Three approaches to calculate economic impacts from pricing schemes on heavy vehicles

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Abstract

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. These effects can be of considerable size and it is thus important to know what the effects are and where they occur. Most of the literature on HVF is concerned with the practical implementation of a HVF, the degree of optimal pricing of a proposed HVF and the traffic impacts. This is interesting because a vast amount of literature exists investigating the relationship between transport and land-use as well as the relationship between infrastructure investment and (regional) economic impacts. This paper aims at describing and comparing a number of studies of the relationship between heavy vehicle fees (HVF) and the economy.

Three different types of models used to assess economic impacts are described: system dynamic models (SDM), 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 similarities in the types and size of the results. Especially the price effects and employment effects are similar in all case studies.

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. A review of freight transport models is given in de Jong et al (2004) who categorise models from the literature in relation to the traditional four stage model. They group models in five categories 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 and in January 2005 Germany commenced operating their sophisticated HVF scheme. Holland, Sweden, United Kingdom, and Ireland are all considering HVF schemes with different technical solutions. Obviously these schemes will have an impact on the transport patterns in the different countries. Transport is mainly caused by demand derived from economic activities (see e.g. Kveiborg and Fosgerau, 2006). When transport cost changes due to new infrastructure, new fees or taxes this will have an impact on the economic activities. 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.

The impact from infrastructure investments has been the topic for many studies during the past years. Regional development has often been used as an argument for investing in motorways to poor regions. The book by Banister and Berechman (2000) gives a comprehensive overview of these effects. They emphasise that three primary conditions must be fulfilled to ensure an additional and sustainable economic growth. A well-functioning local economy, a political will to support the infrastructure investment by additional initiatives and thirdly that the new infrastructure is a major improvement of the existing infrastructure. Also interdependencies between transport and land-use have been topic for many studies throughout the past decades (e.g. Wegener, 1998, Anderstig and Mattsson, 1998). However, the link to the economy has in these studies has often not played a significant role in the analysis. The outcome of the analysis of 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 e.g. environmental quality.

The discussion about HVF has on the other hand primarily been concerned 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 of freight transport using distance dependent taxes or fees is reduced to a question of paying for the wear and tear and some environmental effects. In the recently proposed EU Eurovignette directive (CEC, 2005) 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 that such a limited number of studies have calculated 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 or even greater size and the effects are even more spatial.

This paper will:

- Describe different models that can be applied to analyse the (regional) economic impacts from HVF.

- Compare 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 a model combination of spatial input-output and spatial general equilibrium modelling focusing on regional economic impacts.

In the following section we give a review of three 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.

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 emphasize the elements that characterise the different model types and focus on how the models can be applied to analyse distance dependent HVF. All references to HVF in the remainder of the paper is implicitly referring to distance dependent fees.

System dynamics models

System models are characterised by linking two or more models from different areas to each other using more or less firm interfaces (see e.g. Madsen et al., 2004). Of course such linkages also exist in the other model types addressed in subsequent sections, 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 models as models where the linkages are two-way linkages and the model systems are run iteratively. System *dynamics* models are further characterised by their time dimension. The models compute the development in numerous variables in the different sub-models over time by considering especially their interdependence.

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. Parameters in SDM are usually not obtained from statistical estimation, but from existing literature and by trying initial values and checking resulting dynamic behaviour of the system (de Jong et al, 2004). Many SDM are designed to provide *fast policy analysis*, but many details can be added to the models. SDM models contain many different aspects of the economic and transportation systems, which in combination with the dynamics often imply that a relatively aggregate approach is followed. In for example the ASTRA model (IWW and

TRT, 2003) that covers a large part of Europe only 61 zones and 25 economic sectors are used.

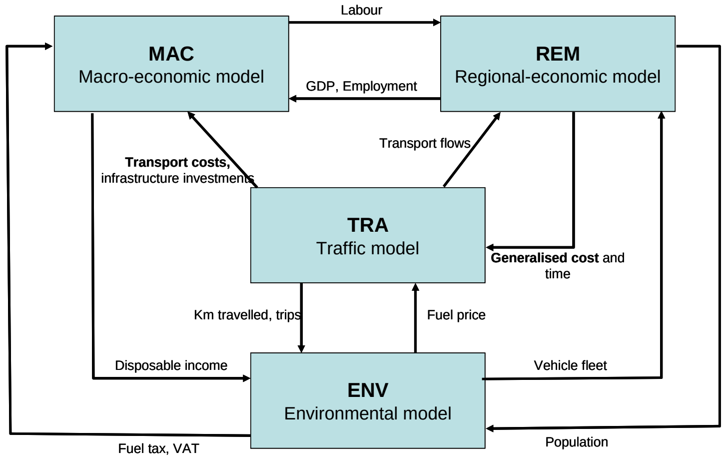

Figure 1. The sub modules of ASTRA and the flow of information between the modules.

A schematic illustration of a typical SDM is shown in Figure 1. The illustrated model consists of four sub models; a macro economic model (MAC), a regional economic model (REM), a traffic model (TRA) and an environmental model (ENV). The core of the models is the traffic model (TRA), which calculates mode and route choice using traditional traffic model approaches and using the inputs from the regional economic model to calculate the OD flows. The transport model can in some cases also include a specific network model. Often the link to these models are not directly included, but are sometimes coupled in external links – like the coupling of ASTRA and the transport model VACLAV described in Kleist and Doll (2005).

The most important elements for our purpose are the linkages between the macro economic (MAC), the regional economic (REM) and the traffic models (TRA). The macro module calculates the level of GDP of goods production in each macro region. This is used as input in the regional economic model together with the level of regional employment. The REM model calculates trade between the regions, and passenger flows between regions based on employment figures in the MAC module.

The TRA model calculates modal split and sometimes also 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. An introduction of HVF would be handled in the TRA model and result in changes in generalised costs (and potentially also in generalised time if congestion levels are influenced).

Transport costs are further fed back to the macro economic model as cost savings from e.g. investments or negative savings from changed taxes. Hence, HVF 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 model.

The systems model approach

The systems approach to modelling effects of HVF is much similar to the SDM approach. The systems approach can be characterised as a formalised structure for interchanging information between different sub-models. The main difference between the two approaches is found in the inclusion of time in the SDM models. It is often possible to increase many more details when time is not included.

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

Table 1. General content of an I-O table.

Intermediate flows $\mathbf{X_0}$	Final demand $\mathbf{f_0}$	Total output $\mathbf{x_0}$
Value added $\mathbf{v_0'}$		Aggregated value added $\mathbf{v_0'e}$
Total input $\mathbf{x_0'}$	Aggregated final demand $\mathbf{e'f_0}$	

$\mathbf{X_0}$ is the *n x n* matrix[1] 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. $\mathbf{X_0 e}+\mathbf{f_0}$ 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 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

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

for the demand driven I-O model and

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

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:

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

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

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

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 relations between demand and supply 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.

Computable general equilibrium models

SCGE models are typically comparative static equilibrium models of interregional trade based in microeconomics using utility and production functions with substitution between inputs. 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.

The main strengths of the SCGE models lie in the comparison of outcomes in different equilibrium. SCGE models are strongly based in microeconomic theory. The advantage of these models are that results are readily interpretable based on a strong theoretical literature. The SCGE models are ‘comprehensive’ and include relations between sectors, supply and demand, households, economic regulations etc. in potentially very complex non-linear ways. The models can thus be used to analyse problems, where many different things are working at the same time and when e.g. behaviour has to be close to reality where it further take proper account of both first and especially the complex second-order effects.

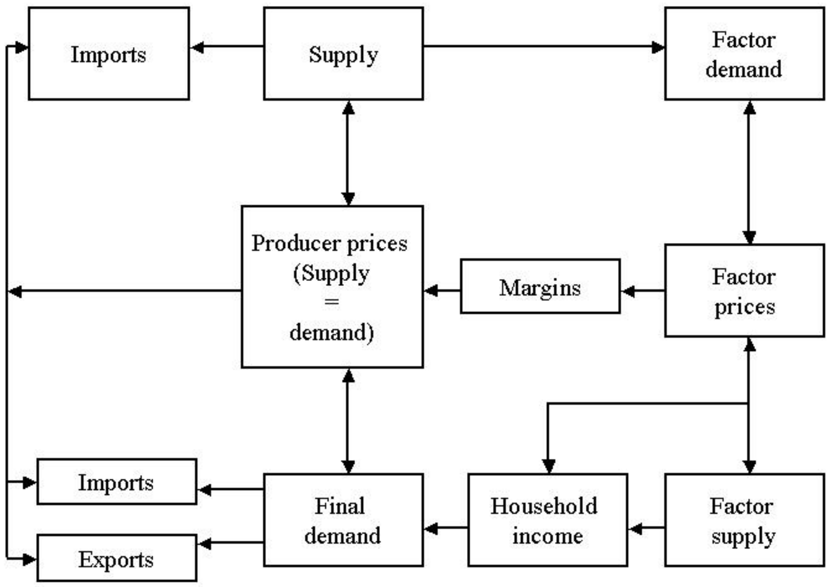

Figure 2. General structure of a (regional) CGE model.

A stylised and very general presentation of a CGE model is shown in Figure 2. The figure illustrates the primary 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 labour taxes, infrastructure tolls like the HVF, and other transport costs are added. 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.

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 too simplified to be of real practical use, but it can easily be extended 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 demonstrates that a SCGE 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 to showhow an expansion of EU will affect Europe's economic geography. In Bröcker (2000) is described how the same 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.

Case studies

Some empirical studies of the relation between road pricing and economic impacts exist. In the following we will discuss the few studies we have found, which have directly addressed the relation between the regional economy and HVF. Most other studies have analysed 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 analysed. The results of the MC-ICAM studies can be found in Henstra et al. (2003).

Input-Output analysis of German HVF

The HVF in Germany is a HVF scheme that affects almost any transport on a North-South or East-West corridor in Europe. 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 using 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, which corresponds to the share of the German fuel tax that is earmarked for road construction purposes. 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 utilisation 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 change 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. This calculation does not include the internal transport undertaken by the firms themselves. The indirect effects come from the increased output price, which influence the input prices in sectors that demand transport services. These changes further lead to increasing output prices in the transport demanding sectors, which again are diffused to those using the output. 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 heavier 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 model does not directly 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.
It is further important to account for 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.
The large positive supply side employment effect will to some extent be offset by the negative demand side employment effect. However, Doll and Schaffer do not calculate magnitude of these effects, but they will probably be of same size as the price effects.

A systems approach using a linear CGE model

The German decision to introduce an HVF initiated a discussion about the German fee and a similar Danish HVF among politicians and transport professionals. The general concern was how the Danish economy would be affected both from the German fee and from a Danish fee. The German fee definitely affects a large share of the international transports related to Denmark and thus affects almost any Danish based international trade. 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, which is summarised in Kveiborg et al. (2004). 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). 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 re-circulated 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 prices 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. Considering 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 from production is conveyed to the market transport costs further increase the commodity price. Hence, final demands by the households or intermediate inputs in other production industries face even higher prices.

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, especially with respect to disposable income. Some regions face a fall in disposable income despite the reduction in income taxes. In general we find that the fees on heavy vehicles much influence the central areas around the capitol Copenhagen lighter 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 lighter. 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 income. This is a result of the use of the revenues created when Denmark introduces road pricing for heavy vehicles, which compensates the loss incurred by higher prices and reduced production. 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.

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 a spatial differentiation of the results is not reported. The results are summarised in Table 2. The most striking result is that the effect on consumers' surplus is negative. This is similar to the results on income before redistribution 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 – a double dividend. Secondly, it is unlikely that the revenue raised from foreign trucks in transit is very large. Hence, all influenced transports 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 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 large revenues. These are 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.

A final interesting thing in this Norwegian study is that they do not find 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).

International, a systems dynamic approach

The ASTRA-T model (Kleist and Doll, 2005) has been applied to analyse the introduction of HVF in the EU countries including, Switzerland and Norway. The basic scenario is a situation where HVF has been introduced in Switzerland, Austria and Germany from 2005. Two scenarios and a combination of the two are analysed. The first scenario (NET) introduces motorway tolls from 2005. The second scenario (DAREA) introduces on all inter-urban roads. Two price levels are analysed for all scenarios: a low price based on a rough estimate of infrastructure costs and a high price including external costs as well. The average price levels for both low and high price levels are beyond the average price level introduced in Germany in 2005.

Discussion

We have discussed a number of different approaches to analyse the economic impacts of road pricing on trucks with respect to the impacts 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.

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 shows similar sized effects. A note of 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 and the model is much less flexible, which thus leaves out some important behavioural effects that are accounted for in the SCGE models.

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.

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 does 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.

It is very important to note that the use of the very large revenues that are generated by HVF schemes must be accounted for in studies like this. However, the overall results are highly dependent on the way the revenues are used. Moreover, 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 is in economic theory found as the most efficient 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 larger impacts on welfare compared to Scandinavia due to the higher current level of congestion.

The results from the Danish case study show large regional differences in the impacts on income and the effects from redistributing income. Some regions even face a negative impact on income (Kveiborg et al 2004). The overall effect on income is positive contrary to the negative consumers' surplus in the Norwegian case. However, the results are difficult to compare as the Norwegian case include fees on passenger transport as well and revenues are in the Norwegian model redistributed using lump sum taxes, which does not lead to additional behavioural effects (double dividend). This emphasises the importance of analysing these effects, which are 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 effects here are 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 magnitude of the impacts are thus in the same range indicating that the economic effects of HVF are non-negligible. The employment effects of the increase in transport costs are not calculated in Doll and Schaffer (2004), but they will reduce the larger positive effects on employment. The effects on private households are very similar in the Danish and Norwegian cases, even though employment effects are not calculated in the Norwegian case study.

Conclusion

In this paper we have highlighted some models that can be used to analyse the economic impacts of heavy vehicle fees. 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.

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-use and transport effects. However, these models are not very consistent or transparent. It is not easy to separate the effects calculated in the different sub 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; and often in a quite detailed way. 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 level of detail used 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. Another objection to the SCGE approach is the intensive use of exogenous elasticities. The complexity of SCGE models makes it impossible to estimate all included elasticities. These are instead taken from existing literature or in some cases guessed. Despite this and despite the lower level of detail especially related to the underlying transport infrastructure, we recommend using the SCGE approach for the evaluation of economic impacts. The SCGE approach potentially takes all relevant combined (economic) impacts into account and they are modelled in an interpretable way such that it is possible to understand the reasons for the observed effects.

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.

The effects in all the reported cases are significant. This emphasises the importance of doing this type of analysis. The specific choice of model employed for the analysis of overall effects seem less important, because they are quite similar, but when more details are required we believe that the SCGE models will provide more credible results.

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