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Options for Reducing Logistics-related Emissions from Global Value Chains

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Abstract

The additional freight movement generated by the growth of world trade carries a significant environmental penalty. This paper examines the nature and scale of this penalty and assesses the opportunities for reducing it. It focuses on the various ways of cutting carbon emissions from international freight movement by sea and air. Assuming that the total value of trade continues to expand, efforts could be made to reduce the ratios of trade value to freight tonne-kms and tonne-kms to emissions. There is currently greater potential to depress the second of these ratios by deploying new transport technologies and operating practices. Many of the 'decarbonisation' measures will cut costs as well as carbon and be self-financing in the short- to medium-term. Internalisation of the environmental costs of international freight transport and / or the application of emissions trading would reinforce the adoption of these measures though the prospects of this happening in the foreseeable future seem limited.

Keywords

Global value chains, logistics, shipping, air cargo, carbon emissions, decarbonisation.

1. Introduction

The proliferation and extension of global value chains are generally seen being beneficial, supporting the growth of world trade and spreading economic development. The transfer of value along these chains, however, has a physical manifestation in the vast quantities of freight moved internationally in vehicles, vessels and aircraft that have a damaging effect on the environment.

Approximately 90% of this freight is moved by sea in what has traditionally been regarded as ‘the most environmentally-sound mode of transport’ (Bode *et al*, 2002). Shipping’s reputation as being an inherently green mode stems mainly from its relatively low energy consumption per tonne-km. Emissions from ships are also much less conspicuous than those of trucks and trains, unless you live and work in the vicinity of a major port. Ships are in fact a major source of air pollution which has adverse effects on human health and local ecosystems. This is because they burn mainly dirty bunker fuel, the tar-like, sulphur-rich residual fraction from the oil refining process. Corbett *et al* (2007) have estimated that around 60,000 people die prematurely each year as a result of inhaling particulate matter from the funnels of ships. Efforts to cut emissions from shipping date back to the 1970s, when the International Maritime Organisation (IMO) launched its MARPOL convention, though the rate of environmental improvement has been very slow, partly because of the difficulty of securing international agreement and enforcing tighter regulations. The establishment of Sulphur Emission Control Areas (SECAs) in several parts of the world, such as the Baltic, North Sea and West Coast of the US, is dramatically reducing emissions in these zones, but elsewhere shipping-induced air quality problems remain a serious problem.

Over the past decade, concern has also grown over shipping’s contribution to climate change. The two main modes of international transport, shipping and aviation, were excluded from the 1992 Kyoto Climate Change Agreement, partly because no officially-recognised means existed at the time for allocating their emissions among nation states. Operators of international transport services by sea and air were therefore excluded from the carbon reduction targets set for those countries covered by the Agreement. They are now being put under increasing pressure, particularly from the UN Framework Convention for Climate Change (UNFCCC) and European Commission, to decarbonize their operations. This is partly in response to mounting evidence that they are significant sources of CO₂ emissions.

The first, and so far only, attempt to carbon footprint logistics worldwide suggested that it accounted for around 5.5% of total greenhouse gas (GHG) emissions (World Economic Forum / Accenture, 2009). Freight transport was responsible for roughly 90% of these emissions with the remainder attributable to the ‘logistics buildings’, the warehouses and freight terminals where goods are stored and handled. The vast majority of these emissions were from freight movements confined to individual countries. Two-thirds of the transport emissions came from trucking, which is predominantly a domestic transport mode and whose cross-border flows account for only a small share of total activity. Shipping and aviation, the dominant modes of international freight movement, account respectively for 20% and 8%. It has been estimated by the IMO that shipping in total emits around 3% of man-made GHGs, 60% of it from container vessels, tankers and bulk carriers, which carry the majority of international maritime trade (Buhaug *et al*, 2009).

International freight transport may represent only a small fraction of total GHG emissions, but it accounts for a substantial proportion trade-related emissions. These trade-related emissions combine the embodied carbon in the products that are internationally-traded with the transport-related carbon emissions. Recent research by Cristea *et al* (2013) indicates that international freight transport represented, on average, a third of total trade-related carbon emissions in 2004, a fraction they find ‘surprisingly large’. They estimate that for the trade in products such as transport equipment, electronic equipment and machinery, transport emissions account for three-quarters of total trade-related emissions.

Projections of future trade growth are factored into forecasts of the future level of shipping and airfreight activity and related CO₂ emissions. Airbus (2013) and Boeing (2013) predict, respectively, 2.6-fold and 2.8-fold growth in air cargo tonne-kms between 2012-13 and 2031-32, while the Lloyds Register et al (2013) anticipate the tonnage of freight moved on 'major seaborne trade routes' increasing from 9 to 22 billion between 2010 and 2030. One study has suggested that CO₂ emissions from shipping could be 2.4 - 3.6 times higher by 2050, even allowing for an energy efficiency improvement per tonne-km of 33-50% over the intervening period (Committee on Climate Change, 2009). With national governments and the European Commission setting targets to reduce domestic CO₂ emissions by 60-80% by 2050, shipping and aviation's share of total emissions could rise substantially by then if no action is taken to constrain their growth.

This paper examines what can be done to restrain the growth of emissions from international freight transport. It begins by considering ways of easing the underlying growth of freight volumes, some of which might inhibit trade growth. Later sections assess the opportunities for reducing the carbon intensity of international freight movements, effectively decoupling tonne-km and CO₂ trends.

2. Restraining the Growth in Freight Volumes

In some future climate emergency, when survival of our civilization depends on the imposition of draconian measures to curb greenhouse emissions it may be necessary to force globalization into reverse and 'relocalise' economies. In the meantime, globalization forces may weaken as some companies 're-shore' or 'near-shore' their production operations for economic reasons. On the other hand, the outcome of the December 2013 WTO Ministerial meeting in Bali is forecast to add \$1 trillion to international trade volumes, mainly by facilitating the movement of freight across international frontiers (Hufbauer and Schott, 2013). The prospect of governments individually or collectively restraining the growth of trade for environmental reasons seems remote. This could, in the longer term, be the indirect consequence of a worldwide policy of internalizing the environmental costs of freight transport. Both international shipping and aviation have been in the enviable position of escaping the high levels of fuel duty imposed on trucking, and to a lesser extent railfreight operations, around the world, some of which recovers environmental costs. The IMO has examined the possible use of market-based instruments, either carbon taxes or emissions trading, to give shipping lines an incentive to improve their carbon efficiency. The International Monetary Fund (2011) has done the same for both shipping and aviation.

The European Commission has brought airfreight operations into the European Emissions Trading Scheme (ETS) and is also considering the inclusion of shipping. The carbon price would, however, have to be pitched at a much higher level than at present to have much effect on trade volumes. Some of this price would be absorbed by the shipping lines and their clients (i.e. the shippers or cargo owners) and some would be offset by efficiency improvements. The overall elasticity of trade volumes to transport-related carbon prices would probably be quite low, reflecting the fact that the fuel component in transport costs typically represents a small % of the value of the goods traded. For example, transporting a full load of 11,500 iPads in a 20ft container from Shanghai to North Germany costs approximately 8 Euro cents per iPad, around 0.03% of the average retail price. Fuel probably accounts for 30-40% of this transport cost. For more basic commodities, shipping costs are a much higher percentage of value, but still relatively insensitive to any carbon prices likely to be imposed in the foreseeable future.

Recent research by Tavasszy et al (2014) has measured the likely effect on international trade flows to and from the Netherlands of internalizing the environmental costs of the global supply chains for eight categories of product (dairy farming, pigs, food crops, oil, plastics, automotive, electronics and machinery). Their analysis, which included 29 types of GHG and non-GHG emissions from both production and transport operations, suggested that internalisation applied at a global level would depress international trade flows in 2040 by only 0.9% against a business-as-usual baseline and reduce

the annual container throughput at the port of Rotterdam by only 0.5%. This study suggests that international trade volumes would not only be relatively insensitive to full recovery through the tax system of the environmental costs of transport; extending the internalisation of externalities to production operations would also have little effect. Any effort to suppress international trade for environmental reasons would not only have adverse economic impacts, it might also prove counterproductive in carbon terms. Reducing the amount of freight transport does not necessarily cut total life-cycle emissions of traded products. Transport-related emissions typically represent a much smaller proportion of total life-cycle emissions than production operations. It is desirable, therefore, to locate these operations where the carbon intensity of production operations is low even if this means transporting goods longer distances to market. This was confirmed for the international trade in food products by Smith et al (2005) and illustrated by a comparative analysis of the life-cycle emissions of agricultural products consumed in the UK but sourced from either the UK or New Zealand. The amount of CO₂ emitted per tonne of dairy produce, lamb and apples supplied to the UK market was, respectively, 52%, 75% and 30% lower when sourced from New Zealand, despite the 18,000 km journey by refrigerated deep-sea container. This reflected the 'less intensive production system in NZ than the UK, with lower inputs including energy' (Saunders et al, 2006: vii). Using a partial equilibrium analysis, Cristea et al (2013) found that 31% of trade (by value) yielded a net reduction in carbon emissions when account was taken of the relative carbon intensity of production in the trading countries. Any attempt to constrain trade volumes for environmental reasons would therefore have to target flows of products whose total life cycle emissions were higher than those of equivalent goods produced locally in the consuming market.

Long before such a radical policy will be seriously entertained, other developments may have significantly 'dematerialized' international trade:

1. *Miniaturisation*: this is already well underway in the computing, electrical equipment and telecommunications sectors, in which products are shrinking while their functionality expands. Flat-screen televisions can have 20% of the cube and 25% of the weight of the cathode ray tube (CRT) equivalents that they have replaced. The substitution of tablet computers for laptops and desktops and replacement of several devices by a smart phone are similarly reducing the amount of material that needs to be transported.
2. *Digitisation*: media products such as books, magazines, software and entertainment are increasingly being distributed digitally rather than in physical form and this trend is set to continue. The supply chains for the paper, plastics and dyes used in the manufacture of the corresponding physical products are transport-intensive and could ultimately be eliminated.
3. *3D-Printing*: this technology can cut freight movement by replacing complex multi-link supply chains with much simpler ones delivering the necessary powders to a 3D printer at or near the point-of-use of the finished product. The potential effect of 3D printing on the transport system has yet to be quantified, though an expert group envisaged a scenario in which, 'Due to the scope for efficiency and inventory gains from additive manufacturing, combined with governmental attention to the offshoring of emissions to China and other manufacturing hubs, transnational corporations meet their emissions targets through reducing the international freight of finished products and domestic freight to move printed objects in 'just-in-time' and 'print-on-demand' business models' (Birtchnell et al, 2012).
4. *Postponement*: postponing the final packaging and customization of products until they reach the end market can substantially cut international freight volumes and related emissions. This is well exemplified by wine. Traditionally it was bottled near the point of production and shipped in bottles and cases. Today between 20-30% of wine is moved in bulk by iso-tank containers to the import markets where it is bottled near the point of sale. The proportion of New World wine exported in bulk rose from 23% in 2001 to 43% in 2010 (Rabobank, 2011). This practice increases the amount of product per cubic metre of ship space by a factor of roughly 2.0-2.5. It has been estimated that "shipping wine from Australia in bulk reduces CO₂ emissions by 164g

for each 75cl bottle, or approximately 40% when compared to bottling at source” (Waste Resources Action Programme, 2011, p.2).

Changes in technology, business practice and consumer preferences can therefore help to decouple the amount of freight movement from the growth of international trade in value terms. Moderating the growth in freight traffic is not an end in itself, however. It is a means to the end of cutting freight-related emissions. The objective, after all, should be to decouple the growth in emissions from the growth of trade. For the foreseeable future, this is more likely to be achieved by cutting emissions per tonne-km than by cutting tonnes-km per \$ billion of trade. The remainder of the paper explores the former option with respect to sea and air transport.

3. Decarbonising International Freight Transport

Several analytical frameworks have been proposed for freight transport decarbonisation, built on similar sets of parameters:

- (i) *Avoid – Shift – Improve (ASI)*: assessing the opportunities for *avoiding* the need for transport, *shifting* freight to lower-carbon modes and *improving* the energy efficiency of the transport operation
- (ii) *Activity – Structure – Intensity – Fuel (ASIF)*: assessing opportunities for reducing the level of transport *activity* (i.e. avoid), altering the modal *structure* of the transport system (i.e. shift mode), reducing the energy *intensity* of the transport operation (i.e. improve efficiency) and cutting the carbon content of the *fuel* (Schipper and Marie, 1999).
- (iii) *Green logistics framework*: unlike the previous two frameworks which were developed for transport in general, this one was specifically designed for freight transport (McKinnon, 2012a). It maps the relationship between the output of a company or national economy and the amount of freight-related CO₂. This relationship is defined with respect to five key parameters: supply chain structure, modal split, vehicle utilization, energy efficiency and carbon content of the energy.

The last of these frameworks will be adopted here and applied to international freight movement.

3.1 Structure of Global Supply Chains

Section 2 discussed the possibility of truncating these supply chains and increasing the degree of national / local self-sufficiency. Even if the global value chain remains intact, however, and value continues to be added incrementally at the same locations around the world, there may be scope for some supply chain rationalization. This generally involves inserting consolidation centres (and sometimes deconsolidation centres) into the supply chain to maximize vehicle and container fill on the trunk (or line-haul) movement. For example, a European retailer can consolidate supplies originating from several Chinese factories at a strategically-located warehouse in China filling the containers with mixed loads destined for one of its distribution centres (DC) in Europe. This maximizes container fill and permits direct port-to-DC delivery in the import market. Manufacturers can apply the same principle. Unilever, for instance, is establishing a logistical hub to consolidate international flows between its European and overseas factories and warehouses (Murray, 2012). Some value-adding activities, such as packaging, can be performed at these consolidation centres, and so they have a statistical presence in the value chain, but their main role is to cut logistics costs. Incorporating consolidation operations into global value chains also yields environmental co-benefits including CO₂ reductions. In some cases, locating DCs at container ports, a concept known as ‘port centric logistics’, can also cut the carbon intensity of a global supply chain (McKinnon, 2013a).

3.2 Choice of Transport Mode and Carrier

The carbon intensity of freight transport modes varies enormously from electrified railfreight operations powered by nuclear or renewable energy at 1-2 gCO₂ per tonne-km to short-haul express air services at around 1900 gCO₂ per tonne-km (McKinnon and Piecyk, 2010). Even within a particular mode, there can be wide variations (DEFRA / DECC, 2012). Shifting freight from a high-carbon to a low-carbon mode can be by far the most effective means of decarbonizing a logistics operation, particularly in the case of trans-continental flows where the gap in carbon intensity between sea and air is huge. But so too is the difference in transit time, from around 1-4 days for an airfreight service from the Far East to Europe to 20-25 days for a maritime service. The air cargo and deep-sea container markets are essentially discrete, catering for different types of commodity and logistical requirement and affording limited opportunity for mode switching. Sea-air services, combining for example a sea movement from China to the Middle East and an air cargo service from there to Europe, give shippers an intermediate option in terms of transit time, cost and emissions, though still account for a small share of the global freight market.

The core airfreight market comprises time-sensitive deliveries of high-value commodities that can bear the premium freight rates. Regular use of airfreight can be justified by the large reductions in inventory it permits, the ability to synchronise production operations around the globe, the opportunity to extend the market areas of perishable product and the marketing benefits of providing customers with rapid fulfilment. A significant proportion of air cargo demand could, however, be switched to slower, less-carbon intensive modes, if business processes were better planned and some long-established practices relaxed. Airfreight services have often to be used because of poor forecasting, failures in production planning and the need to meet a quarterly sales target. In some companies, budgetary controls on the use of airfreight services has been lax, allowing managers to become over-reliant on what was intended to be emergency service. Re-engineering of business processes and a reform of sales methods could reduce this reliance and tilt the balance from airfreight to slower, greener surface modes. Internalising the environmental costs of airfreight would significantly increase freight rates and force companies to reassess the true value of air cargo services to their businesses. MacIntosh and Wallace (2009: 272), nevertheless, concede that, '*Stabilising international aviation emissions at levels consistent with risk averse climate targets without restricting demand will be extremely difficult*'.

Since 2008, many of the large container shipping lines have reduced the speed of their vessels in a practice known as 'slow steaming'. This has been done to varying degrees, but has typically involved a reduction in average speed from 24 knots to 20 knots (Maloni et al, 2013). As discussed in greater detail in Section 3.4, this is one of the most effective means of decarbonizing the movement of freight by sea. It is important to raise the subject in the context of modal shift, because slow steaming has widened the difference in transit time between deep-sea container and airfreight services. There is a risk therefore that it may have encouraged a shift of more time-sensitive traffic from sea to air. There is little evidence of this happening, however. The large difference in freight rates between sea and air will have discouraged such an environmentally-regressive mode shift. Many shippers have also been able to accommodate slow steaming into their global logistics operations with minimal additional cost and disruption, as discussed later.

Within particular modes, shippers can assign more of their traffic to carriers with a superior environmental performance. For this to happen, two conditions must be met. First, shippers must have access to comparable data on the environmental credentials of the competing carriers and, second, they must be prepared to take account of this information in the carrier selection process.

(i) *Environmental benchmarking of carriers*: a common complaint of shippers is that the environmental data provided by major carriers is not consistent. Standard methodologies and reporting methods have been promoted by various organisations such as ISO, the World Business Council for Sustainable Development, the World Economic Forum and EcoTransit, but they themselves vary and

many carriers choose not to use them and opt for a company-specific approach. An important exception is the benchmarking undertaken by the Clean Cargo Working Group which was founded in 2004 and brings together large shippers, such as Walmart, Heineken and IKEA, and major container shipping lines handling around 70% of global container traffic worldwide (BSR, 2013). Data is collected on a consistent basis for all the vessels operated by these shipping lines, permitting a detailed comparison of the participating carriers' carbon intensity on particular trade lanes.

(ii) *Carrier selection criteria*: A survey of 35 large UK-based shippers asked how much importance they attached to a range of criteria in selecting their deep-sea container lines (McKinnon, 2013b). Environmental performance was the lowest rank of the criteria in a selection process dominated by freight rates, condition of the goods, reliability and service frequency. Where these other factors are evenly balanced, environmental impact can become a more important differentiator. In a future carbon-constrained world it may also become a more highly-rated criterion possibly gaining the status of a 'qualifier' in the tendering process.

3.3 Utilisation of Vessels, Aircraft and Vehicles

Under this utilisation heading, the Green Logistics framework distinguishes empty running from the average load factor achieved on vehicles carrying a load. In developed countries, particularly in Europe, heavy emphasis is placed on the utilization parameter in domestic road freight markets because the available data suggests there is a large potential to improve loading. In EU member states, an average of 27% of truck-kms are run empty (de Angelis, 2011), while in a country such as the UK only around 60% of the weight carrying capacity of trucks is utilized on laden trips (Freight Transport Association, 2013). This latter figure requires qualification, however, as many low density loads 'cube-out' before they reach the vehicle weight limit. This highlights one of the analytical problems that one encounters in assessing the possible contribution of improved capacity utilization to decarbonisation, namely the variability of load densities and need to measure utilization in both weight and volumetric terms (McKinnon, 2010).

This problem is compounded by a general lack of data on the utilization of ships and aircraft moving freight internationally. In the case of aviation, there is a further complication in that around 40% of air cargo moves in the bellyholds of passenger aircraft (Airbus, 2008). In wide-bodied jets the freight typically represents around 15-30% of payload weight and in narrow-bodied aircraft 0 -10% (Jardine, 2009). In the case of bellyhold traffic, utilisation must be judged with respect to a mix of freight and passenger traffic. No general data are available on the average loading of dedicated air cargo planes or 'combis' combining passengers and freight. Given the high costs of airfreight, it is assumed that load factors are high, though in the case of express services load efficiency often has to be compromised to maintain rapid and reliable service for time-critical consignments across the network.

The online survey of large UK-based shippers, mentioned earlier, enquired about the loading of deep-sea containers, both inbound and outbound and in terms of weight and volume. This found relatively high levels of utilization, particularly on inbound flows: '46 per cent of the shippers importing containerised freight claimed that 90–100 per cent of the containers they received filled the available space... eighty-three per cent estimated that 70 per cent or more of their containers were completely filled' (McKinnon, 2013b). Most of this container traffic originates in low-labour cost countries in which it is economical to pack containers manually, thereby minimizing the number of containers required to move a given quantity of product and hence deep-sea freight rates. A related interview study established that large shippers make strenuous efforts to maximize container fill, primarily to cut costs, though there is usually a proportional reduction in carbon emissions. In response to the growth of retail supplies of low density consumer products from emerging markets, greater use is being made of taller, 9'6" and high-cube containers. Furthermore, as explained in Section 3.1, logistics systems are being reconfigured to consolidate loads for deep-sea shipment.

In the case of maritime transport, utilization can be measured at the level of the ship as well as the container, though again the data required to measure this are sparse. In environmental terms, it might be desirable to relax port-turnaround times to allow vessels to accumulate larger loads, though the resulting loss of service quality would be unacceptable to many shippers. The issue is further complicated by two other factors. First there is the need to reposition empty containers, particularly on trade lanes with pronounced directional imbalances in trade volumes (Ng, 2012) and, second, the ‘trimming’ of a vessel requires it to take on ballast water to compensate for any lightening of its load. The relationship between loading and carbon intensity is therefore more complex in the case of shipping than it is for other international freight modes.

In summary, it appears that market forces are exerting a strong pressure on shippers and their carriers to maximize loading, possibly making capacity utilisation a less promising source of carbon reductions in global supply chains than in domestic freight markets. On the basis of currently available data it is not possible to test this hypothesis empirically.

3.4 Energy Efficiency of International Transport Operations

In assessing the potential for improving the energy efficiency of freight transport modes, it is helpful to distinguish technological from operational factors.

Technological upgrades: Advances in technology can either be incorporated into new ships and aircraft or retrofitted onto existing vessels and planes. This latter point is significant because ships and planes have a relatively long life span, typically in excess of 20-30 years, resulting in a slow uptake of new, energy-saving technology. Retrofitting offers a means of diffusing new technology more rapidly. The rate of diffusion in the airfreight sector is slowed, however, by the widespread practice of converting older passenger aircraft into dedicated air cargo plans. Airbus (2011) estimate that 69 per cent of the 2,730 additional air-freighters that will be required over the next 20 years to meet demand will be converted from passenger aircraft. The Advisory Council for Aeronautics Research in Europe is also pessimistic about the prospects of refinements to existing aircraft technology yielding large gains in fuel efficiency in the absence of ‘breakthrough technologies’ (ACARE, 2008: 61). IATA, on the other hand, wants its 140 member airlines to stabilise CO₂ emissions from passenger and freight services by 2020 and ensure that any further growth in traffic levels thereafter is kept ‘carbon neutral’ through a combination of fleet renewal, advances in engine and airframe technology, improved operational practices, more efficient air traffic control and a switch to biofuels (IATA, 2009).

The broad range of technologies that can be deployed to improve the energy efficiency of shipping has been reviewed by AEA Technology (2008), Buhaug et al (2009), International Energy Agency (2009), DNV (2012) and others, indicating that the opportunity exists to achieve a substantial reduction in fuel use per tonne-km. A recent report by UNCTAD (2013) acknowledges that ‘*many experimental designs and concepts for eco-friendly ships (for example, wind and solar power) are being reported*’ but suggests that ‘*their application in the near future remains doubtful*’. In the medium to long term, the need for new vessels to meet tightening energy efficiency standards imposed by the IMO will promote the uptake of new technology. According to the IMO rules, all new vessels entering service in 2015 will have to be at least 10 per cent more energy efficient than the average efficiency of vessels built between 1999 and 2009. This threshold will rise to 20 per cent for post-2020 ships and 30 per cent for post-2025 ships. It has been estimated that this measure could save around 263 million tonnes of CO₂ by 2030 (ICCT, 2011a).

On those trade lanes handling the largest volumes of freight, much of the improvement in energy efficiency will accrue from increases in vessel and aircraft size. The new 18,000 TEU ‘triple E’ container vessels, recently introduced by Maersk on Far-East – Europe services, can cut CO₂ emissions per TEU-km by 50% relative to the average container ship currently operating on this route. Forthcoming freight versions of the Airbus 380 will similarly enhance fuel economy by scaling-up payload capacity.

Operational Improvements:

Fuel and emission savings can also be achieved by more efficient operation of existing as well as new aircraft and vessels, through measures that can often be implemented in the short to medium term.

In the case of aviation, operational efficiency improvements fall into three categories: (i) aircraft weight reduction (ii) more fuel efficient flight operations (including lower cruise speeds, less stacking and less circuitous routing) and (iii) optimized ground operations (including reduced queuing and the use of tow trucks for taxi-ing) (Sigouridis et al, 2011).

In the maritime sector, the IMO is supplementing its EEDI scheme with a Ship Energy Efficiency Management Plan (SEEMP) designed to propagate ‘*best-practice measures for fuel efficient ship operation*’ (IMO, 2011: 36). These measures include better engine tuning, improving ‘trimming’, weather-routing and the application of special coatings to the hull. The ICCT (2011a) has forecast that the EEDI and SEEMP initiatives together have the potential to augment baseline reductions in CO₂ emissions per tonne-km for shipping between 2010 and 2030 by a fifth.

One of the most effective means of decarbonising container shipping has been the adoption of ‘slow steaming’. As there is a cubic relationship between vessel speed and fuel use, the % fuel savings far exceed the % deceleration (Corbett et al, 2009). These fuel savings translate directly into reductions in CO₂ emissions. The ICCT (2011b) estimates that cutting average vessel speed by 10% and 20% can cut CO₂ emissions by, respectively, 15-19% and 36-39%. According to Cariou (2011) slow-steaming cut CO₂ emissions from deep-sea container shipping operations 11% over the period 2008-2010. This measure was applied by container shipping lines to address by the problems of over-capacity and high fuel prices during a period of global recession (Notteboom and Vernimmen, 2009). It was often presented to shippers as an alternative to the imposition of much higher bunker fuel surcharges. They then had to adjust their logistical schedules to accommodate the longer transit times. An interview survey of 15 major users of deep-sea container services, found that the vast majority had been able to do this with minimal disruption and additional cost (McKinnon, 2012b).

Various reasons were offered for this finding. First, much of the freight carried by deep-sea container is not very time-sensitive. Moreover, relative to order lead times of several months for many products, a 3-4 day increase in deep-sea transit time is small and corresponding increases in-transit inventories fairly marginal. Some shippers report that longer average transit times have been partly offset by improved service reliability. Some modifications to internal processes have, nevertheless, been required, such as improving the visibility of inbound container flows, prioritising the hinterland movement and reception of more time-sensitive orders and making slight adjustments to production planning. The net effect on global supply chains has, according to this survey, been much less than might have been expected. Given the strength of companies’ commitment to just-in-time, short order lead times and inventory minimisation, one might have anticipated much more resistance by shippers to slow steaming and greater willingness to pay higher freight rates to maintain previous vessel speeds and transit times. In terms of carbon reduction, the apparent ease with which many, though not all, shippers have been able to adapt their global logistics systems to a significant reduction in deep-sea vessel speed is encouraging.

There has been some debate over the long term sustainability of slow steaming in the deep-sea container market. Some argue that it is a temporary phenomenon that will be abandoned once the pre-2007 container growth rates return and / or the bunker fuel price drops by a significant margin. Faber et al (2012), for instance, argue that ‘*The concept that slow steaming leads to a ‘greener’ supply chain is a well understood (if unintended) benefit, but carriers will likely return in large part to pre-2007 speeds when market conditions change and more capacity is required.*’ They advocate, for environmental reasons, the imposition of regulation to resist a restoration of higher speeds. It is questionable if this will be necessary, however. In 2012, global container traffic was 12% above its 2008 pre-recession peak (UNCTAD, 2013) and, despite this, carriers’ commitment to slow-steaming

remains strong. Indeed Maersk's new generation of triple E vessels are designed to sail at slower speeds than their predecessors. It seems therefore that slow steaming is here to stay.

3.5 Switching to Alternative Fuels

There is little prospect of shipping and airfreight switching to low carbon energy sources in the short to medium term. In their forecast of the changing fuel mix for shipping, DNV (2011) envisage little change until around 2020 when a significant shift from bunker fuel (HFO) to marine diesel oil (MDO) is likely to occur to meet much tighter limits on sulphur emissions. The effect of this shift on carbon emissions will be negligible as the two fuels have almost identical carbon content (IMO, 2000: 21). The forecast 5% penetration of the marine fuel market by liquid natural gas (LNG) by 2020 will also have a marginal effect on the carbon intensity of shipping as its carbon content is only 9% less than that of HFO. Use of wind power and solar panels on vessels are not anticipated have any significant effect for several decades, while the practice of cold ironing (i.e. powering of vessels in port with shore-side electricity) will also be confined to a very small number of ports for the foreseeable future.

In the airfreight sector, switching from kerosene to lower carbon fuels will also be fraught with difficulty. Alternative aviation fuels must have a similar energy density, be safe at high altitudes (in freezing conditions), must not corrode on-board fuel systems, be compatible with current fuel distribution systems and available in sufficient quantities (Aviation Environmental Federation, 2008). In addition to satisfying these exacting requirements, the alternative fuel must offer a significant carbon saving on a life-cycle basis. Although, several airlines have successfully trialled biofuel blends, the general view still seems to be that *'no game-changing alternative to burning kerosene is foreseen in the short to medium-term'* (Airbus, 2008: p.18). This parameter in the green logistics framework therefore offers limited potential for decarbonising the movement of international trade.

4. Conclusion

The growth in international trade and increasing complexity of global value chains is making the world economy ever more freight transport-intensive. There are numerous externalities associated with the resulting growth in freight movement, of which climate change is generally considered the most worrying. Although freight transport accounts for only around 6% of total GHG emissions, its share of trade-related emissions is much higher. The forecast growth in international trade will therefore carry a heavy carbon penalty in the form of transport emissions. If some of the more extreme climate change scenarios were to materialise, it may become necessary to contain and even reverse the growth of international trade. For the foreseeable future, however, the aim of public policy should be to decouple the growth of international freight transport emissions from the expansion of trade volumes. This can be done at two levels by reducing the ratios of (i) trade value to tonne-kms and (ii) tonne-kms to emissions. Greater opportunity exists to depress the second of these ratios, by a combination of mutually-reinforcing technological and operational changes. Many of these changes will yield commercial as well as environmental benefits giving companies a clear financial incentive to 'green' their international transport operations. The economic pressure on companies to cut emissions per unit of trade could be reinforced by the internalisation of environmental costs in higher taxation or the application of market-based mechanisms such as emissions trading. In most parts of the world, however, there is little political will at present to implement such policies.

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