BACK- AND FORECASTING FREIGHT TRANSPORT CO2 EMISSIONS: DECOMPOSITION FROM A GROWTH CYCLE PERSPECTIVE

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ABSTRACT

One of today's major sources of greenhouse gas emissions is the transport sector. According to the latest assessment from the IPCC, transportation accounted for 23% of all energy-related greenhouse gas emissions in 2004 (IPCC 2007) having grown by 26% since 1990 (for EU-25). Growth in transport emissions is caused by several factors. Historically, transport volumes have grown with economic development (Tapio 2005, Eurostat 2007) and some therefore argue transport emissions as something we might have to accept in order to achieve desired economic development. Many studies, however, have shown that a decoupling between freight transport work (ton km) and economic activity, as well as freight traffic work (vehicle km) and economic activity, is possible and also feasible (Tapio 2005, Kveiborg and Fosgerau 2007). Nonetheless, there is still a lack of understanding of the complicated interrelation between economic development and freight transport emissions.

This paper seeks to investigate this further and extend previous models to explicitly address long term structural shifts in the economy and its effect on the emissions from all transport modes, as observed thus far, to explain the observed development and predict emissions levels for the next ten years.

The issue is addressed through a *Divisia Index decomposition* method, similar to that of, for example, Lashkmanan and Han (1997). The observed increase in freight transport CO_2-

emissions is caused by several factors, and by using a decomposition model we can calculate the relative contributions of each factor over time (Ang and Zhang 2000). Some of these factors are primarily behavior driven whereas others are technology driven. By doing a decomposition analysis, we can extrapolate likely development into a number of scenarios with different levels of behavioral and technological development.

The findings are line with the patterns predicted by economic growth cycle theories. The Swedish 31% growth in freight transport CO_2-emissions 1990-2008 is primarily driven by the economic development. Structural shifts within the economy causes the tonkms/GDP to decrease over the period and due to a number of other rationalizing efforts among the firms within the economy, this positive effect is even greater for the freight transport CO2 emissions per tonkm. The greatest positive effect is due to organizational improvements reducing the traffic intensity. Also, the increased use of less carbon-intensive fuel sources contributes significantly.

Based on the growth cycle theories, the observed development is extrapolated as to predict outcomes for the coming years. Through such an exercise it is shown that in a "business-as-usual" scenario, freight transport CO_2-emissions are likely to decrease by some 10% over the coming ten year period.

Keywords: freight transport emissions, logistics, carbon footprint, forecast

INTRODUCTION

In the current debate on climate change, there is a growing scientific consensus that the global temperature increase will have to be stabilized around 2^{o} Celsius as compared to pre-industrial levels to "prevent dangerous anthropogenic interference with the climate system" (IPCC 2007). This level has become an official goal for the EU (EU 2005), implying a need for greenhouse gas emissions reductions by 70-85% until 2050 (MVB 2007). In order for this to be feasible, major changes in all sectors of industry are required.

Further, while most sectors within the EU have seen smaller or bigger reductions in CO_2-emissions since 1990, emissions from transportation has grown by 26%, with freight transport being the main driver (Eurostat 2007). Due to globalization, supply chains are lengthened, and with the simultaneous increase in consumption more goods are moved over greater distances on their path from raw material to end consumer (McKinnon 2008). Logistics practices such as just in time and time based distribution have increased the demand for faster and more polluting modes of transport and thus offset measures taken by vehicle producers and transport companies to increase fuel and energy efficiency of vehicles (Kveiborg and Fosgerau 2007, Kohn and Brodin 2008, McKinnon 2008).

Growth in transport emissions is caused by several factors. Historically, transport volumes have grown with economic development (Tapio 2005, Eurostat 2007) and some therefore argue transport emissions as something we might have to accept in order to achieve desired economic development. Many studies, however, have shown that a decoupling between freight transport work (ton km) and economic activity, as well as freight traffic work (vehicle km) and economic activity, is possible and also feasible (Tapio 2005, Kveiborg and Fosgerau

2007). There is still, however, a lack of understanding of the complicated interrelation between economic development and freight transport emissions.

This paper seeks to investigate this further and extend previous models to explicitly address long term structural shifts in the economy and its effect on the emissions from all transport modes, as observed thus far, to forecast emissions levels for the next ten years. In particular, we seek to answer the following:

What coupling exists between economic development and freight transport CO_2 emissions in Sweden as seen over time thus far?

What does this tell us about likely future development of freight transport CO_2 emissions?

What implications does this have on regulatory measures needed to reach set targets for 2050?

We address the issue through a Divisia Index decomposition method, similar to that of, for example, Lashkmanan and Han (1997). The observed increase in freight transport CO_2-emissions is caused by several factors, and by using a decomposition model we can calculate the relative contributions of each factor over time (Ang and Zhang 2000). Some of these factors are primarily behavior driven whereas others are technology driven. By doing a decomposition analysis, we can extrapolate likely development into a number of scenarios with different levels of behavioral and technological development. The carbon emissions of these scenarios may then be compared to emissions target levels for 2050 as set by governments in Sweden and Europe.

Although freight transport decomposition analyses are plentiful, this paper aims at making a contribution in two ways. First, the theories of economic growth cycles will be used to explain observed trends and make predictions for the future. Secondly, the paper aims at connecting these macro economic theories with observed changes in modal shifts, energy efficiency and emissions intensity of the different transport modes. Whereas many other studies choose to focus on one mode of transport (Sorrell *et al.* 2009) or to assume emissions levels only to be closely related to the amount of traffic work performed (Kveiborg and Fosgerau 2007), this paper seeks to investigate these aspects in particular. Thus, the paper will extend previous models and connect micro level changes to macro level theories and offer a new perspective on the issue of CO_2 emissions from freight transport.

The paper is structured as follows. In section 2 we review the theories of economic growth and structural changes as well previous literature that discuss the coupling issue with regards to transportation. The next section describes the decomposition analysis and how it was applied to the Swedish data set. In section 4 the data is analyzed and the observed development is explained based on the presented theories. The paper closes with conclusions and implications for future policy making.

THEORETICAL FOUNDATIONS

Economic growth cycles[1]

When examining GDP over time in real prices, it is often concluded that the long-term economic development is linear, steadily increasing, only interrupted by temporary disturbance. However, if one instead chooses to look at the variations in the yearly growth rates, another pattern emerges, showing cyclic patterns in the economic growth created by variations in the growth rates from around five to six percent to minus one percent (see

[1] This section is based on Lundquist and Olander (2009)

Figure 1). In fact, two growth cycles may be identified in the observed time period. One started in the 1930's, was interrupted by the second world war, and continued thereafter with a strong increase during the 1950's and 1960's, was then decelerated and reached its lowest level during the late part of the seventies. The other growth cycle has progressed half way at present. It commenced during the 1980's and accelerated during the 1990's and after the turn of the millennium. If this wave follows the patterns of the previous it will, after its recuperation from the financial crisis, start to decelerate and reach a new bottom level (Lundquist and Olander 2009).

The explanation to these patterns may be found in radical innovations and infrastructural expansion. These technologies are referred to as "General Purpose" technologies and can be identified as the create discontinuity and structural breaks between two growth cycles. Historically, these technologies have been connected to communication, transportation and energy – technologies which may be used in most economic areas and complement other technologies and operations. The operations that grow out from these technologies take the lead in the structural change that constitutes the first part of the growth cycle (20-25 years).

The second part of the growth cycle, the *rationalization* (appr. 10-15 years), is characterized by more stable economic conditions in terms of social institutions, radical technology, production and international relations. New companies decline in numbers, companies start merging in increasing quantities, economies of scale may be more significant and integration in different markets increases. All this involves gradually increasing competition, especially in foreign markets. Rationalization is increasing sharply with increasing efficiency, cost cutting and declining employment as a result. The process ultimately leads to a structural crisis that makes societies and economies prepared to once again change into new growth directions (Lundquist and Olander 2009).

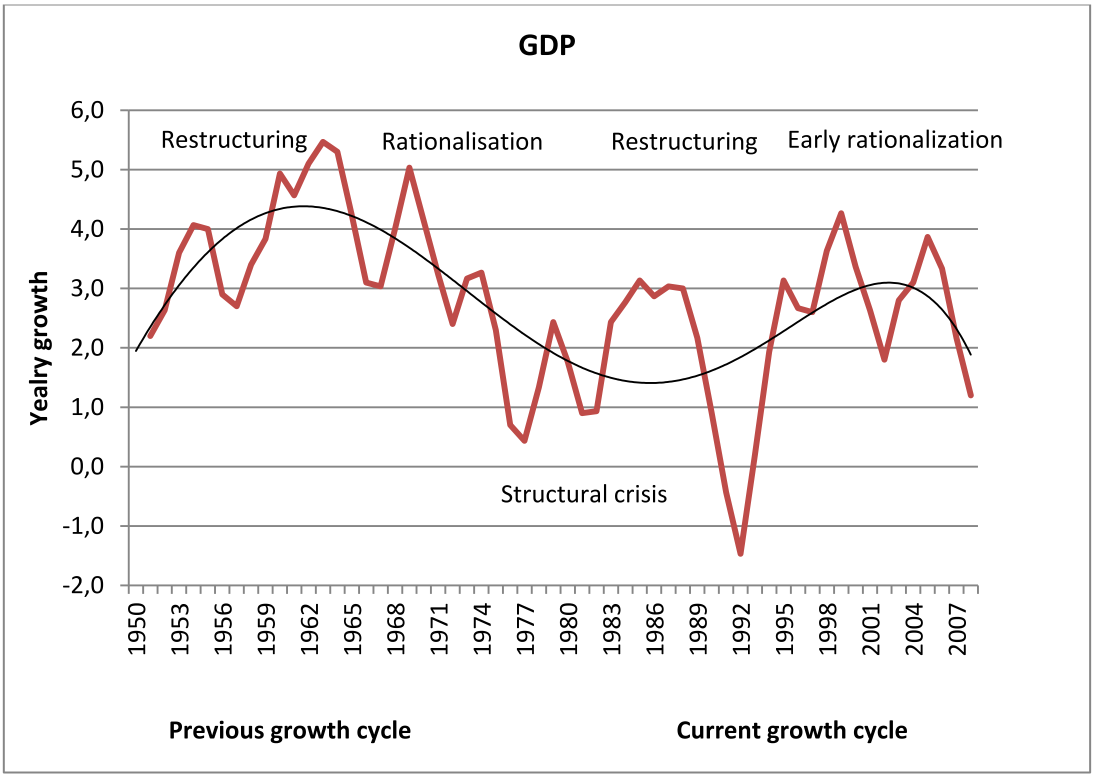

Figure 1. The yearly growth in Swedish GDP shows cyclic trends in the long term development. Yearly growth in percentage. Fixed prices (base year=2000). 3-year moving average. Polynomial trend line.

Describing and forecasting freight transport CO_2 emissions

Through these growth cycles, transport emissions vary as a result of structural changes and different levels of rationalizing efforts among shippers and transport service providers. Despite this, no research can be found on the relation between the two.

The issue of current and future freight transport CO_2-emissions has been addressed by other researchers in different ways. Steenhof et al. (2006) use an approach similar to ours. In their decomposition analysis of surface freight transport in Canada, Steenhof et al. (2006) decompose the growth in freight transport CO2 emissions from 1990 to 2003 into changes in modes, fuel mix, activity, and efficiency. Based on the findings they create a number of scenarios for the development until 2012. However, the relation between structural changes in the economy and transport activity is left out of the analysis.

These aspects are also excluded in Piecyk and McKinnon (2009). Here, the future carbon footprint of road freight transport is addressed through Delphi studies, through which a number of key factors are quantified for 2020. Scenarios are built and for these scenarios emissions levels are calculated. The factors used are similar to those presented in decomposition analyses by for example Kveiborg and Fosgerau (2007) or Sorrell et al. (2009).

Many other decomposition models exist with slightly different purposes and contexts. McKinnon and Woodburn (1996) investigate logistical restructuring and its effect on road freight traffic in the United Kingdom. Lakshmanan and Han (1997) seek to explain the underlying factors of transportation CO_2 emissions in the USA. They consider all modes of transport and both freight and passenger transportation. Kveiborg and Fosgerau (2007) asses the decoupling between economic activity and freight traffic growth in Denmark and Sorrell et al. (2009) decompose road freight energy use in the United Kingdom. All models use a number of conversion factors to relate economic activity or production values to freight transport performance.

This paper uses the same approach, but relies on economic growth cycle theory to provide explanation to the variations in decoupling found in for example Tapio (2005). By using a large Swedish data set and extrapolate the observed development, based on these theories, a number of predictions can be made for scenarios by 2020. The next section will describe how this is done.

ANALYTICAL APPROACH

A decomposition analysis

To investigate the coupling between economic measures and the development of transport emissions we will rely on a *Divisia Index decomposition* analysis, similar to that of Lakshmanan and Han (1996), Steenhof et al. (2006), Kveiborg and Fosgerau (2007) and Sorell et al. (2009). This method is often used to decompose a trend over time to its component parts (Lakshmanan and Han 1997) and has been used extensively in energy research (Ang and Zhang 2000). In particular, the method has been proven useful when data is limited or when one wants to compare data of different types, for example economic measures and freight transport data (Kveiborg and Fosgerau 2007). By using a decomposition model we are able to look at dependencies between key variables through aggregate data. For a more thorough discussion on different decomposition methods see for example (Ang and Zhang 2000).

To describe the logic of the decomposition, let us consider an aggregate measure such as CO_2 emissions within an economy. Trends in such an aggregate measure can be explained as a product of two or more variables. For example, the total CO_2 emissions from industry sector *i* (E_i), can be explained as the product of the sectors emissions intensity ($I_i = E_i/A_i$) and economic output (A_i). This yields for the total economy

$$E = \sum_{\forall i} A_i I_i. \quad (1)$$

If we choose to denote the share of economic output from industry *i* as S_i=A_i/A, with $A = \sum_{\forall i} A_i$, we get

$$E = A \sum_{\forall i} S_i I_i. \quad (2)$$

The goal of the analysis is to investigate these right-hand-side variables over time as to understand in which way they have affected the change in the 'dependent' variable, *E* (Sorrell *et al.*). For example, if we observe a decline in the aggregate CO_2 levels (*E*), is this change due to a change in industry structure (*S*), with production moving from more polluting sectors to less polluting ones, or due to an overall decline in emissions intensity in the different sectors (*I*)? Or in our case; has freight transport CO_2 emissions decreased because of a change to less polluting modes of transport or due to increased emissions efficiency in the current mix of transport modes?

In order to investigate these changes, Equation (2) can be differentiated with respect to time

$$\frac{\partial E}{\partial t} = \sum_{\forall i} \left(AS_i \frac{\partial I_i}{\partial t} + AI_i \frac{\partial S_i}{\partial t} + S_i I_i \frac{\partial A}{\partial t} \right) \quad (3)$$

$$\frac{\partial E}{\partial t} \cdot \frac{1}{E} = \sum_{\forall i} \left(\frac{AS_i}{\sum AS_i I_i} \frac{\partial I_i}{\partial t} + \frac{AI_i}{\sum AS_i I_i} \frac{\partial S_i}{\partial t} + \frac{S_i I_i}{\sum AS_i I_i} \frac{\partial A}{\partial t} \right). \quad (4)$$

Through manipulation we get

$$\frac{\partial \ln(E)}{\partial t} = \sum_{\forall i} \frac{AS_i I_i}{\sum AS_i I_i} \frac{\partial \ln(I_i)}{\partial t} + \sum_{\forall i} \frac{AS_i I_i}{\sum AS_i I_i} \frac{\partial \ln(S_i)}{\partial t} + \sum_{\forall i} \frac{AS_i I_i}{\sum AS_i I_i} \frac{\partial \ln(A)}{\partial t}. \quad (5)$$

This is a weighted sum where the weights

$$w_i = \frac{AS_i I_i}{\sum AS_i I_i} = \frac{E_i}{E}, \quad (6)$$

and hence we arrive at the following expression for the change in the aggregate measure

$$\frac{\partial \ln(E)}{\partial t} = \sum_{\forall i} \frac{E_i}{E} \frac{\partial \ln(I_i)}{\partial t} + \sum_{\forall i} \frac{E_i}{E} \frac{\partial \ln(S_i)}{\partial t} + \sum_{\forall i} \frac{E_i}{E} \frac{\partial \ln(A)}{\partial t}. \quad (7)$$

That is, a change in the aggregate may be expressed as the sum of the changes in the underlying factors weighted by their contribution to the whole. However, this holds true only in continuous time, whereas our data is discrete. We will therefore approximate changes by a two-year moving average

$$\frac{\partial \ln(E_t)}{\partial t} \approx \frac{E_t - E_{t-1}}{E_{t-1}}. \quad (8)$$

This poses some difficulties as an "interaction term" will emerge. This interaction term can be seen as the joint contribution from the different factors (Kveiborg and Fosgerau 2007). We choose to discard this interaction term as it has been shown (Lakshmanan and Han 1997, Oosterhaven and Hoen 1998) that the interaction term will be important only if data has been sampled with large enough time intervals. Since we have one year between the samples the interaction term will be ignored. The same estimation is used for the other variables.

APPLYING THE DECOMPOSITION TO THE DATA

The overall growth in freight transport CO_2 emissions can be said to depend on a number of factors. Previous decompositions have identified a number of critical factors such as economic development, weight-to-value ratios, transport work, traffic work, and energy and emissions intensities (McKinnon and Woodburn 1996, Lakshmanan and Han 1997, Kveiborg and Fosgerau 2007, Sorrell *et al.* 2009). Based on these studies, we choose to decompose the overall growth in freight transport CO_2 emissions according to Figure 2.

The first component trend is the *economic activity* – here represented by the GDP of the economy – which depicts the market value of the goods and services produced in the economy. The decoupling between economic growth and growth in transport work is said to be one of the main targets of policy-makers (EU) and several studies explore this further (e.g. (Tapio 2005, Kveiborg and Fosgerau 2007, McKinnon 2007, Sorrell *et al.* 2009). The second ratio is the *inverse value density*, that is, the weight (volume) of the goods produced in the economy per unit of economic activity. The ratio is influenced by the nature of the products produced in the industry and the 'servicification' of the economy in large. The word "ton" is here a volume measure. Next is the *transport intensity,* depicting the amount of transport work needed in the economy to transport a certain volume of production output. This ratio will be influenced by the industry structure of the economy if seen from a macro perspective and by the logistics structures of the shippers if seen from a micro perspective. A decrease in the ratio may be achieved through changes in the shippers' logistics system with, for example, more local sourcing and production, less off-shore outsourcing, more decentralized distribution systems, and more direct deliveries (Cooper *et al.* 1991, Wu and Dunn 1995, McKinnon and Woodburn 1996). The above ratios can all be said to belong to a "macro domain", depicting the behavioral changes within the economy that shape the demand for transportation. This data is rather easy to come by and for these measures a large data set, depicting the economic development since the 1970's is used. The data was gathered by Statistics Sweden[2].

Although the above ratios all affect the demand for transport, the actual pollution is caused by the use of vehicles and we therefore have to decompose the trend further. This can be done by considering the *traffic intensity* which depicts the amount of traffic work needed per unit of transport work. This ratio is dependent upon the capacity of the vehicles and the degree of utilization of this capacity. Subsequently, the ratio may be decreased through the use of larger vehicles and through initiatives aimed at increasing the fill-rates of vehicles. Next, the *energy intensity* is the measure describing the amount of energy needed to move the vehicle forward, that is, the energy consumed per unit of traffic work. Primarily, this ratio is affected through changes in vehicle design such as changes in aerodynamics, tyre inflation, or vehicle weight. The ratio is also dependent upon the driving behavior (Ang-Olson and Schroeer 2002). Lastly, we find the *emissions intensity* which is determined by the fuel source for the transport mode and is the amount of CO2 emissions per energy used. The use of non-fossil fuels or electric engines with electricity produced from low-carbon sources will decrease this ratio.

The last three ratios can all be seen as belonging to the "micro domain", and may primarily be affected through technology changes. Data for these measures are harder to come by and somewhat shorter time series produced by the Swedish Institute for Transport and Communication Analysis (SIKA) and the Swedish Environmental Protection Agency is used for the analysis. In those cases where freight transport was not dealt with specifically in the statistics, the freight transport share was estimated according to the model presented by the Swedish Environmental Protection Agency. For the sea bound traffic work, which is currently

[2] Available online at http://www.scb.se

not measured, estimations used by the Swedish Maritime Administration was used. The complete data set covers domestic freight transport in Sweden 1990-2008.

$$CO_2\text{emissions} = \text{GDP} \times \frac{\text{ton}}{\text{GDP}} \times \frac{\text{tonkm}}{\text{ton}} \times \frac{\text{vehiclekm}}{\text{tonkm}} \times \frac{\text{kWh}}{\text{vehiclekm}} \times \frac{CO_2\text{emissions}}{\text{kWh}}$$

Figure 2. Conceptual representation of the decomposition

The following data is thus used in the analysis:

X_t = Economic activity (GDP), in year *t,*
M_t = Weight of goods transported, as measured in tons, in year *t,*
V_{it} = Transport work by transport mode *i,* in year *t,* as measured in ton km
K_{it} = Traffic work performed by mode *i* in year *t,* as measured in vehicle km
C_{it} = Energy consumption by freight transport of mode *i* in year *t,*
E_{it} = Freight transport CO2 emissions from mode *i* in year *t.*

From the data we can construct the following variables for our decomposition model:

$\gamma_t = \frac{M_t}{X_t}$ = inverse value density of the economy in year *t*
$\nu_t = \frac{V_t}{M_t}$ = transport intensity of the economy in year *t*
$\sigma_{it} = \frac{V_{it}}{V_t}$ = modal split; share of transport mode *i* in terms of total ton kilometers, year *t,*
$\tau_{it} = \frac{K_{it}}{V_{it}}$ = traffic intensity for transport mode *i* in year *t,*
$\varepsilon_{it} = \frac{C_{it}}{K_{it}}$ = energy consumption per vehicle km for mode *i* in year *t,*
$\kappa_{it} = \frac{E_{it}}{C_{it}}$ = CO2 emissions intensity of mode *i* in year *t.*

It is now possible to decompose the overall trend of transport CO_2 emissions according to the conceptual representation presented in Figure 2. Using the same logic, the following holds

$$E_t = X_t \gamma_t \upsilon_t \sum_I \sigma_{it} \tau_{it} \varepsilon_{it} \kappa_{it}. \quad (9)$$

Further, following the logic of Equations (3)-(7), and expressing the change in a variable Y as $\dot{Y} = \partial \ln(Y) / \partial t$, the change in the total emissions can be expressed as the weighted sum

$$\dot{E}_t = \dot{X} + \dot{\gamma}_{it} + \dot{\upsilon}_{it} + \sum_i \frac{E_{it}}{E_t} \dot{\sigma}_{it} + \sum_i \frac{E_{it}}{E_t} \dot{\tau}_{it} + \sum_i \frac{E_{it}}{E_t} \dot{\varepsilon}_{it} + \sum_i \frac{E_{it}}{E_t} \dot{\kappa}_{it}. \quad (10)$$

DECOMPOSING FREIGHT TRANSPORT DEVELOPMENT

The total growth in freight transport CO_2-emissions in Sweden 1990-2008 was 31%. In Figure 3 this development is depicted alongside GDP and transport work (ton km) for the same period. A certain correlation exists between the three variables. This correlation is however weak as the progress is clearly decoupled at several occasions over the shown 20 years. This indicates that the observed development in emissions cannot be explained only in terms of economic growth or an overall increase in transport work. In order to further investigate the drivers behind the observed development, a decomposition of the emissions – as described in previous section – must be made. The results of this decomposition are found in Table 1.

A number of interesting observations can be made from Table 1. First, over the investigated period, GDP has grown considerably (+41%). Since the amount of transported tons have been more or less on a constant level for the whole period the value density has increased greatly (inverse has decreased -42%). This suggests as a structural shift in the economy, away from goods producing industries towards service-based industries. That less tons need to be transported in 2008 to provide the same economic activity as in 1990 is supported by the results of similar studies in the UK (Sorrell *et al.* 2009) as well as Denmark (Kveiborg and Fosgerau 2007).

The increased transport intensity, as measured in tonkm per ton, implies that within this more service-based economy, every transported ton is transported a greater distance. Despite this, total tonkms have grown at a slower rate than GDP and, more importantly, the amount of emissions produced per tonkm has decreased (see Figure 3). This development may be explained by the growth cycle theory presented in Section 0. From late 1980's until late 1990's, the Swedish economy was in a restructuring phase, driven by the implementation of new general purpose technologies. Transport work grew quickly alongside GDP as firms within the economy prioritized growth instead of rationalization and cost savings. The growth was temporarily interrupted during crises around 1991 and 2001 which were preceded by minor rationalizing efforts by firms competing on receding markets. Overall, the investigated period has been characterized by strong economic growth and tonkms have increased accordingly. Lately, signs of rationalization can be seen as tonkms are once again growing at a slower speed than GDP. The decline in transport CO_2-emissions is a strong indication of rationalizing efforts as many efforts targeted at reducing transportation costs will in fact decrease CO_2-emissions too.

It should also be noted that the transport intensity has been on a more or less constant level since late 1990's. This supports the findings of Sorrell et al. (2009) suggesting that the long-established process of concentrating economic activity may be beginning to weaken although factors regarding more efficient routing may play a role.

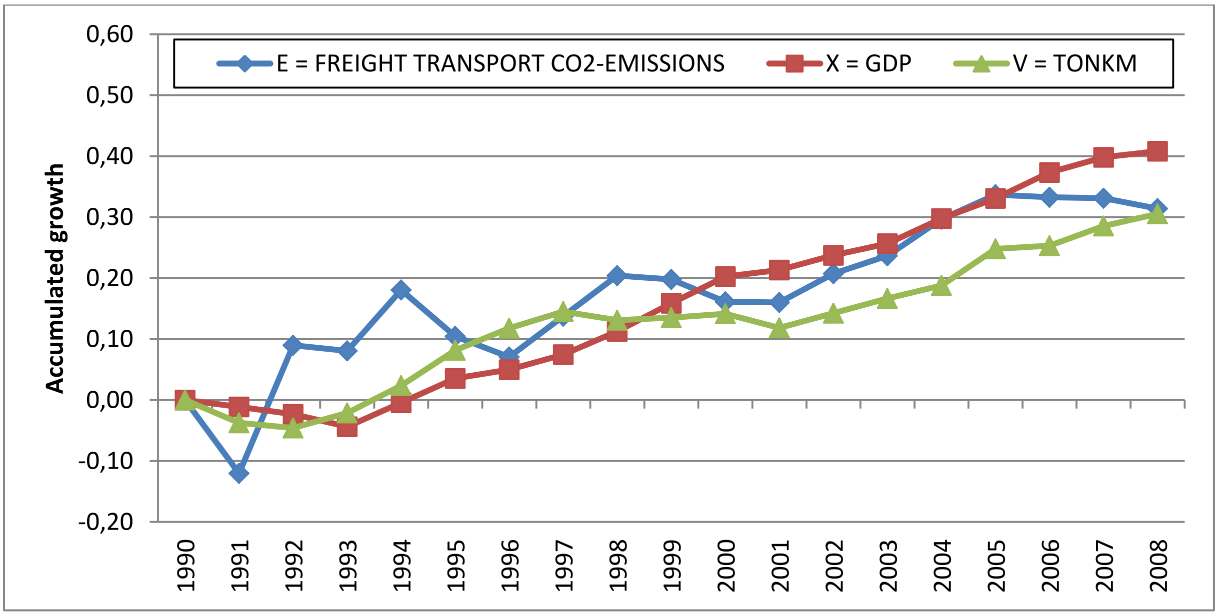

Figure 3. GDP, Tonkm, and Freight Transport CO2 emissions

The growing amount of transport work has been provided by mixed modes of transport, with a growing amount of goods being transported by means of road transport. Most of this modal shift (+8%), however, occurred in the mid-nineties (see Figure 4). Since the turn of the century this effect has been reduced and slightly negative, implying that a greater share of the total tonkms is transported by means of rail and ship and less by means of all-road solutions. One explanation may be an increase in the supply of competitive inter-modal transport solutions and improved infrastructure for containerized transportation.

It can also be seen that the traffic intensity, that is, the amount of vehiclekms per tonkms, has been reduced (-6%). With increasing transport distances, this suggests a significant improvement in the use of transport resources – despite the overall shift towards road transport. The true reason for this cannot be found in our data. Other studies with similar results show this to be a result of less empty running vehicles in combination with larger loads in every vehicle (Kveiborg and Fosgerau 2007). Whether the improvement in our numbers is due to better planning, larger vehicles, consolidation efforts or an increased amount of logistics outsourcing, cannot be analyzed with the available data. It can be shown, however, that for the different modes of transport, the greatest reduction in traffic intensity is found in road transport (-7%). Hence, despite the intensive growth of the economy over the investigated period – which is characterized by growth in transport work – the aggregated measures show clear signs of efficiency improvements.

A somewhat surprising result is the increase in energy intensity (+7%), with ship transport being the only mode of transport displaying improvement. Considering the discussion above, the overall increase is likely to be a side-effect of the improvements seen in the traffic intensity. With larger loads per vehicle, more energy will indeed be needed to move the vehicle forward. Independently of whether the larger loads per vehicle are due to increased fill-rates or larger vehicles, an increase in load will act counterproductively on energy efficiency measures. Energy efficiency actions such as Eco-driving have not managed to offset this development.

A more promising result is the decrease in emissions intensity (-4%) that can be seen for all modes of transport. Since this ratio expresses the amount of emissions *per unit of energy consumed*, it is primarily a measure of the carbon intensity of the energy source. Thus, the observed increase can largely be attributed to technological development and increased use of non-fossil fuels among trucks, trains, and ships. A large improvement is also seen for rail-bound transport which is likely to be a result of newer and cleaner engines.

Table 1. Decomposed growth in freight transport CO2 emissions between 1990-2008

VARIABLE	% Change 1990-2008
GDP	40,82%
INVERSE VALUE DENSITY	-41,84%
TRANSPORT INTENSITY	35,79%
MODAL SPLIT	7,69%
TRAFFIC INTENSITY	-6,28%
ROAD	-6,53%
SHIP	0,34%
RAIL	-0,08%
ENERGY INTENSITY	6,62%
ROAD	6,81%
SHIP	-0,32%
RAIL	0,13%
EMISSIONS INTENSITY	-4,16%
ROAD	-3,07%
SHIP	-0,05%
RAIL	-1,05%
CORRECTION FOR APPR.	-7,57%
FREIGHT TRANSPORT CO2 EMISSIONS	**31,40%**

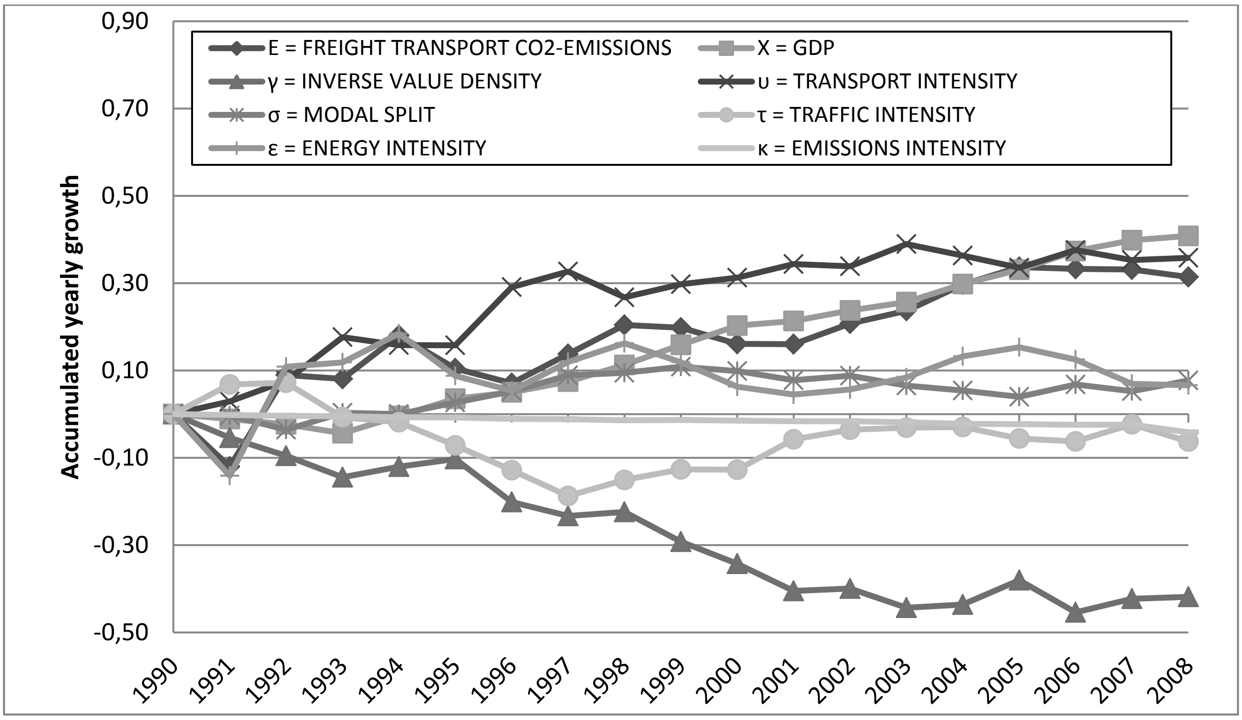

Figure 4. Decomposing freight transport CO_2-emissions over time

IMPLICATIONS FOR FUTURE DEVELOPMENT

From the data three major trends can be identified:

1. GDP has been growing in line with a suggested cyclic pattern
2. The amount of transport work (tonkm) per GDP has been declining due to structural changes in the economy
3. The amount of emissions per tonkm has decreased due to organizational improvements (decreased traffic intensity) and technological improvements (decreased emissions intensity) among the firms of the economy

Considering these three statements, what can be said about the likely future development of freight transport CO2-emissions? Although no forecasts can accurately describe the future, the data from the last 18 year along with the theories of economic growth can tell us something about what is to be expected.

Let us start with the first of the points as this has impact on the others. If the economy is to follow previous patterns the current growth cycle is about to enter the second phase where rationalization is the major driver among firms. Forecasts for economic development can be found for the coming two years[3]. After this, forecasts can be made using polynomial extrapolation based on the theories of economic growth cycles. If this is done, it is indicated that the growth rate will decrease over the coming years. That is, economic growth will decelerate and settle around one-two percent in 2018 once the economy is back to “normal” after the financial crisis. The economy will by then be in a rationalization phase awaiting the next general purpose technology to revive the world economy. In the mean time, cost cutting is the priority. Unemployment will rise and firms will prioritize efficiency improvements of all operations. With the ongoing structural changes in the economy, the amount of transport work per GDP will continue decreasing the way it has over the last 18 years. This will lead to an actual decrease in absolute terms by 2018. Likewise, if current trends are to continue, CO_2- emissions from freight transport will decrease after a short rebound during the recuperation from the financial crisis. Through cost cutting efforts and new technology CO_2-emissions per tonkm will decrease leaving absolute levels in 2018 16% above 1990 levels (see Figure 5). That is roughly a 10 % decrease from today’s level, which is well in line with the truck freight Business-as-usual scenario for 2020 presented by Piecyk and McKinnon (2009).

[3] Available from the National Institute of Economic Research

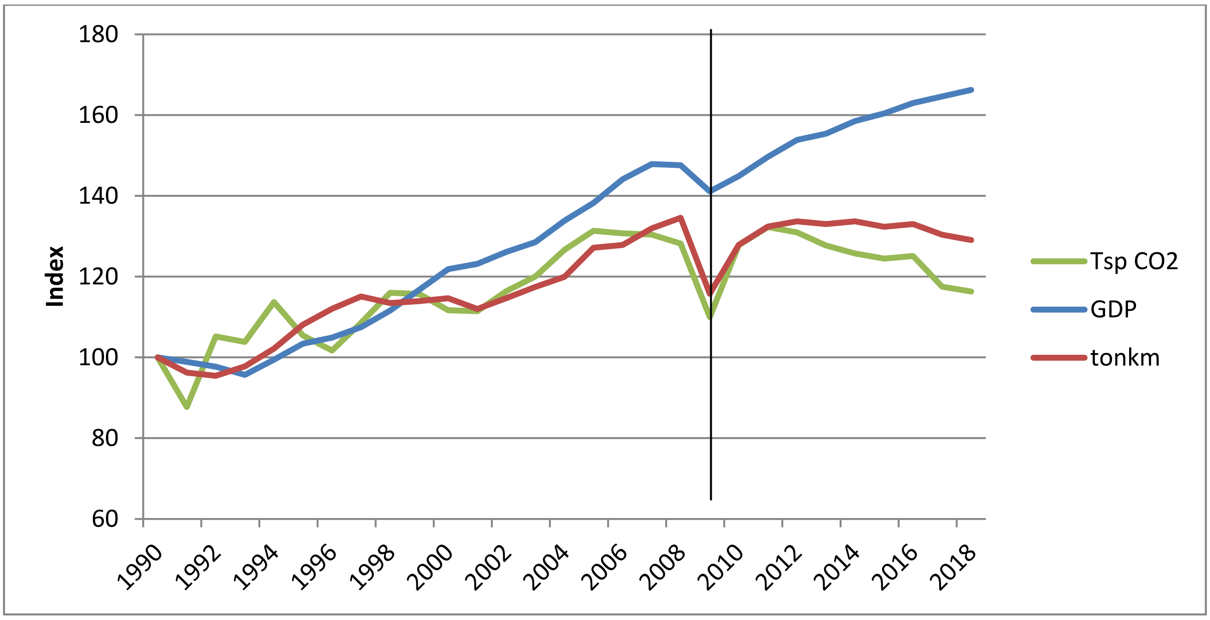

Figure 5. Likely development of GDP, tonkm, and freight transport CO_2-emissions, extrapolated

CONCLUSIONS

Freight transport CO_2-emissions have been growing along with GDP and transport work over the last decades. This growth has not been linear but following a cyclic pattern where the amount of tonkms and CO_2-emissions have decreased during the restructuring phases of the long growth cycles. This can be explained by the fact that during these years industries pursue cost cutting strategies, streamlining their organizations, and rationalizing their operations. Since CO_2-emissions may be reduced through more efficient use of transport resources, emissions decline accordingly. In the observed data, the greatest reductions are due to more efficient use of transport resources and a shift to less carbon-intensive fuel sources. Despite an initial shift towards road transport, the last couple of years have seen a reversed effect with more transport work being performed by means of rail- or sea-bound transport. Overall, this has caused emissions per tonkm to decrease over the last couple of years.

Thus, we can observe a steadily decreasing amount of transport work per unit of economic output as well as a decreasing amount of CO_2-emissions per unit of transport work. Base on these observations and the theories explaining them, the extrapolated data shows us that for the next couple of years: 1) economic growth will slow down, 2) rationalization efforts among shippers and transport providers will continue, and 3) vehicle technology will improve with regards to CO_2-emissions. This yields a “business-as-usual” scenario with freight transport CO2-emissions on levels some 10% below current levels. That is, without intervention or regulatory measures, emissions will be reduced.

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