Impacts of energy use on demand for freight transport: past development and future perspectives

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Keywords

freight transport, maritime freight, decoupling of economic activity and freight transport, energy use, fossil fuels, renewable energy

Abstract

Decoupling of transport and economic growth has gained some significance as a political and scientific issue. Yet there are substantial doubts as to whether it may become a reality. Putting decoupling of freight transport into practice requires to take a closer look at what is being transported for what reasons. The potential for decoupling may vary substantially depending on the kinds of goods considered.

Transportation is extremely dependent on fossil fuels, namely on oil. At the same time most energy use requires transporting fossil fuels from deposits to the places of use. The share of fossil fuels still makes up more than 50 per cent of global transport activity in maritime freight. The absolute volumes have constantly been growing since the end of the second rise in the oil price. Besides volume of energy use, transport of fuels is primarily determined by the location of supply and demand and the kind of primary energy used. Fossil fuels often have to be transported over enormous distances while in many cases renewable energies like the wind or solar radiation are just there.

This contribution takes stock of the relationship between energy use and freight transport. Moreover, it deals with potential future changes in the supply and demand of energy and likely impacts on related transport activity. It takes a look at potential repercussions of business-as-usual-like developments in the demand and supply of fossil fuels as well as a shift towards a higher share of renewable primary energy on demand for freight transport.

Introduction

Decoupling of freight transport and economic growth, or generally economic activity or welfare has become a scientific (Pastowski 1997) and political issue (see also Stead and Bannister 2003). The primary reason for this is that the variety of undesired side effects of transport in terms of its environmental and social costs can not sufficiently be dealt with simply by applying the latest available technology to vehicles and infrastructure. Notwithstanding this, regarding traditional air pollutants and safety of passengers in cars significant progress has been made during the last decades in reducing those undesired impacts. This refers primarily to the situation in highly motorised industrial countries which have pushed technology further ahead and have devoted substantial effort to bringing latest technology to their vehicle fleets. It appears to be that much of that technical progress, even though with some time lag, will also penetrate vehicle fleets in countries with economies in transition and developing countries.

Unfortunately, the scope of those smart technologies lacks to bring about progress in terms of all negative environmental and social impacts. This, besides other externalities and the transport sector's appetite also for other natural resources than fossil fuels, particularly refers to emissions of greenhouse gases (GHG). Introducing the hydrogen economy in the transport sector as a means for making its energy use sustainable still needs to be regarded as science fiction when it comes to making substantial contributions to reducing GHG

emissions from transportation in the short and medium run. Other, off the shelf technological improvements in energy efficiency of cars like downsizing and related reductions in vehicle weight and performance still do not fit the preferences of many consumers and, therefore, lack political support in highly motorised countries. With aviation there is a mode of transport that offers enormous potential for further growth, given its increasing affordability for a growing number of consumers and the very limited volume of time that needs to be sacrificed for covering large geographic distances (Pastowski 2003).

As a result of this and the increasing motorisation in many countries with economies in transition and developing countries, emissions of GHG from the transport sector are on the rise in nearly all regions of the world. However not all such emissions from transport are allocated to the polluters: GHG emissions from international aviation and maritime shipping are not treated under the Kyoto-Protocol and those that stem from upstream operations and transportation of fossil fuels are partly allocated to the exporting countries (Bosi and Riey 2002). A sometimes overlooked portion of those emissions stems from freight transport. Freight transport is in general more energy efficient both in terms of vehicles deployed and operational practices than most motorised passenger transport. The reason for this is that for the most of it freight transport users and the final consumers are interested in high reliability, modest speed and low cost. This results in a higher emphasis on energy efficiency of vehicles and overall operation. While the modes of freight transport that allow for larger transport volumes per vehicle deployed are economically more efficient and in many cases also more environmentally sound, the potential of shifting demand is relatively small (Dalkmann 2002). Owing to the substantial growth in demand for freight transport and more limited remaining potentials for improved technical and operational efficiency than in private passenger transportation significant reductions in GHG emissions will require to take a closer look at options that allow for less demand for freight transport without sacrificing economic growth and welfare. What follows will shed some light on freight transport and how decoupling may play out for a particular group of goods.

Unfortunately, a reduction in demand for passenger and freight transport or even its relative growth is not regarded feasible by the majority of the public, many transport scientists and economists without sacrificing economic growth and well-being. Moreover empirical evidence does not support the hypothesis of breaking the link between economic development and demand for freight transport. Therefore, many politicians are reluctant to take the issue seriously. This is even worse for freight transport than for passenger transport owing to the consumptive character of a substantial portion of passenger transport as opposed to the close relationship between all freight transport and the production and distribution of goods and services. Freight transport is often perceived of as a limitational production factor that is essential for the economy to work. While economic processes in a spatially dispersed economy will not work without some volume of freight transport, what follows suggests that significant reductions in demand for freight are conceivable.

Analytically, strategies for decoupling freight transport activity from the increase in economic activity may address the volume of overall shipments in tons, the length of the distances covered in kilometres or both of them simultaneously. Decoupling in freight transport may thus focus on the following strategies (see also Jänicke et al. 1993, Bradel 1995, Bleijenberg 1996, Pastowski 1997):

- Reducing the number of spatially separated production stages and increasing the share of supplied parts for production and of products for end use which are produced locally or regionally (the tons and the kilometres);
- Decreasing the volume of materials which circulate in the economy per unit of physical product (the tons) through miniaturisation; and
- Substituting transfer of information for transport of physical products (the tons).

Interestingly, some of these options appear to be related to rendering the economy more environmentally sound in general. With regard to foodstuffs spatial proximity of production and consumption may also increase the consumers' trust in the quality of products. Often, even for relatively simple products like a yoghurt the spatial complexity is enormous and the distances that need to be overcome for the distribution of ingredients and the final product are far beyond any expectation of the consumers (Boege 1995). In case of animals for slaughter as well as fresh fruit and vegetables the inverse relationship between transport distance and product quality has been demonstrated. The second and the third option are identical with the general objective to reduce the material intensity of the economy in order to make the utilisation of natural resources more sustainable. However it is clear, that there may also be cases where a reduction of freight transport may result in unwanted environmental and economic trade-offs. Therefore, it is essential to focus decoupling strategies on those options that go hand in hand with other strategies for sustainability and to keep an eye on potential undesired economic side-effects.

The limitations of current freight transport trends—amongst other effects—become visible through its seemingly unlimited appetite for fossil energy and the related growth in emissions of GHG. On the contrary we will soon switch the perspective to:

- How energy use in all sectors of the economy influences demand for freight transport;
- How future developments in the supply and demand of fossil energy may impact on related freight transport; and
- How major changes in energy use may contribute to a decoupling of economic development and freight transport.

Notwithstanding the trend of an increased international division of labour that may bring about additional demand for freight transport a significant fraction of it is about transporting fossil fuels. Even though the share of fossil fuels in freight transport substantially varies by mode considered, it still makes up a major fraction of overall freight transport. Therefore it makes sense to take a closer look at how much freight transport is related to energy use and how likely trends may impact on the both. Moreover we may gain important insights into the transport implications of switching energy use to growing shares of renewable energies.

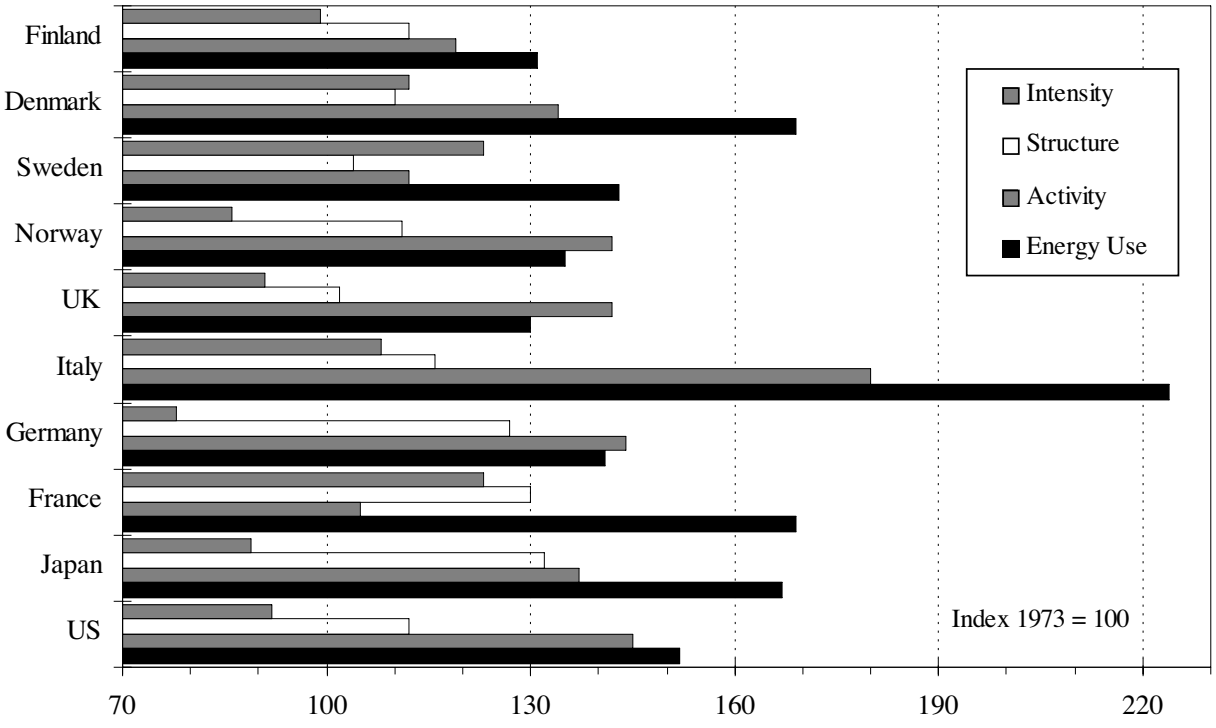
There are growing doubts from geologists as to the possibility of a continuing match of the growing global demand for fossil fuels and related production capacities in the future. This controversial discussion on the existence and timing of a peak namely in oil production but also for other fossil fuels (see Campbell and Laherrére 1998) is a serious issue that is also significant for the extent of transporting those energy carriers. However what follows will not refer to this discussion but instead will assume the relatively optimistic view of the International Energy Agency on the future supply of oil and other fossil fuels as an analytical basis. Notwithstanding this, it is obvious that serious problems in meeting the perceived growing global demand for energy by supply of fossil energy carriers would have substantial repercussions also on the volume of related freight transport.

Reasons and potentials for decoupling of freight transport

With regard to many environmental and social impacts growth in freight transport counteracts achievements made by deploying latest technology and state of the art operational practices not only in the freight transport sector but also efforts made in other sectors for reducing such externalities. Without curbing at least a portion of that growth it appears to be particularly unlikely to make any substantial contribution to reducing the human impact on the global climate caused by emissions of CO_2.

It has been found that the increase in demand for freight transport was the most important single driver for growth in related energy use and GHG emissions (Schipper et al. 1997). Freight energy use has grown substantially in all the countries during the period considered (see Figure 1). The indices reveal the relative growth in overall freight energy use and the relative contributions of its main driving forces. Activity refers to changes in ton-kilometres, structure to the shares of transport modes used, and intensity to energy efficiency in terms of technical features of vehicles and operational practices. The relative changes in activity, structure and intensity show how overall freight energy use would have changed compared to the base year resulting from variations of the respective determinant if the other variables had remained unchanged.

Except for Sweden and France, growth of freight transport activity has been the most important single cause for increases in energy use for freight transport in most of the countries considered. Changing modal shares mostly in favour of less energy efficient road freight have also contributed to more freight energy use. Energy efficiency shows a diverse development. In the case of Norway, the UK, Germany, Japan and the US increases in energy efficiency in freight transport have to some extent offset changes in activity and structure. Moreover CO_2 emissions also vary according to the composition of fuels used for freight transport. This analysis reveals that demand for freight transport is the most important single driving force. This is even more important for maritime freight which was not included in the cited study. Large maritime vessels are the most efficient vehicles for freight transport in terms of energy use and related CO_2 emissions. This means that mitigation of emissions by deploying more efficient modes and technologies will not bring about any substantial effects for maritime freight. Mitigation of related CO_2 emissions will therefore primarily have to rely on options for reducing transport intensity.



Source: Based on data by Schipper et al. (1997).

Figure 1. *Influencing factors of freight energy use in selected industrialised countries (1973 to 1992).*

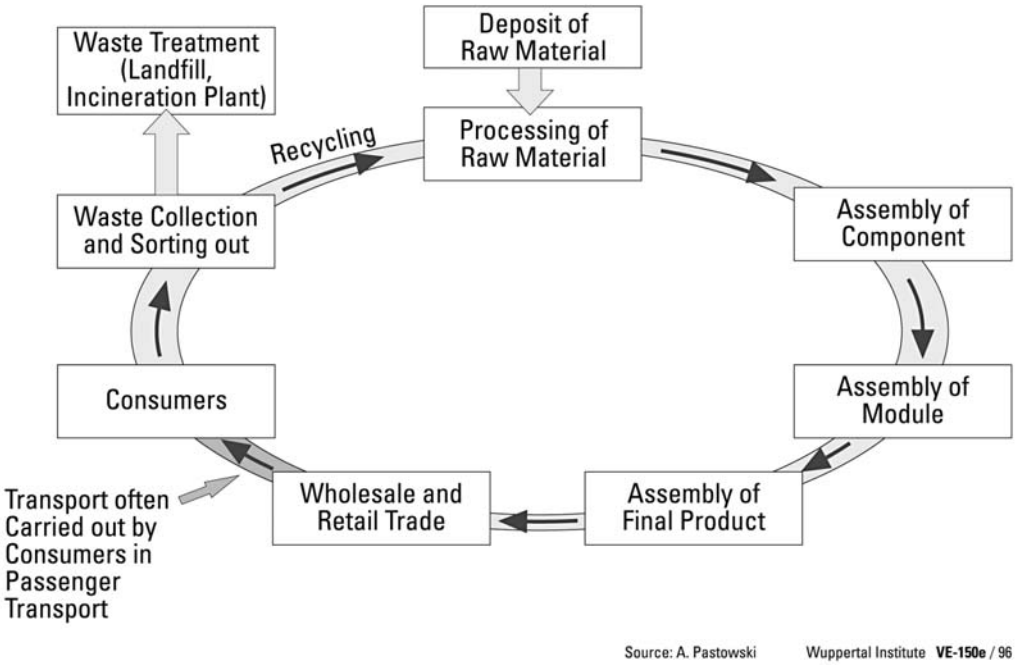


Figure 2. *Freight transport as a means for connecting the various stages of the economic process.*

Transport of freight is a derived demand which means that it is a consequence of decisions that are related to the consumption, production and distribution of goods or services (Cole 1987). Unlike passenger transport where people sometimes travel on a round trip for leisure purposes without a particular destination, there are hardly any examples that may compare in case of freight transport. One of the scarce exceptions are exotic goods where the distant origin is one of their most important features, like for instance drinking Mexican beer in stylish clubs in Europe (Pastowski 1997).

The issue of freight transport demand and the environment is closely related to the globalisation of economic activity. The intensification of the spatial division of labour—a process heavily speeded up by the industrial revolution and still going on under the headings outsourcing and globalisation—is an important determinant of freight transport activity. However, the relevant literature often provides a somewhat biased view on this relationship in that it is focused on the emergence of international industrial production networks which are highly transport intensive. Although such networks are of importance, their overall contribution to global demand for freight transport has remained more limited than previously expected. Thus it appears to be one of the remnants of the "new economy" hype that still exists, even though that bubble has by and large come to nothing.

In fact economic globalisation is not confined to liberalisation in the trade of goods and services but is also comprised of enhanced access for foreign direct investment (FDI). While both forms of economic integration require some volume of passenger transport their effects on freight transport are diverse. Trade in goods obviously is inconceivable without freight transport and, therefore, can be expected to fuel demand. On the contrary, FDI may have at least ambivalent effects. On the one hand, FDI is often used for improving access to regional markets in order to circumvent existing barriers to free trade or simply because emerging markets are expected to make up a substantial portion of future demand. Here, also proximity to major markets, transport cost and crowding out effects on the labour markets of traditional producing countries may play a role. In such cases economic integration may quite well bring about a decrease in overall transport intensity. On the other hand, FDI may be used in order to exploit international differences in labour costs by shifting labour-intensive stages of production to countries where wages are relatively low regardless where the final consumers of those goods are located. Other production factors like for instance cheap energy supply for energy intensive stages of production may have a similar effect. It is because of this diversity of motivations for FDI, why its overall effect on demand for freight transport can not easily be assessed.

Figure 2 shows how freight transport connects the various stages of the economic process (Pastowski 1997). Basically, the economic process as far as it is based on physical goods is about converting raw materials through more or less complex stages of production into goods for end use which are then distributed to the consumers. After use or having become worn those goods as well as residuals from the various production stages end up in land fills and incineration plants or, to a growing extent, are reintegrated into the production process through recycling.

It is clear that the horizontal and vertical differentiation varies widely according to the complexity of the product considered and the spatial structure of its production and consumption. The production of products like a car or a TV-set is typical for complex industrial production networks with several separated production stages the spatial structure of which is subject to industry specialisation and the above mentioned considerations. Opposed to this, fossil energy carriers—as far as those are used in combustion process-

es—are much less complex. They are recovered from deposits, shipped to processing plants like refineries and then distributed to the places where they are utilised. For oil-based fuels and gas there are hardly any remains which need to be transported after use. While for technically complex products there may be multiple shipments of the same materials this is much more limited for fossil fuels for combustion. Therefore the transport requirements for such fuels are fairly transparent and primarily determined by the volumes used and by the locations of extraction sites and users.

This means that freight transport of fossil fuels is simply governed by the geography of supply and demand. It is the changes in the volume of global demand for fossil fuels and in the location of major sources of supply and demand that determine how much freight transport is required. Once the decision has been taken to use fossil energy carriers that can not be supplied on a local or regional basis, this causes a related volume of freight transport activity as a derived demand. While fossil fuels are essential for energy use in most regions of the world, there has hardly been any recent significant liberalisation of trade in such fuels except for some increases in market integration of former COMECON producers that have resulted from the fall of the "iron curtain".

Trends in seaborne transport of fossil fuels

The global use of fossil fuels requires substantial volumes of freight transport activity. The main explaining factors for this are the growing volumes of fuels being used and the partly large geographic distances that need to be covered from the places of extraction to where the users are located. With the exception of aviation (only minor use of planes as tankers for military purposes) all modes of freight transport are deployed for making this happen: pipelines, maritime shipping, inland navigation, railways and road freight. Oil and gas make up nearly a hundred per cent of all goods shipped by pipelines. Even though the volume of drinking water supplied over pipes may be substantial, it is, however, not normally referred to as freight transport. The portion of fossil fuels in total maritime shipping is significantly smaller than for pipelines but is still substantial. For the other modes of transport the shares are even smaller because goods with a higher value added (e.g. high value manufactured goods) or a more dispersed spatial availability and higher sensitivity to transport cost (e.g. construction materials) make up a higher share in intra regional trade than in inter regional trade.

The following analysis is restricted in three ways:

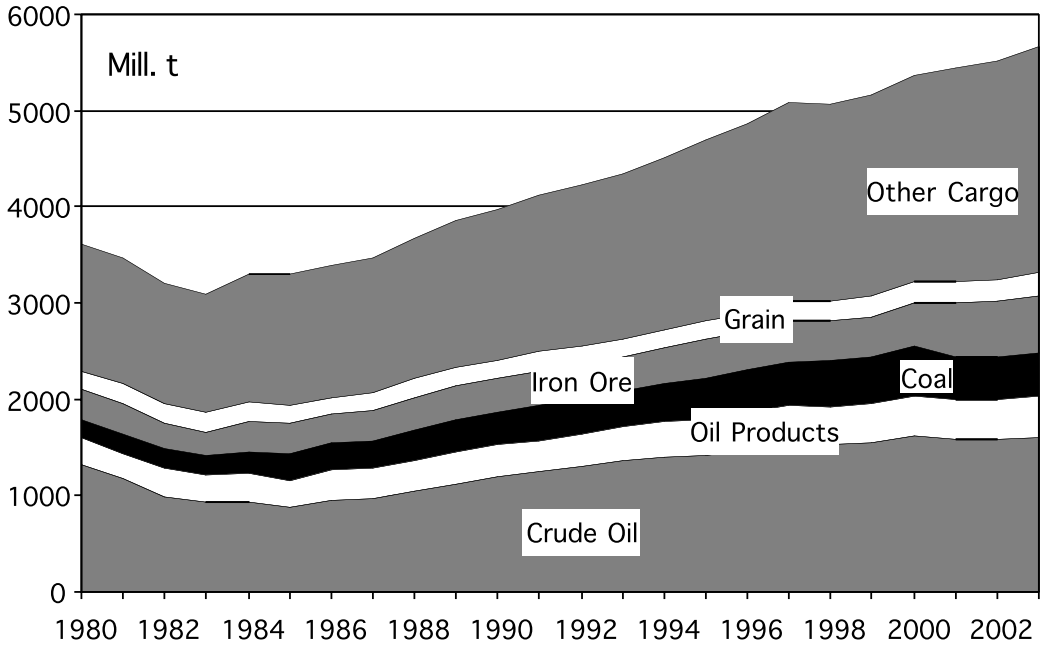
- The scope of freight transport modes and of fossil fuels covered is limited. For reasons of data availability it only deals with global maritime transport of fossil fuels. For that same reason the only fossil energy carriers considered are oil and coal.
- It is clear that most fossil fuels used also need to be transported by other modes of transport than maritime shipping. For coal, tonnage in seaborne transport accounted for 88.5 per cent of international trade in coal, while overland transport made up 11.5 per cent in 2003 (IEA 2004a). Thus seaborne transport captures the predominant share of all coal traded internationally. However for overland transport of oil, pipelines are also significant but not included here.
- Oil products are fully taken into account even though a certain fraction of those are not used as energy carriers but as supplies for the chemical industry etc. This also refers to the related volume of crude oil that is utilised for other than energetic purposes but is not separately treated here.

Taking a closer look at the development of the global volumes in tons of goods shipped by maritime vessels (see Figure 3) and related transport activity in ton-kilometres (see Figure 4) reveals that maritime transport of goods is highly dependent on both the business cycle and the oil price. Notwithstanding this, a long-term growth trend in maritime freight transport is clearly visible which was to be expected based on growth in global GDP and international trade. Moreover, the composition of global maritime freight transport in terms of the various groups of goods carried has changed significantly. The most profound change is the growing share of so-called 'other cargo' which has reached a stage where the name of this category no longer appears to be appropriate. Such a category would normally be reserved for a diversity of relatively insignificant groups of goods. Notwithstanding this, the combined share of crude oil, oil products and coal is still very substantial, perhaps more than one would expect having in mind the storyline of globalisation resulting in ever more complex international production networks. Instead it is clear in terms of energy use and no exaggeration in terms of seaborne trade that we are living in the fossil fuel era.

With the exception of a couple of years preceding the second rise in the oil price the total volume of goods carried by maritime vessels has constantly grown (see Figure 3). However that growth is not what might be expected from the increase in international trade. One important reason for this is that international trade is measured by value which means that stronger growth in trade of high valued but lighter goods results in a disproportionate (smaller) increase in tons shipped. Another reason is that a significant share of goods is traded regionally which does not at all require maritime shipping or only over relatively short distances.

Measured by tons carried in maritime shipping (see Figure 3) the three groups of goods crude oil, oil products and coal have grown substantially in absolute terms but their shares in the overall volume have somewhat shrunk. For the longer period from 1975 to 2003 total tonnage of crude oil, oil products and coal carried by maritime vessels grew by 53 per cent as compared to the average 86 per cent growth for all groups of goods (see Table 1). While tonnage of iron ore has also grown in absolute terms, grain has remained stagnant. A group of goods that was formerly designed as the residual category "other cargo" has shown the second steepest growth behind that of coal. Its volume increased by 132 per cent and its share in the overall volume of maritime freight transport went up from 33 per cent in 1975 to 42 per cent in 2003. It is comprised of many manufactured goods the share of which in world trade has increased substantially.

Notwithstanding the obvious decrease in relative importance during the period 1975 to 2003, in terms of volume



Based on data by Fearnley (2004)

Figure 3. *Volumes of goods carried by maritime shipping by group of goods (2002 and 2003 estimates).*

Table 1. Relative changes in the volumes and shares of groups of goods in maritime freight (1975-2003).

Per cent of tons	Crude Oil	Oil Products	Coal	Iron Ore	Grain	Other Cargo	Total Trade
Change 2003/1975	26,7	84,5	258,3	103,8	75,2	136,3	86,1
Share 1975	41,5	7,6	4,2	9,6	4,5	32,7	100,0
Share 2003	28,2	7,6	8,0	10,5	4,2	41,5	100,0

Based on data by Fearnley (2004); 2003 estimate.

carried, crude oil went up by 27 per cent, oil products by 85 per cent and coal by enormous 260 per cent which roughly is triple the average growth rate of all traded goods that were shipped by maritime vessels. While the volume of oil products grew at nearly the same rate as total seaborne trade, growth in crude oil was significantly below that figure and coal was well above it. In 2003, crude oil alone still made up 28 per cent as compared to 42 per cent in 1975, the share of oil products remained stagnant at around 8 per cent, while that of coal nearly doubled and reached 8 per cent. During that same period the combined share of these fossil fuels fell from 53 per cent to 44 per cent. While average growth of these groups of goods was well below that of all groups of goods, the 44 per cent share in 2003 still represents a major portion in the total volume of goods carried by maritime vessels. At the same time these figures are no proof that the evidenced trend towards a decreasing share of fossil fuels in the volume of seaborne trade will necessarily persist in the future.

Having analysed the changes in the volumes of goods in tons shipped by maritime transport, the next logical step is to take a closer look at freight transport activity of maritime shipping in ton kilometres by group of goods. While time series of maritime freight transport in tons only reflect the changes in volumes shipped, ton kilometres also include the changes in the distances that the goods are carried by seaborne trade. Figures 3 and 4 reveal relatively similar patterns regarding the shares of the various groups of goods and their changes over time for both tons and ton kilometres. At least at the first glance, this seems to render the whole exercise useless.

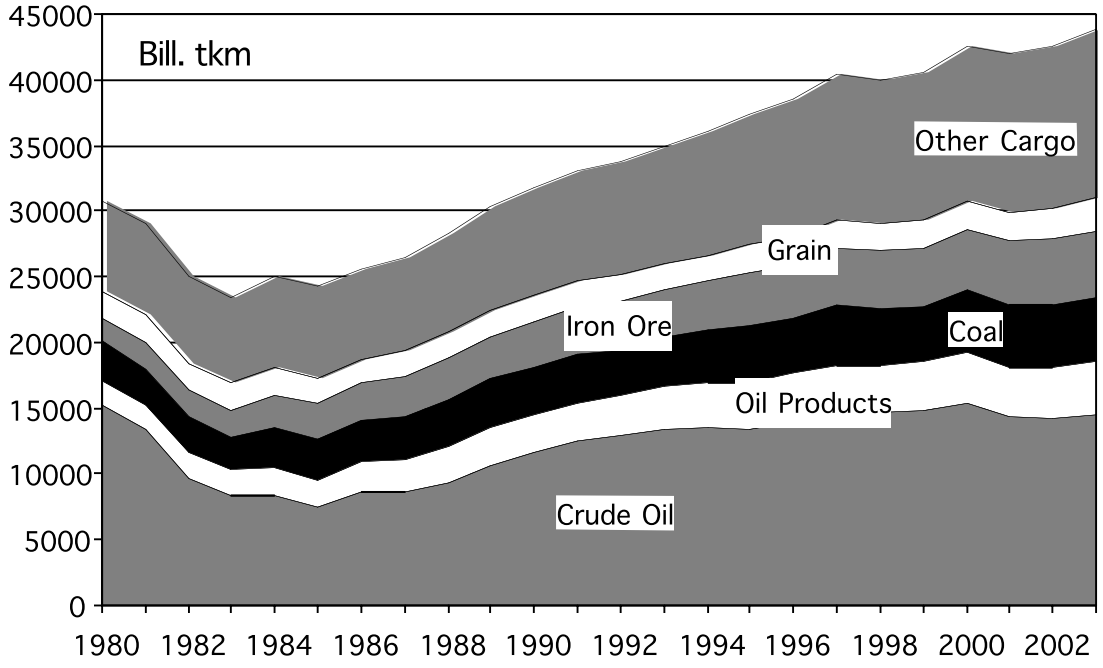
Taking a closer look at both Figures, however, shows that there are significant differences between the both that provide insights into the spatial patterns of transport of the respective groups of goods and how those have changed over time. Obviously, the share of other cargo and its growth is less profound for transport activity by maritime vessels than it is in terms of tons shipped. This suggests that manufactured goods on average are transported shorter distances in maritime freight transport than the other groups of goods. At the same time, the groups of goods crude oil, oil products and coal make up a larger portion of transport activity than of the volumes of goods shipped. This implies that these are shipped over distances that are well above all goods on average.

Similarly to the development in terms of volumes shipped, ton kilometres performed by maritime shipping (see Figure 4) of the three groups of goods crude oil, oil products and coal have grown in absolute terms but their shares in the overall volume have decreased. A visible difference is that even though its share is limited seaborne trade in iron ore has grown at a substantially higher rate in

Table 2. Relative changes in transport activity and shares of groups of goods in maritime freight (1975-2003).

Per cent of ton-km	Crude Oil	Oil Products	Coal	Iron Ore	Grain	Other Cargo	Total Trade
Change 2003/1975	-11,8	159,2	76,1	346,9	83,9	147,3	54,2
Share 1975	57,8	5,5	9,6	4,0	4,8	18,3	100,0
Share 2003	33,1	9,2	10,9	11,7	5,7	29,3	100,0

Based on data by Fearnley (2004); 2003 estimate.



Based on data by Fearnley (2004)

Figure 4. *Transport activity of goods carried by maritime shipping by group of goods (2002 and 2003 estimates).*

terms of ton kilometres that in terms of volume in tons. Obviously, iron ore is transported over increasing distances. Another evident difference is that the growth of the category "other goods" has been much less pronounced in terms of ton kilometres than in terms of tons shipped. Seemingly, trade in these goods displays more of a regional spatial pattern. This is in line with the above mentioned ambiguity of economic integration in the case of manufactured goods that may play out as increased trade but also as increased foreign direct investment with more production facilities that are closer to the centres of demand resulting in contradictory effects on demand for freight transport. This means that trade in manufactured articles is much more flexible than that in primary resources where the locations of supply and demand are often given via the places of deposits of the primary resources, the agglomerations of the human population and high incomes per capita. This results in a rather inelastic spatial determination of related demand for freight transport.

For the period from 1975 to 2003 total ton kilometres performed by maritime vessels increased by 54 per cent as compared to the growth by 86 per cent in terms of volume of goods in tons. This means that relative growth in volume has clearly outpaced that of transport activity. The reason for this is that a bigger share of the growth in world seaborne trade is between countries and regions that are sufficiently far away from each other to necessitate transport by maritime vessels but most of that trade is over medium distances. This challenges the general wisdom that transport cost and time have become obsolete as determinants of economic integration.

During the period from 1975 to 2003, combined transport activity in ton kilometres for crude oil, oil products and coal grew by 13 per cent well below the average 54 per cent growth for all groups of goods (see Table 2). Ton kilometres of iron ore have shown by far the highest growth reaching roughly 350 per cent. Taking account of the increase in tons shipped by around 100 per cent, this clearly hints at substantial changes in the spatial patterns of world trade in iron ore that have resulted in a sharp increase of the distances that iron ore is transported by maritime vessels. The growth in ton kilometres performed for trade in grain has clearly outpaced that of total trade and lifted its share from around 5 to 6 per cent. Other cargo has shown the third steepest growth behind that of iron ore and oil products. Ton kilometres for other cargo have increased by 147 per cent and its share in overall transport activity of maritime shipping went up from 18 per cent in 1975 to 29 per cent in 2003.

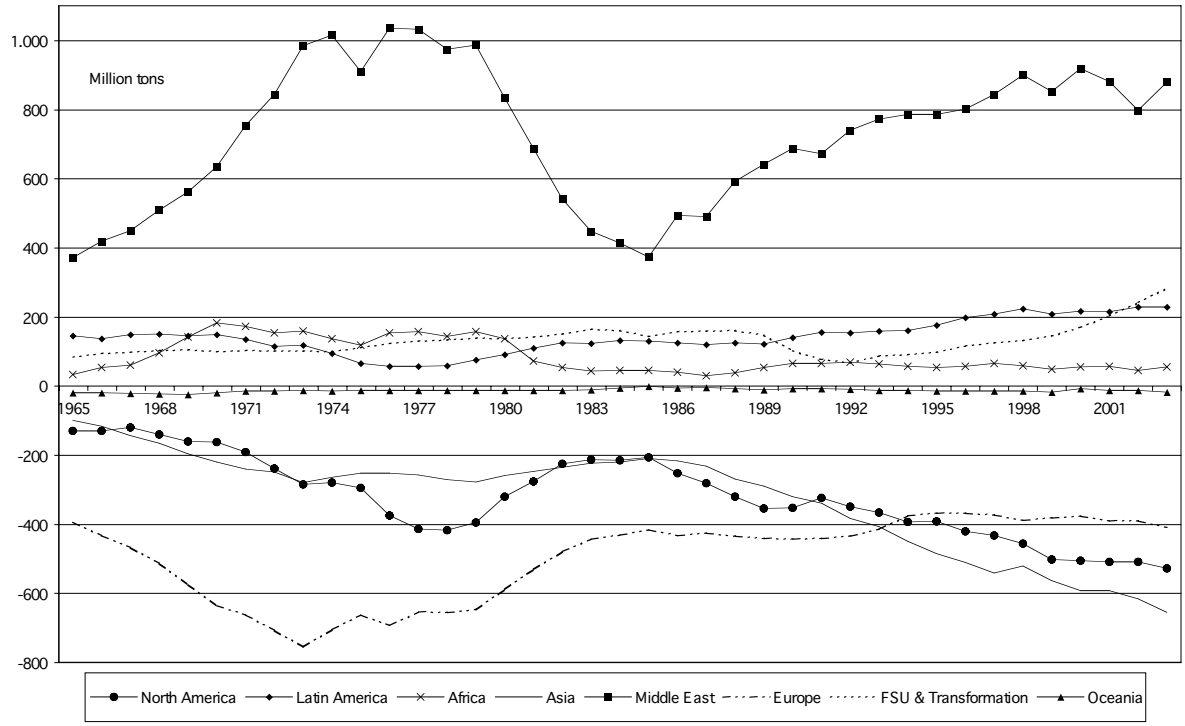
During that same period the combined share of the considered fossil fuels fell from 73 per cent to 53 per cent which means that those still account for more than half of all maritime freight transport activity. In terms of ton kilometres

performed, crude oil went down by 12 per cent, oil products rose by 159 per cent and coal by 76 per cent. While the ton kilometres performed for oil products grew well above total seaborne trade, crude oil was the only group of goods that decreased in terms of ton kilometres. Growth of ton kilometres for coal was more pronounced than growth of total seaborne trade. In 2003, crude oil still made up 33 per cent as compared to 58 per cent in 1975, the share of oil products increased from 6 per cent to 9 per cent, while that of coal slightly rose from 10 per cent to 11 per cent. It may be surprising to recognize that the considered fossil fuels still make up more than half of all ton kilometres in global maritime freight transport. It is also striking that even though tonnage of crude oil in seaborne trade went up by 27 per cent from 1975 to 2003 it dropped by 12 per cent in terms of ton kilometres performed. This clearly suggests that major changes in the spatial patterns of supply and demand must have occurred during that period. It is, therefore, worthwhile to take a closer look at how patterns of inter regional trade in the considered fossil fuels have changed.

Fossil fuels still make up a big portion of all maritime freight transport measured both by volume in tons and by transport activity in ton-kilometres. Even though growth in seaborne transport of the category "other goods" which to a large extent is comprised of manufactured items was more profound during the last decades, carriage of fossil fuels has significantly grown in absolute terms. This means that global energy use substantially contributes to the overall growth in demand for maritime freight transport. Obviously, for global maritime freight transport both the growth in volume and changes in the spatial patterns of supply and demand of fossil fuels are important determinants. Increasing volumes of fossil fuels that need to be transported by maritime vessels result from growth in the global population and GDP per capita which increase demand for energy carriers. As long as no alternatives exist, this translates into growing demand for fossil fuels. A change in the spatial pattern of world oil supply is already evidenced by the fact that the decrease in the share of overall maritime freight transport activity (tkm) was more profound than it was in the portion of volume shipped (t). Therefore it makes sense to take a closer look at inter regional trade in fossil fuels which may shed some light on the changes in the spatial patterns of seaborne trade of fossil fuels. Besides, future expectations with regard to the location of major sources of supply may provide insights into how such changes may further influence maritime freight transport.

Trends in inter regional trade of crude oil and coal

As was already mentioned, nearly all use of fossil fuels requires some demand for freight transport of the various modes available. However, in terms of freight transport of fossil fuels by sea, the utilisation of fossil fuels is not relevant in general. As far as domestic or regional demand matches domestic or regional supply this will, if at all, only give rise to limited demand for seaborne freight transport. It is primarily the supply of fossil fuels through inter regional trade that is relevant for maritime freight transport of those fuels. In the past there have been two major variables that impacted on inter regional trade in oil and coal (see Figures 5 and 6) and related freight transport. These have been the overall increase in global demand for fossil fuels and the changing spatial match of production and consumption in the main consuming regions North America, Europe and, to



Based on data by BP (2004 and various other volumes)

Figure 5. *Net exports (+) or imports (-) of crude oil by world region.*

a growing extent, Asia. On the one hand, this has resulted in a growing need to import fossil fuels for the net importing countries and on the other hand in an increasing potential for regions with deposits of fossil fuels to become net exporters. It is self-explaining that the more fossil fuels are consumed and the less the consumers are able to rely on supply from regional production, the more freight transport is required in order to accommodate demand. This is in principle relevant for all fossil fuels, however it may somewhat differently play out for individual fossil fuels as for oil and coal considered here.

Taking a look at the development of net imports and net exports of crude oil reveals that the overall growth in demand did not result in unambiguous effects in terms of inter regional trade in crude oil (see Figure 5). For this purpose net imports and net exports by world region were determined by subtracting regional consumption from regional production using BP statistics on the both (BP 2004 and various other volumes). The result of this calculation is named net imports or net exports because exports and imports are most likely higher owing to market conditions and seasonal variations in supply and demand. The calculated volumes of inter regional trade thus are somewhat lower than in reality. Taking regionally aggregated trade statistics would provide somewhat different and maybe more precise results. However the calculated net trade based on statistics of production and consumption is a proxy that sufficiently reveals the underlying trends in total volume and spatial structure of inter regional trade in oil and coal.

At the aggregate global level one would expect regional net exports and net imports to be balanced except for some minor imbalances resulting from changes in storage. However, there is a growing discrepancy between global net imports and net exports by region in those statistics basically starting from the early eighties of the last century. As this is an increasing volume of excess demand over production it can not be explained by changes in storage. Persistently growing excess demand for oil can be found at the global level in the statistics since 1981 when it accounted for around 60 million tons reaching 215 million tons in 2002 representing 2 per cent and 6.3 per cent of global consumption respectively with some fluctuations in between. This can only be mentioned here in order to put the cited figures into perspective but without getting into the details. Notwithstanding this, for the purposes of this analysis the share of global excess demand for oil over production in the statistics is not that high and may be disregarded.

During the period from 1965 to 2003 inter regional net exports of crude oil of all world regions grew by 129 per cent from 634 to 1 450 million tons. During that same period net exports of crude oil from the Middle East grew by just 39 per cent. Obviously the volumes of crude oil in seaborne trade have remained well below global growth in trade. The reason for this is that there are significant portions of those traded volumes that are performed through increasingly dense networks of pipelines between neighbouring regions where maritime shipping is not required at all. Another important spatial effect was induced by the two rises in the oil price in the seventieth and early eighties of the last century. The second rise in the oil price reduced economic growth and world trade, demand for oil in general and in particular for crude oil from the Middle East. Both oil price rises stimulated exploration of new deposits and investment in new production facilities in countries and regions which up to that time had not been important oil producers, namely in Europe, Latin America and Africa. Besides the fall of the iron curtain has made the Former Soviet Union a more important net exporter of crude oil.

Figure 5 clearly reveals that the Middle East has played the role of a very flexible supplier. Its share in global net exports rose up to a maximum of 76 per cent in the mid 1970th but as a result of the two oil price rises dropped dramatically reaching its low at 54 per cent in 1985. After that the Middle East's share in global net exports of crude rose again accounting for 72 per cent in 1994 and dropped down to 61 per cent in 2003. Preceding the two oil price rises it were mainly increases in self sufficiency of crude oil consumption in North America, Asia and Europe that allowed to reduce imports from the Middle East. However increases in production and related reductions in imports in North America and Asia had a limited effect both in terms of reduced import volume and the time that intra regional production was not outpaced by demand. In both regions these efforts were only effective until 1985 when the long term trend of decreasing self sufficiency became dominant again.

In Europe the price induced increases in self sufficiency by exploration and production of crude mainly in the North Sea were more profound. While in the past Europe as a region accounted for the highest net import volumes that reached 754 million tons in 1973 it managed to permanently reduce net imports down to the lowest volume of 368 million tons in 1996. However Europe's efforts in increasing production were not sufficiently effective to overcompensate growing demand and the level of self sufficiency in terms of net import volumes of crude has been stagnating starting from 1994. Notwithstanding this, intra regional production was still sufficient to let Asia and North America become the regions with bigger volumes of net crude oil imports in 1993 and 1994 respectively. The only new net exporting regions with growing volumes that entered the scene starting from the 1990s were Latin America and the Former Soviet Union (FSU) and the other Transformation Countries. However, as compared to the Middle East, export volumes remained relatively low indicating that their contributions to global supply remain limited.

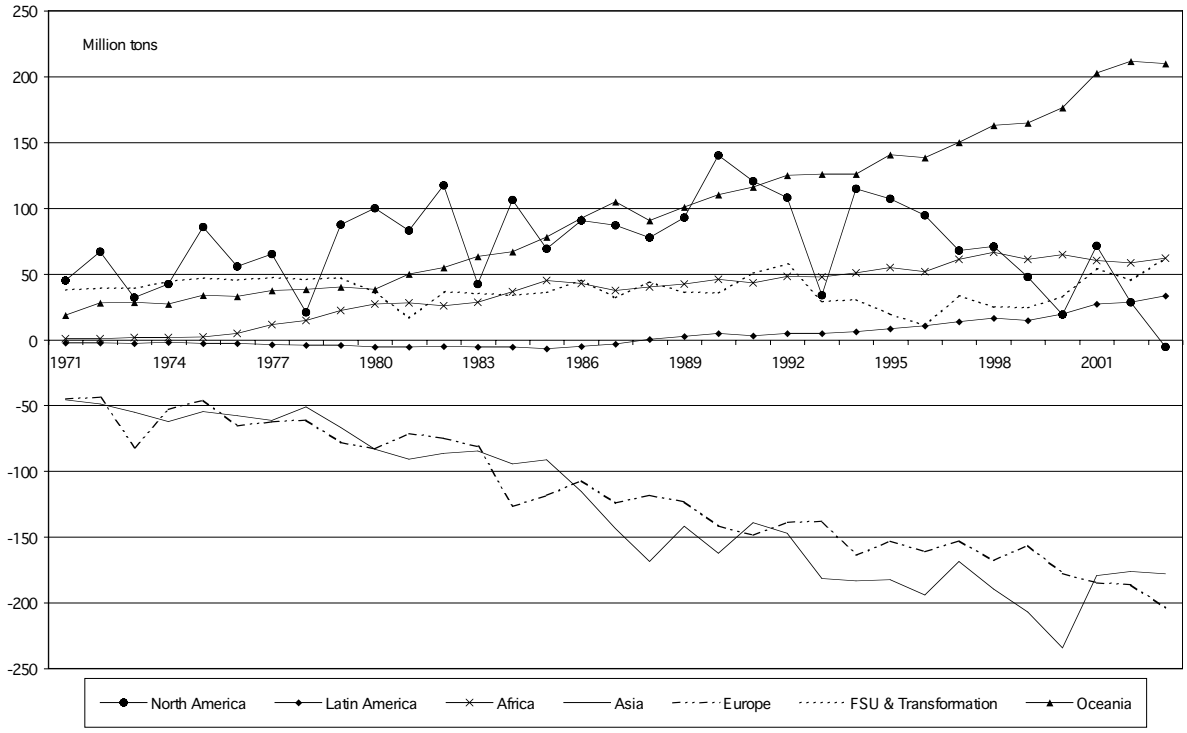
Taking a similar look at regional coal production, consumption and net trade (see Figure 6) provides a somewhat different picture than for oil. Net trade figures for coal were derived from consumption and production data from the International Energy Agency's statistical series "Coal Information" (IEA 2004b and various other volumes). As opposed to the above cited BP-data for oil there are only minor discrepancies between production and consumption figures for the combined major world regions at the aggregate global level that result from changes in inventories. Obviously, there are more persistent trends in the import and export structures and less fluctuations for coal than for oil. Generally, coal deposits have been more dispersed over the globe. Thus many regions are self sufficient in terms of their demand for coal and able to export varying quantities of coal. This is just the other way round for Europe and Asia which within the period considered have always been dependent on imports of

coal displaying fairly stable linear trends of growing coal imports. During the period from 1971 to 2003 inter regional net exports of coal of all world regions grew by 322 per cent from 102 to 328 million tons. During that same period net exports of coal from Oceania grew by 1 027 per cent making this region the by far most important exporter of coal. On the opposite there are Europe and Asia which have increasingly become dependent on imports. Africa as well as the FSU and the Transformation Countries have been net exporting regions during the period considered with a slight upward trend in export volumes during the last few years. North America has been an important exporter of coal but with a high volatility in the volume of exports and has recently turned into a net importing region.

Summing up the aforementioned, global oil consumption has increased substantially and the two peaks in nominal oil prices have resulted in efforts to increase regional self sufficiency where ever additional deposits of crude oil could be explored and exploited. At least for some time this has brought about a more dispersed global spatial production structure and has reduced the dependency on imports of crude oil from the Middle East. For coal there is also a steep upward trend in global consumption. The spatial pattern of coal production, however, has always been more dispersed than for oil. The question arises as to whether this development will persist in the future. For the future, the combination of increasing global demand and decreasing levels of self sufficiency in major consuming regions may quite well result in higher volumes of inter regional trade and, consequently, more seaborne trade of oil and coal. As forecasts of future supply suggest, such a development can be expected to be more pronounced for oil than for coal.

Further perspectives and conclusion

For both oil and coal it is rather likely that demand will further increase based on a growing global population, increasing incomes per capita and the spread of "western" lifestyles amongst new middle classes and new consumers namely in Asia but also other regions of the world (Myers and Kent 2003). From this perspective, further growth in global trade of oil and coal and, consequently, also in seaborne trade of the both fossil fuels are very likely. Whether or not it will be possible to accommodate the potential growth in global demand namely for oil is not the focus of this contribution. There are substantial doubts with regard to sufficient future production capacities of oil to meet the growing demand in the medium to long term owing to geological constraints. However there seem to be at least substantial deposits of coal that may even serve as a substitute for oil in the event that we may soon run out of sufficient oil supplies. Thus in a business-as-usual-scenario global energy use will most likely predominantly play out as growing use of fossil fuels and result in further growth of related trade and freight transport. Besides the growth in the global volume of demand, freight transport of fossil fuels will also be influenced by changes in the location of major producers and consumers or exporters and importers. The location of the producers is more or less given by the geological distribution of relevant deposits. The spatial distribution of production capacities can be influenced by fundamentally new production techniques like deep sea drilling that may help to overcome existing barriers of production or with regard to the path of exploitation by investment in new exploration and production facilities. The location of the consumers will result from changes in demographic and economic geogra-



Based on data by IEA (2004b)

Figure 6. *Net exports (+) or imports (-) of coal by world region.*

Table 3. Imports (-) and Exports (+) of oil and coal by world region or country.

Million tons OE	Oil			Coal		
	1970	2003	2030	1985	2003	2030
Other Countries	410	271	169	4	52	47
Middle East	636	880	2231			
FSU& Transformation	106	339	397	25	32	37
OECD America	-158	-422	-893	47	-23	18
OECD Pacific	-228	-373	-496	-17	-21	77
OECD Europe	-653	-452	-694	-69	-128	-242
China	3	-106	-471	4	43	98
India		-76	-243	-4	-13	-35
Total Imports	-1040	-1429	-2796	-90	-186	-277
Change /1970 /1985	0%	37%	169%	0%	107%	209%

Based on calculations by Bohnenschaefer et al. (2005), revised data for coal in OECD America in 1985.

phy as mentioned above and can not reasonably be influenced.

Given sufficient production capacity to meet global demand as expected by the IEA it can be assumed for oil that the dispersion of global oil production which resulted from the two rises in the oil price will gradually be reversed for most world regions. The Middle East will again become the dominant oil producing and exporting region of the world. There is no doubt that world coal reserves will be sufficient to meet any expected future demand until 2030 and beyond. Moreover coal reserves are widely dispersed (CIAB 2003) which means that most regions will be able to accommodate demand from intra regional production or by imports form neighbouring regions. Recent estimates for imports and exports of coal and oil (Bohnenschaefer et al. 2005) based on BP and IEA statistics provide a perspective on how the spatial patterns of world trade in oil and coal may develop up to 2030 (see Table 3).

For oil there is the expectation that the OECD member countries but also China and India will become substantially more dependent on imports of crude oil until 2030 as compared to 2003. Total trade in oil measured by volume of imports in oil equivalents is expected to nearly double from 1 429 million tons in 2003 to 2 796 million tons in 2030. This means that as compared to 1970 all imports of oil will rise by 170 per cent. Thus the increase in oil imports in the coming around thirty years will be by far more substantial than during the around last 30 years. The by far largest share of all oil imports in 2030 is assumed to come from the Middle East, while the FSU and Transformation Countries will export only slightly more. Exports of oil from other countries will shrink substantially. In terms of freight transport this means that not only the transport volume will nearly double, but also the average distance of oil shipments will rise owing to the growing spatial concentration of the remaining oil deposits mainly in the Middle East. Given the assumed business-as-usual-development in global energy use this will result in a disproportionately higher growth in freight transport activity for global oil consumption.

With regard to coal the relative growth in volume of global imports will lag behind that for oil. However, global imports of coal are expected to grow by around 49 per cent until 2030 as compared to 2003. As compared to oil there will be no significant spatial concentration of coal supplies for export. Rather coal deposits for export will be more geographically dispersed in 2030 than in 2003. The consequences of the assumed changes in coal trade are less significant than for oil. An increase of transport volume by 100 per cent can be expected owing to the growth in volume of trade. Seemingly coal supplies will be at least as geographically dispersed in 2030 as in 2003 or even more which means that the average distance of coal shipments will most likely remain stagnant.

Global consumption and trade of fossil fuels and namely oil and coal that were considered here still make up a major contribution to global demand for freight transport in particular by maritime vessels. Even though the shares of fossil fuels in trade and freight transport both in terms of volume (tons) and transport activity (ton-kilometres) have somewhat shrunk they have still grown substantially in absolute terms. Some of the shrinking in transport of oil has resulted from the two rises in the oil price and induced efforts for more geographically dispersed oil production. This development, however, will not be sustained in the future but we will see oil production for export concentrating in the Middle East again. Thus in a business-as-usual-scenario of global energy consumption not only the growth in volume of consumption and trade of oil and coal but also increasing average lengths of hauls for oil transport will cause substantial increases in freight transport for energy consumption.

Notwithstanding this, in principle, the energy sector offers enormous potential for decoupling economic development and freight transport activity. If fossil fuels became significantly more scarce and costly in the future or if the climate change issue would be taken more serious resulting in a reduction in the use of fossil fuels, then this would have important implications for freight transport that is related to energy use. As far as fossil energy use could be reduced by increased efficiency or local or regional use of renewable energy carriers this would simultaneously contribute to a decoupling of freight transport from economic growth. Solar radiation, the wind, geothermal energy, conventional hydropower and the oceans' waves come for free and do not need to be transported. As one or more of these sources of energy are available in many places on the globe within relatively short reach of human settlements, they do also offer a divi-

dend in terms of reduced transport of coal and oil and thus a lower freight transport intensity of human activity.

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