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Analysis

# Peak globalization: Climate change, oil depletion and global trade

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ABSTRACT

The global trade in goods depends upon reliable, inexpensive transportation of freight along complex and long-distance supply chains. Global warming and peak oil undermine globalization by their effects on both transportation costs and the reliable movement of freight. Countering the current geographic pattern of comparative advantage with higher transportation costs, climate change and peak oil will thus result in peak globalization, after which the volume of exports will decline as measured by ton-miles of freight. Policies designed to mitigate climate change and peak oil are very unlikely to change this result due to their late implementation, contradictory effects and insufficient magnitude. The implication is that supply chains will become shorter for most products and that production of goods will be located closer to where they are consumed.



> "… globalization is creating an environment that will prove hostile to its own survival." (Ehrenfeld, 2005, 319).

> "The moment the world recognizes the passing of the oil production peak as a reality, globalism will be dead both in theory and practice." (Kunstler, 2005, 185).

## 1. Introduction

Based on melting arctic ice and other evidence, it is clear that global warming has begun and existing concentrations of greenhouse gases in the atmosphere will lead to further temperature increases. The timing of the global peak of oil production is less certain, although there is a growing view that maximum production will occur within the next decade. Global climate change and the global peak of oil production will undermine the economic logic and profitability of long-distance, global supply chains of imports and exports. They will lead to a condition of peak globalization, after which the volume of goods traded internationally (measured by ton-miles of freight) will decline. While policies designed to reduce oil depletion and greenhouse gas emissions may work to delay the onset of peak globalization, it is the conclusion of this paper that they will be unable to prevent it.

Global warming and oil depletion will unevenly erode the present long-distance international division of labor by raising transportation costs and decreasing the reliability of freight movement. Global warming will impact transport primarily by interrupting the movement of freight and damaging transportation infrastructure, effects that will increase over time. Oil depletion will raise the price of fuel and hence the cost of moving freight, beginning sooner than the impact of global warming. Further, policies designed to mitigate climate change and peak oil will not reverse peak globalization due to their insufficient magnitude, late timing and impacts on fuel prices. The major implication is that supply chains will become shorter for most products and that production of goods will be relocated closer to where they are consumed, although this will happen neither quickly nor easily.

Existing scholarly literature on globalization and the environment focuses on the impact trade treaties and increased global trade flows have on the ecosystem (Boghesi and Vercelli, 2003; Chapman 2007; Clapp and Dauvergne 2005; Ehrenfeld 2005; Tisdell 2001). This paper makes three major contributions. First, it complements and reverses previous literature by examining how changes in environment can erode global trade flows. The second contribution is the analysis of *both* peak oil *and* climate change in tandem; to date, scholarly analysis of climate change has largely omitted peak oil and vice versa[1] [on peak oil, see De Almeida and Silva (2009), Zhao et al. (2009), Porter (2006), Campbell (2004), Goodstein (2004), Greene et al. (2004). Borghesi (2008) considers issues of peak oil and pollution including climate change]. The primary emphasis of this paper is to show the pathways of the effects of global warming and oil depletion on global trade flows. Finally, the examination of mitigation policies of climate change and peak oil concludes that they are too little and too late to prevent peak globalization and that adaptation policies are not consistent with global supply chains.

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[1] Since they affect primarily the production rather than the movement of exports, the analysis omits issues of peak coal and other resource inputs with physical supply constraints. On peak coal, see Lehmann et al. (2007). Other resources discussed in "peak" context include natural gas, water, phosphates, minerals and uranium.

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## 2. Globalization

Globalization is conceptualized here as the treaty-based liberalization of international trade among nations, a project accelerated with the formation of the European Union's Single Market (1992), the North American Free Trade Agreement (1994) and the World Trade Organization (1995).[2] The reduction of trade barriers has enhanced global economic growth and rapidly increased international trade. Between 1990 and 2006, world output grew from US$ 22,680 billion to $45,941 billion, while global exports grew from US$3480 billion to $12,088 billion. As a percent of world output, exports grew from 15.3% to 26.3% between 1990 and 2006 (IMF, 2008; UNCTAD, 2008). Total international seaborne trade more than doubled (from 2.253 to 4.742 billion tons) over the same period (UNCTAD Secretariat, 2007, 4). By 2008, such shipping consumed 2 billion barrels of oil per year and emitted as much as 1.2 billion tons of carbon dioxide (Oliver, 2008, 1).

This increase in international trade is frequently attributed to three factors: (1) trade liberalization, (2) improved technology — particularly in transportation (e.g., containerization and sea–land, roll-on, roll-off modes) and communications, and (3) the low cost of labor in developing nations, made accessible by both trade liberalization and the new technologies (Dicken, 2007). However, the growth in global exports has just as significantly been supported by a massive physical infrastructure of roads, railroads, ports and airports that connects raw material suppliers, parts and sub-assembly manufacturers with final assemblers and distribution networks between and within nations. Exports are also supported by tens of thousands of ships and aircraft and historically cheap (largely untaxed and frequently subsidized) petroleum fuels. These cheap fuels and efficient technologies made inter-continental and trans-oceanic freight transport inexpensive, in part due to the exclusion from freight rates of external costs such as greenhouse gas emissions and oil depletion.

These factors of policy, technology and cost have changed the international division of labor, lengthening supply chains. For example, the formation of NAFTA led many U.S. manufacturing firms to relocate production to Mexico to take advantage of lower labor costs. When China joined the WTO in 2001, some of those firms relocated there to get the benefit of even cheaper labor despite a very large increase in transportation miles. (Jordan, 2002) Of course, the policy context for the changing geography of supply chains is the specific provisions of the NAFTA, WTO, etc. treaties. However, without the freight transportation system and low cost fuel, formal liberalization would not have resulted in these new patterns of production and longer supply chains. Cost efficient, rapid and predictable transportation is a prerequisite for the exploitation of cheap labor at the end of this long-distance global trade. These supply chains and international division of labor are put at risk by global warming and peak oil.

## 3. Climate change and globalization

Anthropogenic climate change results from emissions of greenhouse gases beyond their temperature neutral absorption. Due primarily to human consumption of fossil fuels, global warming is predicted to have physical impacts relevant to global trade flows. Four major climate changes are particularly important for freight transportation and supply chains. They include: more very hot days and heat waves, rising sea levels, more frequent intense precipitation events, and increases in hurricane intensity (Schwartz et al., 2008, 3).[3] These climate changes will undermine global supply chains by their impacts on both infrastructure and operations of various transport modes.[4]

Due to melting arctic ice and thermal expansion of seawater, sea levels are expected to rise 3 to 6 ft by the end of the century (Lemonick, 2009). The results of such changes in sea level can be severe for all forms of transport infrastructure. "Combined with acute storm surges…, gradual changes in sea level may be expected to damage or render inaccessible low-lying coastal infrastructure including road and railway beds, port and airport facilities, tunnels and underground rail/subway/transit corridors" (Mills and Andrey, 2002. 4). In the United States, the critical ports of the Gulf of Mexico — processing approximately one-sixth of all U.S. trade cargo — are at particular risk (Schwartz et al., 2008, 4).[5] Many airports — both passenger and freight facilities — are located in coastal areas and are thus vulnerable to sea-level rise as well.

By contrast, greater evaporation due to increasing temperature and heat events is expected to *lower* the water level in the Great Lakes, the St. Lawrence Seaway and other river systems.

> "…falling water levels on the lakes will decrease water depths, necessitating shallower draft vessels, and therefore less tonnage capacity per trip. Per *inch* of lost draft, a 740-foot ocean going vessel loses 100 tons capacity, and a 1,000-foot bulk carrier loses 270 tons of capacity. By some estimates, Great Lakes shipping costs could increase by 30 percent due to decreased water levels resulting from climate change." (Caldwell et al., 2002, 10).

Similar impacts may occur on river systems like the Mississippi where lower water levels will reduce traffic of grains and ores destined for export. Further, changed water levels will create problems unloading vessels (e.g., at high tide for seaports), may require vessels to be less than fully loaded to transit harbors and rivers to reach dockside facilities, or require increased dredging costs. (Caldwell et al., 2002. 11–12). Such impacts of global warming will increase the costs of trans-oceanic and inland water shipping, in part by diverting freight to less efficient and more expensive road and rail networks. They will also interrupt and slow the movement of goods along the long-distance supply chains.[6] Other water-related damages include flooding due to more frequent storms, a shift in precipitation from snow to rain, and more concentrated precipitation which will also undermine bridges, railroad beds, and roads used for high-volume freight transport (Schwartz et al., 2008, 4).

Two examples of the kinds of damage and delay that are likely to become common as global warming proceeds are the 1993 Mississippi River flood and Hurricanes Rita and Katrina. "The Midwestern river floods of 1993 devastated railways [and roads and river traffic], with over 4000 miles of track either flooded or idled and over $200 million in estimated losses" (Rossetti, 2002, 9). Hurricanes Rita and Katrina damaged or destroyed railroad bridges (requiring re-routing of traffic) as well as halting barge traffic including all grain exports out of the port of New Orleans for several weeks. Such events are predicted to occur more often with greater damage due to increasingly intense storms. Thus, water-related climate changes will damage infrastructure and otherwise result in increased freight costs

[2] Foreign investment and other provisions of these treaties are omitted as not being central to the present analysis.

[3] In addition, (fear of) the spread of pandemic diseases such as swine flu due to the longer survival of insects in a warmer climate and the movement of disease vectors on cargo carriers may also increase transportation costs if they result in stricter inspections or import restrictions, both of which could violate provisions of the WTO treaty. See Pimental et al. (2005). My thanks to an anonymous reviewer for raising this point.

[4] Climate change is projected to reduce GDP growth which would also negatively impact global trade. For such negative macroeconomic impacts, see Ackerman (2009) and Stern (2007). These macroeconomic dimensions are not discussed here both for reasons of length and due to the focus on transportation costs. Stern (2007, 161-162) estimates a 5–14% reduction of GDP versus its projected growth due to (unmitigated) climate change by the end of the present century.

[5] Storm damage to the Gulf of Mexico coast can also damage oil drilling rigs, oil refineries, port facilities for unloading oil and domestic oil and gasoline pipelines as occurred with Hurricanes Rita and Katrina. Over 60% oil imports enter the U.S. via Texas and Louisiana (Caldwell et al., 2002, 9). Damages to this infrastructure will create additional oil supply pressures to those discussed below.

[6] Trans-oceanic freight movement could also be slowed by more frequent and extreme weather events such as El Niños, changes in trade winds and ocean currents, and more severe storms in the northern Pacific and Atlantic oceans. See Hall (2006) and Schwartz et al. (2008, 54).

and delays, reducing the economic logic of global supply chains. In their study of transport costs, Limao and Venables (2001, 451) conclude that "[a] deterioration of infrastructure from the median to the 75th percentile raises transport costs by 12 percentage points and reduces trade volumes by 28 percent," the sort of impact expected from deterioration of transport infrastructure due to climate change.

In addition, very hot days and heat waves also affect transportation infrastructure and operations. First, frequent hot days will make refrigeration of perishable goods all the more critical. Second, they will reduce engine combustion efficiency for railroads, trucks and aircraft. "This will place a particular burden on air carriers because aircraft will require longer runways or lighter loads" (Caldwell et al., 2002, 11). Third, hot days and heat waves may create softening, rutting, or buckling of pavement leading to slower speed of road segments of supply chains (Mills and Andrey, 2002. 3). In terms of the rail portion of transportation networks, they will also cause heat kinks and buckling in rails and track misalignments (increasing the risk of derailments), resulting in higher rail freight costs and slower movement of goods (Rossetti, 2002, 2 and 11). Higher temperatures and heat events may disable or impair hundreds or perhaps thousands of miles of railways and roads at a time. Higher temperatures and heat events raise costs and cause delays via both infrastructure and transport operations.

Via transportation, global warming will also undermine agriculture and manufacturing. In recent decades, the export of agricultural products has grown faster than overall food production, in part due to refrigeration and cheap and rapid transportation by air and sea (Pfeiffer, 2006, 24). Changes in temperature and precipitation are expected to decrease crop outputs. According to the United Nations, global food production could fall by as much as one quarter by 2050 (Wallis, 2009). Smaller output will reduce food exports and lead to more local food production reducing demand for transportation of food. However, where long-distance food exports are maintained, the geography of food production will change due to the new pattern of heat days and rainfall and this will feed back into physical infrastructure. "The spatial pattern of agricultural production is also likely to change, causing demand for freight transportation in some regions of the United States to increase and in other regions to decline" (Caldwell et al., 2002, 12). Developed over decades, the existing network of roads, railroads, terminals, grain storage facilities, etc. may not in the future be well located for the new geography of agricultural production and export.

Climate changes make the transportation of raw materials, parts, partially assembled products and final goods less predictable, more expensive and more difficult by land, sea and air. Seaborne and air based delivery networks also involve road shipment from port, train terminus or air hub to the factory or distribution site (Gilbert and Perl, 2008, 103). These global supply chains feed into just-in-time (JIT) production and distribution systems where parts are delivered to factories for assembly and finished goods to retail outlets just as they are needed, to avoid tying capital up in inventory. JIT systems increase profits and efficiency but also vulnerability. "… major businesses, both manufacturing and retail, have reduced operating costs through just-in-time delivery strategies, but with the effect of increasing their vulnerability to disruptions or failures of the transportation system from either natural or human causes" (Schwartz et al., 2008, 64). Slower or more unpredictable delivery of freight may disrupt production and distribution and reduce their cost effectiveness.

Thus climate changes will undermine the economic logic of current supply chains by damaging physical infrastructure, creating (perhaps lengthy) delays in freight transit, diverting traffic to less efficient and more expensive modes and increasing operating costs through lower carrying capacity or higher fuel use. Currently, public and private authorities responsible for this infrastructure do not seem to have taken climate change much into account and infrastructure designs reflect this. Perhaps, this omission is due to conclusions that climate change is not imminent. However, there is no reason to expect that climate change will be gradual and many of the phenomena discussed here exist now, their frequency and severity being intensified as climate change proceeds. "Climate scientists expect … new extremes far outside current experience (e.g., the heat wave in Europe in 2003) … and the near record heat in the United States in 2006.…" (Schwartz et al., 2008, 20). As these effects increase, they will make freight transportation more expensive and unreliable thus undermining the economic logic of global supply chains, whatever the degree of trade liberalization. These effects on globalization are reinforced by peak oil.

## 4. Peak oil and globalization

Petroleum is the critical fuel for the movement of goods. Freight transportation consumes 35% of all transport energy use worldwide and virtually all of this fuel is petroleum based (Kahn Ribeiro et al., 2007, 330). The amount of oil consumed in freight transportation depends upon the number of tons of freight transported, the distance, mode and speed of transport, vehicle/vessel design, and engine efficiency, among other factors. Alternative modes of transport — ocean shipping, rail, air, etc. vary in their oil consumption per ton-mile and thus have different sensitivities to changes in fuel prices. International air freight uses roughly fifty times the energy per ton-mile of international marine and diesel rail transport while trucks use thirteen times the energy of international marine and diesel rail transport (Gilbert and Perl, 2008, 240). In this section, the focus will be on the impact of oil supply constraints on ocean shipping and air cargo.

Peak oil refers to the attainment of the maximum conventional oil output (i.e., excluding heavy oil from tar sands, oil shale, etc.), expressed in terms of millions of barrels of crude oil extracted per day (Deffeyes, 2001). As peak oil is neared, there will be an increasing gap — or 'wedge' — between production and demand. As a result, the price of crude oil is expected to both rise significantly and become much more volatile.[7] The increased price results from excess demand and higher costs of extraction and processing of the remaining crude oil. In addition, as supply declines and price rises, it is expected that there may be shortages and interruptions in delivery of both crude oil and refined products, including fuels.

Concerning the date at which global oil production will peak, "… world oil production, according to the International Energy Agency, has been essentially flat for several years and will soon steadily and irreversibly decline. … at some time between 2010 and 2012, new oil production will not be sufficient to keep up with depletion and … world oil production will begin dropping" (Whipple, 2008a,b,c, 34 and 37).[8] As De Almeida and Silva (2009) note, "…most of the relevant published research on the subject points to a significant probability of the PO [peak oil] occurring prior to 2015" (2009, 1274). More optimistic estimates date the peak between 2020 and 2030.[9] As an example of the kinds of oil price increases and volatility that can be expected in the future, the price of crude oil rose from $28 per barrel in 2003, to $37 in 2004, $50 in 2005, $60 in 2006, $67 in 2007, spiking at $147.27 on July 11, 2008 and falling to $53 in November 2008 and $36 in January 2009, before recovering to the low $70s in August 2009.

[7] Assuming a (2008) production level of 84 million barrels per day (mbd), demand increasing at 2% per year and production falling at 2% per year, there would be a shortfall of 33.6 mbd or 40% of demand in five years. 2% is a conservative estimate of both post-recession demand growth and post peak depletion rates.

[8] The recession that began in 2007 may delay the arrival of the peak due to declining oil demand and hence production.

[9] De Almeida and Silva also discuss optimistic oil peak dates (2020 and beyond) as coming from research "…by organizations that, for several reasons (political, commercial, and so on), do not want to admit the reality of the PO and so "predict" that the oil consumption (and, by necessity, its production) will simply go on following the historical growth trends." (2009, 1269). They analyze various reasons underlying the "optimistic" dates for oil peak (e.g., in Cambridge Energy Associates, 2006; U.S. Geological Survey, 2000), a debate beyond the scope of this paper.

(Energy Information Agency, 2009; Schlumberger, 2009, 113). The high price of the summer 2008 reflects the magnitude of pricing that can be expected from oil peak.

Oil price volatility may be the result of oil peak but also of recession when a drop in demand lowers prices. A so-called supply crunch results from insufficient investment in maintaining present oil production capacity as oil companies react to current low prices of oil or difficulties in arranging credit. In early 2009, the International Energy Agency expressed concern about just such supply constraints "…due to lack of investment in new production projects which it sees as falling by 20 percent this year." (Whipple, 2009, 2) Although the timing of oil peak or supply crunch are not certain, supply constraints are likely to occur in the near term, certainly as the global economy comes out of the recession and resumes growth. This will result in increasingly higher fuel prices for freight transport.[10,11]

Although air freight is a small part of trans-continental and trans-oceanic transport, it has grown very rapidly since the 1980s. Air freight carries only 0.3% of total international ton-miles of freight but 35% of shipment values (Gilbert and Perl, 2008, 96). Goods air-freighted include low-value, high weight perishables such as fruit and cut flowers and semi-processed parts for just-in-time manufacturing (Barkin, 2003, 12). Since air freight uses the most fuel per ton-mile of any transport mode, it is very sensitive to fuel costs; peak oil prices will be very damaging to it.

As a taste of things to come, between July 18, 2007 and July 18, 2008, the price of jet fuel rose 82% from \$2.17 to \$3.95 a gallon due to increasing crude oil prices (Jet Fuel Price Monitor, 2008). Oil price increases between 2003 and 2008 resulted in fuel costs rising from 15% to 35% of all airline operational costs (Schlumberger, 2009, 116). Over twenty airlines declared bankruptcy in the first six months of 2008 (Brothers, 2008, 1). In response to increased fuel prices, several airlines slowed the speed of aircraft to curb fuel costs (Moskwa, 2008). Fuel surcharges increased the cost of shipping freight by air. This may greatly reduce long-distance supply of food and impair just-in-time distribution. Though significant for air freight, the impact of peak oil prices on air cargo will be small relative to its impact on ocean shipping.

The expansion of global trade since World War II was largely seaborne trade based on container shipping. At 1/2 cent versus \$1.50 per pound, ocean shipping of cargo is highly price competitive with air freight. This is partly compensated by the value of cargoes shipped, \$61,000 per ton for air freight versus \$131 for sea cargo (Caldwell et al., 2002, 3). The carrying capacity and number of containers per ship plus the speed of container ships reduced the cost of transporting heavy cargo across trans-oceanic distances (Mintzer and Leonard, 2005). Ocean shipping of freight constitutes 96.7% of international trade's transport activity in terms of ton-miles and 49% by shipment value (Gilbert and Perl, 2008, 96). In 2007, there were approximately 70,000 ships using roughly 200 million tons of fuel which was expected to rise to 350 million tons per year by 2030 (Vidal, 2007).

Container ships use bunker fuel oil (what is left over after higher grade fuels are refined) which is untaxed on international journeys according to international treaties. Moderate increases in the price of crude oil and hence bunker fuel would not greatly impact transportation costs. In 2005, on a world average, freight costs were approximately 6% of the value of imports (UNCTAD Secretariat, 2008, 80). However, large increases could have a significant impact; it is possible for ocean shipping costs to rise high enough to impact the global sourcing of production. This began to happen in 2005 due to the increase in bunker fuel prices, a trend which deepened by 2008. In 2008, shipping a standard 40-foot container from Shanghai to the U.S. eastern seaboard cost \$8000. In 2000, when oil prices were \$20 per barrel, it cost only \$3000 to ship the same container (Rubin and Tal, 2008). One response to these increased shipping costs was to slow the speed of cargo ships.[12] One shipping company reduced the speed of its cargo ships from 23 1/2 knots to 20 knots. This lengthened the round trip time of a trip from Hamburg to East Asia from 56 to 63 days, a change that might impact just-in-time production systems (Kirschbaum, 2008).

In addition to raising air and ocean freight transport rates, high oil prices also erode global supply chains by their impacts on production, not considered at length here. First, agriculture is petroleum intensive in terms of fuels for machinery and refrigeration and feedstock for fertilizers and pesticides. Higher oil prices result in higher food production costs. Moreover, perishable foodstuffs are low-value and high weight, the kind of product whose shipment by air is most at risk with higher fuel prices. Thus, increases in air freight rates could reduce the long-distance export of (out of season) produce.

Second, regarding manufactures, the slowing of air and ocean shipping to conserve fuel makes just-in-time systems for production and retail problematic. Further, gasoline and diesel are backup fuels for electricity generation in many countries. During the summer of 2008, when there were shortages of coal and hydro-electric power, manufacturers in several nations could not generate power with high-priced diesel. This reduced export production in the textile industry of Pakistan and in home appliance manufacturers in China. (Whipple, 2008a,b, July 7 and June 16, respectively). Higher fuel costs for manufacturing due to rising oil prices will also undermine the comparative advantage of many Asian manufacturers as they are much less energy efficient than their counterparts in the United States, Japan and Western Europe. "… China's use of energy per unit of gross domestic product is three times that of the U.S., five times Japan's, and eight times Britain's" (Evans-Pritchard, 2008).

Although peak oil prices may impact manufacturing costs and comparative advantage over time, their immediate effect will be on transport costs. As higher oil prices raise transport costs, they erode the comparative advantage of long-distance supply chains effectively counter-balancing the effect of lower trade barriers.

> "…at a \$100 per barrel oil price, transport costs outweigh the impact of tariffs for all of America's trading partners, including even its neighbors, Canada and Mexico. Back in 2000, when oil prices were \$20 per barrel, transport costs were the equivalent of a 3% US tariff rate. Currently, transport costs are equivalent to an average tariff rate of more than 9%. At \$150 per barrel, the tariff-equivalent rate is 11%…" (Rubin and Tal, 2008, 4).

The increase cost of transport will both reduce trade volumes and alter their geography. Limao and Venables (2001, 453) estimated the elasticity of trade volume with respect to transport costs and found that "… a 10-percentage-point increase in transport costs typically [reduces] trade volumes by approximately 20 percent." Higher transport costs will also reconfigure supply chains to a more local or regional pattern.

As the price of oil began climbing after 2005 and especially during 2008, there was much discussion in the business press about the relocation of production facilities. "Even at today's oil prices [then \$117 per barrel], rising transportation costs have already offset China's otherwise slim cost advantage, giving U.S. steel a competitive advantage for the first time in over a decade" (Rubin and Tal, 2008, 6). Ikea opened its first furniture factory in the United States and Emerson relocated

[10] An additional factor that will reduce supplies of oil exports and raise prices is increasing domestic consumption of oil in some exporting nations (often at subsidized prices). Indonesia has ceased exporting petroleum and Mexico is expected to do so within the next decade due both to peaking of domestic production and increasing domestic consumption. See Rubin (2009).

[11] In terms of the macroeconomy, Hamilton (2009) argues that high oil prices have been a major factor in causing recessions since 1973. Thus, peak high oil prices may parallel climate change in terms of having a negative impact on GDP and hence globalization, a point not discussed further here. In addition, high oil prices may contribute to reduced spending on (non-energy) consumer goods which may also inhibit the growth of international trade.

[12] "In global shipping, the increase in ship speed over the last fifteen years has doubled fuel consumption per unit of freight" (Rubin and Tal, 2008).

appliance motor manufacturing from Asia to Mexico (Hoffman, 2008). While such relocation is a logical response to peak oil, it will not be accomplished easily or quickly given large investments in the current international division of labor and supply chains. Moreover, it will not be easy to rebuild manufacturing in the United States and other nations whose companies outsourced production over the past few decades (Engardo, 2008). Nonetheless, higher fuel costs, slower movement, freight and possible fuel supply interruptions make the current supply chain increasingly unprofitable in the peak oil era.

## 5. Policy responses to climate change and peak oil

### 5.1. Climate change policies

As of June 2009, policy responses are too little, too late and too costly (in terms of fuel prices) and thus will not be able to maintain current ton-miles of freight transported; they will not prevent peak globalization. Mitigation policies are designed to prevent or forestall climate change or peak oil. In the case of climate change, these policies aim to reduce greenhouse gas emissions. A common target (e.g., the New Jersey state standard) is 80% reduction by 2050. However, a recent paper argues that mitigation strategies need to reduce greenhouse gas emissions and increase absorption to result in 350 parts per million of these gases in the atmosphere as opposed to the current level of 380 ppm (Hansen et al., 2008).[13] Frequently mentioned mitigation strategies reduce emissions by increased energy efficiencies, lower demand for carbon intensive products, and adoption of low carbon electricity, heat and transportation technologies (Stern, 2007, 345). To implement these changes, policies are proposed that in general and intentionally increase the cost of carbon intensive fuels and technologies whether via direct regulation, taxes or cap-and-trade programs.[14]

Such policies will have both general and specific effects on globalization in terms of consumption, transportation and trade liberalization. The general effect will be to raise the price of carbon and hence carbon fuels. “Elimination of as much as 50 percent of emissions [relative to global business-as-usual emissions in the year 2030] would [require] a carbon tax of $100 per ton of $CO_2$, roughly equivalent to … an oil price hike of almost $50 per barrel” (Ackerman, 2009, 57). This would increase both transportation and production costs.[15] Of course a *lower* policy-set price of carbon would raise fuel costs less, but it would also not reduce greenhouse gas emissions and their consequent impact on transport as discussed above.

The movement of freight by air produces a disproportionate level of greenhouse gas emissions. “The consumption of kerosene in jet aircraft generates 3.2 tons of $CO_2$ for every 1 ton of kerosene consumed. …[due to radiative forcing, the inter-governmental panel on climate change] determined that the overall climate effects of aviation are approximately 2.7 times greater than the effect of $CO_2$ alone” (Smith, 2006). The response to aviation's emissions of greenhouse gases by the European Union is to require that all airlines be covered under the Emissions Trading Scheme and that there be a cap on aviation emissions starting in 2012 (Kanter, 2008). This would require higher air freight costs, fewer flights or more efficient aircraft.

This raises the question about the degree to which aircraft can become more fuel efficient or use less greenhouse intensive fuels. According to Smith (2006), there are no viable bio-fuels and hydrogen is not affordable. The only fuel that might be substituted for kerosene refined from petroleum is a coal-based synthetic fuel which has been tested by the U.S. Air Force. Unfortunately, it has few if any benefits in terms of greenhouse emissions. There are some possibilities for increased engine efficiency and fuel saving air traffic control strategies, but they are unlikely to compensate for the kinds of fuel price increases accompanying significant carbon prices. Shipment of freight by air — especially over long distances — becomes less feasible under such policies.

Ocean shipping of freight has also come under recent scrutiny with much the same result. Here the greenhouse gas emissions stem from the burning of bunker fuel by ships and from idling trucks, locomotives and other machinery in crowded ports. Cargo ships account for 2 to 3% of global fossil fuel consumption and up to 5% of greenhouse gas emissions, even though this mode of freight transportation is the least carbon gas emitting per ton-mile (Vidal, 2007). There have been discussions about including shipping under the Emissions Trading Scheme of the European Union or implementation of a fuel tax. Again, if maritime shipping is covered by greenhouse gas policies, fuel and freight transport costs will rise, perhaps significantly.

Climate change policies may also undermine or contravene trade liberalization in two ways. First, to the extent that ethanol has been developed to reduce greenhouse gas emissions (or to replace petroleum fuels, discussed below), one impact has been to increase grain prices. In 2008, a variety of factors including high fuel and fertilizer prices and diversion of American corn into ethanol, resulted in a spike in food prices. In response, several nations restricted, banned or taxed exports of grains, a direct counter to trade liberalization. (Progressive Policy Institute, 2008) Further, as climate change reduces national food production levels, there may be additional pressures to limit or halt food exports.

Second, there is concern that not all nations *will* adopt carbon pricing global warming policies and that the exports of nations that do *not* do so will have a price advantage in the marketplace; their products will sell at a lower price. One response to this is the border tax adjustment [BTA].

> A BTA is a tax levied on imported goods (or given as a rebate to exporters) to ensure that imports carry the same fiscal burden as domestically produced goods …. Usually, the BTAs apply to the good itself. However, BTAs on embedded substances, such as carbon, could be introduced and administered in the same way as taxes on substances found in products are. (Wysham, 2003, 15).

Border tax adjustments could take care of the competitive issues raised by nations' non-compliance with climate change policies. They appear to some scholars to be compatible with World Trade Organization rules. (New Economics Foundation, 2003; Charnovitz, 2003). However, BTAs adjusting for the carbon content of imports could raise substantial objections by members of trade agreements. Further, policies designed to reduce greenhouse gases of the sort envisaged by the Stern report (including taxes and subsidies) might well raise issues about their compatibility with NAFTA, WTO etc.

With the exception of the modest greenhouse gas reduction targets of Kyoto, (most of which have not been met) and the Emissions Trading Scheme of the European Union (which has not been a success as yet), there are few mandatory greenhouse gas policies in effect. As of the summer of 2008, greenhouse gas emissions were still rising at an increasing rate. Relative to the target levels of greenhouse gases (350 ppm) and the required emissions cuts, climate policies being discussed or already implemented are insufficient in both time scale and magnitude. Thus, policies designed to mitigate climate change will not prevent peak globalization, because they will not forestall climate change and because they are likely to increase fuel and energy costs and thus undermine the comparative advantage of the present long-distance division of labor.

### 5.2. Peak oil policies

In a seminal report commissioned for the Department of Energy, Hirsch et al., (2005) understand peak oil primarily as a liquid fuels crisis

[13] “If the present overshoot of this target CO2 is not brief, there is a possibility of seeding irreversible catastrophic effects” Hansen et al. (2008). Stern (2007, 318) see 450 ppm as the most ambitious greenhouse gas goal that is economically feasible.

[14] Both Ackerman (2009) and Stern (2007) discuss the degree to which such policies are intended to put a price on carbon to create price incentives to reduce greenhouse gas emissions.

[15] Given the lower energy efficiency of some Asian manufacturing sites, this higher cost of fossil fuels could also erode their comparative advantage of production.

(omitting its use as an industrial feedstock). They conceptualize the growing gap between falling, post-peak conventional oil supply and rising global demand for oil as an ever-increasing wedge. For oil depletion, mitigation policies are those which close this gap, either by reducing demand for liquid fuel or increasing its supply, while presuming the same quantity of transportation (passenger- and ton-miles). In selecting policy options, Hirsch et al. use five specific criteria. Viable options (1) substitute for fuels in existing uses, (2) can be produced on a very large scale, (3) use currently or nearly commercial technologies, (4) are "inherently energy efficient," and (5) are "environmentally clean by 2004 standards" (Hirsch et al., 2005) [environmental standards do not include greenhouse gas emissions as there were no pollution standards for these in the U.S. in 2005].

In terms of demand management options, they focus on increasing the fuel efficiency of vehicles, particularly automobiles and light trucks. Their standard improves on the U.S. 2006 mileage standards by 50%, 8 years after adoption. The standards would be 43.5 mpg for passenger cars and 31.5 mpg for light trucks (Bezdek et al., 2006, 20).[16] Ten years after adoption, it is expected that total annual oil savings would be 0.225 million barrels. This option would require several years to be phased in as they assume that only half the car and light truck fleet could be replaced in the first 15 years of this option. They omit consideration of increasing fuel efficiency for military vehicles, aircraft, ships, large trucks and locomotives. Even if they had included them, it is likely that much greater fuel efficiency could be achieved within the necessary time frame.[17]

Their viable supply-side options include enhanced oil recovery, coal liquefaction and oil shale. Improved oil recovery involves techniques to get more conventional oil out of existing wells. The second option is direct coal liquefaction or processing solid coal into synthetic oil. Finally, they see the energy intensive processing of oil shale as an additional way to produce liquid petroleum fuels. These options are not commercially viable at low prices of oil and will involve substantial investment to produce significant amounts of substitutes for conventional oil. Bezdek et al. estimate that, 10 years after implementation of these options, they will result in 4 million barrels per day, in terms of both decreased demand and alternative fuel supply (2006, p. 94). Bio-fuels, whether ethanol for automobiles or bio-diesel for trucks, were not seen as a viable option by Bezdek et al. This is due to their assessment that "… there are no developed biomass-to-fuels technologies that are now near cost competitive" (Hirsch et al., 2005). However, bio-fuel quotas have been adopted for fuel and climate change reasons both by the United States and the European Union. In addition to bio-fuels, Hirsch et al., also reject fuel switching to electricity for electric vehicles and hydrogen fueled vehicles. Again, the primary reasons are cost competitiveness and lack of commercially ready technologies at sufficiently large scales.

Bezdek et al. (2006) conclude that peak oil mitigation will require \$2.6 trillion of investment over a 20 year period. Over the same time frame, these options will result in 44 billion barrels of liquid fuels produced and saved (Bezdek et al., p. xvii). This is the equivalent of 6 million barrels per day. Also, "…the average cost of a barrel of fuel saved or produced for all of the options is about \$60." (p. xxiii) However, they do note that the costs of these four mitigation options will be greater the later they are implemented relative to the onset of the oil peak. While the economic policy options are not spelled out in depth concerning investment in new capital stock of higher mileage vehicles and new fuel production facilities, Bezdek et al. do discuss the possibilities of gasoline taxes, fees and rebates.

The implications of this four-pronged (five with bio-fuels) mitigation strategy for globalization and long-distance supply chains are relatively straightforward. First, it will do little to reduce fuel prices in the short and medium run; instead, it will likely increase fuel and vehicle prices due to higher costs of production per barrel. Second, it will not collectively fill the entire projected wedge between demand and supply. "It is important to note that initiation of all of the options simultaneously does not satisfy even half of the U.S. liquid fuels requirements prior to 2025 [assuming that the peak occurs in 2025 and that the options begin production 20 years prior to peak]" (Bezdek et al., 2006, xxv).

On balance, the Hirsch et al. (2005) peak oil mitigation options may ease the transition to a more regionally based pattern of production and trade, but it is unlikely that they will be able to preserve the current global pattern of trade. This conclusion is stronger the closer to oil production peak such policies are adopted. The fewer years before oil peak that they are adopted, the less they will be able to compensate for declining conventional oil production and the more they will cost. If the emerging consensus view of when oil peak will occur is correct (no later than 2012), we are well within the 20 year time frame for possible full and cost-efficient mitigation of oil depletion. In terms of the timeliness of the peak oil policy implementation, De Almeida and Silva conclude that in regard to such policies, "…almost no country is acting consistently to implement effective mitigation changes." (2009, 1268).[18]

This leaves policies that in effect adapt to peak oil. They are either not considered as viable options or are omitted from the analysis of Hirsch et al. (2005). They include mode shifting from road freight transport to rail or inland water (and from cars to public transportation), reduced maximum speed limits and shorter freight trips via relocation of manufacturing closer to consumption — localization or regionalization of supply chains (and for individuals, shortened work weeks, telecommuting, relocation of work) (Heinberg, 2004). Supply-side options also include grid-connected electric light rail and water borne freight transport both of which are likely to be much slower and able to carry significantly less freight than existing systems (Gilbert and Perl, 2008). These responses to expensive or decreasingly available fuels run directly counter to the globalization of supply chains.

In sum, as with climate change, even the ambitious peak oil mitigation policies delineated by Hirsch et al. (2005) will not prevent the liquid fuels crisis in the United States or elsewhere, particularly if they are implemented close to or after global oil production peaks. In the United States as of early 2009, policies such as those recommended by Hirsch et al. were not being vigorously pursued with the exception of increasing C.A.F.E. energy efficiency standards for automobiles and light trucks in the U.S. and the development of energy efficient and electric vehicles in China and elsewhere. In terms of the Hirsch et al. analysis and a projected oil peak date within a decade, mitigation policies are insufficient, leaving adaptation policies to focus more on local and regional than global supply chains.

## 6. Conclusion

Changes in natural capital are beginning to erode the economic logic of one major aspect of economic globalization: an international division of labor and production based on global supply chains. Over time, peak oil and climate change will result in "peak globalization,"

[16] The standards proposed by the Obama administration for implementation by 2016 are 35.5 mpg for both cars and light trucks (Mufson, 2009).

[17] While increased fuel efficiency will decrease the amount of petroleum fuel consumed (and greenhouse gases emitted) *per vehicle mile*, it will also decrease the (marginal) fuel costs per vehicle mile. This cost reduction will operate similarly to a decrease in the price of fuel and may *increase* vehicle miles traveled thus reducing the benefit of higher energy efficiency to both oil depletion and greenhouse gas emissions. Sorrell et. al. summarizes several studies of this "rebound effect" as being between 20 and 25% for personal transportation in the short run and up to 80% in the long run (that is, the percentage of the efficiency gain lost to increased consumption) (2009, 1360).

[18] The one exception in terms of the adequacy of its peak oil policies is Sweden. However, Sweden's policy goal of weaning itself entirely from petroleum within 15 years, if achieved, will not change the basic conclusions of this paper. See Vidal (2008) and Swedish Ministry for Sustainable Development (2006).

measured in terms of decreasing ton-miles of freight transported, particularly across oceans and continents. The economic logic of the comparative advantage of global supply chains will be overcome by both increasing transportation costs and interruptions and delays in the transit of freight.

This paper has shown the pathways of such effects, in particular via transportation infrastructure and the price of fuels. Climate change will mainly undermine global supply chains by damaging infrastructure as temperatures increase. Higher temperatures may also increase the demand for petroleum fuels (for refrigeration or due to reduced engine efficiency) or possibly reduce oil supply (as with the geographical vulnerability of the U.S. Gulf Coast oil industry to storm surges and hurricanes). Peak oil (as well as other export supply constraints), on the other hand, will have its major corrosive impact via higher fuel prices. Both climate change and peak oil will increase freight transport costs and increase time in transit. They are also likely to result in shortening of supply chains to a more local or regional basis, both due to cost and to lower available quantities of fuel. These pathways have been illustrated by severe weather events and of increasing petroleum prices after 2005 with the July 2008 prices spike of $147 per barrel.

Climate change and peak oil mitigation policies — both those currently in effect and those discussed by Stern (2007) and Hirsch et al. (2005) will not prevent peak globalization [note: the Stern and Hirsch et al. policies go well beyond any policies currently being considered in the United States or other nations]. These policies would use taxes, regulations and/or cap-and-trade programs leading to technological changes that would increase energy efficiency (to reduce oil consumption and greenhouse gas emissions), switch to alternative fuels and different modes of transportation.[19] Such policies will not prevent the shrinking of global supply chains. First, policies that have been implemented are small relative to the amount of greenhouse gas emissions to be reduced and the quantity of liquid fuels to be replaced. Second, the timing of such policies is too late to prevent either climate change or a shortfall of liquid fuels. It is very likely that existing concentrations of greenhouse gases in the atmosphere will result in a 2 °F (or more) increase in average temperatures. As for peak oil, it is increasingly clear that the peak is less than 20 years off, the minimal time Hirsch et al. specify for "filling the wedge" without major disruption. Moreover, as of August 2009, a cap-and-trade climate change/energy bill has been passed by the U.S. Senate but not the House of Representatives. There is no significant discussion — much less policy — explicitly regarding peak oil at the national or global levels (with the noted exception of Sweden), beyond a concern with reducing dependence on foreign oil.

Policies responding to peak oil and climate change may create some contradictions. Climate change policies may exacerbate peak oil impacts on fuel prices. They may also reduce the comparative advantage of some Asian nations that are much less energy efficient that the United States, Japan or Western Europe. Peak oil technologies (such as coal to liquid) may increase greenhouse gas emissions, potentially and partially solving one transportation problem (expensive fuel) at the expense of more rapid onset of climate change and infrastructure damage. It is essential that peak oil and climate change be discussion in tandem, especially concerning their feedback effects. A fuller analysis of peak oil and climate change and their impacts on global trade would also include macro-economic changes (negative growth and inflation), changing demand for carbon- and petroleum-intensive products, and the investments needed for both policies.

Peak oil and climate change undermine key foundations of the current global supply chain and its pattern of comparative advantage.

[19] These policies are designed to reduce emissions per unit of energy consumed or energy per ton-mile. They do *not* consider reduction of ton-miles of or total consumption of goods with their embedded greenhouse emissions. They presume an unchanged standard of living and travel and the existing global supply chain.

This does not mean that globalization is over or even in imminent danger. It does mean that it cannot last as oil depletion and climate change proceed. Offsetting technologies and policies are very unlikely to be implemented in sufficient magnitude or with sufficient promptness to counter peak globalization. The strong implication is that production and trade will need to become more local or regional, although this will not occur easily, cheaply or quickly.

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## References

Ackerman, F., 2009. Can We Afford the Future? The Economics of a Warming World. Zed Books, London.
Barkin, J.S., 2003. The counterintuitive relationship between globalization and climate change. Global Environmental Politics 3 (3), 8–13.
Bezdek, R.H., Wendling, R.M., Hirsch, R.L., 2006. Economic impacts of liquid fuel mitigation options. U.S. Department of Energy, National Energy Technology Laboratory Washington, D.C. http://www.netl.doe.gov/energy-analyses/pubs/Economic%20Impacts%20of%20U.S.%20Liquid%20Fuel%20Mitigation%20Options.pdf.
Borghesi, S., 2008. From Hubbert to Kuznets: on the sustainability of the current energy system. International Journal of Global Environmental Issues 8 (4), 425–444.
Boghesi, S., Vercelli, A., 2003. Sustainable globalisation. Ecological Economics 44, 77–89.
Brothers, C., 2008. Airlines Face 'Desparate' Situation, Official Says. June 3 New York Times.
Caldwell, H., Quinn, K.H., Meunier, J., Suhrbier, J., Grenzeback, L., 2002. Impacts of Global Climate Change on Freight Transport. Center for Climate Change and Environmental Forecasting, U.S. Department of Transportation, The Potential Impacts of Climate Change on Transportation, Washington D. C. http://climate.dot.gov/documents/workshop1002/caldwell.pdf.
Cambridge Energy Research Associates, 2006. Why peak Oil Theory Falls Down. Cambridge, Massachusetts.
Campbell, C.J., 2004. The Coming Oil Crisis. Multi-Science Publishing Company, Brentwood, England.
Chapman, L., 2007. Transport and climate change: a review. Journal of Transport Geography 15, 354–367.
Charnovitz, S., 2003. Trade and climate: potential conflicts and synergies. Beyond Kyoto: Advancing the International Effort Against Climate Change, Pew Center on Global Climate Change. http://www.pewclimate.org/docUploads/Beyond_Kyoto_Trade.pdf.
Clapp, J., Dauvergne, P., 2005. Paths to a Green World: The Political Economy of the Global Environment. The MIT Press, Cambridge, Massachusetts.
De Almeida, P., Silva, P.D., 2009. The peak of oil production — timings and market recognition. Energy Policy 37, 1267–1276.
Deffeyes, K.S., 2001. Hubbert's Peak: The Impending World Oil Shortage. Princeton University Press, New York.
Dicken, P., 2007. Global Shift: Transforming the World Economy. Guilford Press, New York.
Ehrenfeld, D., 2005. The environmental limits to globalization. Conservation Biology 19.2, 318–326.
Energy information Agency, 2009. Crude Oil Prices per Barrel. Department of Energy, Washington, D.C.
Engardo, P., 2008. Can the U.S. Bring Jobs Back from China? June 30 Business Week.
Evans-Pritchard, A., 2008. Oil Price Shock Means China is at Risk of Blowing Up. August 7 Telegraph, UK.
Gilbert, R., Perl, A., 2008. Transport Revolutions: Moving People and Freight Without Oil. Earthscan, London.
Goodstein, D., 2004. Out of Gas: The End of the Age of Oil. W.W. Norton & Company, New York.
Greene, D.L., Hopson, J.L., Li, J., 2004. Transportation Research Record 1880, 1–8.
Hall, C.T., 2006, May 4. Trade winds' slowdown backs warming theory. San Francisco Chronicle.
Hamilton, J.D., 2009. Causes and consequences of the oil shock of 2007–08. Brookings Papers on Economic Activity Spring 1, 215–261.
Hansen, J., Sato, M., Kharecha, P., Beerling, D., Berner, R., Masson-Delmotte, V., Pagani, M., Raymo, M., Royer, D.L., Zachos, J.C., 2008. Target atmospheric CO2: where should humanity aim? Open Atmospheric Science Journal 2, 217–231.
Heinberg, R., 2004. Powerdown: Options and Actions for a Post-carbon World. New Society Publishers, Gabriola Island, BC. 208 pp.
Hirsch, R.L., Bezdek, R., Wendling, R., 2005. Peaking of world oil production: impacts, mitigation and risk management. Science Applications International Corporation. U.S. Department of Energy, Washington, D.C. http://www.netl.doe.gov/publications/others/pdf/oil_peaking_netl.pdf.
Hoffman, W., 2008, July 21. Changing the fuel game. Traffic World.
International Monetary Fund, 2008. World Economic Outlook Database On-line. International Monetary Fund, Washington, D.C.

Jet Fuel Price Monitor, 2008, July 18. International Air Transport Association.
Jordan, M., 2002(July 18). Factories leave Mexico to find cheaper labor. Washington Post.
Kahn Ribeiro, S., Kobayashi, S., Beuthe, M., Gasca, J., Greene, D., Lee, D.S., Muromachi, Y., Newton, P.J., Plotkin, S., Sperling, D., Wit, R., Zhou, P.J., 2007. Transport and its infrastructure. In: Metz, B., Davidson, O.R., Bosch, P.R., Dave, R., Meyer, L.A. (Eds.), Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, United Kingdom. http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter5.pdf.
Kanter, J., 2008, June 27. Europe tells airlines to pay for emissions. New York Times.
Kirschbaum, E., 2008. Slower Boats to China as Ship Owners Save Fuel. Reuters.
Kunstler, J.H., 2005. The Long Emergency. Atlantic Monthly Press, New York.
Lehmann, H., Peter, S., Schindler, J., Zittel, W., 2007. Coal: resources and future production. Energy Watch Group. http://www.energywatchgroup.org/fileadmin/global/pdf/EWG_Report_Coal_10-07-2007ms.pdf.
Lemonick, M.D., 2009. As Effects of Warming Grow, U.N. Report is Quickly Dated. Yale Environment 360.
Limao, N., Venables, A.J., 2001. Infrastructure, geographical disadvantage, transport costs, and trade. The World Bank Economic Review 15.3 (4), 51–479.
Mills, B., Andrey, J., 2002. Climate Change and Transportation: Potential interactions and impacts, Center for Climate Change and Environmental Forecasting, U.S. Department of Transportation. The Potential Impacts of Climate Change on Transportation. http://climate.dot.gov/documents/workshop1002/mills.pdf.
Mintzer, I., Leonard, A., 2005, November/December. Trade and consequences. World-Watch 23–27.
Moskwa, W., 2008. SAS Flies Slower to Save Costs and Emissions. May 20 Reuters.
Mufson, S., 2009. Vehicle emission rules to tighten. Washington Post May 19.
New Economics Foundation, 2003. Free Riding on the Climate: The Possibility of Legal, Economic, and Trade Restrictive Measures to Tackle Global Warming. New Economics Foundation, London. http://www.neweconomics.org/gen/z_sys_PublicationDetail.aspx?PID=167.
Oliver, R., 2008. Shipping's Impact on Air. CNN.com. January 29.
Pfeiffer, D.A., 2006. Eating Fossil Fuel: Oil, Food and the Coming Crisis in Agriculture. New Society Publishers, Gabriola Island, British Columbia.
Pimental, D., Zuniga, R., Morrison, D., 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52, 273–288.
Porter, R.C., 2006. Book reviews. Section Q. Journal of Economic Literature 44 (1), 186–190.
Progressive Policy Institute, 2008, June 8. Five countries have cut off rice exports this year. Trade Fact of the Week. http://www.ppionline.org/ppi_ci.cfm?knlgAreaID=108&subsecID=900003&contentID=254657.
Rossetti, M.A., 2002. Potential Impacts of Climate Change on Railroads. Center for Climate Change and Environmental Forecasting, U.S. Department of Transportation. The Potential Impacts of Climate Change on Transportation. http://climate.dot.gov/documents/workshop1002/rossetti.pdf.
Rubin, J., 2009. Demand Shift, Homer-Dixon, T., Garrison, N. Carbon Shift: How the Twin Crises of Oil Depletion and Climate Change Will Define the Future. Random House of Canada.
Rubin, J., Tal, B., 2008, May 27. CIBC world markets: occasional paper. Will soaring transport costs reverse globalization? http://yaleglobal.yale.edu/about/pdfs/oil.pdf.
Schlumberger, C.E., 2009. The oil price spike of 2008: the result of speculation or an early indicator of a major and growing future challenge to the airline industry? Annals of Air and Space Law XXXIV, 111–149.
Schwartz, H.G., Clark, A.C., Dickey, G.E., Eads, G.C., Gallamore, R.E., Guiliano, G., Gutowskil, W.J., Iwasaki, R.H., Jacob, K.H., Kar, T.R., Lempert, R.J., Paiewonsky, L., Phinlander, S.G.H., Zeppie, C.R., 2008. Potential Impacts of Climate Change on U.S. Transportation. National Research Council of the National Academies, Washington, D.C. http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf.
Smith, C., 2006 (December 19). Aviation and oil depletion. The oil drum Europe. http://europe.theoildrum.com/node/28582006.
Sorrell, S., Dimitropoulos, J., Sommerville, M., 2009. Empirical estimates of the direct rebound effect: a review. Energy Policy 37, 1356–1371.
Stern, N., 2007. The Economics of Climate Change. Cambridge University Press, Cambridge, England.
Swedish Ministry for Sustainable Development, 2006. Peak oil & Sweden: what a small country can do. Energy Bulletin May 8.
Tisdell, C., 2001. Commentary: globalisation and sustainability: environmental Kuznets curve and the WTO. Ecological Economics 39, 185–196.
UNCTAD Secretariat, 2007. Review of maritime transport 2007. United Nations Conference on Trade and Development. United Nations, New York.
UNCTAD Secretariat, 2008. Handbook of statistics on-line. United Nations Conference on Trade and Development. United Nations, New York.
U. S. Geological Survey, 2000. US geological Survey World Petroleum Assessment 2000. Reston, Virginia, USA.
Vidal, J., 2007. CO2 Output from Shipping Twice as much as Airlines. March 3 Guardian, UK.
Vidal, J., 2008. Sweden Plans to be World's First Oil-free Economy. Guardian, United Kingdom. May 22.
Wallis, D., 2009. U.N. Says Food Production May Fall 25 Percent by 2050. Feb. 17 Reuters.
Whipple, T., 2008a, June 16. Peak Oil Review.
Whipple, T. 2008b, July 7. Peak Oil Review.
Whipple, T., 2008c. Peak oil. Bulletin of the Atomic Scientists 64 (5), 34–37.
Whipple, T., 2009, April 13. Peak Oil Review.
Wysham, D., 2003. Sustainable Development in North and South: Climate Change Policy Coherence in Global Trade and Financial Flows. March 25 Institute for Policy Studies.
Zhao, L., Feng, L., Hall, C.A.S., 2009. Is peakoilism coming? Energy Policy 37, 2136–2138.