Why do CO2 emissions from heavy road freight transports increase in spite of higher fuel prices?

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Abstract

The paper analyses why CO2 emissions from heavy road freight transports increase in spite of higher fuel prices. Swedish time series data for the period 1990-2011 are analyzed with help of indicators. The logistic efficiency of the road transports improved especially in the 1990-ties due to the allowance of heavier trucks. Also the energy efficiency increased during that period. Since then there have been improvements but no major efficiency gains have been realized. Today potentially cost effective technologies exist to further reduce the CO2 emissions from heavy road freight transport. However, technical, institutional and financial barriers reduce the incentives for the transport firms to imply these. Split incentives caused by contract structures or ownership patterns can impede the employment of these technologies, as the firms that invest in the technologies have little incentive to do so. If fuel savings are realized rebound effects can appear that cancel out improved energy efficiency. The internalisation of the social marginal costs can lead to modal shifts to less carbon intensive modes, but shippers minimize their total costs and take into account quality aspects when choosing transport solutions. There are obstacles for the increase of the share of non-fossil energies in form of access to raw material, infrastructure for vehicles that can use the alternative fuels etc. On the national and international road freight transport markets staff costs are often more important than taxes and fees. Deeper knowledge of the impacts of different policy measures is required in order to understand why the CO2 emissions increase despite increased fuel prices. A better understanding of the implications of the lack of thresholds and other model simplifications in the Swedish Samgods model is also needed and an analysis of what is required to better mirror the contracts that we observe in reality. It is also necessary to study the role of the lighter trucks in the transport chains.

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1   INTRODUCTION

1.1 Background

Most of the CO2 emissions within the transport sector (that stand for 1/3 of the total CO2 emissions on the Swedish territory) are from passenger cars and heavy trucks.[1] In spite of increased traffic, the CO2-emissions from cars has decreased by nine per cent since 1990. This reduction can be explained by the use of more energy effective cars and an increased use of bio fuels. This decrease was counteracted by the around 44 per cent increase of the CO2-emissions from heavy trucks and other heavy vehicles during the same period, (Naturvårdsverket, 2012). CO2-emissions from heavy trucks have decreased since 2006.[2] However, they are expected to increase again if no additional policies are implemented.

Both Sweden and the European Union have quantitative targets for CO2 emissions. Taxes on fuel based on their carbon content are used to control emissions. As CO2 emissions are directly linked to fossil fuel consumption, it is easy to calculate the emission volumes via the amount of fossil fuel used. Administrative and informative measures are also applied. In contrast to these measures, fuel taxes are particularly useful when there is asymmetric information (e.g., regarding the available technology, between the firms and the government). This follows mainly from taxes and other economic instruments' ability to decentralize decision making to the firms who are best equipped to make such decisions.

The Swedish diesel and gasoline tax consists of two parts: the energy tax and the tax on CO2 content in the fuel. The purpose of the CO2 tax is to control CO2 emissions. The energy tax can be seen as an instrument to internalize externalities other than those that can be associated with CO2 emissions.[3] The diesel price (including tax) increased nearly four times as much as the GDP between 1990 and 2011 and that the diesel price was subject to larger fluctuations.[4] The increase of the diesel price was partly due to the abolishment of the kilometre tax for heavy trucks in the beginning of the 1990-ties. Diesel prices have shown similar fluctuations as crude oil prices, although the fluctuations have been somewhat moderated by the tax.[5]

The observed development of higher fuel prices and higher CO2 emissions from heavy trucks is somewhat puzzling. Our purpose is to investigate and try to explain the historical development in Sweden since 1990.

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[1] with over 3,5 tonnes total weight
[2] There was though an increase for the CO2-emissions from light trucks, (Johansson, H, 2012).
[3] To some extent both the energy and CO2 tax may have fiscal motives as they raise tax revenues.
[4] See Figure 11 in Annex.
[5] See Figure 12 in Annex.

1.2   Scope and structure of the paper

This paper analyses how CO2-emissions from heavy road freight transports in Sweden have developed since 1990.[6] Indicators are applied for transport demand, modal split and transport prices (chapter 2), the logistic efficiency of road freight transports (chapter 3), the energy efficiency of these transports (chapter 4) and the CO2-intensity of the fuel used for heavy road freight transports (chapter 5). We discuss how different factors and circumstances influence the indicators. In chapter 6 we compare the in Sweden observed price elasticities to modeled elasticities from the literature and the Swedish national freight model. In chapter 7 some conclusions are drawn.

2   SWEDISH FREIGHT TRANSPORT MARKET

2.1   Freight transport intensity

Freight transports have grown rapidly, both in Sweden, the rest of Europe as well as the wider world. Increased transport volumes will, ceteris paribus, lead to increased demand for energy and more CO2 emissions. The time series data for Sweden show that the tonne kilometre development in general follows the development of the GDP (in fixed prices) in the short run. In the longer run we see some decoupling. This becomes very clear in the recession year 2009 when both GDP and tonne kilometres dropped a lot. Figure 1 shows that the tonne kilometers have increased faster than GDP in the 1990-ties while it is the other way round since 1999. This means the transport intensity has decreased and a decoupling process has started since that year. The difference between GDP-growth and tonne kilometre growth has increased since 2008-[7]
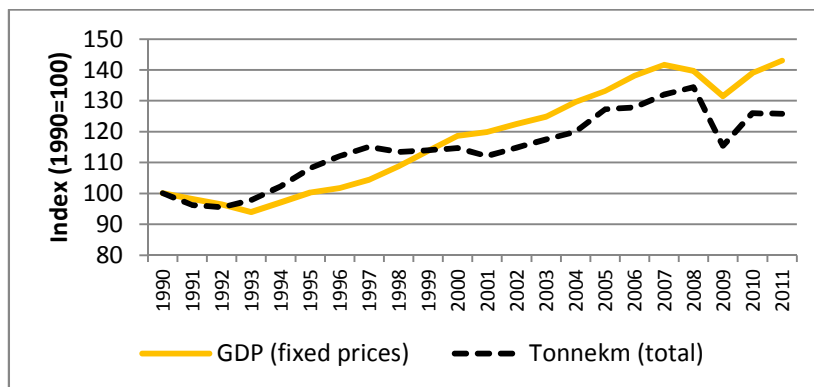
Sources: Statistics Sweden, Trafikanalys

Figure 1: Development of GDP (in fixed prices) and total tonne kilometres performed on Swedish territory 1990-2011

The amount of cargo transported in, to and from Sweden was quite stable over the period 1990 - 2011. This means that the increase in tonne kilometres was caused by the increase in transport distance and the creation of centralized

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[6] For a theoretic analysis see (Mandell, Nilsson, & Vierth, 2013)

[7] Similar developments are described for the UK (Pagnolucci; D Bonilla, 2009) and Denmark (Kveiborg & Fosgerau, 2004)

production and ware house systems. (McKinnon, 2010) develops that the trend has been driven all over the world by a) the wider sourcing of supplies and b) the centralisation of industrial production and ware houses (including increased foreign trade). He states that "these processes cannot continue indefinitely" and sees that the expansion of market area is now at an advanced state in mature countries but not in all parts of the world and that CO_2 taxes or emission-trading prices would have to be set to a high level to return to more decentralized systems. McKinnon emphasizes that it is necessary to carry out trade-off analyses related to CO_2 emissions in order to determine the net carbon impact of transport and ware housing/production.

2.2 Modal split

If we have a closer look at the different modes of transport, the tonne kilometre increase on the Swedish territory was, in most of the years, highest for heavy road freight transports (the most CO_2-intensive mode of the three modes included in Figure 2). Rail transports have been quite stable during the 1990-ties and increased since the turn of the millennium. The development for the sea transports to, from and between Swedish ports on Swedish territory, was about the same as for the total tonne kilometers.[8]
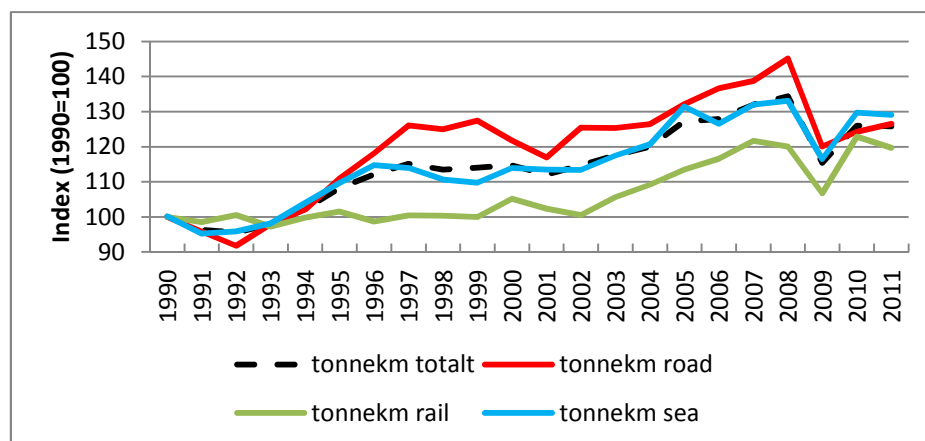
Source: Trafikanalys

Figure 2: Development of tonne kilometres road, rail and sea and in total in Sweden 1990-2011, Index (1990=100)

The share for road transports was lowest in 1992 (36 per cent) and highest in 1999 (42 per cent). The rail share is with much lower than shares for heavy road and sea; the share dropped in the 1990-ties and increased in recent years. In 2011 around 24 percent of the total tonne kilometres in Sweden were performed by rail.

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[8] Sweden has by definition no inland waterway transports.
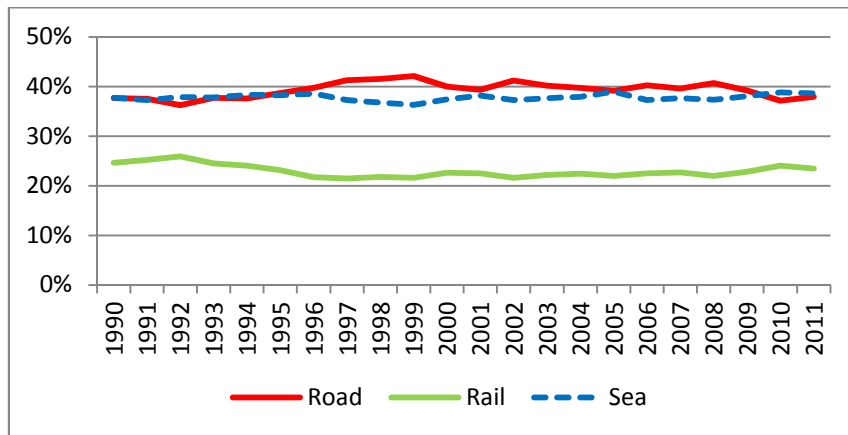
Figure 3: Modal split (tonne kilometres by road, rail and sea in Sweden) 1990-2011

The CO2-intensity of the energy used, expressed in gram CO2 per tonne kilometre, differs between the modes. Shifting from road to less CO2 intense modes can reduce the CO2-emissions per tonne kilometre. The internalisation of the social marginal costs of the transports including CO2 emissions, would probably lead to modal shifts.[9] Both the EU and several national governments have ambitions and/or actual programs to promote rail, inland waterway and sea transports to facilitate shifts from road. According to the White Paper (COM(2011)144 final, 2011) 30 per cent of the road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050. [10] In this context one has to be aware that shippers take into account quality aspects (above the transports costs) when choosing transport solutions.[11]

VTI studied the potential for mode shifts on behalf of the Swedish Institute of Communication Analysis SIKA, (Vierth & Mellin, 2008). One result in the study is that there are large transfer potentials from long distance road transport to combined road rail transport. It is however noted that there are barriers in form of insufficient rail infrastructure capacity and insufficient flexibility and co-operation along intermodal chains.

2.3 Transport prices

Statistics Sweden (SCB, 2012) publishes freight rates for road and sea transports since 2004. Figure 4 illustrates how the sea transport prices fluctuate. The rates increased more than the GDP between 2004 and 2008 and have dropped by about 30 per cent units since then. The road transport prices, on the other hand, increased during the whole period 2004-2012. The growth rates for the GDP and the road freight transport prices were about the same till 2007; since that year the road transport prices have grown faster than the GDP.

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[9] The internalisation of the external effects is e.g. described in (Nilsson, Mandell, & Vierth, 2012)
[10] The Marco Polo programme for example "aims to free Europe's roads of an annual volume of 20 billion tonne-kilometres of freight by transferring freight from road to rail or short-sea shipping routes or inland waterways. See http://ec.europa.eu/transport/marcopolo.
[11] See e.g. (Vierth, I., 2012)

One has to be aware that different segments of the freight market use the road respectively the sea mode. Further wise, the sea transport rates are to a high extent negotiated at a global level and the road transports at a national or European level.
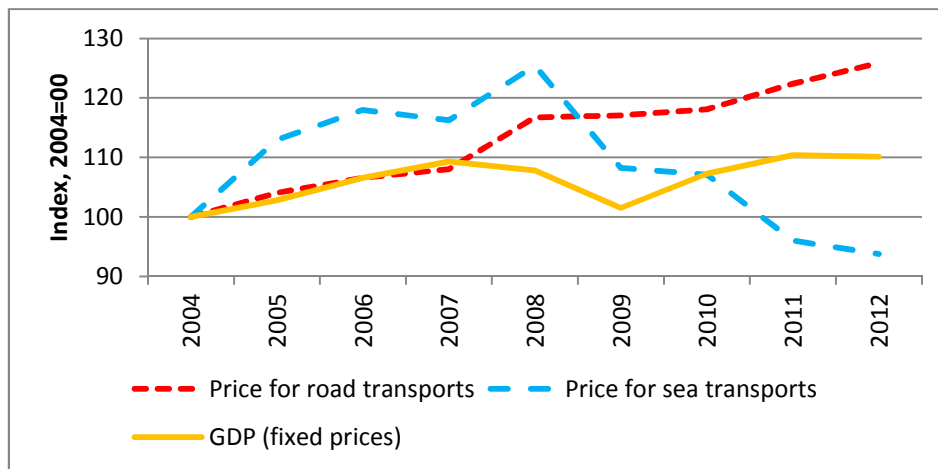
Source: Statistics Sweden (SCB)

Figure 4 Freight rates for road and sea transports 2004-2012, Index (2004=100)

3   LOGISTIC EFFICIENCY OF ROAD FREIGHT TRANSPORTS

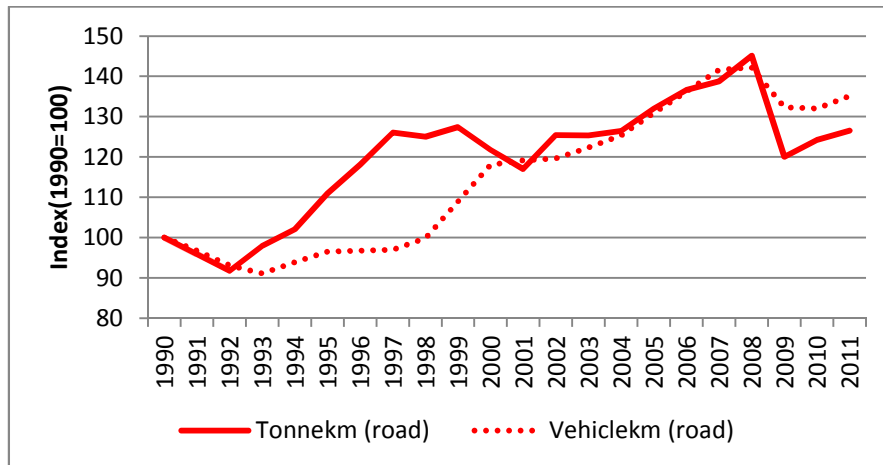### 3.1 Vehicle utilization

Load factors

The relation "tonne kilometres / vehicle kilometres" indicates how many truck kilometers are needed to perform a certain amount of tonne kilometres. If the vehicle utilization is increased, there is a corresponding reduction in fuel consumption and CO_2-emissions per tonne kilometre.[12] One has also to be aware of the fact that the commodity mix changed towards more light, often high value, goods. Figure 5 shows that the vehicle kilometres and the tonne kilometres developed in the same way except for the periods 1993-1999 and 2008-2011.[13] The allowance of heavier trucks in 1990 (max 56 tonnes total weight instead of max 51.4 tonnes total weight) and 1993 (max 60 tonnes total

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[12] There is also a potential for the other modes to increase vehicle utilisation but below we focus in road transports.

[13] The tonne kilometre figures are taken from Trafikanalys and the vehicle kilometre figures from the HBEFA-model. The HBEFA-model is used in the calculation of the national emissions in Sweden. Originally the Handbook of Emission Factors for Road Transport (HBEFA) was developed on behalf of the Environmental Protection Agencies of Germany, Switzerland and Austria. In the meantime Sweden, Norway, France as well as the JRC (European Research Center of the European Commission) are supporting HBEFA. See http://www.hbefa.net/e/. The truck vehicle kilometres used in the HBEFA model differ in some years to the truck vehicle kilometres published by Trafikanalys. The HBEFA-figures are used as they are compatible to the HBEFA figures for fuel consumption.

weight) led to more efficient heavy road transports due to a better use of the capacity per truck.[14]

Second order effects (that lead to increased CO2 emissions) can appear in form of shifts from rail to road. However, a review of the Swedish time series 1975-2005 for the total transports by commodity shows that it is difficult to find evidence of road and rail taking volumes from each other, (Vierth, o.a., 2008). There is though more direct competition between the modes in the market segment for long distance transports.[15]

Source: Trafikanalys, HBEFA

Figure 5 Road tonne kilometres and vehicle kilometres in Sweden 1990-2011, Index (1990=100)

Beyond the use of heavier trucks, several different measures can be applied to increase the truck utilization. (McKinnon, 2010) lists e.g. improved back loading, use of more space efficient handling systems, packaging and more transport efficient order cycles. He stresses the "inter-functional relationship" between freight transports and production, inventory management and that it is in many cases rational for the firms to prioritize other activities over the improvement of the transport efficiency.[16] In Figure 5[17] we observe that the load factor decreased during/after the recession in 2008. The drop in demand contributes to the lower load factor since 2008/2009. However, the share of domestic traffic without load[18] decreased from 37 per cent in 2008 to 17 per cent in 2011.[19] This

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[14] One has to be aware that the tonne kilometre figures are based on questionnaires that are sent to a sample of road transport firms and that the vehicle kilometre figures are based on traffic counts, information from vehicle inspections, information about sold fuel etc.

[15] See e.g. (Vierth, I; Karlsson, R, 2012)

[16] Under some circumstances it can be beneficially (for the reduction of the CO2 emissions in total and the climate) to increase the CO2-emissions from road freight transport in order to achieve savings in other fields.

[17] where we compare aggregate figures for tonne kilometres and vehicle kilometres

[18] collected via the national survey that comprises Swedish trucks

[19] http://www.trafa.se/sv/Soksida/#query=*&mainfacet=22&mainfacetname=category;statistik&tabindex=2&pagingnr=8&queryex=Statistik;Vägtrafik,Statistik;Vägtrafik|Lastbilstrafik&sort=

indicates that the overall lower load factor cannot be explained by an increase in empty trips.

In 2011 the Swedish transport authorities studied the load factors and empty transports for the land based transports in a government commission, (Transportstyrelsen, Trafikverket, Trafikanalys, & VINNOVA, 2011). The authorities do not suggest detailed policy measures. They conclude that neither their literature studies nor their discussions with stake holders indicate that revised laws and regulations would have any large impacts on the use of the truck and train capacity.

Share of empty trips and average transport distances

The load factors (for the loaded trips and all trips) are tentatively higher for longer distances.[20] And, as mentioned in section 2.1, an increase in the average transport length can be observed. The share of international transports, that are tentatively longer than domestic transports, has increased over time. The average distance of the domestic transports increased from 75 kilometres (2000) to 103 kilometres (2011).

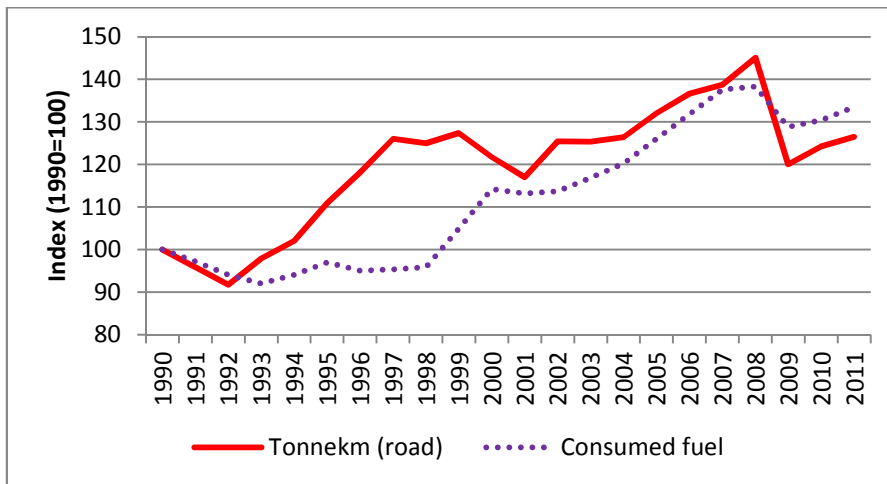## 3.2 Consumed fuel per tonne kilometre

The heavy road freight transports carried out in Sweden have become more effective in that way that the amount of fuel used has increased less than the tonne kilometers performed. See Figure 6. The decrease of the fuel consumption per tonne kilometre can among other things be explained by the use of vehicles with a larger capacity. The efficiency improvement was as expected highest in the 1990-ties due to the allowance of heavier trucks. (see 3.1).

Another reason for the large decrease in fuel consumption per tonne kilometre during the 1990-ties is that there was a remarkable reduction of the fuel consumption per truck kilometre during that period. (See 4.1.) The fuel savings were much less since then as focus was moved to the reduction of the HC, NOx, and PM emissions (and the EURO classes were introduced). The reduction of the fuel consumption per truck kilometres continued several years after the 1990-ties because if the replacement of old trucks with a high fuel consumption.

However, one has to be aware that our analysis is very aggregated and does i.e. not include developments in different market segments and a lot of explaining variables. One phenomenon that should be studied more in detail is why the amount of consumed fuel grew faster than the tonne kilometres performed at the end of the 1990-ties.

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sort:reverse:meta:docdate Trafikanalys webb page. The share of empty trips was 24 per cent in 2000.

[20] The economic incentives to fill the vehicles and to avoid empty transports are higher for longer transports.

Figure 6 Development of tonne kilometres and consumed fuel 1990-2011, Index (1990=100)

The overall drop in demand contributes to the higher fuel consumption per tonne kilometre since 2008. The higher fuel consumption per tonne kilometre is one explanation for the increase of the road transport prices in 2008 (see 2.3).

(Hovi & Andersen, 2010) study Norwegian time series data for the period 1993-2008. They conclude that road freight transports have become more effective due to a better use of the capacity, a lower share of empty transports and due to the fact that the longer transports have increased most. Hence the overall "logistic trends" are as expected the same as in Norway and Sweden.

4 ENERGY EFFICIENCY OF HEAVY ROAD FREIGHT TRANSPORTS

4.1 Consumed fuel per vehicle kilometre

The development of the total truck kilometres and the total consumed fuel are highly correlated. [21] Figure 7 shows that there was a decrease for the total truck kilometres and total fuel consumption during the 1990-ties and an increase since then. The energy efficiency (expressed as fuel consumption per vehicle kilometre) improved since the end of the 1990-ties as the total vehicle kilometres increased more than the total fuel consumption.[22]

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[21] The development took place in spite of the fact that the overall traffic volume and congestion increased in some parts of the Swedish road network. The introduction of congestion taxes in Stockholm has though decreased the level of congestion.

[22] This development took place in spite of the fact that heavier trucks were used.
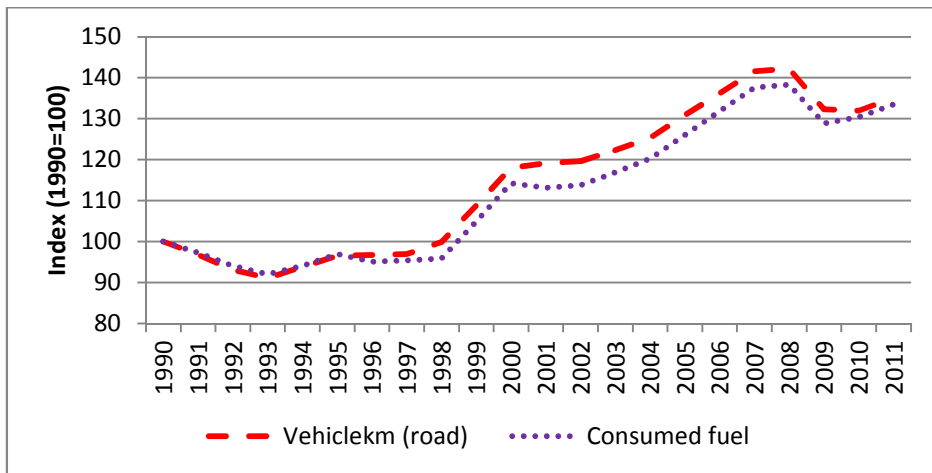
Source: HBFA

Figure 7 Development of vehicle kilometres and consumed fuel 1990-2011, Index (1990=100)

The later development differs somewhat from the development in Norway. (Thune-Larsen, H.; Hagman, R.; Hovi, I. B.; Eriksen, K.S., 2009) state that the CO_2-emissions from domestic road freight transports in Norway have increased more than the corresponding truck kilometres performed but less than the corresponding tonne kilometres performed.

4.2 Measurements to improve fuel efficiency

The in Figure 7 described development implies that other factors than the use of heavier trucks have counteracted the increase in fuel consumption per truck. These factors are for example the technical characteristics of the trucks and the driving style and the design/maintenance of the roads[23]. There have only been incremental efficiency gains from the refinement of the trucks' technology since 1990. This can partly be explained by the cutting of NOx and particle emissions at the expense of CO_2 emissions, (McKinnon, 2010).

The Ricardo study, that was prepared for the UK Department for Transport (Baker, Cornwall, Koehler, & Petterson, 2009) concludes that several fuel and CO_2 saving technologies (like improved turbo-charging engines, low rolling resistance tyres, improved aerodynamic profiling, hybridization and anti-idling devices) can be deployed in trucks in the short to medium term. The Ricardo study and the TIAX study (K. Law; M. Jackson; M. Chan, 2011) estimate that near-term technologies can reduce the CO_2-emissions per truck by at least 30 per cent,

Driver training, where transport firms monitor driving performances and give the their staff incentives to drive fuel-efficiently, can reduce the fuel consumption per vehicle kilometre, ceteris paribus. In Sweden courses in eco driving are mandatory for truck drivers since 2008. The Transport Administration stresses that eco-driving improves both efficiency (e.g. leads to

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[23] For road related measures see (KNEG, 2012)

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less CO2-emissions and to less accidents) and the transport firms' profitability (Trafikverket, 2013).

Since 2006 Swedish truck and fuel providers, carriers, forwarders and shippers, researchers and public agencies co-operate within the KNEG-network (Climate Neutral Freight Transportation).[24] KNEG:s goal is to halve the climate impact of road freight between 2005 and 2020 by improving the logistics efficiency as well as the efficiency of the trucks and fuel used. A further aim is to increase the use of renewable fuels, (KNEG, 2009). To date most of the reduction of the CO2 emissions were due to more efficient trucks (over 50 per cent) and fuel (around 40 per cent) and only six per cent due to logistic measures, (KNEG, 2012) .

(Mellin & Pyddoke, 2013) carried out an interview study addressing voluntary climate measures with eight firms that are KNEG-members. One result of the study is that the firms apply several voluntary measures but cannot say what a) the specific costs for these measures are and b) whether these measures lead to significant reductions of the CO2-emissions. The authors discuss the potential of standardised methods to calculate emissions. (In the meantime the CEN standard SS EN 16258 *Methodology for calculation and declaration of energy consumption and GHG emissions of transport freight and passenger transport services* has become available.[25]

4.3 Barriers to the implementation of fuel saving technologies

A study performed by CE Delft on behalf of the International Council on Clean Transportation ICTT[26] identifies barriers to the implementation of potentially cost effective fuel efficiency improving technologies in the European freight sector (Aarnink, Sanne; Faber, Jasper; den Boer, Eleco, 2012). The study finds that there are technological, institutional or financial barriers when it comes to the implementation of fuel saving technologies.

Technological barriers

Even though technologies are commercially available there may be uncertainties related to the technology itself and the market developments.

Institutional barriers

Split incentives (principle agent problems) can impede the implementation of energy-efficient technologies as the firms that invest in these technologies have little incentive to do so. Split incentives can result from *contract structures*; i.e.

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[24] Today the KNEG-network as 16 members.
[25] See http://www.sis.se/sociologi-service-f%C3%B6retagsorganisation-och-ledning-och-administration/tj%C3%A4nster/tj%C3%A4nster-f%C3%B6r-konsumenter/ss-en-162582012.
[26] http://www.theicct.org/ The International Council on Clean Transportation (ICCT) is an independent nonprofit organization founded to provide first-rate, unbiased research and technical and scientific analysis to environmental regulators. ICCT: s mission is to improve the environmental performance and energy efficiency of road, marine, and air transportation, in order to benefit public health and mitigate climate change.

when carriers (hauliers, transport companies) can pass their fuel costs directly to shippers or logistics providers (forwarders).

According to (Greater Than, 2011)[27] who performed questionnaires with 1 100 carriers and logistics providers in Europe[28] the following contracts are common
- *open book contracts*, where shippers and carriers agree on a *fixed operational margin.* These contracts remove much of the incentives for the carriers to improve the trucks' fuel efficiency (unless this is a specific criterion in the contract).
- contracts where carriers and shippers agree on a *fixed per unit price.* This price is protected by "*fuel escalators*" through which carriers can pass on increases in fuel costs to shippers.[29]
- contracts where forwarders add a *commission* on top of the transport costs. This means the higher the transport costs, the higher the commission, which reduces the incentives to save fuel costs. Furthermore logistics providers often work with *fuel surcharges* in order to pass on fuel cost increases to shippers; also these surcharges reduce the incentives to use energy-fuel technologies and trucks.

There is no complete empirical information about the relative use of open book or fixed prices contracts in Europe. According to (Luman, 2011) around 70 percent of the road transport companies in Belgium apply fuel causes to pass on fuel prices increases to shippers. In a small Swedish study (Hansen, 2009) all eight carriers use fuel escalators or index adjustments. In the Greater Than study (Greater Than, 2011) around 55 per cent of the 1 100 interviewed firms use fuel surcharges. Around 20 per cent of the firms use open book contracts on a regularly basis.

Split incentives can also be caused by *ownership patterns* of trucks and trailers. Logistics providers do usually not own vehicles and do therefore not invest in fuel saving technologies themselves. The logistics providers would have to invest in these technologies while the carriers would benefit from reduced fuel consumption. The same type of problem appears for carriers that lease their vehicles. It happens also that different firms own truck and trailer, (IEA, 2012).

(Greater Than, 2011) find that 92 percent out of the 1 100 interviewed carriers and logistics providers do not prioritize fuel savings and do not have fuel savings as a specific target during the operations. (When investing in new vehicles, fuel efficiency was though one of the top priorities.) *Greater Than* think that the low prioritization of fuel savings can be explained by the contract structures described above and traditions (e.g. beliefs that the transport sector perceives fuel as a necessity that is hard to influence). (Khan, Harmelink,

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[27] http://www.greaterthan.eu/en/about-us/purpose-people-2618693 Greater Than's vision is to make road transport more energy efficient, producing less CO2 emissions and more profitable. Greater Than's mission is to change current business models, incentivise improvements and make transport buyers encourage fuel reductions.
[28] None of the interviewed firms is from Sweden.
[29] The calculation of fuel escalators (drivmedelstillägg) in Sweden is i.e. described in (Åkeriföretag, 2013)

Harmsen, Irrek, & Labanca, 2007) find that energy related measures are generally given low priority, when energy costs are only a small share of a firm's total costs.

Also *lack of information* can be obstacles. Firms that are not aware of fuel saving measures will obviously not invest in them. (Aarnink, Sanne; Faber, Jasper; den Boer, Eleco, 2012) mention that there is no commonly agreed standard for expressing the fuel efficiency of truck and trailer. According to (Johansson, H, 2012) energy efficiency improvements claimed by the truck manufacturers are seldom confirmed in real traffic. This can probably be explained by the fact that changes in driving style (e.g. same speed uphill as downhill) cancel out the energy efficiency improvements.

Once an investment decision for a fuel saving technology has been made, *additional transaction costs* will result, such as costs for negotiation, implementing and monitoring contracts. (Faber, o.a., 2009) state that these aspects can be very costly and lead to further *hidden transaction costs*. Especially for smaller companies, the transaction costs can act as barriers.

Financial barriers

Finally financial barriers can limit for the introduction of new solutions. According to (McKinsey & Company, 2009) fuel saving technologies in the transport sector have relatively high upfront capital costs compared to other sectors. (Goodyear Dunlop, 2012) find that 40 percent of the fleet managers in a sample of 400 that were surveyed, lack funds to replace older trucks. Normally payback period of two to three years are often required for the investments in fuel saving technologies, (AEA and Ricardo, 2011). The Swedish road freight transport sector is characterized by a high share of small carriers. Around 40 per cent of all firms are one man companies and around 80 per cent have less than five employees. For detailed information about the freight transport companies' profitability see (SIKA, 2009).

Also the level and development of the fuel prices[30] influences the adoption of new fuel saving technologies. The value of the technologies depends on the fuel prices; the higher the fuel price, the shorter is the payback period. Uncertainties about the fuel prices can impede the adoption of fuel saving technologies. The annual mileage of the respective trucks does of course also influence the payback period. (Dargay & Gately, 1997) conclude, based on an econometric study, that "consumers do not necessarily respond in the same fashion to rising and falling prices, nor equivalently to sudden and substantial price rises as to minor price fluctuations: demand is not necessarily reversible to price changes.

Another aspect that has to be kept in mind is that the road freight market is deregulated at the national and the EU level. The share of the fuel costs differs between carriers (and drivers) from different countries that operate on a deregulated market. (Hovi & Hansen, 2011) find that the staff costs are by far

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[30] see Annex

more important than taxes and fees.[31] The share of foreign trucks in Sweden has increased since the 1990-ties and is today about twenty per cent, (Trafikanalys, 2012).

Figure 8 illustrates that truck and fuel costs are quite similar in Norway, Sweden and Poland. However, the staff costs differ a lot, their share of the total transport costs lies between 12 per cent in Poland and around 40 per cent in Norway.
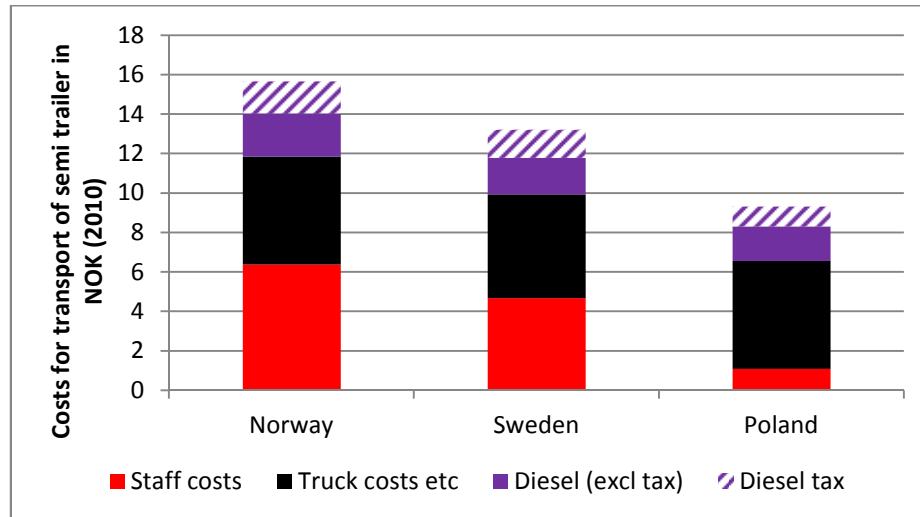
Source: (Hovi & Hansen, 2011)
Figure 8: Transport costs for semi-trailer in NOK (2010)

4.4   Rebound effect and elasticities of fuel use in respect to fuel price

(de Borger & Mulalic, 2012) study the determinants of fuel use in the trucking industry in Denmark using aggregate time series data over the period 1980-2007. They estimate an econometric model that captures *the linkages between the demand for road freight services, the characteristics of the truck fleet* (that determines fuel efficiency and the demand for fuel). The model allows them also to identify and estimate the *rebound effect* of improvements in fuel efficiency.

Rebound effect

As fuel efficiency improves, the variable unit costs per tonne kilometre are reduced. This leads to lower prices for road transports (when a competitive market structure is assumed). In turn, the lower road transport prices stimulate the demand for road transport services, which raises fuel consumption (and the CO_2-emissions). In other words, the reduction in fuel induced by higher fuel efficiency is partly offset and "the end total fuel use" responds less than proportionally to the exogenous changes in fuel efficiency. A rebound effect of approximately 10 per cent in the short run to 17 per cent in the long run is estimated. This means that a 1 % improvement in fuel efficiency reduces fuel use by 0.90 % (in the short run) to 0.83 % (in the long run).

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[31] (Hovi & Hansen, 2011) assume all costs form the respective country and do not take into account the case where a driver from country A works for a transport frim from country B.

Elasticities of fuel use in respect to fuel price

(de Borger & Mulalic, 2012) find that carriers react to higher fuel prices by a) raising the average capacity of the trucks (which in turn increases the fuel consumption per truck so that the total fuel consumption increases) and b) investing in more efficient trucks (so that the fuel consumption decreases). The authors estimate elasticities[32] of the fuel use with respect to the fuel price of -0.13 (in the short run) to - 0.22 (in the long run). They explain the relatively low elasticities with the rebound effect and the impact of the fuel prices on the size/age composition of the fleet.

The authors conclude saying that their empirical analyses of the determinants of fuel consumption by carriers and the estimation of the rebound effect are highly relevant for the evaluation of policy measures as higher fuel taxes, regulations for fuel efficiency and truck dimensions.

5 CO2-INTENSITY OF USED FUEL IN ROAD FREIGHT SECTOR

Finally it is possible to reduce the CO_2 emissions from road freight transport by energy sources containing no or low carbon. This can be biofuels, biogas (Kågeson & Jonsson, 2012) or electricity (electric motorways). The Swedish government aims for a fossil fuel independent vehicle fleet for passenger and freight transports and all modes. (KNEG, 2012) discusses several obstacles for the increase of the share of alternative non fossil energies: access to raw material including distribution, production plants, infrastructure for vehicles that can use the alternative fuel. Policy measures can be necessary to overcome these and/or promote the use of these energy sources.

6 MODELLING POLICY IMPACTS

6.1 Observed elasticities

Elasticities usually come from econometric models or network models. The modelled elasticities are defined using the 'ceteris paribus' condition. They are valid under the assumption that all other things do not change.

Elasticities can also be calculated from observations of the impact of a change (e.g. a change of fuel prices) where other things can change.[33] Figure 9 comprises the development of the diesel prices (including tax), the consumed litres diesel, the prices for road transports and road tonne kilometres for heavy trucks in Sweden 2004-2011. The fuel prices fluctuated a lot and increased by 70 per cent; the fuel consumption fluctuated and increased much less but

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[32] An elasticity gives the impact of a change in an independent variable on a dependent variable, both measured in percentage changes. If the impact of a 1% increase in the price for a road transport service on tonne kilometres is a decrease in truck tonne kilometres by 0.3%, the price elasticity of the demand for road tonne kilometres is -0.3 (=-0.3/1). An elasticity can be positive or negative. If an elasticity (in absolute values) exceeds 1, the dependent variable is called 'elastic. If the elasticity value (in absolute terms) is between 0 and 1, the dependent variable is 'inelastic'.

[33] This is normally done in form of before and after studies.

followed the fuel prices at large. At first glance this seems to indicate a positive price elasticity for diesel. However, one must take into account that the freight demand varied during the same period.[34]

The road transport prices increased in all years; they were about 20 per cent higher in 2011 than in 2004. In spite of increasing road transport rates the road tonne kilometres increased in all years, except 2009,
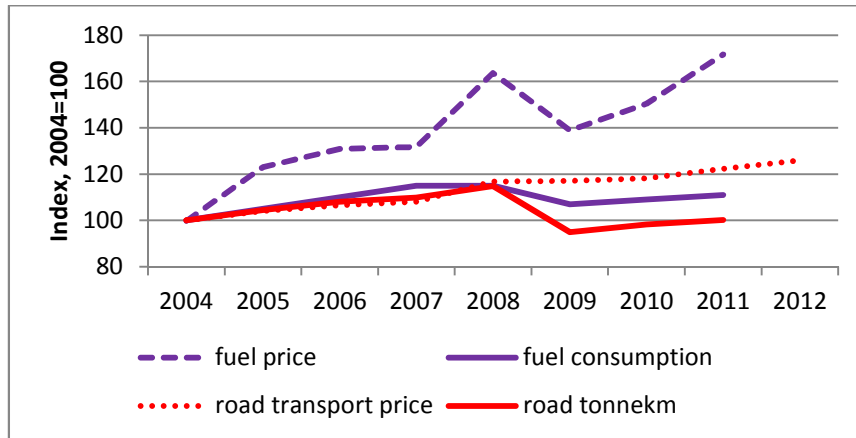
Sources, Swedish Energy Agency, HBEFA, Statistics Sweden, Trafikanalys

Figure 9 Development of diesel prices (incl tax), diesel consumption, prices for road transports (both in running prices) and road tonne kilometres, Index (2004=100)

Typically demand decreases when fuel or transport prices increase and vice versa which gives price elasticities that are negative. The road transport price elasticity of tonne kilometres 2004-2008 is positive and lies around 1. One could think that this is caused by omitted variables.
In 2008 the amount of tonne kilometres dropped in the same way as the fuel prices and increased again but not as much as the diesel prices. The fuel price elasticity of litres fuel consumed is also positive (except in 2007) but less elastic than the road transport price elasticity of tonne kilometres.

We are aware of the fact that we cannot draw long going conclusions out of our back of the envelope calculations for the relatively short and fluctuating period 2004 – 2011. But it can be illustrated the fuel consumption (and CO_2 emissions) and road tonne kilometres in general increased in spite of higher fuel prices and road freight transport rates.

6.2   Modelled elasticities

Elasticities in litterature

(de Jong, G.; Schroten, A; Van Essen, H.; Otten, M.; Bucci, P, 2010) compiled long term elasticities for long distance road freight transport. They derived the following *best guess elasticities* from the ranges in the literature. See Table 1. The fuel price elasticity with regard to fuel use includes changes in fuel

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[34] See 3.1

efficiency, logistic efficiency and demand. The vehicle kilometre price elasticities consist of changes in mode, logistic efficiency and demand. The tonne kilometre price elasticities consist of changes in mode and demand.

Table 1: Price elasticities

Price change	Impact on		
	Fuel use	Vehicle km	Tonne km
Fuel price	-0.3	-0.2	-0.1
Vehicle km price		-0.9	-0.6
Tonne km price			-1.0

The best guess road transport price elasticity of tonne kilometres is -1.0 and the best guess fuel price elasticity of litres fuel used is -0.1. The elasticities have about the same absolute size as our roughly calculated elasticities above in Figure 9 but the opposite sign.

Elasticities caculated with Swedish Samgods model

The Swedish national freight transport system Samgods assumes a fixed transport demand. The model system comprises a logistics modul which allows to take into account shipment sizes, economies of scale and consolidation in the transport system, which makes the model more realistic (than the former model that was limited to mode and route choice and used the same network).[35] The model is deterministic and minimises the annual logistics costs of hypothetical shippers of different size. We calculated with help of the Samgods model transfers from smaller to larger trucks[36] and a 2.5 % decrease of the road tonne kilometres due to a ten per 10 increase of the distance based[37] road transport costs (an elasticity of -0,25).[38]

The Samgods model does not distinguish between the short and medium term perspective and does not take into account different types of actors (carriers, forwarders, shippers) and their contracts. The model does only distinguish between large, medium and small shippers. Perfect competition is assumed and that the shippers take into e.g. changed fuel taxes (that are faced by the carriers) when they choose their transport solutions. It is assumed that the fact that the relative costs between e.g. different modes always lead to lead to revised choices of transport solutions.

We see a need to analyse the implications of the simplifications that are used in the model and what is needed to better mirror the circumstances that we observe in reality. It is for example necessary to distinguish between the short term perspective (with existing contracts and owner ship patterns for vehicles) and a medium and long term perspective (where contracts can be revised).

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[35] For information about the Samgods model see (de Jong, Ben-Akiva, & Baak, 2008), (Vierth, I.; Lord, N.; McDaniel, J., 2009).

[36] The Samgods model distinguishes between five different truck sizes

[37] The distance based costs comprise mainly the fuel costs.

[38] The model results were calculated with a test version from September 2001; detailed results concerning shifts between vehicle types within the modes are thought not stable yet.

7 CONCLUSIONS

The CO2 emissions from heavy trucks in Sweden have increased since 1990, even though they were reduced due to the economic recession. The CO2 emissions from light trucks increased also during the economic recession.

For heavy trucks no further decreases are expected if no additional policies are implemented.

The logistic efficiency of the heavy road freight transports in Sweden (expressed in vehicle kilometres per tonne tonne kilometre) improved especially in the 1990-ties due to the allowance of heavier trucks. Also the energy efficiency (expressed as fuel consumption per vehicle kilometre) increased during that period. Since there have been improvements but no major efficiency gains were realized.

Today different potentially cost effective technologies to further reduce CO2 emissions from heavy road freight transport, are available. However, technical, institutional and financial barriers may substantially reduce the incentives for the transport firms to improve the fuel efficiency of their trucks.

Institutional barriers are related to incentive structures that involve several stake holders. Split incentives can impede the employment of energy efficient technologies, as the firms that invest in the technologies have little incentive to do so. Split incentives can result from contract structures, where carriers can pass their fuel costs directly to shippers, ownership patterns for trucks and trailers, lack of information and transaction costs.

If fuel savings are realized rebound effects can appear. Usually the improvement of the trucks' fuel efficiency implies lower unit costs per tonne kilometre, which in turn leads to lower road transports prices. The lower road transport rates (can) stimulate the demand for road transports, which raises the CO2-emission. This calls for complementary price policies, e.g. increasing the CO2-tax.

On the national and international road freight transport markets staff costs are more important than taxes and fees. The staff costs correspond to between twelve per cent (in Poland) and 40 per cent (in Norway) of the total transport costs. The share of foreign trucks in Sweden has increased since the 1990-ties and is today about twenty per cent.

CO2 emissions from freight transport can be reduced by shifts from road to less CO2-intense modes. The full internalisation of the social marginal costs would probably lead to modal shifts. But one has to be aware that shippers minimize their total costs and take into account quality aspects above the transports costs when choosing transport solutions.

There are obstacles for the increase of the share of non-fossil energies in form of access to raw material including distribution, production plants, infrastructure for vehicles that can use the alternative fuels etc.

The increase in tonne kilometres was caused by the increase in transport distance. Economic measures would need substantial penalties to break this global trend and to return to more decentralized production and ware house systems with lower transport demand and CO_2 emissions.

A better understanding of the impacts of different policy measures to reduce the CO_2 emissions is required in order to understand why the CO_2 emissions for heavy trucks increase despite increased fuel prices.

More in depth knowledge about the barriers for the adoption of fuel saving technologies and the rebound effect that cancels out the effect of energy efficiency measures is desirable.

A better understanding of the implications of the lack of thresholds and other model simplifications in the Swedish Samgods model is also needed and an analysis of what is required to better mirror the contracts that we observe in reality. It is also necessary to study the role of the light trucks in the transport chains and their CO_2 emissions.

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9 ANNEX
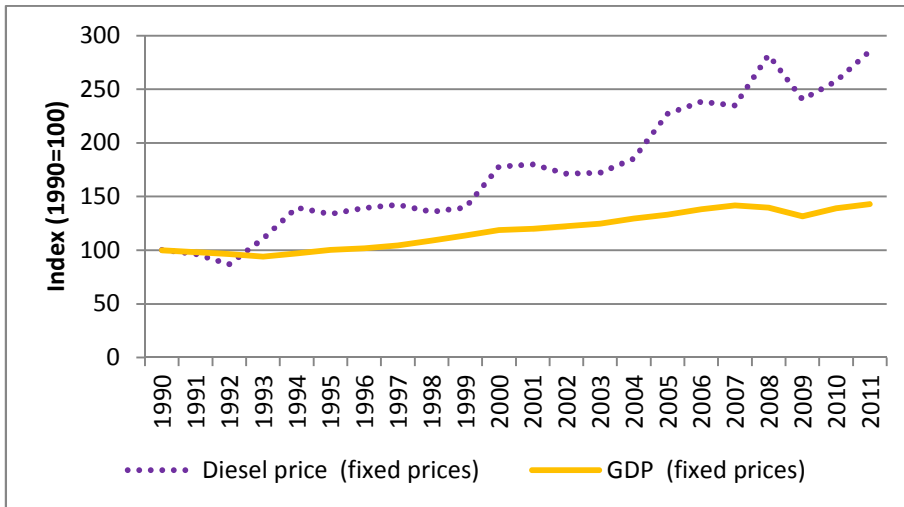
Source: Energimyndigheten

Figure 1 Development of diesel price (in fixed prices) and GDP (in fixed prices), Index (1990=100)
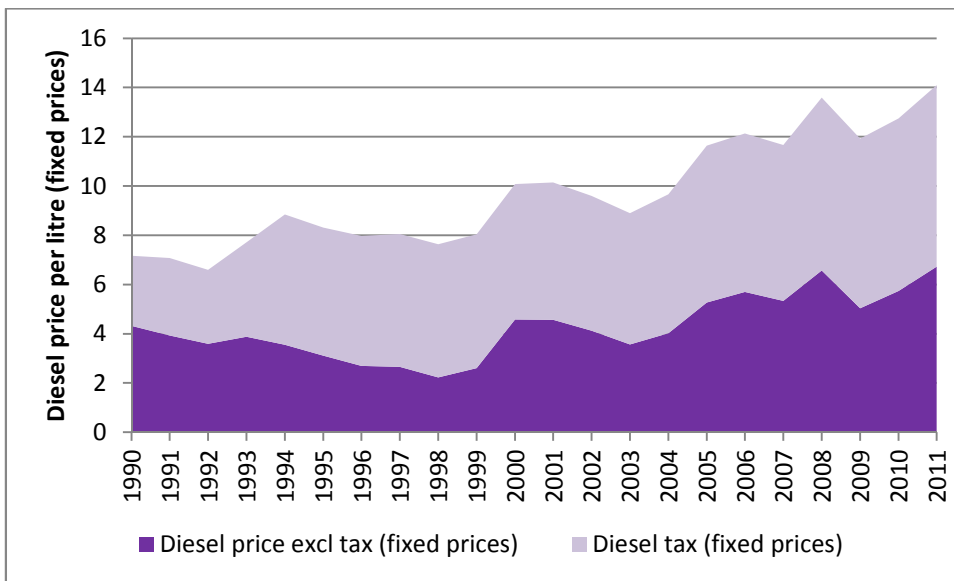
Source:Energimyndigheten

Figure 2 Development of diesel price excluding taxes (in fixed prices) and diesel tax (in fixed prices), Index (1990=100)

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