

In specific markets, the differences among transport modes are generally small. Differences depend more on logistical characteristics and technology (*e.g.* emission standards) than on mode *per se* (Van Essen *et al.*, 2003). In a recent study, emissions factors for the Netherlands were compared. The results for pollutant emissions of long-distance container transport are shown in Figure 8.14. The NO_x and PM_{10} emissions per tonne-kilometre are highest for sea shipping. In this case, emissions of rail transport are lower than those of road transport. The differences among the modes depend on the emission factors and the energy efficiency of each mode. The average emission factor for heavy duty vehicles in this case is about the level of Euro-3.

At least as important are the differences in the average vehicle utilisation. In the specific case of the non-bulk market in the Netherlands, the average utilisation of freight trains (86%) is considerably higher than the average utilisation of trucks (26%), articulated truck-trailer combinations (33%) or inland vessels (64%), which is directly reflected in the emission levels per tonne-kilometre.

For comparison, the CO_2 emissions per tonne-kilometre for the same case: long-distance non-bulk container transport are also presented. In both cases, the CO_2 emissions of road transport are again higher than those of rail transport are also presented. Just as for the pollutant emissions, the differences in CO_2 emissions per tonne-kilometre are strongly dependent on vehicle utilisation. The emissions of a fully loaded truck are comparable to those of competing modes, when the whole transport chain is considered.

Figure 8.14*a*. **NO_x emissions per tkm for long-distance container and other freight transport**

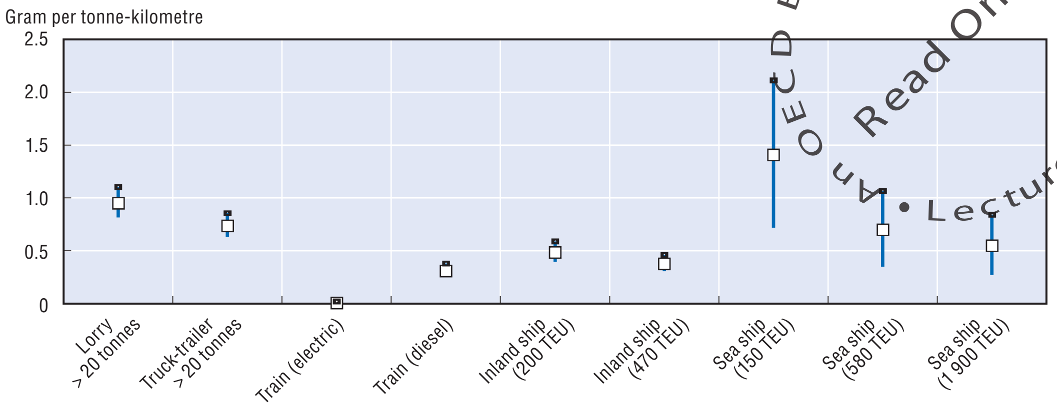


Figure 8.14*b*. **PM_{10} emissions per tkm for long-distance container and other freight transport**

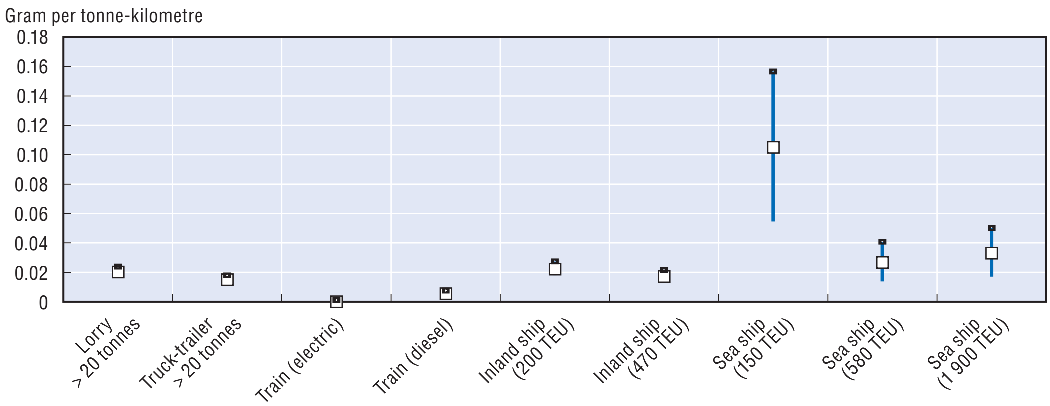
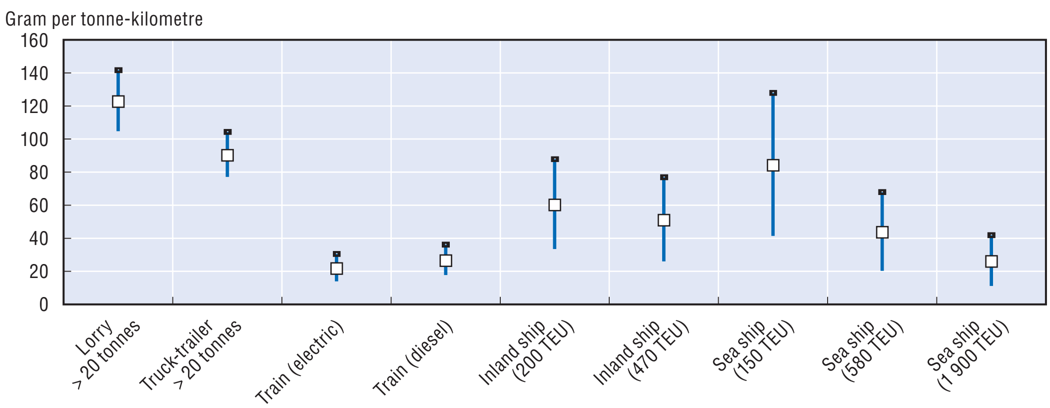


Figure 8.14*c*. **CO_2 emissions per tkm for long-distance container and other freight transport**



Note: The graphs are based on data on logistical characteristics, energy mix and emission factors for the Netherlands. Bandwidths are based on a 15% variation of the load factor and, for the non-road modes, also a variation in detour factor and with or without transport to/from loading points. "Other" freight transport refers to non-bulk freight transport.

Source: For all three graphs, Den Boer *et al.* (2008).

8.4. Perspectives for improving environmental performance of freight transport

As presented in Section 8.2, the CO_2 emissions of transport show an increasing trend. This is in contrast to the ambitious CO_2 reduction targets discussed within the post-Kyoto climate policy and which have already been adopted by some regions and countries (*e.g.* the European Union). In the short term, many developed countries will be able to meet their CO_2 reduction goals under the Kyoto Protocol without drastic measures in the transport sector. For the long term, however, CO_2 emission reductions of 40% to 80% compared to 1990 are expected to be necessary, in order to limit the effects of global warming to acceptable levels. Given the expected growth of the transport sector in the next decades, and its strong reliance on fossil fuels, such long-term reduction goals cannot be met without significant contributions from the transport sector.

In this section, the main options for CO_2 reduction in international road and rail freight transport will be discussed:[2]

- International road freight transport:
  1. Technical measures.
  2. Non-technical measures.
- Measures for CO_2 reduction in international rail freight transport.
- General measures for CO_2 reduction in international surface freight transport:
  3. Biofuels and other alternative fuels.
  4. Measures aimed at volume reduction and modal shift.

Pollutant emissions of long-distance freight transport can most effectively be reduced by further tightening of vehicle emission standards.[3] Also the measures aimed at volume reduction and modal shift may contribute to a reduction of pollutant emissions, *e.g.* a shift towards electric rail transport in combination with a shift to greening electricity production. The options for reducing noise emission from international transport are briefly discussed at the end of Section 8.4.

Technical measures to improve energy efficiency in road freight transport

Fuel costs are a significant part of the operating costs of heavy duty vehicles. Hence, efficiency improvement has traditionally been an important driver in vehicle and engine developments for freight transport. Furthermore, the engine in a heavy duty application is generally used in a more energy-efficient way, because of a smaller power-to-weight ratio than passenger cars and the use of an optimised gearbox (Smokers and Kampman, 2006).

As a consequence, the potential for further efficiency improvement in road vehicles for freight transport seems rather limited, especially in the sector of long-distance transport. For urban distribution, trucks and city buses, the driving pattern is generally more dynamic, so engine improvements and application of a hybrid power-train may offer significant fuel economy benefits.

The main technical options for improving energy efficiency in heavy duty vehicles are (Smokers and Kampman, 2006):

- Low rolling-resistance tyres (≈ 6%).
- Engine improvements (≈ 5%).
- Reduction of air resistance (≈ 6%).
- Increased weight limit to 44 or 60 tonne (≈ 9-20%).

- Lightweight construction (≈ 7%).
- Hybrid propulsion for city buses and distribution trucks (≈ 15%).

The percentages between brackets are fuel-consumption reduction values for new vehicles. For the current heavy duty vehicles that are used for international road freight transport, the overall reduction potential is about 20% per vehicle-kilometre. The potential reduction of an increased weight limit has not been counted yet. This could result in an additional reduction of up to 20%.

While pollutant emissions from heavy duty vehicles are regulated, CO_2 emissions are not. For passenger cars, fuel efficiency standards have been developed in various parts of the world. The tightest ones are currently developed in Europe. For heavy duty vehicles, only Japan has introduced CO_2 emission standards, aiming at a reduction of 12% of the average CO_2 emissions per vehicle-kilometre of heavy duty vehicles, between 2002 and 2015 (ECMT, 2007). The European Commission is investigating the costs of various technical options for improving the fuel efficiency of heavy duty vehicles, which might be followed by the development of some kind of fuel efficiency standards for these vehicles as well. An important precondition for such a standard would be the development of a reliable test-cycle for heavy duty vehicles or engines. This is probably more complicated than for passenger cars because of the larger variety in applications of heavy-duty vehicles and a related larger bandwidth of vehicle weight, which is a key driver for fuel consumption.

Non-technical measures to improve energy efficiency in road freight transport

Besides technical measures, a number of non-technical measures can also be implemented to reduce fuel consumption in passenger cars, vans and heavy-duty vehicles. In the following subsection, the main options, according to Smokers and Kampman (2006), are listed.

Eco-driving

The main elements of a fuel-efficient driving style (eco-driving) are:

- Maintaining a low engine rotations-per-minute by early shifting to higher gear during acceleration and driving in the highest possible gear at more constant speeds. At a given power-demand, the engine load (torque) is higher when the engine is operated at low rpm. At higher loads, the engine's efficiency is better than under part-load conditions.
- Anticipative and smooth driving in order to avoid unnecessary (strong) accelerations and to reduce the unnecessary waste of kinetic energy by strong braking.

Depending on their initial driving style, drivers of passenger cars may save between 5% and 25% fuel directly after an eco-driving course. Smokers *et al.* (2006) estimated, however, that the long-term average improvement for passenger cars is of the order of 3%. The potential may be improved by the use of a gear-shift indicator or a fuel-economy meter.

Although the maximum reduction potential for trucks is smaller than for passenger cars, for this application the fuel-consumption reduction potential of eco-driving is estimated to be 5%. The reason for this higher potential lies in the fact that professional drivers may be expected to better maintain an efficient driving style and that they may be expected to receive more intensive or more frequent training. The CO_2-abatement costs associated with eco-driving depend on the costs of lessons, the assumed effectiveness and the fuel price. Both for passenger cars and for trucks, the abatement costs are expected to be negative for most combinations of fuel price and costs of lessons (Smokers *et al.*, 2006).

In the long term, the effectiveness of eco-driving is expected to decrease as many technical measures implemented to improve energy-efficiency of vehicles do this by improving the part-load efficiency of the engine.

Traffic measures

Various traffic measures can be implemented to smooth the traffic flow and reduce driving dynamics. Examples are synchronisation of traffic lights and lower speed limits on congested highways. These undoubtedly reduce fuel consumption and CO_2 emissions per vehicle-kilometre. On the other hand, such measures also tend to improve the flow of traffic and to reduce congestion, which may result in increased traffic. This may counteract possible benefits per vehicle. Moreover, for international road transport, this type of measure is not expected to have large reduction potential, since international road transport mainly uses motorways.

Improved logistics

According to Pischinger *et al.* (1998), Pischinger and Hausbergerm (1998), and Bates *et al.* (2001), improved logistics could lead to a reduction in road freight kilometres, resulting in 10% to 20% fuel consumption reduction based on the following measures:

- Improved logistic organisation.
- Better co-ordination among all transport operators (also intermodal).
- Improved route planning.

CO_2-avoidance costs are estimated to be negative, meaning that the cost of implementation of these measures is lower than the cost savings. To get these types of measures implemented, it is important to learn about the reasons why these measures are currently not applied. This generally has to do with organisational reasons. It should also be noted that the resulting reduction of the overall cost of transport may in turn increase transport demand, which may partly counteract the absolute reduction in fuel consumption and CO_2 emissions.

The current vehicle utilisation of long-distance road freight transport (like in the Netherlands, see Section 8.3) leaves room for improvement. The current vehicle utilisation is a trade-off between the direct costs in vehicle-kilometres and the various costs of optimising logistical chains. The latter include costs related to time losses, lower flexibility and storage, which might increase when vehicles are used in a more efficient way. Therefore, optimising logistics is not just a task for the transport sector, but it is also strongly related to governmental measures, in particular transport pricing.

Measures to improve energy efficiency in rail freight transport

Diesel trains are responsible for only 0.5% of the EU25 CO_2 emissions. Efficiency improvement for these vehicles therefore does not have a high policy priority. The efficiency of modern electric trains has improved greatly, due to the use of power electronics and regenerative braking. The effects of this, however, are partly compensated by the increase in energy consumption because of increased speed. For electric trains further well-to-wheel efficiency improvements, or CO_2-emission reductions, are stimulated by the fact that electricity generation is part of the EU-ETS Emission Trading System (Klooster and Kampman, 2006).[4]

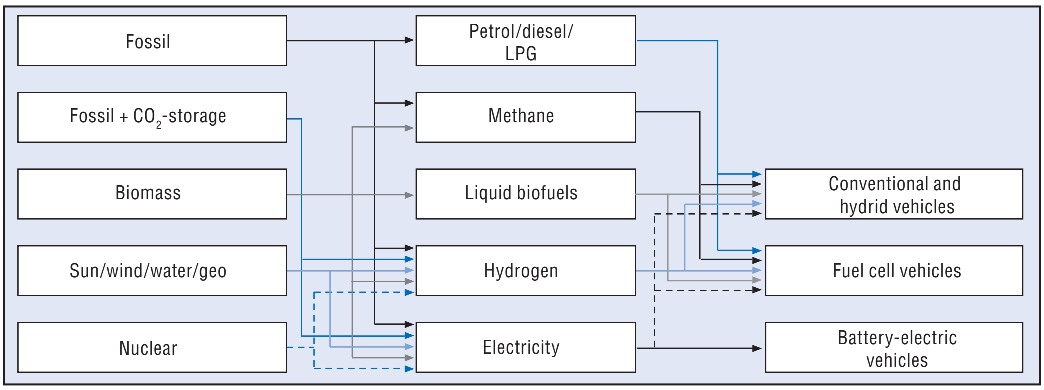
In order to further improve the energy efficiency and reduce engine emissions of trains, there is a range of technical measures available (limited to measures that are relevant for freight trains):

- Non-engine based measures to increase energy efficiency (Nielsen *et al.*, 2005):
  1. optimising physical parameters: mass reduction, improved aerodynamics and decreasing friction;
  2. regenerative braking with energy recovery;
  3. energy-efficient driving, to optimise speed at all times during the journey, for instance reducing braking; and
  4. increasing the load factor.
- In-engine measures for diesel trains.

Biofuels and alternatives

Oil is presently the dominant energy source for the transport sector, but in the long term, a multitude of energy chains could become available on the basis of fossil energy, various sustainable sources and nuclear power. This is illustrated in Figure 8.15.

Figure 8.15. **Primary energy sources, secondary energy carriers and use of energy in vehicles**



The graph shows various routes from primary energy sources, via secondary energy carriers to final use of energy in vehicles with different propulsion systems.

Source: Van Essen (2008).

In the left hand column of Figure 8.15, the range of available primary energy sources is presented. The centre column shows the various categories of secondary energy carriers, into which the primary energy sources can be converted, for distribution to final energy use applications. Energy carriers include traditional fuels (petrol, diesel and LPG, from refining of oil or synthetically produced from gas or coal), various fossil and renewable alternative fuels (*e.g.* natural gas, biogas, bioethanol, biodiesel, biomass-to-liquids [BTL] and hydrogen), as well as electricity. On board vehicles, these energy carriers are converted into propulsion-energy, using various power-train technologies. These are displayed in the right-hand column of Figure 8.15.

It is clear from this graph that an advantage of hydrogen and electricity is that both can be produced from all possible primary sources. Similarly, internal combustion engine based power-trains (conventional as well as hybrid) and fuel cell power-trains can be fed with all possible fuels, whereby hybrid configurations are also able to partly use electricity.

Alternative fossil fuels

Liquefied petroleum gas (LPG) and, especially, compressed natural gas (CNG) are presented as clean fossil alternatives for petrol and diesel. By the application of three-way catalysts and tightening of emission limits, the air-quality related advantages of LPG and CNG vehicles compared to petrol have been greatly reduced (Hendriksen *et al.*, 2003). CO_2 emissions of LPG vehicles are in between those of petrol and diesel vehicles. The well-to-wheel greenhouse gas emissions of CNG vehicles are some 20% lower than those of petrol vehicles, and as such comparable to those of diesel vehicles. The CO_2 benefit of CNG, however, is strongly affected by the origin of the natural gas and the associated transport distances.

For example, as Europe is now a net importer of natural gas, it may be assumed that the additional demand for natural gas for vehicles on CNG will be met by imports from the Russian Federation, the Middle East and South-West Asian countries. Data from Concawe (2006) and Smokers *et al.* (2006) show that while natural gas vehicles on average EU-mix natural gas have 23% lower well-to-wheel greenhouse gas emissions, this benefit reduces to 17%, or 8%, when imported gas is used that is transported over a distance of 4 000 respectively 7 000 km. The role of LPG and CNG in the context of a CO_2 policy for the transport sector therefore seems limited in Europe.

CNG could play a role in various transition paths towards the use of biogas and hydrogen, but in this context, the investment in a CNG distribution infrastructure for transport probably only makes sense if it is part of a more integral, regional approach to promoting the use of natural gas, biogas or hydrogen.

The same can be said for LNG and for new alternatives such as DME (dimethyl ether) and synthetic diesel derived from natural gas (GTL, or gas-to-liquid) or coal (CTL, or coal-to-liquid). GTL and CTL allow the production of high-value transport fuels from other fossil sources. This is economically attractive on the one hand because remote sources of especially natural gas can be exploited and on the other hand because blending of synthetic components into diesel enables further improvements in fuel quality which are necessary to improve the efficiency and emissions of modern combustion engines.

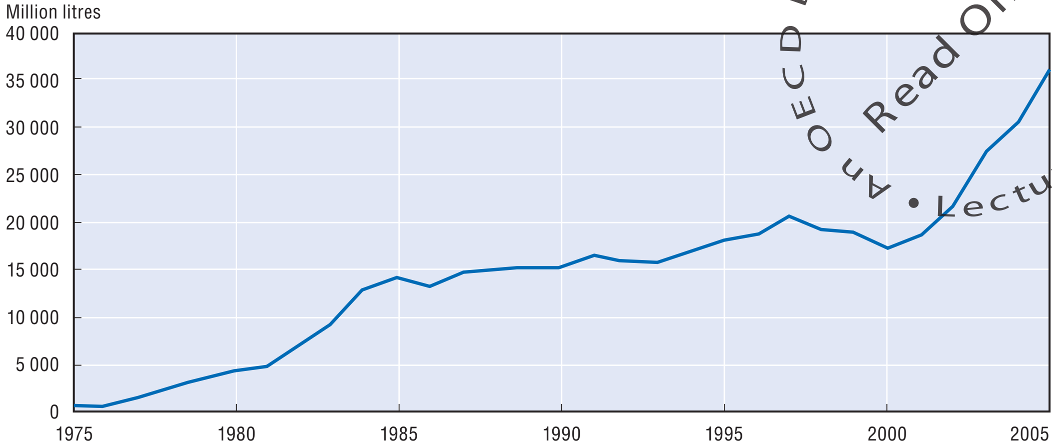
Biofuels

Production and use of biofuels has increased greatly in recent years, both in the EU and globally. The current biofuels industry is composed of two main sectors: biodiesel and bioethanol. Globally, bioethanol production exceeds biodiesel production by a factor of 10, as can be seen in Figure 8.16 and Figure 8.17. In the EU, this ratio is reverse, with biodiesel production being 10 times higher than bioethanol production. This has to do with government policies of various member states, the rapeseed production potential of the EU (rapeseed oil is one of the main raw materials that can be converted to biodiesel) and the relatively high share of diesel in EU fuel sales. In 2005, 3.9 million tons of biofuel were produced in the European Union, marking a 65.8% growth compared to 2004. Production of bioethanol is much lower in the EU, but also increased significantly, by 70.5%, between 2004 and 2005.

Biofuels have the advantage that the CO_2 that is emitted during combustion is equal to the CO_2 that is taken up by the biomass during cultivation. However, they still contribute to climate change because of greenhouse gas emissions during cultivation of the biomass (N_2O emissions mainly, due to fertiliser use), transport and production of the biofuel.

Figure 8.16. **Global ethanol fuel production**

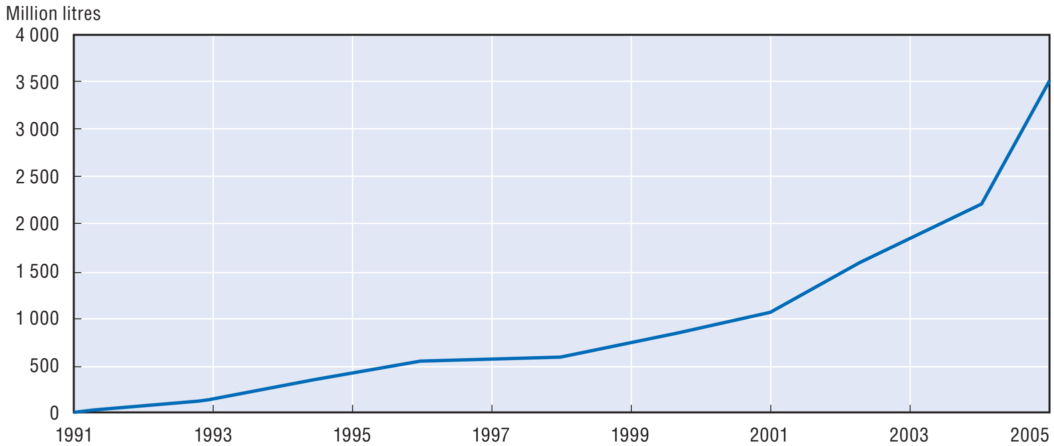
1975-2005



Source: WWI (2006).

Figure 8.17. **Global biodiesel production**

1991-2005



Source: WWI (2006).

Compared to fossil diesel and petrol, figures for the European Union show that current biofuels (biodiesel and bioethanol) achieve, on average, well-to-wheel greenhouse gas reduction percentages between 30% and 60% (Concawe, 2006).[6] However, new biofuel processes are currently under development, that are expected to achieve a greenhouse gas reduction of 80% to 90%. In the coming years, these new biofuels, often called second-generation biofuels, could be developed further.

Even though biofuels have a greenhouse gas emission advantage, they also have some negative effects. First of all, the cost of most biofuels is higher than that of fossil fuels.[7] The only exception is bioethanol from Brazil. Costs from European biofuels may come down in the future due to learning effects; however, costs will also depend on demand and supply.

Secondly, concerns about the potential negative effects of biofuels on biodiversity are growing. The substantial rise of the demand for biomass from both the biofuel and bioenergy sector puts additional pressure on farmland and forest biodiversity, as well as on soil and water resources. It may also counteract other current and potential environmental policies and objectives, such as waste minimisation or environmentally oriented farming (EEA, 2006b). EEA (2006b) concludes that significant amounts of biomass can technically be available to support ambitious renewable energy targets, even if strict environmental constraints are applied. However, it also concludes that environmental guidelines need to become an integral part of planning processes at the local, national and EU levels. Other studies confirm that the biofuel potential is certainly not unlimited, due to constraints regarding biodiversity, food production, water availability, etc. (see *e.g.* WWF, 2006).

Long-term options: Hydrogen and electricity

In the long term, also hydrogen and electricity can be envisaged to play a role in the energy supply of the transport sector. It should be noted here that both are *energy carriers* and not *energy sources*. As such, the well-to-wheel efficiency and CO_2 emissions depend on the primary source and conversion processes that are used to produce hydrogen and electricity. Given that the "cap" on CO_2 emissions in the EU-ETS includes electricity generation, application of electricity in transport *does* already have well-to-wheel efficiency benefits in EU countries. For hydrogen, this would only be the case if it was produced from renewable.

Box 8.3. **A system-efficiency perspective**

The example of hydrogen shows that in some cases, measures to improve the energy efficiency of the transport sector should not just be reviewed at the level of a vehicle-to-vehicle comparison, or a well-to-wheel comparison, but that a system-wide approach is necessary, in which the relation of a given energy source with other applications outside the transport sector is taken into account, and in which the overall target is optimisation of system efficiency, rather than optimisation of the efficiency of transport. Already now, the efficiency of *e.g.* refineries is closely linked to processes in other sectors, through the use of process-energies and the generation of by-products. This will probably be even more the case for future fuel production systems. An interesting example already is the Fischer-Tropsch process for production of synthetic fuels, of which the overall system efficiency and well-to-wheel CO_2 emissions are strongly dependent on the weather and where electricity, that can be generated as a by-product, is used.

Many authors present visions of a "hydrogen economy" that will solve all our future energy problems. It is, however, highly questionable whether distribution of energy in the form of hydrogen is the most optimal solution from a system point of view. Possibly, a more limited role for the production of hydrogen as a buffer to match demand patterns with the supply patterns of renewable energy in the context of an "all-electric society" would be more appropriate.

Volume reduction and modal shift

The trends in the environmental performance of transport, including those for international road and rail freight transport, are strongly driven by the growth of transport volume. Limiting the expected growth of transport volume can reduce the environmental impacts of transport. For limiting the growth of CO_2 emissions from freight transport, the available technical options seem unable to compensate for the expected growth in transport volume. Therefore, an effective mix of measures for limiting transports' contribution to climate change could include measures that curb transport demand growth.

In specific cases, measures aiming at a shift of transport volumes to the most efficient modes of transport can be an effective approach. However, the net impacts of modal shift measures depend a lot on the type of measure and on the logistical and environmental performances of the various transport modes involved in that particular situation.

In addition, specific measures aimed at modal shift, like building new rail infrastructure, may boost the transport volume of rail without decreasing road transport volumes. In those cases, the net effect is higher transport volume and higher total emissions (Van Essen *et al.*, 2003). Therefore, measures that try to reduce the environmental impacts of transport by forcing modal shift should always be assessed on their environmental impacts, rather than on their impacts on the modal split as such.

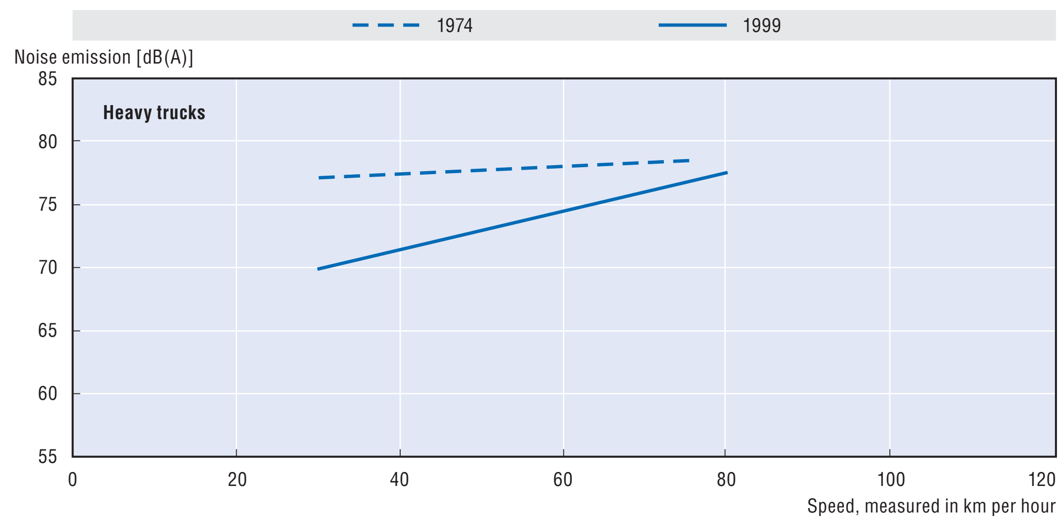
Reducing noise emissions

There are essentially two routes to noise abatement (Den Boer and Schroten, 2007). First, noise emissions can be reduced at their source, through measures relating to vehicles/ drivelines, tyres, road surfaces and traffic management. Second, noise can be abated by reducing the exposure of people, by means of anti-propagation or insulation measures (by increasing the distance between source and recipient, for example, hampering noise propagation by insulating buildings or constructing noise barriers).

In Europe, the United States, Japan and Australia, noise limits apply to road vehicles. Of these various limits, the European limits are the most stringent (Close, 2001). Within the European Union, noise type-approval limits have been in force since 1970. However, despite these limits, since then there has been no tangible reduction of noise emissions under real driving conditions for passenger cars, and only a 2-4 dB(A) reduction for heavy duty vehicles (Den Boer and Schroten, 2007). Figure 8.18 shows the difference between the noise level of heavy duty vehicles in 1974 and 1999 for various speeds.

Figure 8.18. **Noise levels of heavy duty vehicles**

1974 and 1999



Source: Blokland (2004).

There is plenty of scope for reducing ambient noise levels by at least 3-4 dB(A) in the short term, using currently available technology. The most cost-effective measures are those addressing the noise at source (Den Boer and Schroten, 2007). This includes noise from the engine, exhaust, mechanical systems and contact between tyres and road, or wheels and track. The associated costs are generally limited, for vehicles and tyres at least. There are signs that use of composite brake blocks on rail wagons also comes at a modest cost.

8.5. Conclusions

The most important environmental impacts from the transport sector are caused by emissions of air pollutants, CO_2 and noise. International road and rail freight transport are responsible for a minor, but increasing, share of these transport emissions.

The CO_2 emissions of international road freight transport are increasing all over the world, and there is not yet a sign that this trend is to be curbed soon. For this challenging problem, there is no single cure available. A mix of measures, like increased motor fuel taxes, stricter fuel efficiency standards for vehicles, promotion of alternative fuels and logistical improvements, is needed.

The contribution of road and rail freight transport to air pollution is decreasing in most parts of the world, mainly due to various vehicle emission standards that have been implemented around the world and are periodically tightened. Only in those parts of the world that have an extremely high growth in transport volumes, the overall emissions of air pollutants may not yet decrease.

Noise is an important environmental problem which, just like air pollution, has severe health impacts, causing high numbers of deaths each year. There are various measures that could be taken to reduce the contribution of freight traffic to ambient noise levels. The most cost-effective measures are those addressing the noise at source.

An effective policy for reducing the environmental impact of international road and rail transport should aim at improving the environmental performance of all modes of transport, as well as ensuring a level playing field for the various modes. Regulation, infrastructure measures and pricing measures that take fully into account the environmental costs can contribute to this.

Notes

1. This chapter is an edited version of the paper *The Environmental Impacts of Increased International Road and Rail Freight Transport – Past Trends and Future Perspectives*, written by Huib van Essen, CE Delft, the Netherlands, for the OECD/ITF Global Forum on Transport and Environment in a Globalising World, held in Guadalajara, Mexico, 10-12 November 2008 (*www.oecd.org/dataoecd/10/62/41380980.pdf*).
2. Much of Section 8.4 is based on the assessment made by Smokers and Kampman, 2006.
3. One should keep in mind that a tightening of standards for pollutant emissions can lead to higher CO_2 emissions.
4. It should in this context be kept in mind that an improvement in the efficiency of electric trains will *not* reduce CO_2 emissions in the EU overall – as long as the total "cap" of the EU-ETS remains unchanged. Reduced electricity use by the trains would lead to lower permit prices and higher emissions in other sectors covered by the EU-ETS.
5. Conversely, increased electricity use stemming from a more widespread use of electric trains – or electric road vehicles – will *not* increase EU-wide CO_2 emissions (even if the electricity at the margin is generated by coal-fired power plants), as long as the "cap" remains unchanged.

6. Data presented in Creutzen *et al.* (2008) indicate that the climate benefits of biofuels are significantly smaller, and could even be negative.
7. OECD (2009) addresses briefly the costs of current subsidies to biofuels production. Measuring these subsidies in terms of how much is paid per tonne of CO_2 emissions avoided gives estimated implicit prices in excess of USD 1 000. Given that the price of CO_2 in the mitigation scenario described in OECD (2009) does not rise above USD 50 (2005-dollars) until sometime after 2025, these subsidies seem a rather costly way of achieving emissions reductions.

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Globalisation, Transport and the Environment

Chapter 9

Policy Instruments to Limit Negative Environmental Impacts: An Economic Perspective

by

Kurt van Dender, Philippe Crist, James J. Corbett and James Winebrake[1]

This chapter provides an overview of current responses to climate change. It looks at how CO_2 emissions from transport may evolve, assuming current energy prices do not change strongly. It discusses road transport, shipping and aviation in relation to CO_2 emissions.

Transport activities have adverse environmental and health impacts, of which local and regional air pollution, climate change and noise impacts are the most important. This chapter is a non-comprehensive overview of existing and potential policies to deal with these negative impacts, with a focus on international transport. "International transport" is here defined as those transport activities that are mainly derived from the globalisation of economic activity, not as cross-border transport flows in a more narrow sense. Surface transport, aviation and maritime transport are discussed. The focus is on climate change, treating other adverse impacts (including aviation noise and local and regional pollution from shipping) more succinctly. Policies to reduce transport's greenhouse gas emissions are assessed against the background of a broader discussion of how to deal with the free-rider problem. CO_2 abatement in road transport is discussed in some detail, while just a few issues related to maritime transport and aviation are mentioned.

9.1. Introduction

Road, maritime and air transport contribute to global emissions of greenhouse gases, and all these modes of transport are generally expected to grow quickly. The transport sector is at the same time widely expected to contribute to the abatement of greenhouse gas emissions. Climate change is a global public bad; abatement of greenhouse gases is a global public good. The absence of a central authority that can decide on, impose and enforce climate change policies clearly shows in actual policy. The Kyoto Protocol is an attempt to advance policy in the face of national sovereignty constraints. The approach has met with criticism because of its limited coverage of global emissions, its focus on cap-and-trade systems rather than carbon taxes, its lack of true enforcement mechanisms, and its focus on CO_2 abatement rather than stimulating the development and adoption of non-carbon-intensive technologies. Alternative approaches seek broader country participation, and sometimes propose enforcement through the World Trade Organization. Stimulating the use of alternative technologies requires complementary measures to overcome failures in markets for technological development and diffusion.

Road transport is a major source of greenhouse gas emission, and road transport volumes are likely to continue growing. The desirability and the design of abatement policies in road transport pose some difficulties. In the EU and the US, policies are in place that limit energy consumption in transport, even if these policies were introduced for reasons other than climate change. How much further abatement should be demanded from road transport? And which policy instruments ought to be used? These questions are discussed, focussing in particular on possible justifications for fuel economy standards. In particular, the reasons for the limited power of the market for fuel economy to diffuse more energy-efficient technologies are investigated.

Maritime and air transport represent smaller shares of total emissions, but growth has been, and may continue to be, rapid. Both sectors have been less targeted by policies to reduce energy consumption and greenhouse gas emissions than road transport. This suggests that relatively cheap abatement options may be available in those modes, compared to road transport, but fleet turnover in shipping and aviation is slow, and this limits the diffusion of available technological improvements. Maritime transport and aviation could be integrated into carbon trading schemes. Some of the research on the effects of including aviation in trading schemes is discussed. In general, it is found that incentive-based policies are flexible in allowing low-cost abatement options to be taken up. This is important, as technology continues to evolve. Moreover, incentive-based policies stimulate efforts to look for such low-cost options. Standards, however, can be useful complements to incentive-based policies in a number of circumstances.

9.2. The problem of climate change and current responses

Climate change is potentially very costly. The consequences of climate change are uncertain (*e.g.* Stern, 2006) and geographically diverse (*e.g.* Aldy, 2006). It is very likely that some regions will incur damages, while other regions may experience some benefits. Catastrophic damages are possible as well; and according to some (*e.g.* Weitzman, 2009), their importance has been understated in much of the economic analysis of climate change up to now.

Climate change is driven by the *stock* of greenhouse gases, and to a lesser extent by the speed at which the stock grows. Greenhouse gas emissions largely determine the change of the stock, as dissipation is slow. Since the location of most greenhouse gas emissions is irrelevant, climate change is a global public bad and emission abatement a global public good. As there is no global authority to implement and enforce policy measures, any attempt to design an efficient abatement policy must confront the free-rider problem. Free-riding means that individual nations, or groups of nations, benefit from other nations' abatement efforts, and this reduces all nations' incentives to abate.

The challenge of climate change has triggered a wide range of responses. Some countries, *e.g.* in Scandinavia and France, have introduced so-called carbon taxes, and several other countries consider doing so.[2] In many countries, states, cities, companies, and universities have taken a variety of initiatives to reduce emissions. The main multilateral response to climate change is the Kyoto Protocol. This Protocol came into effect in 2005, and requires adhering countries to reduce emissions to a level defined in terms of the reference year (5.2% reduction compared to 1990 for industrialised countries as a whole; 8% for the European Union). In the context of the Protocol, the European Union has introduced the EU Emission Trading Scheme (EU-ETS) as a mechanism to reduce the costs of attaining targets by allowing trade in emission permits. The ETS covers about half of total EU emissions, or roughly 8% of global emissions in 2007. The United States opted out of the Kyoto Protocol, and developing countries are not part of it. The non-participation of the US and the fast growth in some of the non-covered countries have substantially reduced the coverage of the Kyoto Protocol: in its original form, about 65% of global emissions in 1990 were covered, whereas actual coverage is now about 32%. If the EU attains its Kyoto target, global emissions in 2010 are expected to be 26% higher than in 1990, compared to a business-as-usual growth of 27.5%.

The Kyoto Framework provides only a limited contribution to the reduction of greenhouse gas emissions, compared to the business-as-usual scenario. The overall approach behind the Framework has also been criticised on various grounds. These criticisms imply that the Kyoto approach is not the ideal blueprint for future, more comprehensive climate change management institutions. Three points of critique are briefly mentioned here.

First, the Kyoto approach has been described as "narrow and deep". The share of global emissions covered is fairly small, and the covered sources will have to make quite deep and costly cuts to meet targets, while no effort is required from non-covered sources. Several observers, including *e.g.* Ellerman (2008), favour "broad and shallow" approaches. Broad coverage means that, at the very least, the US needs to be part of an agreement, because of its large share of global emissions and because of the weak incentives for developing nations to join if the US does not participate (*e.g.* Aldy *et al.*, 2008).[3] In order to increase the chances of co-operation, an enforcement and sanctioning mechanism is required. Stiglitz (2006) argued that a country's failure to charge somehow for greenhouse gases in fact constitutes a subsidy to carbon-intensive production, and as such could be sanctioned under the provisions of the World Trade Organization (WTO), although it is not obvious that the WTO is ready to take on this task. The developing countries need to be included in an agreement as well, although the efforts required from them may initially be modest. The idea is that a broad but shallow system can gradually evolve into a deeper system.

Second, the cap-and-trade approach as adopted in the EU and which will possibly be adopted in the US, could be inferior to a system of carbon taxation. Nordhaus (2007) argued a *global* harmonised carbon tax outperforms a cap-and-trade system, as a tax would avoid the difficult problem of deciding on baseline levels of emissions and would create no rents, and consequently no costly rent-seeking (see also Stiglitz, 2006). A tax would also be better suited to deal with uncertainty over abatement costs, given that marginal benefits of abatement are highly elastic (as abatement is defined over emissions while impacts depend on the stock of greenhouse gases). Furthermore, taxes generate valuable public revenue, which grandfathered permits do not. Aldy *et al.* (2008) pointed out that cap-and-trade systems can be modified to improve their performance relative to taxes (by auctioning permits, by introducing safety-valves and allowing inter-temporal reallocation of permits, etc.), so that the practical difference between "good" cap-and-trade systems and taxation approaches is ultimately small.[4]

The level of the tax or the price of a permit can be determined by referring to marginal damage estimates or by referring to a target for atmospheric concentrations of CO_2. According to Aldy *et al.*, 2008, with marginal damages of USD 10 per tonne of CO_2 (USD 36.7 per tonne of carbon), the price of gasoline in the US would increase by USD 0.09 per gallon (USD 0.023 per litre). The marginal damage cost estimate in the Stern report is about USD 85 per tonne of CO_2, so the price changes need to be factored up by 8.5 if these higher estimates are taken into account. An atmospheric concentration target of 450 parts per million is thought to correspond to a global temperature increase of about 2 °C, and requires carbon prices similar to those of the Stern report. A price of USD 10 per tonne of CO_2 could lead to concentrations of 550-650 parts per million (3-3.6 °C temperature increase).[5]

If the price of carbon is to be determined in a top-down approach, a global administering and sanctioning mechanism is called for. Aldy *et al.* (2008) suggested the WTO as the most straightforward choice for housing such an organisation, although it is not obvious that the WTO is ready to take up such a role. One of the main tasks of the administration would be to monitor "fiscal cushioning", *i.e.* countries' efforts to reduce the effective carbon tax by tweaking other attributes of national taxation schemes. The problem of calculating "effective carbon taxes" would be highly relevant for the transport sector (see below). It is far from obvious, however, that progress with multilateral co-ordination of greenhouse gas abatement efforts will be made through a multilateral top-down approach. A different scenario is that the US will introduce its own cap-and-trade system (see Meckling, 2008, for an assessment of the changing position of corporate lobbies), while the EU continues with the ETS and develops it to more stringent system where caps are stricter and permits are auctioned. Separate trading schemes may later be connected to exploit further gains from trade.

International aviation and maritime transport are not covered by the Kyoto Protocol. Instead, the Protocol recommends that ICAO and IMO develop policies for these sectors. However, while the Kyoto approach is one of common but differentiated responsibilities (implying relatively strong efforts from richer countries), ICAO and IMO have no such tradition of differentiation. This slows down progress on policy development within these organisations, leading other bodies (notably the EU) to implement (in the case of aviation) or threaten to implement (in the case of shipping) measures for international aviation and shipping. A gradual approach, with relatively limited efforts from non-Annex 1 countries in early stages, may be the most productive way forward here as well. Kågeson (2009) discussed what such a gradual approach could look like.

Ellerman (2008) emphasised the importance of "club benefits" for a cap-and-trade system to be feasible: the European Commission managed to get new member states to sign on to the ETS because the cost of doing so was diluted in the larger package of costs and mainly benefits of joining the European Union. Conceivably, the US – with a stronger federal structure than the EU – could make continued access to club benefits for US states conditional on joining a US carbon trading scheme. On a global scale, the club benefits relate mainly to those offered by the WTO (Stiglitz, 2006).

With a bottom-up approach, there are likely to be differences between the emerging trading schemes. For example, the EU-ETS does not include transport and is not likely to include road transport any time soon. A US system, however, may include transport from the start (Ellerman *et al.*, 2006). At any rate, the relation between prevailing transport policies and carbon pricing schemes needs careful consideration; this is discussed further in Section 9.4.

A third criticism of the Kyoto-type approach is that its focus on abatement of greenhouse gases, in particular CO_2, is too narrow. For example, Barrett (2007) argued for a broader approach that includes adaptation, incentives for technological development, and the development and sharing of knowledge. Aldy *et al.* (2008) and Newell (2008) concurred that the social returns on technological innovation and diffusion are larger than the private returns, so there is a case for policy intervention. One policy approach would be to increase carbon prices over marginal damages, but this instrument may be poorly targeted. The economic understanding of which policies work best is limited, especially where transformative technological change is concerned. It is sometimes argued that financial incentives are insufficiently powerful to ensure the adoption of alternative technologies, so that standards may become desirable. This may be the case, for example, when end-users valuation of improved energy efficiency is low (too low?), as is often argued to be the case in private vehicle markets. This issue is discussed further in the next section.

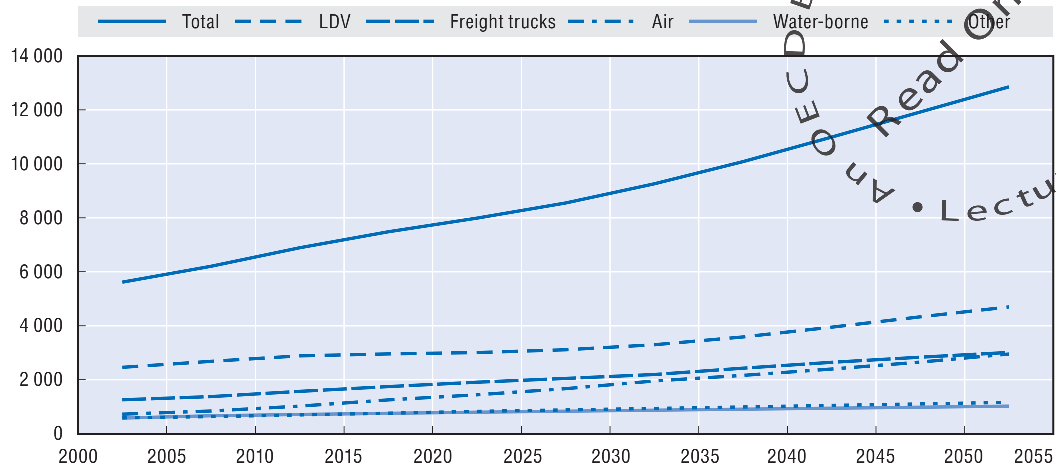
Summing up, it seems likely that progress with broad climate change management systems will take place through a bottom-up process, with the gradual emergence of regional systems adapted to regional circumstances. Different conditions may lead to different treatment of transport sectors in the regional systems. A potential problem with this process is the limited incentives for nations with low willingness-to-pay for abatement, to join. Technological change is key for handling climate change. This holds for transport at least as much as for other sectors, and policy approaches that focus on reducing transport's carbon intensity deserve close attention. The challenge for the sector is immense, as will be clear from the next section.

9.3. Transport and CO_2 emissions: Where demand would like to go

The ITF produced a first transport outlook in 2008. It used the IEA/ETP's MoMo model to construct projections of CO_2 emissions, focussing on road transport under alternative assumptions on the evolution of demand. The ITF business-as-usual (BAU) scenario is the same as the IEA/ETP 2008 reference scenario. Figure 9.1 displays a key model output: tank-to-wheel CO_2 emissions from vehicles, in million tons of CO_2 equivalent, from 2000 through 2050.[6] The emission paths for the transport modes contained in the MoMo model are shown. Section 9.4 emphasises emissions from *light duty* vehicle emissions. This is justified given the large share of these emissions in the total, but it is clear that emissions from air transport are expected to grow more rapidly than those from light duty vehicles;

Figure 9.1. **World tank-to-wheel CO_2 emissions**

Business-as-usual scenario, 2000-50, million tons of CO_2-equivalent



Source: ITF calculations using the IEA MoMo Model, Version 2008.

Table 9.1. **Modal shares in world vehicle CO_2 emissions**

BAU, 2000-50, %

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Freight + passenger rail	2.1	2.2	2.3	2.5	2.7	2.8	2.9	2.9	2.9	2.9	3.0
Buses	6.8	6.3	5.7	5.4	5.2	4.9	4.6	4.3	4.1	3.8	3.6
Air	12.9	13.5	14.8	16.8	18.1	19.5	21.1	21.5	21.8	22.3	23.0
Freight trucks	22.4	22.2	22.8	23.4	23.9	24.0	23.7	24.1	24.1	23.8	23.4
Light duty vehicles	43.8	43.3	41.9	39.5	37.6	36.4	35.6	35.6	35.9	36.4	36.5
2-3 wheelers	1.6	1.8	2.0	2.2	2.5	2.6	2.6	2.6	2.6	2.5	2.4
Water-borne	10.4	10.8	10.3	10.2	10.0	9.8	9.5	9.0	8.6	8.3	8.0
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: ITF calculations, using the IEA MoMo Model, Version 2008.

aviation emissions policy is briefly discussed in Section 9.6. Emissions from other modes, including shipping, are expected to grow as well. In addition, it is likely that the BAU underestimates emissions from shipping (see Section 9.5). Table 9.1 provides details on the model composition of global vehicle emissions.

Emissions from light duty vehicles grow strongly over the model horizon: emissions in 2050 are nearly 91% higher than in 2000. Growth is moderate between 2010 and 2030, but accelerates after 2030. The drivers of light duty vehicle emissions are the following: the size of the car stock, the intensity with which vehicles are used and the carbon intensity of the energy sources used. The growth of the total vehicule stock is the key driver of increased emission levels, with global ownership levels expected to rise threefold, from 669.3 million vehicles in 2000 to 2 029.9 million vehicles in 2050.[7] This expansion in turn is the consequence of increased ownership rates that occur mainly in emerging economies. The technological composition of the stock changes, as the share of conventional gasoline vehicles is assumed to decline from 87% to 68%, while that of diesel vehicles increases from 12% to 26% and that of hybrid gasoline vehicles rises from 0.1% to 4%. Hence, there is a shift to less carbon-intensive technologies, but not a major switch to truly low-carbon technologies.

The emission profiles in Figure 9.1 directly depend on assumptions concerning the size of the vehicle stock, vehicle use and vehicle technology. It is useful to note that the BAU scenario presented here is an outline of "where demand would like to go". By this it is meant that the supply of energy is assumed to be fairly elastic, so that strong growth in demand does not lead to strong increases in the price of transport energy. This is not a straightforward assumption, given for example the growing concern about supply side constraints and consequent high prices in oil markets, which recently were shown to affect demand. In addition, the development of GDP drives demand, and the current crisis may lead one to think the BAU assumptions are optimistic (see endnote 6).

9.4. Road transport[8]

Abatement costs

In deciding how to achieve an abatement target for greenhouse gas emissions, it makes sense to start with the cheapest abatement opportunities and select increasingly expensive options until the target is reached. Applied general equilibrium models of various degree of detail that have been used to obtain economy-wide views of greenhouse gas abatement opportunities, their costs and their effects on emissions (*e.g.* Proost, 2008 and Abrell, 2007) have often found that the "optimal" effort in the transport sector is small compared to its share in total emissions.

The rationale for the limited effort in transport is that abating in transport is expensive, with high costs for technology as well as for behavioural change. There are several reasons why abatement technology is relatively expensive in transport. First, there are few cheap low-carbon substitutes for conventional engine technology. Second, transport fuels have been relatively expensive (compared to other sectors) in many parts of the world, mainly because of relatively high taxes. These high prices have induced the market to take up cheap abatement options already, making further reductions expensive. Third, transport fuels are less carbon-intensive than *some* other fuels, so that carbon taxes would have smaller effects on energy prices in transport than in other sectors. For example, introducing a tax of USD 50 per tonne of carbon in the US would increase the price of coal by about 140%, while the price of gasoline would rise by 6% (Parry, 2007), implying more limited incentives for abatement in transport.

While the arguments explaining relatively high abatement costs in transport are sound, they are challenged on various grounds. One objection is that the assumptions on costs of alternative technology embedded in the general equilibrium models can be too high, as no account is taken of declining costs when production levels rise. Experience suggests that costs indeed do generally decline. Whether this will also hold for technologies such as batteries, etc., is plausible but uncertain. Another objection is that the arguments explaining higher costs in transport are partly empirical, but also are partly based on economic inference: further abatement in transport "must" be relatively costly because energy was relatively expensive in the past and alternatives have not yet been adopted. This inference relies on the assumption that transport markets work very well, in the sense that all surplus-improving technological potential is realised. Abandoning this assumption modifies results, as is discussed next for the market for vehicle fuel economy.

A case for fuel economy standards?

It is sometimes argued that improving vehicle fuel economy for passenger vehicles is a no-regret abatement option, because the discounted savings on fuel expenditures outweigh the costs when using standard private discount rates. However, there is evidence that consumers use very high discount rates when deciding on fuel economy, resulting in limited investment in it. For example, Turrentine and Kurani (2007) found that consumers implicitly require payback periods of three years or so for investments in better fuel economy, indicating that implicit discount rates are high. Work done for the impact assessment of the EC's proposed fuel economy regulation (EU, 2007) found that the discount rate that equalises increased vehicle costs and reduced fuel expenditures is around 20%, much higher than standard values for private discount rates.[9] While not definitive evidence, this might be interpreted as an indication that there are market imperfections beyond consumer short-sightedness that justify a policy intervention.[10]

Why would high discount rates be used when deciding on fuel economy? One argument is that consumers pay little attention to fuel economy, because they care more about other attributes, and the share of fuel costs (and therefore *a fortiori* the size of savings from better fuel economy) in total purchase and usage costs is small. Given that processing information on how fuel economy translates into probable savings on fuel expenditures takes costly effort, consumers may decide a detailed calculation is not worthwhile. From a policy perspective, this problem may be overcome by providing better information on potential savings from purchasing better fuel economy. From an analytical perspective, the argument says that consumers make inaccurate decisions on fuel economy, but not that they systematically invest too little.

Recently, Greene *et al.* (2008) suggested a framework that implies a systematic undervaluation of fuel economy compared to the textbook model of an expected utility maximising consumer. They showed that when consumers are loss-averse[11] and uncertain about factors that determine optimal fuel economy, they will invest less in fuel economy than consumers who maximise expected utility.[12] The uncertain factors that affect fuel economy choices are the gap between real and labelled fuel economy, the lifetime of the car, the amount of driving and fuel prices, among others. Among those factors, uncertainty on realised fuel economy is the main driver of low investment, according to a calibrated numerical exercise. The numerical example also suggested the impact of loss-aversion is large, as the expected saving from a fuel-economy improvement of USD 405 for an expected utility maximiser is equivalent to a loss of USD 32 in the case of loss aversion.

According to Greene *et al.* (2008), low willingness-to-pay for fuel economy by consumers translates into strategies on manufacturers' part that steer vehicle design towards more marketable attributes, like power and comfort. With such a supply response, available fuel economy turns out lower than in a world where consumers are averse to loss. A manufacturer will be disinclined to use technology to provide better fuel economy if there is large uncertainty about whether consumers will want to buy it and about how competitors will respond to the same problem. A fuel economy standard can correct this problem, as it clarifies what performance level needs to be reached by a manufacturer and by its competitors.

The loss-aversion argument can seem compelling. It provides a theoretical argument for consumers' low willingness-to-pay for fuel economy improvements, argues convincingly that this demand curve is what producers take into account when deciding what fuel economy levels to provide, and that a standard is a good way of making sure manufacturers deviate from this demand curve and provide better fuel economy. The case for a standard would be particularly strong when fuel taxes are low and incomes high, as both factors exacerbate the gap between consumers' aspirations (which drive supply decisions) and policy targets for fuel economy. This gap is wide in the US, but it also prevails in Europe. For example, it is reasonable to think that the failure of the voluntary agreement in the EU to reduce CO_2 emissions from passenger cars was partly caused by the lack of policy initiative to support the agreement during a period of strong economic growth and declining real fuel prices, at least in the early years.

However, it is not clear that loss-aversion provides a basis for policy intervention, unless one explicitly takes the hypothetical market outcome that would be obtained in the absence of loss-aversion as the norm, instead of letting consumers optimise according to their loss-averse preferences. Doing so might open up discussions on a wide array of interventions, as loss-aversion is not unique to this particular market.

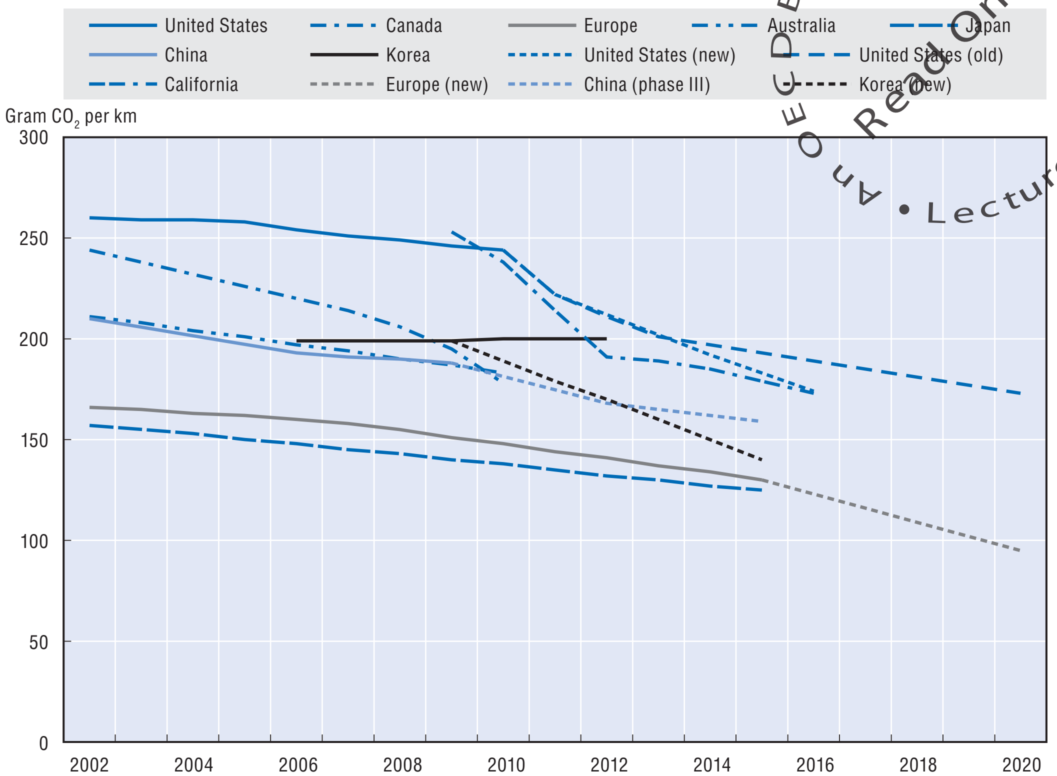
While it is not clear that loss-aversion justifies a correction of a failure in the market for fuel economy, a different approach is to focus on cost effectiveness and ask whether loss-aversion and uncertainty could affect the choice between quantity-based regulation and prices to attain an abatement target, however defined. Loss-aversion and uncertainty on the part of consumers lead to uncertainty for producers on how much to invest in fuel economy, and this results in fuel economy levels that reflect high implicit discount rates. Higher fuel prices increase what consumers want to pay for fuel economy but do not affect their treatment of uncertainty, so do not alleviate producer uncertainty either. Consequently, governments cannot be sure how effective a tax-based approach will be in triggering investments. If governments cares about such investments, for example because they believe this makes policy less prone to reversibility by future policy makers (Glazer and Lave, 1996; Barrett, 2005) or because they wish to stimulate the diffusion of new technologies (Aldy *et al.*, 2008), then they may favour a quantity-based approach over a price-based one, precisely because the quantity-based approach reduces flexibility. In this approach, where the government has a preference for *how* fuel consumption in transport is reduced, the choice for a standard for fuel economy may be justified.[13]

Given these arguments for fuel economy standards, it appears that existing and proposed standards require bigger improvements in fuel economy than can be justified by market imperfections. Indeed, the stringency of standards seems consistent with a policy approach that starts from the assumption that technology to improve fuel economy is very cheap, or that implicitly attaches a very high value to reducing greenhouse gas emissions and improving energy security, but which lacks a clear view on what costs are imposed on consumers. Possible motivations for ambitious abatement targets were mentioned above, and Barrett (2005) noted that policies to stimulate technology take-up may be required. Nevertheless, with the current evidence, the basic message from the analyses of the general equilibrium type remains valid: abatement costs in transport appear to be relatively high.

Despite their weak connection to market failures, prevailing and proposed fuel economy regulations would not attain a stabilisation of global CO_2 emission from road transport. According to JTRC (2008b), stabilisation through 2050 at 2010 levels requires attainment of a fleet-average fuel economy of 3.5 litres per 100 km (approximately 67 miles per gallon) in 2050. Figure 9.2 shows different fuel economy standards converted to the New European Driving Cycle (NEDC) test cycle, and expressed as gram CO_2 per km.[14]

Figure 9.2. **Comparison of fuel economy and GHG standards**

Harmonised to the New European Driving Cycle, gram CO_2 per km



Sources: Data from International Council on Clean Transportation, Feng An – Innovation Center for Energy and Transportation and International Transport Forum.

Climate change and other costs of transport

This section briefly discusses the relative importance of the main external costs of transport by comparing estimates of their current order of magnitude, looking at averages over a large class of users. When considering energy and transport policies, this comparison provides some indication on how policy priorities could be defined. Table 9.2, taken from Small and Van Dender (2007), presents estimates of the main marginal external costs of road passenger transport, and classifies them according to whether they depend mainly on fuel consumption (climate change and oil dependency) or on vehicle-miles travelled. For comparison, the fuel-related external costs are converted to a marginal cost per vehicle-mile, using the fleet average fuel efficiency for passenger vehicles (*i.e.* 22.9 miles per gallon for the US in 2005).

The three studies listed in Table 9.2 (excluding the last column) are unanimous in finding that congestion involves larger external costs than fuel-related externalities, and except for the "low" Harrington-McConnell values, the same is true of air pollution and accidents. In nearly all cases, congestion alone is found to outweigh the fuel-related externalities by a large margin. If the higher fuel-related figures in the last column of the table are used, the picture changes somewhat, although even then fuel-related externalities do not dominate other externalities. However, the validity of the averages in the table as guides for policy can be questioned. In the case of climate change, the main problem is the

Table 9.2. **Marginal external costs from automobiles**

US cents per mile, 2005 prices

	Harrington McConnell (US and Europe)		Sansom *et al.* (UK)		Parry *et al.* (US)	High fuel-related[1] (US)
	Low	High	Low	High		
Fuel-related						
Climate change	0.3	1.2	0.5	2.0	0.3	3.7
Oil dependency	1.6	2.7	n.a.	n.a.	0.6	2.4
Driving related						
Congestion	4.2	15.8	31.0	35.7	5.0	5.0
Air pollution	1.1	14.8	1.1	5.4	2.0	2.0
Noise, water	0.2	9.5	0.1	2.5	n.a.	n.a.
Accidents	1.1	10.5	2.6	4.5	3.0	3.0
Total	**6.6**	**50.6**	**35.3**	**50.1**	**10.9**	**16.1**
Per cent fuel-related	22	7	1	4	8	38

n.a.: Means not estimated, in some cases due to an explicit argument that the quantity is small. Fuel-related costs are converted from per gallon to per mile using prevailing average fuel efficiency.

1. High fuel-related: same as Parry *et al.* except for climate change (USD 0.76 per gallon, from Stern (2005) and oil dependency (USD 0.55 per gallon), from the high end of range in Leiby (2007), Table 1. All numbers were converted to 2005 US price levels.

Sources: Harrington and McConnell (2003); Sansom *et al.* (2001); Parry, Walls and Harrington (2007).

enormous uncertainty, as mentioned before and emphasised by Weitzman (2007). With respect to energy security, the argumentation underlying the numbers is not entirely convincing; see Small and Van Dender (2007) for a discussion.

The best policy responses to fuel-related and mileage-related externalities are quite different. Raising the price of fuel induces a mileage reduction but also, and to an increasing extent, an increase in fuel efficiency (Small and Van Dender, 2007). This means that a fuel tax is not a very effective instrument to address mileage-related externalities, and a distance-based tax would perform much better (see Parry and Small, 2005, for a numerical illustration). However, using a distance-related tax to address a fuel-related externality, such as global warming, would fail to elicit one of the most important responses needed, which is an increase in fuel efficiency of vehicles. In addition, although better than a fuel tax, a mileage tax is not ideal for handling congestion, which varies greatly over time and place. There is strong evidence that the response to imposing targeted congestion charges (*i.e.* ones that vary by time and place) would involve a lot of shifting of trips across time periods, modes and routes, and much less overall reduction of trips; thus the most efficient policies would aim at shifting trips in this manner rather than simply reducing all trips.

The climate change cost calculated by Parry *et al.* (2007), shown in the next to last column of Table 9.2, is based on a damage estimate of USD 25 per tonne carbon, at 2005 prices, a figure found in several reviews (*e.g.* Tol, 2005) but significantly lower than those in Stern (2006). The marginal cost of damage from carbon emissions is, however, highly uncertain.

Weitzman (2007) provided an insightful discussion of a rationale for using higher marginal damage estimates than those implicit in Table 9.2. In his view, the most important issue is uncertainty about the prospects and consequences of unlikely, but extremely damaging, results of climate change. The standard cost-benefit framework generally does not deal explicitly with such events, but may instead implicitly use the discount rate to do so. Weitzman (2009) attempted to allow an explicit treatment of extreme events (extreme in their probability and in their consequences). His proposed framework to deal with structural uncertainty found much stronger support for policies to mitigate quickly than in the traditional model.

For the transport sector, this means that policy design is more conveniently thought of in terms of cost effectiveness than in terms of market imperfections within the transport sector. With ambitious abatement targets, decarbonisation through alternative technologies should be part of a long-run strategy. Research and development will only be realised if there is a strong policy commitment to climate change targets. Public funding for research is justified to the extent that the expected social returns exceed the expected private returns, and to the extent that policy commitment remains uncertain (Newell, 2008).

Damage estimates of the orders of magnitude shown in Table 9.2 provide guidance to a transport policy that deals with driving-related externalities. For an energy policy to deal with climate change, the large uncertainty on impacts justifies measures to reduce carbon emissions, arguably also in transport. A fuel economy standard can be seen as one element of such a strategy, as it helps control the expected growth of emissions. More ambitious abatement targets require large-scale deployment of alternative technology. Measures to stimulate the development and use of alternative technology may be justified, but it could be difficult to see a strong case for major policy-directed changes in transport activity on climate change grounds. An "ideal" approach to controlling energy use is not likely to reduce motor vehicle travel very much, but will instead accomplish most of its results through technological changes specifically targeted to energy savings, mostly through the use of more fuel-efficient vehicles and alternative fuels. By choosing technological solutions when permitted, consumers will avoid major behavioural changes, such as changes in travel mode, trip patterns, and home and work location, which evidently are more costly for them. Measures to address congestion may induce changes in patterns of travel demand that imply reductions of greenhouse gas emissions, but probably not enough to meet ambitious abatement targets.

Road transport and cap-and-trade systems

Road transport in many countries is subject to policies that reduce fuel consumption and greenhouse gas emissions below no-intervention levels. The EU, for example, has high fuel taxes and has recently introduced a fuel-economy standard. The US has lower fuel taxes but the CAFE standard has been binding for decades.[15] How should such pre-existing policies be accounted for in the design of a broader cap-and-trade system?

As a starting point, one can calculate the price of carbon that is implied by current policies in road transport. For example, Ellerman *et al.* (2006) found that the CAFE standard in the US corresponds to a price of USD 90 to USD 110 per tonne of carbon. Fuel taxes in the EU imply considerably higher carbon prices. These carbon prices are higher than what is expected in cap-and-trade regimes, and consequently there are efficiency gains from including road transport in a cap-and-trade scheme (which aims to minimise abatement costs by equalising marginal costs across sectors). The EU has chosen not to include road transport in the EU-ETS, however. Ellerman *et al.* (2006) proposed inclusion of road transport in any future carbon trading scheme, because of the potential efficiency gains of doing so.

A potential problem with this calculation is that prevailing policies do not address climate change externalities alone. The CAFE programme was introduced to deal with energy security, and climate change justifications emerged only later. The level of fuel taxes in the EU is determined by many factors, first and foremost as a relatively efficient way of raising revenues for general public expenditure. Fuel taxes in the US (and *e.g.* Japan) are lower, and the revenues are largely earmarked for road infrastructure expenditures. Nevertheless, a comparison of energy security costs and climate change costs might suggest that current US fuel taxes are sufficiently high to cover these externalities, if moderate values are used for carbon damage. In order to decide how a tax or a standard ought to be changed if it is to address climate change (where it did not before), it needs to be made clear which external costs a fuel tax (or a standard) is supposed to address, and to what extent it is a revenue-raising instrument. Parry and Small (2005) assumed that fuel taxes are a second-best instrument to address local and global pollution as well as average marginal external costs of congestion, and found that current US taxes should be roughly doubled while UK taxes should be halved, if they were to be set at the second-best level. The congestion costs were the main component of the tax. If congestion were to be addressed by a separate instrument (where and when necessary), second-best fuel taxes both in the US and the UK would be lower than they currently are. Sansom *et al.* (2001) found that UK charges per vehicle-kilometre are below marginal social costs. While this result differs from the Parry and Small (2005) study, both studies found that the congestion component dominates the marginal cost. Excluding congestion would bring UK charges roughly in line with marginal costs (Sansom *et al.*, 2001, Table B). Climate change is much less important, given the assumptions on marginal damages used in this study.

9.5. Maritime transport

CO_2 emissions

According to Buhaug *et al.*'s (2008) central estimates in a study prepared for the IMO, overall tonne-miles will grow by 30% to 46% by 2020, and by 150% to 300% by 2050. Container activity is projected to grow by much more: 65% to 95% by 2020, and 425% to 800% by 2050. This growth, if realised, will have important implications for fuel use and CO_2 emissions, since container vessels have more powerful engines and operate at higher speeds than most other vessels.

The IMO projections assume increases in fuel efficiency stemming from changes in average ship size (where this makes commercial sense, larger ships being more fuel-efficient at constant load factors than smaller vessels), changes in speed (estimated vessel fuel consumption has been modelled based on a third power relationship between speed and engine power output) and technical improvements to new vessels. The IMO baseline projections assume no changes in the regulation of CO_2 emissions or fuel consumption and so changes in efficiency (due to vessel design or operation) are assumed to track those improvements that are cost effective under prevailing oil prices and commercial imperatives.

The IMO study also assesses the potential emission reductions from technological improvements. The bottom line is that, despite significant energy efficiency improvements (albeit slowly diffused through the fleet), CO_2 emissions from international shipping would grow by 10% to 26% by 2020, and 126% to 218% by 2050 under baseline assumptions. Realising maximum potential efficiency improvements, coupled with significant speed reductions and more intensive use of low-carbon fuels, can lead to stabilised or slightly decreasing CO_2 emissions from international shipping (low estimates), but these developments are unlikely to occur without significant policy changes and interventions.

The economic analysis of abatement strategies in shipping is hampered by the paucity of information on abatement costs, but some observations can be made:

- First, if abatement costs for CO_2 follow patterns similar to those for NO_x and SO_x, then abatement costs in shipping are lower than in other transport modes.
- Second, changes in operational strategies – mainly reducing speed – provide the easiest short-run options for abatement. Reducing speed is costly, as it slows down the supply chain, but such costs may be limited, as reliability may be just as important as speed. Furthermore, the opportunity costs of holding inventories, which are inversely related to speed, decline as overall economic conditions are less favourable (slow steaming is one response to overcapacity). In the longer run, dispersion of technological innovation through fleet turnover can reduce emissions. However, turnover in the sector is slow and there is a large potential for leakage (moving less efficient vessels to regions where regulation is weaker or absent) as long as regulation is geographically restricted. Similar problems characterise abatement options in aviation.
- Third, while one might expect fuel economy choices in shipping to be optimal from at least a profit-maximising point of view, the fact that the incidence of the fuel cost depends strongly on the particulars of shipping contracts[16] creates principal-agent problems that distort fuel economy choices. This problem is less prevalent in container shipping markets, however.

The outlook for multilateral action on handling shipping emissions is not simple (Kågeson, 2009). The IMO faces difficulties in moving forward, as countries not bound by Annex 1 of the Kyoto Protocol favour action from those countries that are, while the latter favour broader multilateral initiatives. If progress from the IMO side is unsatisfactory, the European Union may choose to move unilaterally, possibly with a regional trading scheme or inclusion of shipping into the EU-ETS, in addition to emission-dependent harbour dues and binding CO_2-index limits. However, such trading schemes are prone to evasion by rerouting cargo through trans-shipment hubs.

Other emissions

Apart from generating greenhouse gases, emissions from maritime transport contribute to local air pollution in port communities as well as to regional air pollution. Marine bunker fuel is a residual fuel, rich in contaminants, and no post-combustion treatment is required. One consequence is that the sulphur emissions per tonne-mile are higher for ships than for other modes (Wang and Corbett, 2007). Requiring the use of higher quality fuels will reduce emissions per unit of fuel burned, and the International Maritime Organization has placed some – not yet very stringent – limitations the sulphur content of fuels. It sets global caps for SO_x that become more stringent over time, and defines sulphur emission control areas (SECAs) where stricter standards apply (including the Baltic Sea and the North Sea, and likely other areas in high-income regions in the future[17]). Since 2005, the global limit is 4.5% sulphur content, whereas in SECAs, the maximum is 1.5%. The world average sulphur content of fuel was 2.7% in 2004. Wang and Corbett (2007) suggested that the benefits of turning the US West Coast into a SECA exceeded the costs by a factor of about 2, and that reducing sulphur content further to 0.5% increases the factor to about 3 (the exact result depending on the size of the SECA).

NO_x is regulated in IMO through the NO_x Technical Code with certification requirements for existing engines and standard test cycles to be applied to engines installed after 2011.

Particulate matter, particularly black carbon, is recognised to be an important pollutant and GHG compound, but it is not regulated separately at this point – though fuel-switching and improved engine performance of low-NO_x engines should reduce particulate emissions.

The contribution of shipping to local air pollution is large in some areas. International trade routes are generally not far from land and pollutants travel over large distances. The costs of reducing emissions from shipping may be relatively low, given a longer history of regulation for other sources. For example, for the proposed US-Canada SECA, compliance costs are expected to be no larger than those of further abatement from land sources. Abatement costs in shipping are estimated at USD 2 600 per tonne of NO_x, USD 1 200 per tonne of SO_x, and USD 11 000 per tonne of PM. For comparison, the abatement costs for highway diesel trucks are USD 2 700 per tonne of NO_x and USD 17 000 per tonne of PM. The cost estimates include the increased refinery costs, as well as the costs of engine control, catalysts, reductants for NO_x and additional fuel costs. Compliance costs are not expected to affect demand in an appreciable manner, as there are few substitutes for maritime transport and the costs will increase the price of a new vessel by no more than 2% and operating costs no more than 3%. The price of shipping a container could rise by about 3% (USD 18).[18]

A sustainable intermodal freight system

It seems likely that maritime transport will increasingly improve its environmental performance as it responds to two motivating forces. First, regulatory and advocacy attention will impose pressure external to the maritime transport market, through both international and territorial policy action. Second, the continued development of environmental performance metrics in global, multi-firm supply-chain networks will create market-based incentives for less-polluting maritime transport.

Angel *et al.* (2007) identified three dimensions of globalisation and the structure of the global economy: foreign direct investment; international trade; and global networks of firms as vehicles for production, trade and investment. The first is a hallmark of maritime transport, as discussed in Chapter 3 with regard to fleet registry, ownership and crewing trends. The second is the defining business of global shipping. And global shipping firms are at least described within the third dimension; in fact, one can observe that containerisation especially is promoting the vertical integration of firms in international logistics.

There is also a shift from national-level regulation and negotiated trans-boundary territorial agreements (which are *de facto* global standards applicable to a region), to global frameworks of environmental standards that address region-specific requirements and network requirements for international supply chain processes. The clearest recent example is the proposed revisions to the International Maritime Organization MARPOL Annex VI.

Moreover, global environmental concerns (*e.g.* biodiversity and climate change) are driving growing interest and importance of industrial practices, whether directly controlled or outsourced among international firms. The assumption that industry sectors will meet expectations driven by market attention has diffused new standards and practices along the international supply chain (Corbett and Kirsch, 2001; Corbett, 2005) as part of global integration of environmental dimensions of product and service quality (Pil and Rothenberg, 2003).

Maritime transport is being required, like other global industries, to better protect the resources and services the environment provides for future generations, and to mitigate the impacts on ecosystems, global climate and ocean processes, as well as human health. These demands oblige the maritime sector to consider the policy instruments for setting standards, including international treaty, national regulation, industry-based standards, requirements negotiated through third-party agreements (non-governmental organisations) and industry associations (Angel *et al.*, 2007). Firm-based and third-party standards exist for other industry sectors, with examples including the US Energy Star ratings, the ISO 9000 and ISO 14000 standards, etc. For shipping, the classification societies have provided third-party standards for environmental management that some maritime firms are adopting (American Bureau of Shipping, 2005).

A sustainable intermodal freight system is one that enhances goods movement around the globe in a way that is environmentally responsible, equitable and efficient. Such a system involves all current primary modes of freight transport – road, rail, water, air and pipeline – working in harmony. But a sustainable intermodal freight system also has trade-offs. The demands placed on the freight system are currently driven by consumer value for commodities and finished products. The level of this value will often dictate the method and mode of transport. In practice, meeting consumer demands will be demonstrated through cost, time-of-delivery and reliability. Shippers make their decisions on transport-mode based on a complicated calculus of how badly a consumer needs a good (and thus, how much they are willing to pay to have it shipped). Some consumers and businesses are willing to pay more to receive an item almost immediately and with high reliability – often equating to air or truck service; while others are comfortable waiting for a good and paying less – implying a rail or water mode of transport.

Regulation raises some fears in the maritime industry with regard to the changing nature of shipping competiveness, as illustrated by debates about phase-in periods for double hulls, cleaner fuels and less-toxic hull coatings. However, as firms shift to network-based standards in response to environmental concerns, maritime transport may recognise that competitiveness will be enhanced by adopting operations and technology that meet increased demands by shippers for transparency and improvement with regard to environmental benchmarks – especially for energy, CO_2 and emissions. More importantly, the attributes of maritime transport that compare best with other modes may create conditions where modal competitiveness favours this sector.

Interestingly, however, the modes of transport that are emphasised in the marketplace (namely, those that deliver goods quickly), are also the most polluting. Air and truck freight emit more than 10 times more CO_2 than rail and ship; alternatively, the emissions controls for trucking result in more similar PM emissions among the on-road, rail and water modes per cargo movement. Until the environmental and human health impacts of these emissions are incorporated into the price of the transport, the true social costs of freight transport decisions are not addressed. This may imply strong consideration of policies that attempt to internalise such external costs – *e.g.* through technological mandates, emissions standards, fees or taxes.

A sustainable intermodal freight transport solution will require co-ordinated efforts among industry, government and academia, along with improved understanding by the general public about how their food, clothing, housing and other material needs are delivered. As these efforts proceed, the maritime transport industry will continue to involve technologies (including environmental control technologies for air emissions, ballast water, hull coatings, etc.), energy systems (including alternative fuels, increased power plant efficiencies, improved hull and propeller designs, and even novel concepts like wind-assist kites) and operational changes (such as speed reduction, mode rebalancing, and changing route patterns).

9.6. Aviation

Climate change

Similar to maritime transport, the share of aviation emissions in global carbon emissions is small, but it is generally expected to grow fast. According to the business-as-usual scenario in Figure 9.1, emissions from aviation are set to grow faster than those of any other mode. While shares in emissions say nothing about abatement costs, it is often taken for granted that aviation should contribute to abatement.

A wide range of abatement measures can be thought of: charges (such as the UK air passenger duty or the Dutch ticket tax[19]), travel restrictions, emission standards, air traffic control reform, airport regulations or charges, limits on airport expansion, use of alternative fuels,[20] fuel or carbon taxes, and inclusion of aviation in emission trading schemes. The usual pros and cons can be listed for these various measures. Some measures, *e.g.* a large-scale adoption of biofuels, can be seen as voluntary industry measures or as responses to the introduction of carbon charges. Charges and standards may more usefully be regarded as complements than as substitutes. The inclusion of aviation in trading schemes is proposed or decided on in several regions: the European Union has decided to include domestic flights and all aviation to or from the EU in the ETS, and Australia and New Zealand are expected to include domestic aviation in their carbon trading schemes.

While trading schemes help equalise marginal abatement costs across the included sectors, and hence work towards reducing overall abatement costs, the trading schemes are not comprehensive and this leads to some shortcomings. For example, partial trading schemes involve a problem of leakage: passengers may choose to travel to destinations where carbon is cheaper, and airlines have incentives to use less energy-efficient aircraft outside of the trading zones. As long as charges are on a segment basis instead of an origin-destination basis, airlines may also change their network structure, *e.g.* by making more intensive use of hubs near to trading zones so as to make flight segments within trading zones shorter. Airlines that dominate such hubs are in a better position to make such changes, so they may see their competitive position improve under a trading scheme. It is worth noting that policies to internalise external costs can be expected to affect competitive interactions in general, to the extent that different firms have different options in responding to changes in costs and regulations. The question, hence, is whether imperfect policies have excessively strong effects, that could be avoided by better policy.

According to Forsyth (2008), the scope for emission abatement in aviation through better fuel efficiency is limited, at least at the level of the industry. Fleet renewal tends to reduce emissions per passenger-kilometre by about 1% per year, but the possibilities of speeding up this process seem limited. Putting a price on carbon, hence, will primarily affect airlines' variable costs. To the extent higher costs lead to higher fares, flight volumes will be affected. However, by many accounts, these effects are not negligible, but not very large either. Forsyth (2008) estimated that, with a carbon price of EUR 20 per tonne CO_2, fares will increase by 2% to 6% if carbon costs are fully passed through to passengers. Schröder (2008) estimated a cost increase for airlines of 2.5% to 5%, and a demand reduction of 2.1% to 4.6%, for an ETS where 15% of permits are auctioned and the cap equals 95% to 97% of the average emissions of 1995-97. In a report for the UK Commission for Integrated Transport, Wit *et al.* (2003)

estimated the increase in short-haul fares to around 3.5% and long-haul fares by about 6%. By taking an overall fare elasticity of demand of –0.8, the DETR arrived at a reduction of demand for short-haul and long-haul travel by around 3% and 5% respectively. CE Delft (2002) calculated the impact of the introduction of an emissions charge to be levied in European airspace and found that a charge of EUR 50 per tonne CO_2 might decrease air transport volume by roughly 2% for EU carriers. Anger *et al.* (2008) used a macroeconomic model to estimate the impact of including aviation in the EU-ETS, and found limited effects. Aviation would be a net buyer of permits, requiring about 2.5% of the total supply of permits; at a permit price of EUR 40, demand for airline services was estimated to be 1% lower than the baseline in 2020, while emissions drop by 7.5%. The authors pointed out that if permits were auctioned, the revenues should not be recycled to non-ETS sectors, as this potentially undoes carbon savings.

Many studies assume that increased carbon costs will be entirely reflected in higher fares, *i.e.* pass-through is complete. However, the extent of pass-through of cost increases to fares depends on the structure of the market. Under a Cournot competition structure – which is assumed to be appropriate for some air travel markets – pass-through is limited as long as no firms exit the industry, but fares can rise by more than carbon costs if there *is* exit.[21] When permits are distributed for free, exit is discouraged, and this limits the impact of the carbon pricing scheme on abatement (Forsyth, 2008). The impact of carbon prices also depends on the (real or artificial) scarcity of airport capacity. When capacity is scarce, the introduction of carbon permits may do little more than reduce the opportunity cost of capacity (*i.e.* it may reduce the value of slots), while fares are hardly affected. Irrespective of the social value of such a transfer, the impact of the carbon price on greenhouse gas emissions would be limited.

Aviation noise

The damage caused by aviation noise is considerable. Noise damage is concentrated around airports, and it varies strongly among airports, depending on the size of the population exposed, and among aircraft types. Lu and Morrell (2006) found that average noise costs per landing ranged from EUR 16 at Stansted to EUR 774 at Heathrow, with Schiphol holding the middle with EUR 377. For comparison, according to the same source, the costs of emissions per landing (including many local pollutants and CO_2) are estimated at EUR 626, EUR 1 004 and EUR 842 for the same three airports.

Noise pollution has been on the agenda for much longer than climate change, and a wide variety of measures is in place. Noise reduction at the source, as reflected in certification noise levels, has reduced perceived noise levels by about one-third over 30 years (Girvin, 2009). Aircraft manufacturers design new aircraft taking noise-related policies into account. The fact that new aircraft do better than FAA and ICAO limits suggests that manufacturers design to the strictest standards in the market (often European airports). Airport noise levels can be reduced through land-use measures, defensive expenditures, rules for operational procedures and restrictions on operations. Some of these measures directly, and considerably, affect an airport's capacity. All these measures are used to varying degrees. Girvin (2009) observed that EU airports are more autonomous in this respect than those in the US, as in the latter, airports are limited to restrictions on operations and operational procedures.

Policies have been effective. For example, while US air traffic increased by a factor of 3.5 between 1975 and 2000, exposure to significant noise declined by a factor of 16. But expectations of continued traffic growth and increased resistance to noise (from a higher-income population and well-organised interest groups) call for further action, while abatement costs increase. As in other areas of environmental policy, it then becomes increasingly important to try to keep the costs of further abatement down, and this increases the attractiveness of incentive-based measures, such as noise charges. Noise charges are in place in some airports, and are calculated on the basis of a variety of formulas and aircraft categories.[22] However, many airports rely on command-and-control measures, which are unlikely to minimise costs. In this context, Niemeier (2008) showed evidence that noise constraints determine (peak) capacity at several large airports. "Government failure" of using inadequate noise reduction policies hence not only inflates the costs of attaining some target level of aviation noise, it also exacerbates the costs of inefficient use of scarce capacity. More widespread adoption of noise charges could reduce the costs of noise abatement. Given the strong dependence of impacts on local conditions, charges should *not* be harmonised among airports, but harmonisation of the mechanisms to calculate them may be desirable.

9.7. Conclusions

The picture on climate change management in transport that emerges from the preceding sections is two-fold. Modes for which pre-existing policies are weak, such as shipping and aviation, seem to be candidates for integration into broader efforts to introduce climate change policy frameworks. Surface transport is characterised by stronger existing policies, and its integration in such broader frameworks is less straightforward.

The shape of the broader climate change policy frameworks is uncertain. Much of the economic analysis is on top-down approaches, and studies how multilateral efforts can handle the sovereignty constraint as well as possible. Actual policy developments, however, look more like a bottom-up approach, where different jurisdictions introduce more or less broad policies. This tendency should not be too surprising, given the importance of "club benefits" in making effective climate change policy possible. While the bottom-up approach conceivably leads to gradual expansion of geographical coverage (*e.g.* by linking up US and EU carbon trading systems), the inclusion of developing economies like China and India remains problematic.

Inclusion of aviation and maritime transport in cap-and-trade systems that cover other sectors is desirable from a cost-effectiveness point of view. Both for aviation and maritime transport, technological abatement options are limited in the short run because of slow fleet turnover. In maritime transport, the impression is that operational measures can reduce CO_2 emissions to some extent in the short run, at relatively low cost. In aviation, there is some scope for abatement through better air traffic control and airport congestion management (as well as technology in the longer run), but the main intra-sector abatement is likely to come from lower demand. Available estimates put an upper bound of about 5% on demand reductions, at prices of around EUR 20 per tonne CO_2. Imperfect competition and airport congestion limit the extent of pass-through of cost increases to ticket prices, and hence limit the demand responses. The aviation sector is thus likely to be a net buyer of permits. Both in aviation and shipping, there is considerable scope for leakage, as long as trading schemes are not very comprehensive. Nevertheless, inclusion of these modes in trading schemes is desirable if overall abatement is to be cost-effective. Other incentive-based measures can yield similar benefits, but seem less acceptable. Broadening the geographical scope of trading systems for maritime transport and aviation is likely to be a gradual process, perhaps along the lines discussed in Kågeson (2009).

Road transport is characterised by relatively stringent pre-existing policies. The EU has high fuel taxes and has recently introduced fuel-economy standards. The US has low fuel taxes, and fuel economy is determined by the fuel economy standard, that is now set to be tightened. In the EU, road transport is not included in the ETS. In various US proposals, the idea is to include the sector, possibly through upstream trading between refiners. Since the pre-existing policies are relatively stringent, abatement costs for CO_2 in road transport are relatively high, and exceed current and expected prices for carbon permits. This seems undesirable from a narrow cost-effectiveness point of view, but since the prevailing policies serve other purposes than just greenhouse gas reductions, it is not immediately clear if the welfare cost of further tightening of these policies is very high. For example, higher fuel taxes in the US seem justified if the goal is to handle congestion (in a blunt way) and increase infrastructure cost coverage, and this policy would reduce greenhouse gas emissions. It deserves emphasis, however, that the policy justification is congestion management and infrastructure provision, not reducing greenhouse gas emissions.

Within the static welfare economic framework used above, the case for tighter fuel economy standards or higher fuel taxes in road transport to reduce greenhouse gas emissions is weak. It is often argued, however, that policies are needed to increase the deployment of more fuel-efficient vehicles through the fleet. The reason is that the market for fuel economy provides only weak incentives to improve fuel economy, given consumers' rational response to various uncertainties surrounding the investment in fuel economy. Given the additional market failures in research, development and diffusion of new technologies, a fuel economy standard could increase fleet fuel economy and the adoption of alternative technologies. And since using less carbon to produce prevailing mobility patterns is likely to be a cheaper way to reduce the risks of climate change than drastically changing the structure of transport activity, such standards could complement market-based instruments in surface transport, aviation and shipping.

Notes

1. This chapter is an edited, updated version of the paper *Policy Instruments to Limit Negative Environmental Impacts from Increased International Transport – An Economic Perspective*, written by Kurt van Dender and Philippe Crist, Joint Transport Research Centre of the OECD and the International Transport Forum, for the OECD/ITF Global Forum on Transport and Environment in a Globalising World, held in Guadalajara, Mexico, 10-12 November 2008 (*www.oecd.org/dataoecd/12/53/41612575.pdf* and *www.internationaltransportforum.org/2009/workshops/pdf/Environmental.pdf*). Some paragraphs are also taken from the paper *The Impact of Globalisation on International Maritime Transport Activity: Past Trends and Future Perspectives*, written by James J. Corbett and James Winebrake, Energy and Environmental Research Associates, United States, for the same event (*www.oecd.org/dataoecd/10/61/41380820.pdf*).
2. There are, however, a wide range of exemptions, refund mechanisms and/or upper limits on the tax payments in these taxes, so the link between CO_2 emissions and the effective tax rate facing a given source is in many cases rather weak.
3. The US is taking active part in discussions about a post-Kyoto agreement to combat climate change. On 26 June 2009, the US House of Representatives embraced President Obama's climate change initiative that aims to cut US greenhouse gases by 17% below 2005 levels by the year 2020, and 83% by 2050, *i.e.* through the implementation of a cap-and-trade system with some auctioning of permits included.
4. See OECD (2008) for a further discussion of environmentally related taxes and emission trading systems in practice.

5. OECD (2009) provides further discussion of carbon prices needed to achieve different concentration targets. In an "optimal" policy, carbon prices would increase over time.
6. The projections do not account for the current economic and financial crisis. If the current shock is transient and the world economy returns to the same growth mechanisms as before, the attainment of the transport demand and emission levels as sketched will be delayed by five years or so (well within the margin of error of the model). But if there are profound changes to the functioning of the economy, either because of policy or because of adaptation to economic realities, more modest growth paths can be expected. In either case, the climate change problem still looms large.
7. The BAU assumes a decline of the intensity of vehicle use in developed economies. The average light duty vehicle is driven about 18 000 km per year in OECD North America in 2000, assumed to decline to about 16 000 km per year in 2050. In OECD Europe, average use declines from 13 000 km to 11 000 km per year over the same period. The underlying assumption is that an expansion of the vehicle stock in these economies reduces usage of each individual vehicle. In non-OECD economies, the average distance driven is assumed to remain more or less constant throughout the period.
8. A more extensive version of the arguments developed in this section can be found in Van Dender (2009).
9. Number taken from a 12 March 2008 e-mail exchange with Richard Smokers, with permission.
10. If policy steers the use of technology towards fuel economy, the cost needs to be calculated as the difference in surplus produced by the use of technology best liked by consumers, and the surplus from using technology to improve fuel economy.
11. Loss-aversion means that consumers evaluate outcomes in terms of changes from a reference state of wealth, and that losses are valued more than equivalent gains (to a larger extent than can be explained by declining marginal utility).
12. It was noted in JTRC (2008a) that, contrary to expectations, fuel economy decisions for company car fleets and for freight trucks are prone to similar imperfections as those for privately owned light duty vehicles. Loss-aversion may help explain this phenomenon as well.
13. The government may also prefer using a standard because it cares strongly about reaching the abatement target, perhaps out of a sense of urgency, and less about how much it will cost to get there. This argument has no direct relation with the issue of loss-aversion.
14. One litre of petrol causes emissions of 2.3434 kg CO_2 when being used, while a litre of diesel causes emissions of 2.6823 kg CO_2.
15. On 19 May 2009, President Obama proposed a tightening of the CAFE fuel efficiency standards. Beginning in 2012, an average 5% annual increase in fuel efficiency will be required until 2016, when automakers' combined car fleets should average an efficiency of 35.5 miles per gallon.
16. In different contexts, vessel owners, cargo owners or shippers may foot the fuel bill.
17. In March 2009, the Maritime Environment Protection Committee of the US and Canada proposed the introduction of an Emission Control Area for NO_x, SO_x, and particulate matter (MEPC 59/5/X, 27 March 2009), see *www.epa.gov/oms/regs/nonroad/marine/ci/420f09015.htm*. This Area would comprise the main coastal zones of the US and Canada.
18. See *www.epa.gov/oms/regs/nonroad/marine/ci/420f09015.htm*.
19. Although it is not clear that these measures were primarily intended to curb greenhouse gas emissions. While the UK air passenger duty is being increased, the Dutch ticket tax has been discontinued.
20. See *www.icao.int/WAAF2009/Documentation.htm* for background on the potential of alternative fuels.
21. When there is Cournot competition, companies compete on the amount of output they will produce, which they decide on independently of each other, and at the same time.
22. Examples include Prague (*www.prg.aero/en/site/o_letisti/zivotni_prostredi/pristup_k_hluku.htm*) and Zurich (*www.unique.ch/dokumente/umw_Environmental_Report_2007.pdf*).

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Chapter 10

Policy Instruments to Limit Negative Environmental Impacts: International Law

by
Markus W. Gehring[1, 2]

This chapter provides an overview of international law's limits and opportunities in combating the adverse effects of transport on the environment. It examines these limits and opportunities in turn for international air transport, international shipping, road transport and other regimes which regulate, for instance, the transport of hazardous waste. This chapter thus examines the opportunities and limits of policy instruments in addressing negative environmental impacts arising from transport. It breaks down responses by multilateral, regional and unilateral approaches.

Although international law in general does not exclude the possibility of unilateral action, it strongly encourages multilateral approaches. States have considerable freedom to regulate their own vessels and set the rules applicable in their own territory, particularly if they adopt non-discriminatory legislation. Regional initiatives offer several successful models to debate, design and adopt innovative rules which later can find their way into global regimes. Although international regimes on occasion act as constraints on governments' abilities to regulate activity that is harmful to the environment, the international law provides many opportunities to adopt new instruments to regulate environmental impacts from increased international transport.

10.1. Introduction

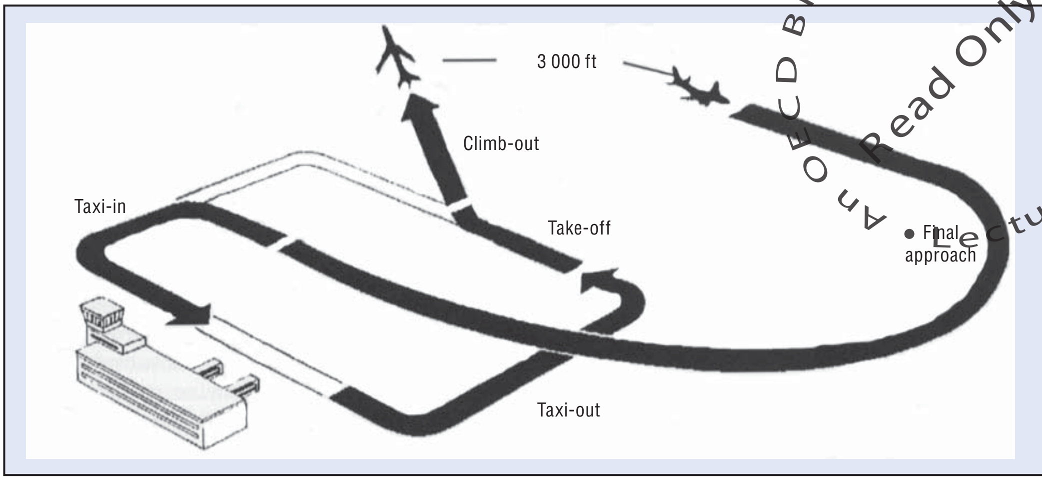
In recent decades, international trade in goods and services has grown at average rates of 6% or more per year and, according WTO (2008), international transport and travel has grown at an average 14% to the value of USD 3 260 billion in 2007 (WTO, 2008). Since 1950, trade in agricultural products has increased five-fold and trade in manufactured goods has increased by a factor of more than 500 (Kraemer, Hinterberger and Tarasofsky, 2007). These upward international economic trends have naturally led to corresponding increases in transport of goods, largely by sea, and of people, largely by air. However, transport can adversely affect the environment in a number of ways, including through the emission of greenhouse gases (carbon dioxide and others), nitrogen oxide (NO_x) and sulphur oxide (SO_x), as well as particular matter and noise. Efforts to combat these adverse effects are often stymied by concerns over cost, as well as international commitments that may prevent states from regulating most effectively to achieve particular environmental goals.

International legal instruments address potential environmental impacts in terms of all forms of pollution, including SO_x and NO_x, noise, particulate matter and greenhouse gas emissions (GHGs), especially CO_2. GHG emissions are particularly relevant for their negative contribution to climate change. As resource-intensive production and resource extraction has tended to shift from developed countries to developing countries, the pattern of global CO_2 emissions has changed, since the emissions arising from these activities will be assessed as part of the developing countries' total where they occur, rather than as part of the developed countries' total, where the relevant goods are eventually consumed. While developed country emissions might fall as a result, overall emissions might increase following this cross-border shift due to the use of less efficient production techniques in developing countries. Policy makers seeking to impose costs on CO_2 abatement should therefore be careful to ensure that their policies do not backfire and result in increasing CO_2 emissions (Kraemer, Hinterberger and Tarasofsky, 2007).

10.2. International air transport

At present, many industrial sectors are being scrutinised for their "carbon footprint" and impact upon the environment. However, the aviation industry has come under particular inspection. Although figures vary, the International Civil Aviation Organization (ICAO) cites a report from the Intergovernmental Panel on Climate Change that estimates aircraft do, currently, "contribute about 3.5 per cent of the total radiative forcing (a measure of change in climate) by all human activities".[3] It is widely accepted that this figure will rise (Wit *et al.*, 2005), and carbon dioxide emissions from aviation are expected to grow by about 175% between 1990 and 2050 (Centre for Clean Air Policy, 2004). In addition, especially during their take-off and landing cycle, aircraft emit nitrogen oxide (NO_x). This gas contributes indirectly to radiative forcing, though its effect is mixed – it contributes both to warming by assisting the production of ozone, and to cooling, by removing methane from the atmosphere.[4]

Figure 10.1. **Take-off and landing cycle**



Source: Fleuti and Polymris (2004).

International progress has been sought on this matter, with a 2005 agreement seeking reductions by the end of 2008.[5] Nevertheless, it is anticipated that 2025 NO_x levels will be 2.75 times higher than the 2005 levels (Fleming, 2007). Similarly, SO_x, emitted from aircraft predominantly as SO_2 but often oxidised in the process, contributes to the wider impact of aviation transport on the environment. Both NO_x and SO_x are likely to lead to radiative forcing which is regionally located near the flight routes and can cause greater concern for cities with airport hubs. Moreover, local noise pollution can generate disquiet for residents living near airports and airfields. International progress has been made on these issues, though there remain concerns for many countries and their populations

Certain legal boundaries also affect initiatives aimed at addressing these environmental concerns, as is briefly outlined in the following section of this paper.

Limits in international law

Multilateral initiatives

The principal legal instrument regulating international air transport is the Chicago Convention of 1944, which established the International Civil Aviation Organization (ICAO) with its headquarters in Montreal. The Convention and organisation both have virtually global membership. As such, their principles and policies are fundamental in the shaping of initiatives designed to confront the environmental impact of international air transport.

The principle of respect for national sovereignty is extremely important in international law. Rules of international air transport are no different. The concept of a state's sovereign jurisdiction over its territory extends to the airspace above its land.[6] Article 1 of the 1944 Chicago Convention, entitled "Sovereignty", "recognize[s] that every State has complete and exclusive sovereignty over the airspace above its territory". Article 6 expands upon this notion, stating that "[n]o scheduled international air service may be operated over or into the territory of a contracting State, except with the special permission or other authorisation of that State, and in accordance with the terms of such permission or authorisation".

It is immediately noteworthy that Article 1 refers to "every State", rather than, as it does in other articles, "contracting States". Furthermore, the article does not claim to create or establish the rule regarding airspace sovereignty, but rather "recognizes" the principle. The use of this language, in applying to all states irrespective of their voluntary adhesion to the treaty and in codifying an already existing rule, has important implications:

- First, it indicates that the rule is one of customary international law. It is both respected by states in practice and constitutes the *opinio juris* of the international community (Mendes de Leon, 2002, p. 484).
- Second, and consequently, it indicates that the principle is, to all intents and purposes, inviolable. This creates a very powerful tool for states to utilise in seeking to regulate their own airspace in terms of environmental impact. Of course, it also poses a significant obstacle to a state wishing to take action to regulate the environmental impact of international air transport more widely.

It is also important to be aware of the annexes that ICAO promulgates from time to time. These annexes establish standards regarding international air transport, including environmental standards. ICAO set up the Committee on Aviation Environmental Protection (CAEP) in 1983 to deal precisely with the environmental impacts from international air transport, including both noise pollution and engine emissions.

The ICAO Assembly adopted Resolution A36-22 on the recommendation of work undertaken within the CAEP in early February 2007. Appendix L addressed "market based measures, including emissions trading". The Preamble to this Appendix recognised that "[c]ontracting States are responsible for making decisions regarding the goals and must use appropriate measures to address aviation's greenhouse gas emissions taking into account ICAO's guidance". However, it also recognised that "the majority of the Contracting States endorse the application of emissions trading for international aviation only on the basis of mutual agreement between States", which resulted in the "need to engage constructively to achieve a large degree of harmony on the measures which are being taken and which are planned [to be taken]". Indeed, the interaction among states in air transport is at the heart of understanding the limits and opportunities. Therefore, state-level action aimed at addressing international transport seems to be limited by the need to engage with other states, on the basis of mutual agreement, to ensure harmony on any particular initiative. And as the matter currently stands, states appear somewhat restricted to multilateral negotiation forums within the ICAO. This does not prevent any state from adopting a leadership role to push forward with discussions or tabling motions aimed at addressing more determinedly the issue of air transport's environmental impact. But the lack of progress to date raises broader questions concerning the most appropriate and efficient body in which to vest regulatory authority over environmental matters related to aviation, and the role of ICAO in a post-Kyoto world.

The ICAO annexes contain what are known as Standards and Recommended Practices (SARPs), which place further limits on the unilateral undertaking of environmental measures. The SARPs, though without the force of an international treaty, entail legal obligations for the contracting states to the Chicago Convention. Such states have "accepted an explicit legal undertaking to collaborate in securing the highest practicable degree of uniformity in regulations, standards, procedures and organisation in relation to (air navigation)" (Milde, 1998, p. 254).

The ICAO SARPs are the current multilateral mechanism used to govern or guide, at an international level, the consequential national regulations concerning air transport. Compliance with these standards is the central cause for concern for most states. Without that compliance, the inherent need for co-operation on uniform rules in international air transport is jeopardised. Article 33 of the Chicago Convention seeks to ensure that compliance by ensuring that these SARPs are recognised, on a reciprocal basis, by every contracting state.[7] This means that certificates of airworthiness and certificates of competency and licences "issued or rendered valid by the contracting State in which the aircraft is registered, shall be recognised as valid by the other contracting States, provided that the requirements under which such certificates or licences were issued or rendered valid are equal to or above the minimum standards which may be established from time to time…". This article therefore dictates that one state may not reject or discriminate against the aircraft of another state, where that aircraft is complying with the standards annexed to the Chicago Convention. Article 33 therefore represents a further constraint on states seeking to take unilateral action to curb international air transport's contribution to global warming and CO_2 emissions. Using a method of reciprocity in international air transport can have the unfortunate side effect of hindering positive unilateral progress in a given area, such as the environment. States must therefore ensure that any initiatives put in place do not have the effect of invalidating another state's annex compliant air transport framework.

Bilateral initiatives

International air transport, since the late 1940s, has been conducted on a bilateral basis. Departing from the multilateral treaty approach at Chicago, states sought to establish more detailed agreements which would determine the capacity, frequency and cost of air traffic flowing between two territories. That model largely remains the predominant model today and there exist tens of thousands of international bilateral treaties between nations. These treaties include legal conditions for their members. There is an increasing tendency to include environmental clauses within such agreements. The US and EU Agreement of March 2007 provides an example of such an accord. Article 15(2) of the Agreement states:

> When a party is considering proposed environmental measures, it should evaluate possible adverse effects on the exercise of rights contained in this Agreement, and, if such measures are adopted, it should take appropriate steps to mitigate any such adverse effects.[8]

Ultimately, therefore, both parties to this agreement are obligated to first evaluate the possible adverse effects that any state-level action might have and, second, take appropriate steps to mitigate those adverse effects. Failure to do so would result in the violation of this article of the Agreement. Regarding international law, the breach of a signed and ratified international convention is a serious matter. As such, a material breach of this Agreement could lead to the other Party invoking that breach "as a ground for terminating the treaty or suspending its operation in whole or in part".[9] As such, another important limit within the environmental field of international aviation is the possible existence of an international treaty between two parties which places stipulations upon the commencement of any given initiative to address environmental impacts, including emissions. These agreements affect the economic investment and growth of the air transport industry between the two states, and are generally respected in international aviation matters.

Unilateral initiatives

A recent dispute between the US and the EU concerning the noise pollution generated by certain aircraft provides a useful case analysis of how regulation at the European level fares on the international stage. At the heart of the matter was an EU regulation addressing environmental concerns of international air transport which was adopted outside, and in opposition to, the co-operative framework of ICAO. This regulation sought to address the growing disquiet surrounding the noise pollution created by civil aircraft around the airports of the EU member states. In the period between the proposal and its adoption, several rounds of negotiations between the US and the EU took place in an attempt to placate the US's reservations concerning what it regarded as a "purely protectionist" (Knoor and Arndt, 2002, p. 4) measure which had a "disparate impact on US interests" (United States Department of State, 2000, p. 17).

The EU stated that it was adopting this measure because the US had deviated "from the internationally agreed upon ICAO Chapter 2 phase-out schedule" (EU Commission, 1999, p. 12). Each chapter indicated an ever-decreasing limit on the noise that registered aircraft were permitted to make. The US had progressed on this phase-out faster than agreed upon and there were worries from both the EU aviation market and the noise-abatement lobbyists that this would be an incentive to the US owners and operators to move their Chapter 2 aircraft into the territory of the Community. The method of *hushkitting* such Chapter 2 aircraft to comply with the standards under Chapter 3 of Annex 16, thereby facilitating their operational use within the EU, was therefore countered by the EU with the promulgation of this regulation. Although "hushkitted aircraft meet Chapter 3 standards, … their performance is near the bottom of the acceptable noise range allowed by [that] chapter…" (Fischer, 2000). Therefore, according to the EU, while these aircraft technically complied with the Chapter 3 requirements, this did not mean that they were required "to accept them as Chapter 3 aircraft" (Fischer, 2000).

A number of policy and economic arguments to this EU regulation were fielded by the US. More important for this chapter, however, were the purely legal objections. What limit did the US allege the EU had transgressed in adopting this regulation? Principally, their concern was that both the design and effect of the measure was discriminatory. For instance, the measure appeared to advantage European states over non-European ones regarding the use of the aircraft in question. Importantly, the measure was also alleged to be discriminatory in that it distinguished between Chapter 3 compliant aircraft which had been recertified and Chapter 3 compliant aircraft which had always been so certified. As such, the regulation also violated Article 33 of the Chicago Convention, requiring all states to recognise the validity of airworthiness certificates issued by any other contracting state. As the US had technically complied with those standards, the EU's decision not to recognise those certificates violated Article 33.

However, before the matter reached a formal court, the ICAO Council, in June 2001, adopted Chapter 4 noise standards within Annex 16. These standards offered "member-states a great deal more flexibility in the definition and enforcement of their national and local noise abatement policies" than did the previous set of standards (EU, 1999, p. 7). As a consequence, the EU Council, in mid-October 2001, officially recognised the "prospect of replacing the 'hushkits' Regulation in the near future" (EC, 2001). It finally took those steps in late March 2002, adopting Directive 30/2002 "on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Community airports". Article 15 of that Directive explicitly repealed the "hushkit" Regulation. The Directive avoided stipulating design methods to carriers seeking to comply with the Directive and effectively defused the dispute between the two Parties.

This brief case analysis provides useful lessons for states seeking to understand the limits and opportunities within international aviation law for taking initiatives within the environmental sphere. First, it indicates, as noted above, that Article 33 of the Chicago Convention presents a sticking point for states seeking to take unilateral action. Second, it is clear that any measures must not be seen by another state as discriminating against them, either legally or as regards their air transport economy. However, these aspects of the case do not ultimately rule out unilateral action aimed at international air transport. Indeed, an equally important lesson to be taken from this case is that the EU ultimately achieved its desired goal of quieter planes by establishing Chapter 4 noise standards within the ICAO framework. A state must be aware, therefore, of the restrictions in place while recognising that global standards can be achieved from initially unilateral beginnings.

Indeed, the EU itself has not been deterred by the above dispute. It is currently preparing to bring all flights that land or take off from a European airport within its emissions trading scheme from 2012.[10] Again, this will originally be a Europe-wide scheme that could ultimately lead to a more global system of carbon trading. It has been argued that the scheme is compatible with the Chicago Convention and general rules of international air law, given that the intended EU scheme is a market-based initiative, expressly recognised as a legitimate progression of air transport within the preamble to the Chicago Convention (Delft *et al.*, 2005, p. 17). Whether this initial scheme will in fact survive legal challenges from other ICAO members will be seen in the coming years.

Opportunities in international law

Article 38 of the Chicago Convention provides, in part, that "Any State which… deems it necessary to adopt regulations or practices differing in any particular respect from those established by an international standard, shall give immediate notification to the International Civil Aviation Organization of the differences between its own practice and that established by the international standard".[11]

The principal goal of this article is to ensure that states are fully aware of the practices and regulations in operation in any given state. Therefore, where a state considers it "impracticable to comply in all respects with any international standard, it has an unconditional legal duty, under Article 38 of the [Chicago] Convention, to give immediate notification to… ICAO" (Milde, 1998, pp. 254-255). Through this mechanism, it was anticipated that contracting states within ICAO could assess, with full information, the air navigation standards of every other contracting state. Although safety and efficiency was the principal goal behind this article, the passage of the Convention article reproduced above does not distinguish between differing standards below or above that of the international standard. Therefore, the article permits states to deviate from the international standard, such as an aircraft's carbon dioxide emissions, provided immediate notification is given to the ICAO. Use of this article is therefore possible by states seeking to implement unilateral measures regarding the environmental impact of air transport.

States may also seek recourse to what has become known as the "effects" doctrine in seeking to regulate international air transport. This essentially allows a state to "assume jurisdiction on the grounds that the behaviour of a party is producing 'effects' within its territory" (Shaw, 2003, p. 612). For instance, placed in an aviation context, Abeyratne (1996) is of the opinion that "if… engine emissions of aircraft adversely affect the territories of [other] states… the state in which such aircraft are registered or leased or chartered would incur legal liability at international law" (Abeyratne, 1996, p. 291). As such, the injured state might legitimately exercise prescriptive jurisdiction over the activity. Such a principle is fully embraced by a number of states, the United States and the United Kingdom being robust in their use of the doctrine within the area of competition law. Classically expounded in US v. Aluminium Co. of America, "any State may impose liabilities, even upon persons not within its allegiance, for conduct outside its borders that has consequences within its borders which the State reprehends".[12]

As a consequence, where a state is seeking to regulate activity outside its borders, such as aircraft emissions which adversely affect that state, it might employ this doctrine in executing state-level regulations. Clearly, the political and economic ramifications of unilaterally restricting the freedom of another state's air transport are a separate consideration and the "effects" doctrine has yet to be confirmed directly for areas beyond competition law.

Environmental air taxes which do not specifically address fuels themselves could probably be justified under international law related to air quality or long-range transport of pollutants. These would need to be strictly non-discriminatory regulations, affecting the goods and services from different states equally, as otherwise they could face challenges in ICAO and the WTO.

International trade law, under the disciplines of the WTO Agreements, is often seen as limiting states' regulatory autonomy, particularly in social and environmental fields. However, both the General Agreement on Tariffs and Trade (GATT) and the General Agreement on Trade in Services (GATS) include specific exceptions designed to allow member states to pass measures that are aimed at environmental protection. Thus, Article XX of GATT reads: "[N]othing in this Agreement shall be construed to prevent the adoption or enforcement by any contracting party of measures… *b)* necessary to protect human, animal or plant life or health; … *g)* relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption." Any measures taken must, nevertheless, not be applied in such a manner that would constitute a disguised restriction on international trade, or a means of arbitrary or unjustifiable discrimination between countries where the same conditions prevail. Article XIV of GATS contains environmental and health exceptions in similar terms to the GATT.

Countries are thus permitted under WTO law to take environmental protection measures, as long as the same standards are imposed on both domestic and foreign producers and providers, and there is no disguised protectionism. The essential compatibility of the WTO regime with domestic environmental and health measures has been confirmed by the WTO Appellate Body in cases such as *Gasoline*[13] and *Asbestos*.[14] In the context of international air transport services, however, the relevance of trade law may be limited by most states' reluctance to commit to full liberalisation of the sector under GATS' positive list approach.

WTO law on subsidies, labelling and procurement provide other potential opportunities to combat the negative environmental effects of transport (Kraemer, Hinterberger and Tarasofsky, 2007, p. 2). First, the WTO subsidies regime under the Agreement on Subsidies and Countervailing Measures does not prohibit outright all payments made by a government to its industries. Under the "traffic-light" approach, subsidies in the "green light" category are likely to be permitted; these include subsidies that are not tied to export performance, do not require domestic content and do not target specific industries.[15] As long as the subsidy is carefully implemented, then, domestic governments may be able to encourage more energy-efficient air transport through payments to good performers or to advance technological developments.

Second, a domestic government may wish to encourage the use of "eco-labels", or the provision of information to the consumer on the environmental impacts of the goods or services being consumed. In the context of air transport, for instance, airlines could begin voluntarily reporting on the efficiency of their aircraft, allowing consumers to choose the most energy-efficient and least polluting airline to travel with. As long as the labelling scheme (or other schemes for informing consumers) remained voluntary, it would most likely not breach any relevant WTO agreements. If the scheme became mandatory, implemented through domestic laws, there is more risk that it would violate the non-discrimination provisions of GATT[16] or GATS,[17] or that it would constitute an unnecessary obstacle to international trade under the Agreement on Technical Barriers to Trade.[18] However, for the non-discrimination provisions to become relevant, environmentally damaging goods and services must be considered "like" (that is, equivalent to) cleaner goods and services, since the provisions only apply to like products. The "process and production method" debate then becomes relevant here to a discussion of whether air transport services that are delivered using highly environmentally damaging aircraft are "like" competitors' services that are delivered using more efficient planes. There is no clear answer as yet from the Appellate Body on this issue, so the use of mandatory labels, certification requirements or information-provision requirements remains only a potential opportunity for environmental regulation (WTO, 2000).

Third, public procurement provides another potential opportunity for governments to encourage environmentally friendly air transport. Governments might, for instance, express a preference for less polluting airlines (those using newer planes, or those who actively engage in carbon offsetting programmes) when purchasing transport services for their staff. Although procurement is partly covered by the plurilateral WTO Agreement on Government Procurement (GPA), where it applies, the GPA does permit the consideration of non-economic factors, including the GATT/GATS-style exceptions for human, animal or plant life or health (McCrudden, 2008). Nevertheless, the extent of this possibility under the GPA is uncertain, and, as for eco-labels, governments' ability to incorporate environmental criteria into their purchasing decisions while still remaining GPA-compliant is thus somewhat unknown.

Attempts to address the climate change impacts of aviation must contend with a substantial number of other issues. A major one is the issue of accounting – exactly how to account for GHG emissions coming from the aviation industry. Under Kyoto, for instance, countries' emissions are assessed against a baseline, but while domestic aviation and marine emissions are included in each country's total, emissions from international shipping and aviation are currently separately reported.[19] In 1996, the Subsidiary Body for Scientific and Technological Advice (SBSTA) of UNFCCC identified eight options for emissions accounting:

- No allocation (that is, emissions from international aviation would remain in the international sphere rather than be allocated to any particular country).
- Allocation of global bunker fuel sales and associated emissions to Kyoto parties in proportion to their national emissions.
- Allocation to parties according to the country where the bunker fuel is sold.
- Allocation to parties according to the nationality of the transport operator.

- Allocation to parties according to the country of destination or departure of the aircraft or vessel.
- Allocation to parties according to the country of destination or departure of passengers or cargo.
- Allocation to parties according to the country of origin of passengers or owner of cargo.
- Allocation to the party of all emissions generated in its national space (van Velzen and Wit, 2000).

A study carried out for the Dutch Civil Aviation Authority in 2000 examined the quantitative effect of each of these eight scenarios on the national emissions of 23 major aviation nations (EU15, Switzerland, Norway, US, Canada, Russian Federation, Brazil, Japan and Australia) (van Velzen and Wit, 2000). The considerable differences in results, as shown by the study, highlight the effect that the various accounting policies can have on a state's ability to meet its Kyoto targets. Consensus on the most appropriate means of accounting will thus be required before market-based mechanisms for addressing the GHG impact of international air transport are likely to be successful.

One final note is important. In aviation, GHGs and carbon dioxide in particular are not the only contributors to climate change; they may in fact represent only 25% to 33% of the total contribution (Centre for Clean Air Policy, 2004). One study concludes that condensation trails (contrails) from aircraft may have contributed to a 0.2 °C to 0.3 °C per decade temperature increase between 1973 and 1994 (Minnis *et al.*, 2004). However, contrails are probably best addressed through technical and optimisation tools, such as altering flight paths to reduce their formation, rather than policy instruments backed by international law (Centre for Clean Air Policy, 2004).

While unilateral action or regional action is not encouraged under international law, flag state jurisdiction over carriers can be used to increase environmental standards, as can certain provisions of international trade law. In conclusion, it can be noted that multilateral action in many fields (including new international environmental instruments) presents a broad array of options to regulate environmental consequences from international air transport, while avoiding discrimination against one particular air-faring state.

10.3. International space transport

As commercial space travel becomes an increasing likelihood over the coming decades, states are becoming aware of potential legal implications. The opportunities and limits in place for state-level action to sustainably manage the environmental impact of this new means of transport are, currently, uncertain. For instance, the point at which air transport becomes space transport has no accepted international definition. This is obviously important, as a state maintains sovereignty over its airspace and would usually be keen to enlarge its territorial jurisdiction. Indeed, at state level, this delimitation has been defined, though in dissimilar ways. Australia, for instance, regards space activities as those occurring or intending to occur 100 km in altitude.[20] The UK, on the other hand, has stated that "for practical purposes the limit is considered to be as high as any aircraft can fly" (Shaw, 2003, p. 464). Therefore, neither the limit itself, nor its method of calculation is stipulated by international law. This currently leaves a state free to determine "outer space" above its own airspace. However, the ability for a state to potentially extend this limit indefinitely, far into the reaches of outer space, and thereby to extend the sovereignty it possesses over its own airspace, seems doubtful. A geostationary orbit around the earth, on which many satellites are placed due to its advantageous geosynchronous properties, lies 36 000 km from the earth's equatorial surface. Although the Bogota Declaration, signed in 1976 by a number of equatorial states, claimed that "the segments of geostationary synchronous orbit are part of the territory over which equatorial States exercise their sovereignty",[21] many states and legal authors have rejected this (Jakhu, 2007). It seems, therefore, that the international community rejects claims of sovereignty at 36 000 km (over a limited resource, it must be added), but have reached no agreement below that limit.

States must also begin to be aware of the environmental impact of transport vehicles such as Virgin Galactic's aeroplane/space ship hybrid that will soon undertake space tourism and, in the not too distant future, space transport between countries. As Virgin itself admits, "the technology that still delivers payloads and people to space has a high negative environmental impact and has remained essentially unchanged for half a century".[22] An average rocket[23] will use 3.5 million pounds of fuel in each launch. For comparison, 2.5 thousand million pounds of gasoline is used in the entire US in one day. The contribution is therefore not negligible, and its use can be expected to increase strongly over the coming years. How states wish to proceed in ensuring the sustainable development of this means of transport remains largely undefined.

The opportunities available to states to ensure that CO_2, SO_x, NO_x and other harmful emissions do not outweigh the benefits offered by this mode of transport are currently only starting to be discussed in international legal circles. For instance, one of the environmental problems of this mode of transport appears to have been addressed in the UN Convention on International Liability for Damage Caused by Space Objects, which establishes absolute liability for damage due to space debris.[24]

10.4. International maritime transport

Ships are major sources of greenhouse gas emissions and other environmental pollution. While the aviation and road transport sectors have come under heavy pressure to limit their emissions, the shipping industry has thus far been spared; greenhouse gas emissions from international shipping are not presently regulated by national, regional or international regimes. The need to regulate bunker fuel emissions was recognised during early UNFCCC negotiations, but no decision was made to allocate ship emissions to national totals.[25] However, efforts to regulate maritime carbon emissions on a global scale are taking place at the IMO, as provided for under Article 2.2 of the Kyoto Protocol.[26] Sea transport is also responsible for other environmental impacts such as sewage, invasive species, SO_x/NO_x pollution and particulate matter.

The Convention on the Inter-Governmental Maritime Consultative Organization was adopted by the United Nations Maritime Conference in Geneva, 6 March 1948. Although the organisation changed its name to the International Maritime Organization (IMO) in 1982, it retained the broad mandate to "provide machinery for co-operation among Governments in the field of governmental regulation and practices relating to technical matters of all kinds affecting shipping engaged in international trade"[27] and "provide for the consideration by the Organization of any matters concerning shipping and the effect of shipping on the maritime environment that may be referred to it by any organ or specialised agency of the United Nations."[28] Furthermore, the organisation serves as the specialised agency of the UN in the field of shipping and the effect of shipping on the marine environment.[29] This mandate justifies the role assigned to the IMO under Article 2.2 of the Kyoto Protocol. To fulfil its mandate, the organisation can consider and make recommendations on matters remitted to it, draft conventions, agreements or other instruments for consideration, and provide machinery for consultation and the exchange of information.[30] Membership in the organisation is open to all states – it currently has 168 members and three associate members (Hong Kong, China; Macau; Faroe Islands) – making it one of the most inclusive routes to a global emissions scheme. In the UN Convention on the Law of the Sea, Article 192 (Part XII – Protection and Preservation of the Marine Environment), states agreed on general obligations to protect and preserve the marine environment. These obligations mandate states to jointly or individually take necessary measures to prevent, reduce and control pollution of the marine environment from any source.[31]

Limits in international law

Multilateral initiatives

Developments in regulating maritime carbon emissions started at the IMO in 1997, when it adopted a resolution requesting that the Marine Environment Protection Committee (MEPC) consider the feasibility of CO_2 reduction strategies for ships.[32] The language was strengthened and clarified in 2003 when the IMO passed Assembly Resolution 963(23), which dictated that the Marine Environment Protection Committee identify and develop the mechanism or mechanisms needed to achieve the limitation or reduction of GHG emissions from international shipping. In doing so, MEPC must give priority to the establishment of a CO_2 baseline, develop a ship profile index and guidelines for a CO_2 emission indexing scheme, and evaluate technical, operational and market-based solutions.[33] Two years later, the MEPC approved a set of interim guidelines for voluntary ship CO_2 emission indexing on a trial basis that would allow ship owners to evaluate vessel and fleet performance in regards to fuel efficiency and CO_2 emissions.[34] The following year, MEPC 55 (October 2006) set out a work plan to have the CO_2 baseline, CO_2 emission indexing scheme and technical, operational and market based solutions complete by MEPC 59 in July 2009.[35]

MEPC 57 (April 2008) considered follow-up actions to resolution A.963(23), including progress made in line with the work plan adopted by MEPC 55 in 2006. One of the meeting's major contributions was the development of fundamental principles as a basis for future regulation of shipping GHG emissions. In the MEPC's view, a coherent and comprehensive framework should be:

1. effective in contributing to the reduction of total global greenhouse gas emissions;
2. binding and equally applicable to all flag states in order to avoid evasion;[36]
3. cost effective;
4. able to limit, or at least, effectively minimise competitive distortion;
5. based on sustainable environmental development without penalising global trade and growth;
6. based on a goal-based approach and not prescribe specific methods;
7. supportive of promoting and facilitating technical innovation and R&D in the entire shipping sector;
8. accommodating to leading technologies in the field of energy efficiency; and
9. practical, transparent, fraud free and easy to administer.[37]

Given these considerations, the MEPC 57 Working Group on GHG Emissions from Ships moved to consider short-term and longer-term measures for such a framework during an inter-sessional meeting of the Working Group on GHG Emissions from Ships, held in Oslo, 23-27 June 2008. The Working Group was instructed to consider short- and long-term measures brought up at MEPC 57,[38] and:

1. Develop a mandatory CO_2 design index for new ships and submit it to MEPC 58 for approval.
2. Review the existing CO_2 operational index guidelines (MEPC/Circ.471) with a view to finalisation at MEPC 58 and, in particular:
   a) develop a methodology for a CO_2 baseline in terms of efficiency; and
   b) consider the purpose of the CO_2 operational indexing scheme.
3. Further develop mechanisms with GHG reduction potential for international shipping with a view to selecting the most promising measures for consideration at MEPC 58, *inter alia*:
   a) global levy/cap and trade hybrid mechanism;
   b) Emissions Trading Schemes (ETS) and/or Clean Development Mechanism(CDM); and
   c) best practices on the range of measures as identified by MEPC 57 and how they can be implemented by ship builders, operators, charterers, ports and other relevant partners to make all possible efforts to reduce GHG emissions, with the aim of developing a resolution as appropriate.
4. Consider the level of reductions that can be achieved, address the design, implementation, cost benefit, capacity building and regulatory/legal aspects as well as the impacts for the shipping industry, the flag and port states and other stakeholders as appropriate, associated with each of these options.[39]

The Oslo inter-sessional meeting was meant to develop and finalise certain aspects of a GHG emissions framework, but the process stalled because of the contentious issues at hand. A draft CO_2 Design Index was developed for submission to MEPC 58, but mandatory application was questioned by "non-Annex I" nations, and those same nations did not support the development or implementation of reduction mechanisms proposed by Denmark (a global fuel levy) and the EU (an emissions trading scheme) (Lloyd's Register, 2008, pp. 3-5). The issues were addressed again at MEPC 59 in July 2009. The outcome of MEPC 59 (see *www.imo.org*) will be presented to the United Nations Conference on Climate Change in Copenhagen in December 2009. Ultimately, a decision will have to be made as to whether an emissions scheme will be pursued under the auspices of the IMO, or under the UNFCCC.

Unilateral initiatives

Due to the failure to reach a consensus within the IMO, the European Commission is likely to launch consultations on potential legislative proposals to amend the ETS to include the maritime industry.[40] The United States may also be forced by the courts into adopting a unilateral solution – several US states and non-governmental organisations have filed formal letters of intent to sue the EPA over its failure to regulate CO_2 emissions from ships and aircraft.[41] These unilateral efforts may make international solutions to shipping emissions more difficult to achieve, though the nature of the shipping industry necessitates global action.

Opportunities in international law

The regulation of shipping emissions represents a significant legal challenge as ships operate largely outside of national boundaries. States have limited jurisdiction over maritime emissions that occur outside their borders, especially when those emissions happen on the high seas.[42] But UNCLOS itself contains provisions on the protection and preservation of the marine environment (Part XII). This mandates states to take jointly or individually as appropriate, necessary measures to prevent, reduce and control pollution of the marine environment from any source (Article 194 UNCLOS). Part XII provides states with an opportunity to regulate the environmental impacts and while Article 211 UNCLOS largely refers to IMO or other global initiatives, it also mandates flag states to adopt laws and regulations for the prevention, reduction and control of pollution.

The international process for establishing new regulatory requirements is further complicated by the complex relationships that exist between the flags of convenience and the large shipping interests (ICCT, 2007). Specifically, 75% of the world's merchant vessel fleet is registered in non-Annex I Kyoto parties, yet is mostly owned by shipping interests in Annex I countries.[43] Political willpower is hard to come by due to the key role that maritime transport plays in the global economy. Estimates suggest that 90% of the world's goods (by volume) are transported by sea. However, shipping is also the most efficient form of transport and could play a key role in reducing worldwide GHG emissions if the right actions are taken.

Port states generally have considerable freedom to impose requirements on ships passing into their internal waters for docking, or to refuse permission to enter to ships not meeting the requirements. Thus, although regulation on the high seas is legally complicated, regulation could effectively be imposed at points of departure or arrival with sufficient co-ordination of port state laws.[44] Regulation from flag states also serves as an opportunity to take responsibility for pollution caused by vessels, though as indicated, this may depend on the political will of the flags of convenience, which may be concerned about losing their comparative regulatory advantage over other potential flag states.

IMO's *Study of Greenhouse Gas Emissions from Ships* (IMO, 2000) provided a comprehensive evaluation of potential avenues for the reduction of shipping related GHG emissions. First, it assessed international regulative measures related to maritime safety (SOLAS) and marine environmental protection (MARPOL 73/78) to identify restraints to the potential for emissions reduction from international shipping.[45] Safety and environmental regulations that may conflict with the objective of greenhouse gas emissions reduction include measures limiting cargo carrying capacity (*e.g.* double-hulling), measures introducing additional energy consumers (*e.g.* increase in onboard equipment), measures affecting general efficiency (*e.g.* traffic routing) and miscellaneous measures (*e.g.* mandatory retention of slops, reduction of NO_x and SO_x emissions, ballast water management, prohibiting Tributyltin in antifouling paints).[46]

IMO (2000) also considered market-based approaches to emissions reductions, but cautioned that a number of facts must be understood before attempting to seek an effective solution:

- It is difficult to define the nation or territory where "generation" of sea transport services takes place.
- It is also difficult to determine the country of ownership of a vessel, or who is the real owner or responsible for its operation.

- The majority of the world's bulk shipments either start or finish their journey in an Annex I country.
- Bunker fuel is commonly sold to ship operators by dealers independent of the major oil companies, making tax collection administratively difficult.
- Measures to reduce industry-wide emissions must be global in scope if they are to be equitable and avoid "free-riders", but some actions taken by Annex I countries may have a significant impact on global emissions.
- The international shipping industry has a history of adopting solutions to common safety and pollution problems through the adoption of global uniform standards.[47]

Market-based measures addressed by the study include environmental indexing, a voluntary agreements programme, a carbon charge on bunker fuel, common emissions standards and emissions trading.[48] Its conclusions included:

- Carbon charges on bunker fuels are not a viable option, due to huge evasion possibilities.
- A voluntary agreements programme does not seem to be a very efficient policy tool for international shipping. However, some reductions may be achieved by local agreements, etc., or agreements between Annex I countries/IMO and ship owners, where Annex I countries co-ordinate their efforts.
- Environmental indexing does not seem to be a very efficient tool to reduce emissions, even if some reductions may be achieved on voluntary basis.
- Emission allowance trading, either along with other sectors in Annex I countries or as a separate system outside the Annex I countries seems to be a non-viable option, due to severe problems capturing emissions from the shipping industry.[49]
- Energy or emission efficiency standards seems to be a promising option, especially for new vessels.
- Emissions credits sales, resulting from abatement measures on new ships and possibly also existing ships, is also a very promising option, and could in the long run provide very strong economic incentives for ship owners to reduce emissions through technical measures.[50]

In December 2007, the Centre for International Climate and Environmental Research (CICERO) released a report building on the IMO's study and examining five different schemes for the regulation of carbon dioxide emissions from ships: a cap-and-trade scheme, a design emission standard, an operational emission standard with fee, a charge (tax) on emissions from ships, and a combined cap and charge scheme (CICERO, 2007). The schemes studied were assessed for three kinds of efficiency: *environmental* efficiency, actually achieving reductions in GHGs; *cost* efficiency, aiming to minimise the cost to society of the regulation; and *administrative* efficiency, seeking as little use of resources to implement the regulation as possible.[51] The schemes included some market-based instruments, such as emissions taxes and emissions trading, as well as some "command-and-control" instruments, such as mandating emissions standards that ships must meet. Hybrid schemes were also considered; for instance, a standard combined with a tax for not meeting the standard, or a credit for operating at a higher level than the standard requires.

The report concluded that standards-based mechanisms are likely to be more acceptable than a tax or a cap-and-trade system, but provide less incentive to reduce emissions than market-based mechanisms. The combined cap-and-charge scheme was found to be a compromise position with medium performance both on acceptability and incentive. The report noted a gap, though, between what is currently feasible and what is ultimately desirable in regulating maritime GHG emissions.

SO_x/NO_x and sewage

Of course, greenhouse gases are not the only environmental concern posed by international shipping. The major international legal instrument in the area, the International Convention on the Prevention of Pollution from Ships (known as MARPOL 73/78),[52] contains rules on the emission of various polluting substances, including NO_x and SO_x. Annex VI of MARPOL 73/78 sets up SO_x emission control areas, which impose stricter limits on SO_x emissions in a geographical area. While the global limit for the sulphur content of fuel oil was set after 20 years of debate at a relatively ineffectual 4.5%, within SECAs the limit is reduced to 1.5% (DieselNet, 2008). Following agreements at MEPC 57 and 58, these limits are both set to progressively reduce over time.[53] Ships can also use certain emission reduction techniques (such as an exhaust gas cleaning system) instead of meeting the 1.5% sulphur content, as long as SO_x emissions are kept below 6 g SO_x per kWh (DieselNet, 2008). There are currently two SECAs in operation: one in the Baltic Sea and another in the North Sea/English Channel. Any MARPOL Annex VI party can propose a new SECA, and the EU has indicated[54] that it may seek to have the Mediterranean Sea designated as a SECA. The US and Canada has also proposed a SECA extending for 200 nautical miles from the entire North American coast, with an even lower sulphur content requirement of 0.1% to be imposed.[55] Compliance with and enforcement of SECA limits may be a problem, though, under UNCLOS rules which give states little jurisdiction over vessels outside their territorial waters. Although nations could report foreign flag vessels that breach SECA limits to the flag state authority, there is no guarantee that any action will be taken against the ship owner (Bunkerworld, 2008).

NO_x is regulated in a similar fashion to SO_x, with certain global limits in place and stricter limits applying in NO_x emission control areas. The global limits are set to decrease over time to 2016, down to around 3 g NO_x per kWh. These standards are expected to be met through technological advancements and combustion process optimisation (DieselNet, 2008).

Annex VI of MARPOL 73/78 also addresses ozone-depleting substances, including halons and CFCs. Ozone-depleting substances are now banned on all ships, except for new installations of hydro-CFCs which are permitted until 1 January 2020 (IMO, 2008).

Other environmental problems such as sewage have also been subject to regulation under MARPOL 73/78.[56] Annex IV (as reformed in 2004) prohibits old ships from discharging sewage close to land and mandates port facilities for sewage treatment. It also requires new ships to be equipped with sewage treatment facilities aboard or a special tank system. In September 2008, these rules became binding. The IMO has also become a forum for debates on the problem of invasive species carried mainly through ballast water. The International Convention for the Control and Management of Ships' Ballast Water and Sediments has been negotiated under the auspices of the organisation. In November 2009, this Convention required 12 more ratifications to enter into force.[57] It contains the general obligation in Article 2 to "undertake to give full and complete effect to the provisions of this Convention and the annex thereto *in order to prevent, minimize and ultimately eliminate the transfer of Harmful Aquatic Organisms and Pathogens* through the control and management of ships' Ballast Water and Sediments" (emphasis added).[58]

Regional seas agreements

Various regions of the world have adopted agreements designed to protect the regional marine environment, and these agreements provide a further opportunity to regulate maritime transport in those areas. The OSPAR Convention, signed in 1992 and entering into force in 1998, sets out a strategy on (*i.a.*) the discharge and emission of hazardous substances in the North-East Atlantic Ocean.[59] The Convention strategy aims to achieve a near-zero concentration of synthetic substances in the marine environment, and close to background values for naturally occurring substances, by 2020. To that end, the OSPAR Commission maintains a *List of Chemicals for Priority Action*, as well as a *List of Substances of Possible Concern*. OSPAR's "sister agreement", the 1969 Bonn Agreement, establishes rules on surveillance of the North Sea for pollution from shipping, and requires information-sharing, joint clean-up operations, and research and development.[60] Under the work of the Bonn Agreement, oil slick pollution from marine transport has reduced by around 50% since 1990.[61]

The 1976 Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean contains a "Dumping Protocol"[62] aimed at combating pollution by dumping from ships and aircraft. Dumping of listed material is either outright prohibited, or permitted with certain authorisations. The Protocol applies to all ships and aircraft registered in a party's territory or flying its flag. The 1981 Lima Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific commits its parties to take all necessary measures to prevent, reduce and control pollution, particularly from vessels.[63] The 1983 Cartagena Convention includes similar obligations covering the wider Caribbean region,[64] while the 1985 Nairobi Convention covers the Indian Ocean adjacent to the East African states,[65] and the 2002 Antigua Convention (not yet in force) covers the North-East Pacific.[66] Such regional conventions provide important opportunities within international law to regulate the pollution caused by international shipping.

Trade law

As mentioned above in the context of international air transport, trade law provides the possibility of regulation for environmental purposes, under Article XX of GATT and Article XIV of GATS. Since much international trade in goods, and some movement of people, occurs by sea, the GATT/GATS exceptions present an opportunity for regulation under international law. Domestic governments could, for instance, take measures restricting the delivery of goods from ships that do not meet environmental standards on GHG, SO_x or NO_x emissions. Under the terms of GATT/GATS, the governments would need to ensure that the measures taken do not constitute arbitrary or unjustifiable discrimination between countries, nor a disguised restriction on international trade. International trade law also does not override other disciplines, so measures taken under GATT or GATS affecting maritime trade in goods must be compliant with any other relevant laws (such as UNCLOS, MARPOL 73/78 or other IMO conventions). Nevertheless, trade law does not necessarily represent as important a limit on environmental regulation as it is occasionally made out to be, and indeed it could provide an initial opportunity to frame protective measures.

WTO rules on subsidies, labelling and procurement all apply similarly in the present context of marine transport as for air transport, discussed earlier. Thus, there may be scope for domestic governments to encourage more environmentally friendly sea transport via the use of carefully implemented subsidies, labelling of goods delivered by standards-compliant vessels, or procurement preferences for cleaner shipping providers. However, as noted, the exact scope of this opportunity to regulate remains uncertain within WTO law.

Port states

Port state authority

UNCLOS affirms that "matters not regulated by this Convention continue to be governed by the rules and principles of general international law". As a result, new or separate conventions may give states the authority to apply new international environmental policies to vessels. Port states have a high degree of jurisdiction over visiting vessels, second only to the flag state. This is because ports/internal waters are considered to be integral parts of a nation's territory. One way that port states have used this jurisdiction to overcome the pre-eminence of the flag state is through regional memorandums of understanding (MOU). The prime example is the Paris MOU on Port State Control. These MOUs derive their authority from Articles 216, 218, 219, 220 and 226 of UNCLOS and require the parties to investigate a certain percentage of ships a year for compliance with UNCLOS and applicable rules and standards established through competent international organisations or general diplomatic conference. If the release of a vessel following such an investigation would present an unreasonable threat of damage to the marine environment, the ship can be detained for repairs or required to proceed to the nearest appropriate repair yard (usually in a state with lower costs).[67]

Ships in territorial waters

Sovereignty over the territorial sea is exercised subject to UNCLOS and to other rules of international law.[68] The primary constraint on state action is the right of innocent passage.[69] However, the right of innocent passage is limited in several ways. First, any act of wilful and serious pollution contrary to UNCLOS rebuts the presumption of innocent passage.[70] Second, the coastal state can prescribe laws (in conformity with UNCLOS and other rules of international law) regarding the preservation of the environment of the coastal state and the prevention, reduction and control of pollution thereof.[71] Where there are clear grounds that the vessel has violated these laws, the coastal state may undertake physical investigation of the vessel and may institute proceedings.[72]

The end port state may also undertake an investigation of the suspected vessel upon request.[73]

The UNCLOS definition of pollution may limit or enhance the ability of states to prescribe and enforce national laws under the Convention, as it only regulates pollution of the marine environment. Specifically: "the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in… deleterious effects…"[74] Although it was initially seen by the maritime states as impeding coastal/port state excesses relating to enforcement, the Convention subjects much of Part XII (Marine Pollution) to a binding dispute-settlement mechanism under Part XV (ITLOS). This may present opportunities for vigorous enforcement if a state is clearly within its rights. In conclusion, one can summarise: "The LOSC avoided enumerating new standards for particular forms of pollution. Instead, it proclaims a general regime of powers and duties which builds upon the codification and development of existing and future pollution control conventions. Thus, the LOSC incorporates by reference those existing as well as future instruments to be adopted under IMO auspices. In this regard, the convention is riddled with terms of reference such as 'applicable international rules and standards', 'internationally-agreed rules', 'international rules', and 'generally accepted international rules and standards'. These rules of reference have the advantage of automatically incorporating the technical standards set by IMO as these are continuously adopted and amended to keep up with changing circumstances" (Khee-Jin Tan, 2006, p. 195).

10.5. International land transport

Road transport

While international agreements such as the Kyoto Protocol clearly affect road transport pollution via GHG emissions from vehicles, international law does not contain any specific agreements or conventions relating to road transport pollution. Rather, it is generally regulated at lower levels of government, such as the City of London's Low Emission Zone.[75] The main legal instruments to regulate road transport are the Convention on Road Traffic of 19 September 1949 and the Convention on Road Traffic of 8 November 1968. Both were adopted within the UNECE, though as of May 2008, ratification had broadened considerably, to 93 and 68 states respectively.[76] These international road transport instruments contain mainly security-related provisions (although recent amendments, introducing bike lanes, could be seen as a way of regulating environmental questions). The UNECE lists as future challenges for the transport sector, noting that in the foreseeable future, the transport sector will continue to face the following main challenges: "a continuous increase in the consumption of fossil fuels and related CO_2 emissions, which will result in an increased contribution to climate change; […] and old, unsafe and highly polluting road vehicle fleets, particularly in eastern and South-eastern Europe, as well as in the Caucasus and central Asia, which result in higher accident rates and environmental impacts."[77] However, besides vehicle standards, no international agreements to address these challenges have yet been adopted.

Recognising that 44% of its goods are moved by road, and that 84% of CO_2 emissions attributable to transport are due to road transport (European Commission, 2001), the EU has made various proposals including harmonising driving times and fuel taxes, producing uniform road transport legislation, and implementing "Euro" standards on NO_x emissions and particulate matter. The Euro VI standards would reduce NO_x emissions by 80% (down to 0.4 g NO_x per kWh) compared with Euro V standards, bringing the EU into closer alignment with US vehicle standards by 2013 (European Commission, 2007). In addition, the "Greening Transport Package" adopted in July 2008 provides a range of measures aimed at better road transport efficiency, further internalisation of the costs of congestion and pollution, and measures to address noise pollution (European Commission, 2008).

There is thus much opportunity for international law to address issues related to international road transport pollution. Harmonisation of emissions-standards for new vehicles is one area of potential that could support international trade in vehicles themselves by removing the technical barrier of a multiplicity of standards, while also serving to impose limits on NO_x pollution and GHG emissions.

Rail transport

International rail transport has thus far only received international legislative attention as to its feasibility, mostly on a regional basis. The *Convention relative aux transports internationaux ferroviaires*[78] concerns international carriage by rail. Its main aim is to facilitate rail transport by train of passengers and goods. Some 42 states from Europe, North Africa and the Middle East have ratified the Convention. It has adopted the Protocol of

Vilnius in 1999, which entered into force in 2006, and which contained *Regulation Concerning the International Carriage of Dangerous Goods by Rail* (RID – Appendix C to the Convention) concerning dangerous goods transport.

The relevant industry organisation, the International Union of Railways (UIC), is also studying the impact of rail transport on the environment with studies on for example noise, diesel emission, energy efficiency, climate change and eco-procurement.[79]

10.6. Other international legal regimes

The negative environmental impacts of transport can arise not only from the emissions by the transporting vehicle of harmful substances, such as GHGs, NO_x or SO_x, but also from risks posed by the goods themselves being transported. International law thus provides mechanisms to regulate the transport of hazardous goods in an effort to avoid negative environmental impacts that might occur if the goods are inadequately prepared for transport, or if an accident occurs as the goods are released. One major instrument in this regard is the Rotterdam Convention, adopted in 1998 and entering into force in 2004.[80] The Convention, with 128 parties as of May 2009, establishes a prior informed consent (PIC) procedure for the import of a wide range of hazardous chemicals. The procedure requires parties to determine, for each chemical listed in Annex III of the Convention, whether they will permit the transport of the chemical into or out of their territory. Information provision is a key element of the Convention, and a Decision Guidance Document, with information on the Annex III chemical and its effects, is distributed to all parties to assist their decision. Where a decision is made to allow export or import of chemicals, all other parties must be informed, and certain labelling requirements must be met. Exporting countries must ensure that an export does not contravene the importing country's decision under the PIC procedure. New chemicals can be submitted for inclusion in Annex III by two parties from two of the seven different geographical regions established by the Convention.

The Rotterdam Convention thus provides an opportunity to regulate the potentially detrimental environmental impacts of both the transport and use of hazardous chemicals.

The UNFCCC also aims to regulate all GHG emissions and thus is in general also applicable to emissions from global transport. However, the Kyoto Protocol only mentions the transport sector as a general obligation of Annex I parties to adopt: "*vii)* Measures to limit and/or reduce emissions of greenhouse gases not controlled by the Montreal Protocol in the transport sector" [Article 2.1.*a)vii)*], and then mandates the IMO and the ICAO with combating GHG emissions in their fields: "The Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organization and the International Maritime Organization, respectively" (Article 2.2). It is not certain that a post-Kyoto agreement will task these organisations again with GHG reduction efforts, since the success has been fairly limited.

10.7. Conclusions

Possibilities exist in both the IMO and the ICAO to find new ways of regulating and reducing GHG emission. This could follow the (only partly successful) model of regulating NO_x and SO_x and noise emissions from air and sea transport, while land transport remains by comparison under-regulated in international law. Although international law in general does not exclude the possibility of unilateral action, it strongly encourages multilateral approaches. As detailed above, states have considerable freedom to regulate their own vessels and set the rules applicable in their own territory, particularly if they adopt non-discriminatory legislation.

Regional initiatives offer several successful models to debate, design and adopt innovative rules which later can find their way into global regimes. As shown in the instance of noise regulation for air transport, unilateral and/or regional approaches can serve as triggers for international or global discussions and regulations. Particularly with regards to climate change, this example could play an important role in the near future, when the EU will apply its ETS unilaterally to international air and potentially even sea transport.

While the focus in the past has often been on security of international transport in multilateral fora and instruments, a growing shift can be identified. States are moving towards addressing the environmental challenges posed by increased international transport. Two international organisations – the ICAO and the IMO – have been tasked with a strong role to address climate change and other environmental challenges arising from international transport. Further more detailed legal research is needed to identify existing rules that might require changes, and to analyse the potential for new rules and environmental instruments that could be likely to be adopted in these international regimes.

This chapter mentions only a few opportunities below the level of international laws. However, on a practical level, it should be noted that many further innovative instruments have potential as well. For instance, industry self-regulation and business associations have a large potential to encourage and test new ways to address environmental impacts from increased international transport.

Although international regimes on occasion act as constraints on governments' abilities to regulate activity that is harmful to the environment, the international law does provide many opportunities to adopt new instruments to regulate environmental impacts from increased international transport. Indeed, the global environment is waiting for international law to fill the gap that will be left by the Kyoto Protocol's effective end in 2012.

Notes

1. This chapter is an edited version of the paper *Policy Instruments to Limit Negative Environmental Impacts from Increased International Transport: Constraints and Opportunities in International Law*, written by Markus W. Gehring of the Centre for International Sustainable Development Law, Montreal, Canada, for the OECD/ITF Global Forum on Transport and Environment in a Globalising World, held in Guadalajara, Mexico, 10-12 November 2008 (*www.oecd.org/dataoecd/16/9/41579487.pdf*).
2. Markus W. Gehring thanks and acknowledges Gareth Price, CISDL, and Jarrod Hepburn, CISDL, for their many contributions to the research, writing and editing, and also thanks Prof. Richard Janda, McGill Law Faculty and Prof. Marie-Claire Cordonier Segger, CISDL for their insights. He also thanks Frederic Perron-Welch for his excellent research assistance.
3. See *www.icao.int/icao/en/env/aee.htm*; Full report online, *www.grida.no/climate/ipcc/aviation/index.htm*.
4. Miake-Lye *et al.*, 2000; CICERO, 2007, p. 21.
5. ICAO Council, 3 March 2005, Committee on Aviation Environmental Protection.
6. ICJ, Nicaragua Case (1986), p. 128. "The principle of respect for territorial sovereignty is also directly infringed by the unauthorised overflight of a state's territory…"
7. Chicago Convention (1944), Article 33.
8. US/EU Air Transport Agreement (2007) at Article 15(2).
9. Shaw (2003), p. 854. See Vienna Convention on the Law of Treaties (1969), Article 60(1).
10. See *http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:008:0003:0021:EN:PDF*.

11. Convention on International Civil Aviation, 1944, 15 U.N.T.S 29, Article 38.
12. *US v. Aluminium Co. of America* (1945).
13. WTO, *US – Gasoline* (1996).
14. WTO, *EC – Asbestos* (2001).
15. SCM Agreement (1995), Parts II and III.
16. Articles I:1 and III:4.
17. Articles II:1 and XVII:1.
18. Article 2.2.
19. Decision 2/CP.3 of the Conference of the Parties under the UNFCCC.
20. Australia Space Activity Act (2002). Australia, however, in a note to the Secretariat of the UN General Assembly Committee on the Peaceful Uses of Outer Space, stated that, despite the Act's amendments, there remained no definition of "outer space" in Australian domestic law.
21. ITU, Bogota Declaration (1977).
22. *www.virgingalactic.com*.
23. Virgin Galactic's space access system claims to be "radically different" and will use much less than this figure.
24. See UN Office for Outer Space Affairs, *www.unoosa.org/pdf/publications/STSPACE11E.pdf*
25. Refer to UNFCCC INC 2 Decision 9/2, COP Decision 4/CP.1, COP Decision 2/CP.3, referenced in IISD report of Norwegian non-UNFCCC Technical Workshop on Emissions from Aviation and Maritime Transport at *www.iisd.ca/YMB/SDOSL/*.
26. Article 2.2: "The Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organization and the International Maritime Organization, respectively."
27. *Convention on the International Maritime Organization*, Article 1(a).
28. *Ibid.*, Article 1(d).
29. *Ibid.*, Article 59.
30. *Ibid.*, Article 2.
31. United Nations Convention on the Law of the Seas (UNCLOS), available at *www.un.org/Depts/los/convention_agreements/texts/unclos/closindx.htm*.
32. COP (1997) MARPOL 73/78, Resolution 8.
33. IMO Resolution A.963(23), *IMO Policies and Practices Related to the Reduction of Greenhouse Gas Emissions from Ships* (2003), s. 1.
34. IMO, MEPC/Circ. 471, 29 July 2005.
35. IMO, MEPC 55/23, Annex 9.
36. This point was highly contested by developing nations (Brazil, China, India, Saudi Arabia, South Africa and Venezuela) based on common but differentiated responsibilities. See MEPC 57/WP.8, 2.2.
37. See MEPC 57/WP.8, Report of the Working Group on GHG Emissions from Ships, 2.1.
38. See MEPC 57/WP.8, Annex 1 for a list of short- and long-term measures proposed.
39. Draft TOR for the meeting, MEPC 57/WP.8, Annex 3.
40. *www.reuters.com/article/environmentNews/idUSL1639411220070416*.
41. *www.earthjustice.org/news/press/2008/earthjustice-will-sue-epa-to-reduce-global-warming-pollution-from-ships-and-aircraft.html*.
42. Consider the following UNCLOS provisions: Article 45 – Innocent Passage, Article 87 – Freedom of the High Seas, Article 91 – Nationality of Ships, Article 92 – Status of Ships, Article 94 – Duties of the Flag State.
43. Eivind Vagslid, IMO, in IISD (2007).

44. CICERO (2007), p. 12, and CE Delft *et al.* (2006), p. 246.
45. IMO (2000), p. 136.
46. IMO (2000), pp. 141-147.
47. IMO (2000), p. 149.
48. See IMO (2000), pp. 150-162 for an in-depth discussion of each possibility.
49. Kågeson (2009) presents an opposing view.
50. IMO (2000), p. 168.
51. CICERO (2007), p. 1.
52. See *www.imo.org/Conventions/contents.asp?doc_id=678&topic_id=258*.
53. See *www.imo.org/Newsroom/mainframe.asp?topic_id=1709&doc_id=10262*.
54. See *http://safemedproject.org/filebank/documents/task37O/Consolidated_Final_Report_(E).pdf*.
55. See *www.epa.gov/oms/regs/nonroad/marine/ci/420f09015.htm*. The proposal was approved at MEPC 59, 13-17 July 2009.
56. MARPOL 73/78, Annex IV: Prevention of pollution by sewage from ships.
57. IMO, Status of Ratification of IMO Conventions: *www.imo.org/Conventions/mainframe.asp?topic_id=247*.
58. See TEMATEA for more information on invasive species and related conventions: *www.tematea.org*.
59. *www.ospar.org*.
60. *www.bonnagreement.org*.
61. *www.bonnagreement.org/eng/html/Briefing_document/Briefing%20document.htm*.
62. The Protocol for the Prevention and Elimination of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft.
63. Articles 3 and 4.
64. Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region, Articles 4, 5 and 6.
65. Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region, Articles 4, 5 and 6.
66. Convention for Cooperation in the Protection and Sustainable Development of the Marine and Coastal Environment of the North-East Pacific, Articles 5 and 6.
67. *UNCLOS*, Article 226.1(c).
68. *UNCLOS*, Article 2.3.
69. *UNCLOS*, Article 17. Remember that a distinction exists between coastal states and port states.
70. *UNCLOS*, Article 19.2(h).
71. *UNCLOS*, Article 21.1(f).
72. *UNCLOS*, Article 220.2.
73. *UNCLOS*, Article 218.3.
74. *UNCLOS*, Article 1.1(4).
75. *www.london.gov.uk/mayor/environment/air_quality/lez.jsp*.
76. See UNECE Transport Division, *www.unece.org/trans/conventn/legalinst.html*.
77. UNECE Transport Division, *www.unece.org/trans/presentTransDiv.html*.
78. See Intergovernmental Organisation for International Carriage by Rail, *www.otif.org*.
79. See *www.uic.asso.fr/environnement/spip.php?page=sommaire*.
80. Rotterdam Convention Secretariat, *www.pic.int*.

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