A comparison of economic impacts from pricing schemes on heavy vehicles in transport

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Abstract

This paper aims at describing and comparing a number of studies of the relationship between heavy vehicle fees (HVF) and the economy. Most of the literature on HVF is concerned with the practical implementation of a HVF and the degree of optimal pricing of a proposed HVF. This is interesting because there exists a vast amount of literature investigating the relationship between transport and land-use as well as the relationship between infrastructure investment and (regional) economic impacts. Using pricing or fees can to a very large extent be compared to infrastructure investment because both change the costs of transport between two locations.

An analysis of the German HVF concerns several issues with economic impacts being one of them. There are some interesting features in both the German and the Swiss HVF related to the use of the revenues. The analysis should concern both the direct (the effect stemming from imposing the fees on the economy without accounting for the use of revenues) and the indirect effect stemming from the use of the revenues. In both Germany and Switzerland the fees are supposed to be used for infrastructure investment. This may give completely different results from the effects arising from e.g. lowering income taxes.

Four different types of models can be used to assess economic impacts: system dynamic models (SDM), general equilibrium models (CGE) and spatial general equilibrium models (SCGE) and input output models (I/O); also various combinations of these model types can be applied. The general description of these different models types is supplemented with three case studies using I/O and SCGE models on HVFs in Germany, Denmark and Norway. The results from these case studies show some similarities in the types and size of the results despite that they are found using different types of models and in different countries.

1. Introduction

In recent years we have seen an enormous growth in the number of models aimed at analysing the relationship between the national and international economy, transport, land-use and the environment. The models are categorized in four categories by de Jong et al (2004) with some overlapping features of the five types of models: - *System Dynamics Models (SDM), Computable General Equilibrium Models (CGE), Spatial CGE models (SCGE)* and *Input-output based approaches (I/O)*. Many countries consider introducing or have already introduced various forms for heavy vehicle fees (HVF) for the use of infrastructure. Switzerland introduced a distance dependent HVF in 2001 applicable for all vehicles on all roads. In January 2004 Austria also introduced distance dependent HVF on motorways and some other main roads. Germany has simultaneously been working on a very sophisticated HVF scheme, which should have been introduced late 2003. However, due to technical difficulties the introduction was postponed until January 2005. Holland, Sweden, United Kingdom, Ireland and Denmark are all considering HVF schemes similar to the German scheme, but are all considering various technical solutions. Obviously these schemes will have an impact on the transport patterns in the different countries. Moreover, transport is caused by a demand determined by the economic activities. So the real driving forces for freight transport is the economic activities. When transport cost changes either due to new infrastructure, new fees or taxes this will have an impact on the economies. However, the impact will vary between different countries and different regions depending on the actual supply of infrastructure and on the structure of the regional economies.

This paper will:

- Describe different possible models that can be applied to analyse the (regional) economic impacts from HVF.
- Compare some case studies of HVF impacts on the economy: A German study using I/O approach, a Norwegian study using a spatial general equilibrium model, and a Danish study using model combination of input-output and general equilibrium modelling focusing on regional economic impacts.
- Demonstrate that HVF effects on the regional economy can be compared to investments aimed at improving regional economic development.

The impact from infrastructure investments has been the topic for many studies during the past years. Regional development has often been used as the political argument for investing in a fixed link to an earlier disconnected island or for constructing a motorway to a poor region. The book by Banister and Berechman (2000) gives a comprehensive overview of these effects. Also the interdependencies between transport and land-use have been the topic for many studies throughout the past decades (e.g. Wegener, 1998, Anderstig and Mattsson, 1998). However, the economic link has in these studies often been hidden in the background and has not played a significant role in the analysis. The outcome of the analysis of e.g. infrastructure investment has in the transport and land-use interaction models been on transport demand in terms of changes in OD matrices and the resulting changes in environmental quality.

The discussion about HVF on the other hand has primarily been about financing infrastructure more than about managing transport (CEC, 2001). Freight transport is mostly inter-urban where congestion is often not a primary concern. Hence, the regulation or taxation of freight transport is reduced to a question of paying for the wear and tear and some environmental effects. In the newly proposed EU Eurovignette directive (CEC, 2004) it is suggested that the HVF should in the first instance be based on infrastructure financing. This is considered a first step towards the original objective of fair and efficient pricing which has been stated since the white paper “Fair and efficient pricing” in 1995 and reinforced in the EU white paper “European transport policy – Time to decide” from 2001”. Using distance dependent HVF focus is on making those who actually use the infrastructure pay for the use. On the other hand focus is also on how to implement this without damaging one’s own transport industry. This is illustrated through the German desire to use (some of) the revenues to lower fuel taxes and/or registration taxes; the same is considered in the UK, where this objective is also directly stated.

It is striking to see how few studies that have illustrated the economic impacts of all these considerations. Especially when compared to the many studies about the impact from infrastructure investment on regional economic development and when – as will be demonstrated in this paper – the regional impacts of HVF can be of comparable size.

In the following section we give a review of four different models that can be used to analyse the link between HVF and economic impacts. In section 3 we present some case studies that have used three different types of models and in section 4 we discuss the general implications of introducing HVFs and we discuss the differences in the model types that can be highlighted using the case studies. In section 5 we summarise the main findings in a conclusion.

1. Models for evaluation economic impacts from HVF

In this section we give a short description of the model types that are typically used for evaluating impacts of infrastructure changes and regulatory policies. We do not try to give in dept descriptions of the specific elements of the models, but will try to emphasize the elements that characterise the different model types.

1.1. System dynamics models

A general feature of SDM models is that they link two or more models from different areas to each other using more or less firm interfaces. Of course such linkages also exists in the other model types, but in the latter models this linkage is often one-way linkages such that one model delivers exogenous inputs to the other model(s). We define system dynamics models as models where the linkages are two-way linkages and the model systems are run iteratively. Not all SDMs are feasible for the type of analysis we consider here. The model must at least contain a regional economic sub-model and/or a macro economic sub-model to be able to focus on the interrelations between transport regulations and economic performance.

We have chosen to present an international SDM to illustrate how such a model system can be used to assess economic impacts of HVF. The model we will focus upon is the ASTRA model (ASTRA, 2000). This model contains all the relevant elements and it is a model developed for long-term assessments.

The ASTRA SD model

ASTRA consists of four major sub modules; a macro economic module (MAC), a regional economic module (REM), a transport module (TRA) and an environmental module (ENV). The core of ASTRA is the transport module (TRA), which resembles a traditional four-stage traffic model both for passenger and freight transport. However, the first two stages of the four stage model is substituted by a macro economic module and with the regional economic module, which calculates trip generation (demand for passenger trips and freight movements) and distribution (OD trip matrices for passengers and interregional trade in tons for freight).

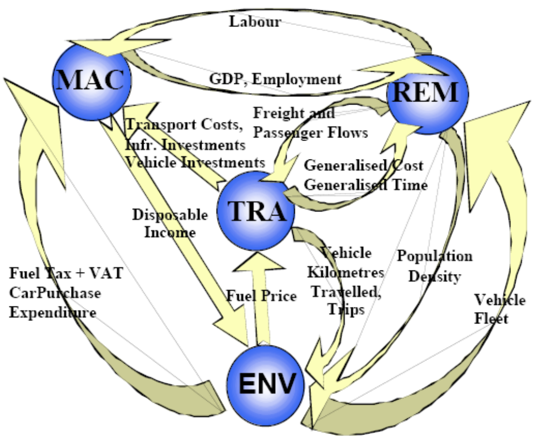

Figure 1. The sub modules of ASTRA and the flow of information between the modules.

The principal structure of the ASTRA model is outlined in Figure 1. The most important features to notice here are the exchange of information between the macro economic, the regional economic and the transport module. The macro economic model is based on an input-output structure giving the sectoral exchanges within each region, but the model also contains a separate module representing the supply side by determining the supply of production factors, and a supplementary demand side module giving the different elements of final demand. The macro module calculates the level of GDP of goods production in each macro region.

This is fed into the regional economic module together with the level of employment per region. The REM module calculates trade between the regions, and passenger flows between regions[1] based on the employment figures in the MAC module. The trade flows are further converted to physical flows (in tons) using a weight to value factor and again converted into three types of freight flows (two types of bulk and other types of goods).

The trade flows and the passenger transport between regions are used as inputs in the transport module to calculate mode choice and assignment on a relatively aggregate network. It should be noted that the trade flows from the REM module are interpreted as the tons lifted. This indicates that the weight to value rations are a combination of both the weight to value ration and a 'handling factor' indicating the amount of tons lifted related to the amount of tons produced (or traded); see e.g. Fosgerau and Kveiborg (2004) for additional information about the distinction between the two factors.

The TRA module calculates modal split and assignment taking into account time and monetary costs as well as the capacity of the infrastructure. Monetary costs include e.g. HVFs and inclusion of the capacity makes it possible to calculate changes in transport costs due to infrastructure investments. The time and monetary costs are joined into generalized costs, which are used in the regional economic module to distribute freight volumes between regions.

Transport costs are further fed back to the macro economic module as cost savings from e.g. investments or negative savings from changed taxes. Hence, taxes also have a direct influence on the macro-economic performance or aggregate demand in the various regions and economic sectors beyond the indirect effect through the regional economic module.

Obviously the ASTRA model and the included sub-models are only examples of how a SDM model can look like. The specific type of sub-models used varies from model to model. The following examples of pure economic models could be used as the macro economic sub-model and regional sub-models in an SDM.

1.2. Input-output based models

An input-output model is based on input-output tables that specify the amount of output from a given industry that is used in another industry for production, and for final consumption in private households or by the government. An I-O table similarly tells how the inputs to one

[1] The ASTRA model uses a different region structure for passenger flows. The EU15 regions are organised in functional regions based on other characteristics such as urbanisation etc. The freight flows and trade are calculated between large geographical regions (4 regions within EU15).

industry are composed of outputs from other industries. The general content of an I-O table is shown in expression (1).

$\mathbf{X_0}$	$\mathbf{f_0}$	$\mathbf{x_0}$
$\mathbf{v_0}'$		$\mathbf{v_0}'\mathbf{e}$
$\mathbf{x_0}'$	$\mathbf{e}'\mathbf{f_0}$	

(1)

$\mathbf{X_0}$ is the *n x n* matrix[2] of intermediate flows with typical element x_{ij}^0, which denotes the value of deliveries from industry *i* to industry *j*. $\mathbf{f_0}$ denotes the vector of final demand in households, by the government and net exports. $\mathbf{X_0e}+\mathbf{f_0}$ gives an industry's total output, where $\mathbf{e}$ is an *n*-element summation vector. $\mathbf{v_0}'$ is a row vector specifying the value added (labour and capital) in each sector. The first *n* columns give the input structure into the *n* industries; and the first *n* rows give the output structure of the *n* industries.

To use the I-O tables as a model we need to calculate either the input coefficients $a_{ij}^0 = x_{ij}^0 / x_j^0$ or the output coefficients $b_{ij}^0 = x_{ij}^0 / x_i^0$, and in matrix notation as $\mathbf{A}_0 = \mathbf{X}_0 \hat{\mathbf{x}}_0^{-1}$ and $\mathbf{B}_0 = \hat{\mathbf{x}}_0^{-1} \mathbf{X}_0$. Using this we can write the output from the industries as

$$\mathbf{x}_0 = \mathbf{A}_0 \mathbf{x}_0 + \mathbf{f}_0 \Leftrightarrow \mathbf{x}_0 = (\mathbf{I} - \mathbf{A}_0)^{-1} \mathbf{f}_0 \tag{2}$$

for the demand driven I-O model and

$$\mathbf{x}_0' = \mathbf{v}_0' (\mathbf{I} - \mathbf{B}_0)^{-1} \tag{3}$$

for the supply driven model. The models can be used in two ways either to calculate changes in output due to demand changes using (2) and assuming that the input coefficients are fixed, or a supply driven change assuming the output coefficients are fixed:

$$\mathbf{x}_1 = (\mathbf{I} - \mathbf{A}_0)^{-1} \mathbf{f}_1 \tag{4}$$

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[2] *n* denotes the number of industries in the model.

$$\mathbf{x}_2{}' = \mathbf{v}_2{}'\left(\mathbf{I} - \mathbf{B}_0\right)^{-1} \tag{5}$$

Using (2) and (4) we obtain the usual Leontief I-O model and using (3) and (5) we get the so-called Ghosh I-O model.

We are interested in the supply driven changes, where the costs in the transport industry are changed due to the HVF. This approach is due to Jones (1976), who argued that the forward multipliers described by the Ghosh inverse matrix $(\mathbf{I}\text{-}\mathbf{B})^{-1}$ are better suited to describe supply driven effects. However, there has been some debate on the appropriateness of this approach started by Oosterhaven (1988, 1989). The opposition has arisen because the Ghosh supply driven model is often interpreted as quantity effects. Oosterhaven (1988) shows that this is not an appropriate interpretation. Diezenbacher (1997) shows that the Ghosh model interpreted as a price model is equivalent to a Leontief price model, but that it requires fewer steps of calculation. This means that the Ghosh forward multipliers model can be used to calculate price changes due to changes in e.g. the value added in the supplying industries. However, we cannot use the Ghosh I-O model to calculate the changes in production.

There are some serious shortcomings in the use of the Ghosh I-O model. There are no demand and supply side relations so that the demand side can react to the changes in the prices. The price increases will affect final demand and disposable income leading to a further decline in demand. Moreover, intermediate demand will also decline due to the price increases. These effects are not possible to include in the model. Increasing prices on intermediate inputs will further lead to a reduction in production and a substitution between goods. Substitutions effects are also not possible due to the fixed Ghosh inverse matrix and the changes in production are also not included. A further shortcoming comes from the use of revenues. The I-O model does not specify this. However, the effects from the use of revenues may be very significant and highly dependent on how they are used, which we will see below. An ad hoc method that can be applied is to use a standard forward Leontief I-O model to see the effects of using the revenues for e.g. construction or lowering taxes. This approach can provide answers to effects on employment and disposable income, but only due to the use of the revenues and not due to the primary effect of introducing HVFs.

1.3. Computable general equilibrium models

We have chosen to group both spatial (SCGE) and non-spatial (CGE) versions of this model under the same heading as many of the characteristics of the models are the same. The main difference between the spatial and non-spatial CGE models in relation to analysing the relationship between HVF and the economy is the possibility to differentiate the transport costs. The non-spatial versions can obviously not take properly account of distance based HVFs, but only include an average transport cost increase. For this specific purpose it seems crucial to include the spatial differentiation. The same objection can be made towards the non-regional input-output models discussed in the previous section.

Van den Bergh (1997) describes a very simplified and stylised spatial general equilibrium model to demonstrate the suitability of this model tool to analyse different types of policy instruments. Van den Bergh's model however, is to simplified to be of real practical use, but it would only take some small adjustments to enrich it towards real policy analysis such as the HVF question raised here. One of the earliest spatial CGE models in Europe is described in Bröcker (1998b) who describes how such a model can be set-up using data that are available in almost all countries. The model is an international model, but the same methodology applies to national models as well if data on this level of detail is available. Bröcker (1998a) applies this model on how an expansion of EU will affect Europe's economic geography and in Bröcker (2000) is described how the model can be applied to the assessment of spatial economic effects of transport. The Bröcker methodology has also been applied in the Norwegian PINGO model (Ivanova et al, 2003). PINGO is a national model describing interregional trade; the model is used for the analysis of the national transport plans, where investments are the main focus. Spatial CGE models have been used for some time. Partridge and Rickman (1998) give a review of primarily early American and Australian based models. Despite this very early development still only very few practical applications have been published.

Here we can only give a very short general introduction to SCGE models and how they can be used to analyse economic impacts of HVF.

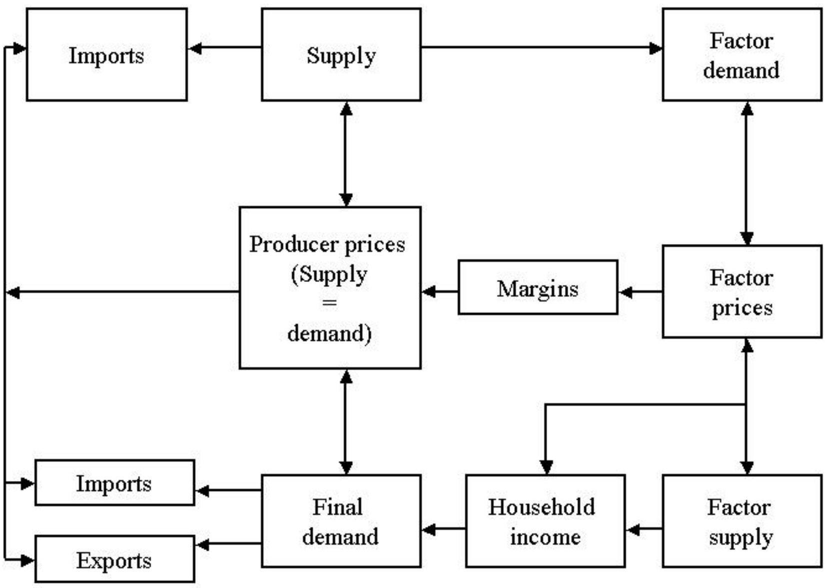

Figure 2. General structure of a (regional) CGE model.

A stylised and very general presentation of a CGE model (not necessarily spatial) is shown in Figure 2. The figure illustrates the important components of a CGE model and the important links between them. The supply (or the production of goods) creates demand for value-added factors (labour and capital), and goods and services as intermediate inputs. These inputs can be met locally or through imports from abroad or from other regions, when the model is spatial. In the non-spatial versions inputs can only be met from production in other industries. Demand for input factors interacts with factor supply to determine factor prices. To this price we add labour taxes, infrastructure tolls like the HVF, and other transport costs. The sum of these elements determines the product prices. The households own the input factors. When they supply these factors they are paid rent (capital) and wages. Supply of factors thus determines household income, which again influences final demand for goods and services. All goods and services can be met by local production or through imports from abroad or regional import.

The general equilibrium concept arises because prices are found through the equilibrium of supply and demand for goods, services and factors. The equilibrium solution thus includes all first order and second order effects that arise due to trade of intermediate products. This adaptation of both supply and demand to the inferred changes is what distinguishes the CGE approach from the input-output approach described above. In fact the CGE approach is better suited from a theoretical point of view for analysing economic impacts from distance based heavy vehicle fees than both the I-O approach and the SDM approach due to the consistent treatment of all relevant economic effects. However, the CGE models are most often highly non-linear and often rather complex in the structure. This means that these models are difficult to calibrate due to the information required to do that. The CGE models are very often limited in the level of detail as a result of these difficulties both with respect to the number of zones and industries and with respect to the detail in the infrastructure. This further implies that the CGE model do not take the variation of the fees on different types of infrastructure explicitly into account. The same critique applies to the I-O analysis. However, in the SDM approach there is most often a very explicit representation of the infrastructure, which means that the differentiation in the fees is taken directly into account. On the other hand the analysis and results that we are interested in is on a rather high level of aggregation. This means that the high level of differentiation in most cases will not influence the results significantly.

2. Case studies

There have some empirical studies of the relation between road pricing and economic impacts. Many of these studies analyse the relation between optimal pricing and welfare. In the

MC-ICAM study this was one of the defined tasks. In this study four case studies were analysed using different types of models inter-urban road pricing on passenger cars and on heavy vehicles. The study investigates the welfare effects of first-best and some second-best marginal cost pricing scenarios. The results of the analysis are measured using welfare functions, whereas the pure economic impacts are not directly accounted for. The results of the MC-ICAM studies can be found in Henstra et al. (2003).

2.1. Input-Output analysis of German HVF

The HVF in Germany is a scheme that affects many other countries because almost any transport on a North-South or East-West corridor in Europe is bound to pass through Germany. Moreover Germany is the largest economy in Europe with a very large trade with other countries, which means that a lot of the international transport goes to and from Germany.

However, we have only found two studies investigating the impacts from the German HVF. The one study will be reported below as the Danish study of the impacts in Denmark and the second is reported in Doll and Schaffer (2004) and concerns the effects in Germany.

Doll and Schaffer's analysis is carried out in a model based on I/O analysis based on a German 70 sector I/O table for 1998. Changes in transport costs are taken as given corresponding to the changes in average infrastructure costs for the different types of vehicles. The calculations reported in the Paellmann report (Paellmann, 2000) result in an average toll of 0.15 Euro. This average cost is reduced by 2.3 Euro-cent because this corresponds to the share of the German fuel tax that is earmarked for road construction purposes. The motorway toll in Germany is thus planned to be 12.7 Euro-cent. Other German studies have estimated the different reactions by road hauliers and the industries trying to avoid the cost increases (Rothengatter and Doll, 2002). Better utilization of vehicles (reduced empty running, higher load factors etc.), but also increased uses of secondary roads exempt from HVF tolls together with the compensation mentioned above reduce the average transport cost increase from 5.6 per cent to 4.2 per cent.

In order to introduce the transport cost increase the 4.2 per cent increase is introduced as an increase in the output coefficient from the sector 'Road transport'. The direct effects on prices in the other sectors in the German economy are then dependent on the demand for transport services. The indirect effects are caused by the output price increases in the sectors that absorb the transport services. Hence, increases in output prices in the transport using sectors are further passed on to the other sectors depending on the individual demand of output from other sectors. The total price effects are captured in the I/O based analysis by the Ghosh inverse matrix as explained above.

The calculated price effects in the ten most affected industries range from 0.07 per cent to

0.18 per cent (reporting minimum and maximum values). The transport industry is obviously more heavy influenced and face price increases of approximately 5 per cent. The price change for the German economy as a whole is on average 0.11 per cent.

The effects calculated so far are only supply driven effects. The use of the I/O based table does not allow for any demand side substitution effects, which could mean reduced demand for transport. To identify the supply driven effects produced quantities are furthermore assumed to remain unchanged. Another important effect is to take account of the generated revenues and demand side effects. The revenues from the German toll are earmarked for additional infrastructure investments (83 percent of the revenues). A traditional input output model using the Leontief inverse matrix finds these effects. Doll and Schaffer (2004) report only the employment effects of the use of the additional investments. The recycling of the revenue through additional investments is estimated to generate around 45.000 jobs. This effect should be reduced slightly due to the adverse effect due to higher transport costs, which may create job losses. However, Doll and Schaffer do not calculate these counter-effective effects.

2.2. Denmark, a spatial CGE inspired I-O model

Denmark is like many other countries considering road pricing for heavy vehicles. The discussion has partly been initiated by the German decision to introduce an HVF. The general concern was how the Danish economy would be affected both from the German fee and from a Danish fee. The German fee will definitely affect a large share of the international transports related to Denmark and thus affect almost any international trade in and out of Denmark. The effects for the Danish economy of national and international HVFs are analysed in a regional economic model, which has many similarities with a SCGE model, but the model is an advanced input-output based model, which can be interpreted as a completely linear SCGE model where trade coefficients are fixed similar to the I/O model. The Danish model – LINE – is described in Madsen et al. (2003), and in Madsen and Jensen-Butler (1999, 2002). Many approaches (e.g. Oosterhaven and Elhorst, 2004) use so-called loosely coupled models to analyse economic impacts from various transport policies. This is also the approach used in the Danish analysis reported here. The transport prices are calculated exogenously to the regional economic model. Optimally the formation of transport prices should be calculated endogenously like in many SCGE models (e.g. Ivanova et al 2003, Rich et al, 2004). The exogenous calculation of transport prices and costs has one advantage though. It makes it possible to include many details like variations in types of roads and spatial differentiation. This is not (always) possible in the more aggregate SCGE models. The endogenous calculation of transport costs can only include some general distances as proxies for the costs of transport from *A to B* and possibly an average time dependent driver wage.

The characteristics of the LINE model is the spatial split into regions characterized as a place for production, place for residence and place for consumption. Added to this are two international regions; one for import and one for export. This means that every actual region is represented three times, because a region can be used for all three purposes. However, this is only a way of structuring the flows of value-added factors and commodities in the regional economy. The model further keeps track of both the monetary flow (the price and cost formation in production, through taxes and transport etc.) and the physical flows of factors and commodities.

The analysis focuses on two different scenarios, in the first scenario Germany, Austria, UK and Switzerland has operating kilometre based HVFs and a reduced form of the Eurovignette is operating in the Netherlands and Scandinavia. In the second scenario distance based HVFs are also introduced in these remaining countries. The estimated revenues from the fees are recirculated into the economy by lowering income taxes. The reported results focus as in the German case described in the previous section, on price changes, employment changes and changes in disposable income. The focus of the study has been on the regional differentiation of the impacts and a differentiation of 15 counties in Denmark is used. The exogenously calculated changes in total transport costs in the two scenarios are 6 and15 per cent.

The impact on the Danish economy comes through increasing prices on the goods imported as intermediate inputs to the production. This raises the output price on domestic goods both for domestic consumption and for exports. The price on exported goods thus rise due to increasing input prices, and due to increasing transport costs for bringing the goods to the export markets. A fall in exports is an outcome of this increase in the export prices. When we consider domestic HVF there is an immediate effect on the price for inputs in production, which is higher than the impact from increasing import prices. This raises output prices. When the output form production is brought to the market there is again an addition to the transport costs, which makes the goods even more expensive for the users (final demand by the households or as intermediate inputs in other production industries).

When the direct and indirect effects of the changes in transport costs in the two scenarios are calculated we get the effects for Denmark shown in Table 1. There are large regional differences though, especially with respect to disposable income. Some regions experience a fall in disposable income despite the reduction in income taxes. In general we find that the fees on heavy vehicles much less influence the central areas around the capitol Copenhagen than the more peripheral regions. This is a consequence of the composition of the industries in Copenhagen and in the other regions. In Copenhagen there is a large service production and relatively less production of industry goods. Fees on heavy vehicles influence the service industries much less. The opposite composition is found in the peripheral regions.

Table 1. Consequences of HVF in two scenarios. Per cent changes for Denmark.

Impact on	HVF in Germany, Austria, Switzerland and the UK	HVF in D, AU, UK, S, DK, CH, NL
Changes in total transport costs	6 %	14 %
Price change in DK	0.05 %	0.21 %
Production change	-0.09 %	-0.18 %
Change in export	-0.25 %	-0.68 %
Change in export prices	0.22	0.58
Disposable income	-0.04	0.19
Employment	-1821	-2723

It is especially interesting to note the positive effect on disposable income. This is a result of the use of the revenues created when Denmark introduces road pricing for heavy vehicles. Denmark is to some extent a transit country with many Scandinavian and German vehicles. This creates revenue from the foreign trucks that can be used together with the revenues from Danish trucks to lower the income tax. The disposable income is in most Danish regions positive from this recycling method. However, the impact in some peripheral regions from the introduced fees is so large that even the revenue cannot offset the negative impact.

2.3. Norway – An SCGE approach

Ivanova et al (2003) describe an SCGE model – PINGO – that can be used to assess the regional economic impacts of HVFs. PINGO is a model derived from the state of the art Bröcker (1998) model, but applied at a regional rather than a national level. The model describes the trade flows between the regions in Norway and it is linked to a network model (NEMO). The model has been used to evaluate a marginal cost pricing strategy for interurban road transport taking into account local and global pollution, infrastructure depreciation, noise, accidents and congestion. The tax level has been set to reflect a first best situation given the model and data limitations. These limitations are mainly lack of time and spatial differentiation as well as the exact type of vehicle used. The revenues are redistributed to the producers and consumers as a lump sum subsidy.

The economic evaluation of the introduced taxes is performed as a cost-benefit analysis using a welfare function comprised of the sum of changed indirect utilities in the SCGE model plus the changes in external costs of transport: $\Delta W_i=\Delta C_i+\Delta E_i+\Delta A_i+\Delta I_i$, where C_i is the consumers surplus, E_i is the environmental costs, A_i is the accident costs and I_i is the maintenance costs. The results are described in Henstra et al (2003), but no spatial differentiation of the results is reported. The most striking result is that the effect on consumers' surplus is negative. This is similar to the results obtained in the Danish study. However, in the Norwegian case consumers' surplus is negative despite the income redistribution. There are two immediate explanations for this difference. The redistribution in the Norwegian case is lump sum. This means that there are no additional gains due to a lower income tax - the removal of distortionary taxes. Second, it is unlikely that the revenue raised from foreign trucks in transit is very large. Hence, all the transports that are influenced will have an impact on the prices of Norwegian produced and consumed goods. HVF in other countries like Denmark and especially Germany will lead to large revenues due to transit trucks. This revenue can then be used to compensate the decline in disposable income caused by the higher prices on the consumer goods.

Table 2. Welfare effects of introducing marginal cost pricing in Norway. (Million Euro per year)

	MCP for all modes	MCP only for road transport
Consumers' surplus	-13	-6
External costs	66	60
Total	53	54
Revenue	679	389

Another important outcome of the Norwegian study is the very high revenues raised. This is much larger than the Danish case. The explanation is that both heavy vehicles and passenger cars are tolled. This may thus be an additional explanation for the negative total impact on consumers' surplus. Moreover, the revenues are very much larger than the impacts on welfare. This indicates a potential for increasing consumers' surplus through alternative redistribution schemes.

Another interesting finding in this Norwegian study is that they do not calculate large differences between a do nothing scenario and the two marginal cost pricing scenarios. This is mainly due to the existing transport taxes, which capture most of the external costs (Henstra et al, 2003).

3. Discussion

We have discussed a number of different ways of analysing the economic impacts of road pricing on trucks with respect to the impacts in general on different sectors and on different regions. We have also demonstrated this in three different case studies. The impacts from the case studies are difficult to compare directly because of different countries and different types of pricing structures and levels. The results are therefore not directly showing the different results that different types of models can provide. Despite this there are some interesting things, which can be found when comparing the results. In this section we will look at the differences and similarities of the case studies and we will compare the different methodologies.

The primary effect from road pricing on heavy vehicles is that the prices on the produced goods increase. This happens both due to direct effects and indirect effects, because output from production is used as intermediate input in other industries. However, there are other effects that may influence the indirect effects. If there is a significant amount of congestion before the HVF is introduced then there is also a positive effect on transport costs due to a reduction in congestion caused by the HVF. The magnitude of this effect compared to the direct changes in transport costs will differ significantly depending on the level of congestion. Whether the reduction in transport costs due to reduced congestion for those goods that are still conveyed after the introduction of HVF can outweigh the higher costs due to the fee is an open question. We cannot say which of the effects are largest in the case studies referred here, because they do not take congestion into account and because congestion in interurban freight transport in Norway and Denmark is not considered a big problem. From the theoretical analysis we can conclude that the impact on prices due to the congestion effect is smaller than the total change in transport costs due to HVF.

Another precondition for increasing transport prices is the use of revenues. If revenues are used to improve the infrastructure or used to reduce other tolls and fees on freight transport (e.g. fuel taxes or registration taxes) this will obviously have an impact on transport costs, which must also be taken into account. A large proportion of the German HVF will be used for improvements and maintenance of the German infrastructure. Hence, the change in transport costs is lower than the 0.15 Euros per km. There has also been discussion about using the revenue from the German HVF to reduce fuel taxes in Germany. Using the revenue in this way will influence vehicles from different countries in different ways. Some foreign vehicles will experience a higher increase in transport costs than German vehicles. The German vehicles are more likely to use fuel from Germany due to special rebates negotiated with the oil companies in Germany. Foreign vehicles are likely to have similar arrangements in their own countries and will thus not benefit similarly from the German reduction in fuel taxes. Moreover, when infrastructure investments are financed via HVFs as suggested in the German scheme this can lead to a reduction in the government budget or to an increase in other government activities, because of savings on the budget for investments in infrastructure.

The choice of use of revenues and the effect of doing this is very dependent on the existing conditions in the different countries. Using revenues to reduce income taxes would probably be a good solution in Scandinavia due to the high level of current income taxes. This would thus have a higher impact on welfare than using the revenues for improvements of the infrastructure. In Germany, the Netherlands or in the UK infrastructure improvements would probably lead to a larger impact on welfare due to the higher current level of congestion. Economic theory suggests using the revenues to reduce the most distortionary taxes leading to the largest impact on welfare. However, it is very difficult to find the levels of these taxes.

The results from Norway and Denmark show large regional differences in the impacts on income and the effects from redistributing income. This is so despite the Norwegian case with lump sum redistribution. Some regions even face a negative impact on disposable income (Kveiborg et al 2004). This points out the importance of analysing these effects, which may be politically very important.

Another very important effect of HVF is the impact on employment. Higher transport costs and thus higher prices on the input to production lead to a reduction in the demand for other input factors such as labour. The effect here is similarly dependent on the potential effects on transport costs stemming from reduction in congestion and from the use of revenues. The magnitudes of the employment effects in the Danish show a decline of 0.07 per cent in scenario 1 and 0.10 per cent in scenario 2. The effects in Germany are much larger in absolute terms. It is expected that an increase of 46.700 jobs is possible due to an investment of 90 per cent of the generated revenues. This corresponds to a 0.13 per cent increase in employment in Germany. The employment effects of the increase in transport costs are not calculated in Doll and Schaffer (2004). The effects on disposable income in the Danish and The Norwegian cases are very similar.

The different types of models are very likely to give different outcomes from the introduction of HVF. However, the Norwegian CGE model and the Danish model give quite similar results, but also the analysis of employment effects in the German case study show similar sized effects. However, caution should be made to the comparison between the German I-O approach and the two Scandinavian models, which are both within the general equilibrium approach. The reported I-O calculation does not take the negative impact on employment from higher production costs into account.

The main difference between the two Scandinavian models is the linearity of the equations in the Danish model. This means that some of the adjustments in e.g. labour supply and substitutions between various input factors in production are not possible. The model is in this respect similar to an input-output approach, where all coefficients are fixed.

4. Conclusion

In this paper we have highlighted some models that can be used to analyse the economic impacts of heavy vehicle fees. The various models are not all equally useful for this task and differ with respect to the effects they are able to analyse. The SDM models are very general because they take into account both economic, land-us and transport effects. However, these models are not very consistent or transparent. It is not easy to separate the effects calculated in the different models and the total effects are not easily interpreted. There is a danger of double counting. On the other hand these models are capable of providing answers to effects in many different areas including economic and regional economic impacts. Consistency is retained in both the I/O models and the CGE models. However, the I/O models are of limited use because they cannot include the substitution effects of changed transport costs and they must assume that changes only occur in prices due to the interpretation of the Ghosh supply models. The most consistent approaches to analyse economic impacts thus seems to be the CGE models and especially those including various regions. However, these models are often quite complex and cannot use the same level of detail included in the SDM models. Moreover, the SCGE models do not give explicit answers to the transport impacts, but can only provide insight into the pure economic changes. Such changes cannot be directly used as changes in transport demand.

Three case studies have been analysed. The studies differ with respect to country and to the type of model. This has made it difficult to compare the calculated impacts directly. However, there are some similarities reported in the studies. E.g. the size of the employment impacts is similar and the possible negative impact on income is found in two of the studies. To give further insight in the differences of the calculated impacts we should use the same case study and apply the different types of models. This has not yet been done, but would be very fruitful in order to indicate whether the models do in fact provide similar results.

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