1 INTRODUCTION

The aim of this paper is to study and compare welfare economic benefits in the form of reduced negative externalities accompanying differentiated or uniform distance dependent road tax schemes. More specifically, we investigate various schemes of a kilometre based road tax on heavy goods vehicles (HGV’s).

There is a considerable ongoing debate about whether to introduce differentiated road taxes for HGV’s as opposed to a more simple system such as e.g. a simple uniform km-tax or a vignette-system. One question is whether a system enabling differentiation can provide sufficiently larger welfare effects to justify the additional costs of such an advanced system. Our aim is to investigate the efficiency disregarding e.g. distributional and other equity and fairness issues.

Road taxes can basically work in three ways to reduce the negative externalities from HGV’s.

1. By reducing the total demand for transport (the total tonne kilometres).
2. Given the demand for transport, by influencing the modal split, i.e. by changing the mode choice of the freight (towards e.g. rail or water).
3. Given the demand for transport and the mode choice, by influencing the choice of the vehicle type, by increasing the utilisation of the vehicle, the route choice and time of delivery.

Recent studies (Doll and Schaffer, 2004, Kveiborg et al., 2004, Henstra et al. 2003.) indicate that the effects of road taxes on total demand and mode choice are relatively small, i.e., the first and the second types of changes.

In this project we study the third type of impact. We focus on the choice of vehicle type and the utilisation of the vehicle and ignore the time of delivery for now.

With respect to passenger transport and congestion recent papers have shown that a large part of the potential efficiency gain of an ideal road tax is achieved with a simple uniform kilometre tax (e.g. Parry, 2002 and Verhoef and Small, 2004). Also the London congestion charge scheme and the Stockholm trial indicate that very large gains can be obtained from simple pricing schemes.

Parry (2002) studies the efficiency of different policy measures with respect to reducing traffic congestion on freeways. Their results show that a uniform congestion tax typically achieves more than 90 % of the maximal efficiency gains that can be achieved by an "ideal" congestion tax (that takes heterogeneity
among drivers' value of times into account). Thus for the congestion externality, it is possible to achieve a considerable gain by using a simple uniform tax.

In this paper we examine whether a similar result can be found with respect to other negative externalities in the case of HGV’s. We do not analyse congestion impacts of HGV’s since its contribution to the overall level of congestion is expected to be small. The negative externalities considered in this work are road maintenance, emissions of greenhouse gasses and particles, noise, and accidents. In line with the results of Parry (2002) our results from this analysis of the present Danish national and international HGV traffic and demand for freight transport also indicate that the potential gains associated with these negative externalities are more or less accounted for by a simple uniform kilometre tax.

Parry (2002) uses a generic model. The model is not calibrated to a region-specific network but the analysis is simulated with variations in key parameters. The success of the uniform road tax arises because the uniform tax successfully makes travellers substitute away from peak-period freeway travel towards other modes and off-peak travel and thus takes the congestion on the whole network into account. In contrast, other systems that do not take congestion of the whole network into account are less successful in reducing congestion. Thus, the result in Parry (2002) shows that the important consideration is to choose the policy that generates the efficient substitution from the congested freeway onto other modes and travel at other times (off-peak), when focus is on economic efficiency. The creation of fast and slow lanes is of less concern.

In this paper we use a different approach and an elasticity mechanism is not active in our present preliminary model and the results presented this paper. Alternatively, we in a sense, consider hypothetical differentiated tax schemes with a perfect effect on behaviour that result in various scenarios for the HGV traffic segmented on HGV types. We assess, calculate and compare the total welfare costs of the considered negative externalities resulting from various scenarios for the usage of 48 different HGV types and their associated vehicle-type kilometres to meet a given fixed total demand for transport taking into account the average loads of the different vehicle types. Thus, the important driver in our result can still be compared to the one in Parry (2002). In the present paper a uniform road tax is successful since it increases the incentives to use bigger HGV’s, which reduces the overall number of kilometres driven. Our results indicate that the total welfare effect of the fewer required HGV kilometres is larger despite the higher costs per kilometre of large trucks on accidents, pavement damage, noise etc. as compared to small trucks per kilometre.

It is worth to recall the caveats of our approach. Our results are not to be considered as the actual effects of a road tax for HGV’s. First of all, and most importantly, it does not take into account the practical restrictions on the use of a HGV that are implicitly incorporated in the truck choice of the shippers. Thus, our results clearly overestimate the short run effects that can be expected from a HGV fee. It is only to be considered as an indication of the maximum welfare gain that can be achieved by reducing the negative externalities.
Secondly, our model does not take into account effects of changes in the total demand for goods kilometres, potential mode shifts, traffic growth and changes in the infrastructure. These effects are expected to be particularly important in the longer run. Today, HGV transports are already regulated by a vignette taxation system, and an alternative tax system with a comparable level of taxation is thus not expected to have additional effect on the generally increasing demand for HGV transport driven by the growing economic activity. Previous studies (Kveiborg et al, 2004, Henstra et al, 2003) have further shown that a HGV fee of the current magnitude does not significantly provide incentives to use other means of transport. Thus the generally increasing demand for transport is not expected to change the relative magnitudes of our results and conclusions. However, increasing congestion and associated increasing operational cost will possibly motivate mode shifts in the longer run.

As mentioned earlier, we are focusing on the efficiency of the different tax systems. Thus, we do not consider whether there can be other arguments than efficiency to introduce a differentiated tax system despite the larger system costs. One such argument could be fairness or distributional aspects. It is obvious, that a uniform kilometre road tax is not necessarily fair in the sense that a bigger vehicle generates more negative externalities than a smaller vehicle and this is not reflected in the system. Thus, the uniform kilometre tax does not fully reflect the polluter pays principle.

We have not discussed the effects of the internal kilometre costs for the different vehicles types. However, this is obviously important to include in a complete welfare economic analysis of different tax schemes, and when realistic behavioural changes induced by the fees are investigated.

Our aim of this study is to identify and compare the potential welfare effects of differentiated distance dependent HGV fees. The analysis does not provide the "realistic" or the actually expected effects of a specific vehicle fee structure. It enables a comparison of different schemes and indicate whether a specific differentiation of the fee is feasible based on the size of possible additional welfare effects as compared to alternative schemes, e.g. a simple uniform tax.

2 METHOD

We proceed by a more detailed description of the approach we have used in the analysis: The model of maximum potential changes of external cost.

The objective of introducing differentiated vehicle fees is to optimise welfare. However, welfare is influenced by many other aspects related to the interaction between transport and other sectors. In this analysis we thus pursue a partial optimisation of external costs directly related to the use of heavy vehicles:

Minimise “External costs of road freight transport”

S.t. “Road freight transport remains unchanged”
Besides the pure external costs there are other elements that influence overall welfare and may have important spill-over effects. We have not taken the changes in transport costs into account even though we find that they are very large. Changes in general transport costs can thus influence the transport price and transport demand. This effect is not introduced here. Changes in transport prices work through economic interactions with very complex effects on transport demand. We have due to this complexity not included these effects even though this may influence welfare.

Our minimisation problem can be formulated in mathematical terms, for which we need some notation:

\[ X_{m,v} : \text{Vehicle km on road type } v \text{ using vehicle type } m \]

\[ L_m : \text{Load in tonne on vehicle type } m \]

\[ T_{m,v} : \text{Transport performance (tonne km) on road type } v \text{ using vehicle type } m \]

The vehicle types \( m \) is a composite of \( m \in \{s e x a\} \), where \( s \) denotes the size of the vehicle, \( e \) denotes the environmental class of the vehicle and \( a \) denotes the number of axles. The classification by axles is in our study directly linked to the size of the vehicle and is not an independent dimension.

We can thus write the minimisation problem as

\[
\begin{align*}
\text{Min} & \quad \sum_{m,v} \alpha_{m,v} X_{m,v} + \sum_{i,m,v} \beta^i_{m,v} X_{m,v} + \sum_{i,m,v} \gamma_{m,v} X_{m,v} \\
\text{s.t.} & \quad \sum_{m,v} T_{m,v} = \sum_{m,v} T^0_{m,v} \\
& \quad T_{m,v} > T^0_{m,v}
\end{align*}
\]

where \( \alpha_{m,v} \) is the marginal external costs per km for road wear and tear, \( \beta^i_{m,v} \) is the marginal external environmental costs per km for emission of substance \( i \) (\( CO, HC, \) particles, \( CO_2, NO_x, SO_2 \)), \( \gamma_{m,v} \) is the marginal external costs of noise emissions per km, and \( \lambda_{m,v} \) is the marginal external accident costs per km. A \( "0" \) indicates the existing use of vehicles and similarly \( "1" \) indicates a situation after some change in the use of vehicles. The second set of constraints ensures that transport that can only be undertaken by a specific type of vehicle is not exchanged by transport by another vehicle type. For example certain trips in a city centre, where local legislation restricts large vehicles from entering or certain types of goods that can only be conveyed by large trucks. The constraints can also be used to maintain a certain amount of transport on different types of roads. Not all trips can be substituted to the motorways and primary roads.

The objective function in (1) is linear meaning that the optimum will always be a corner solution. Without the second set of constraints it is not difficult to see that the optimal solution to the programme is the \( X_{m,v} \) for which the sum of the marginal external costs are minimised in general. Only one type of vehicle will be chosen and the size of \( X_{m,v} \) is determined by the relation

\[ \sum_{m,v} T_{m,v} = \sum_{m,v} T^0_{m,v}. \]
Transport is related to traffic through \( T_{m,v} = L_{m,v} X_{m,v} \) where it is assumed that the average load \( L_{m,v} \) is the same for all trips. This is obviously not exactly correct, but the relation is an approximation that is often applied. The average load will not remain unaffected by the amount of goods that a certain vehicle category must accommodate. Changes towards larger vehicle will most likely reduce the average load on the larger vehicles because a number of trips is of a certain kind, where only smaller parcels of amounts of goods, \( M_{m,v} \) are delivered. Changes towards smaller vehicles will most likely lead to higher average loads because the larger loads in larger vehicles can be used to fill smaller vehicles completely. Hence, the average load is a function of the amount of goods that is conveyed: \( L_{m,v} = L_{m,v}(M_{m,v}) \), \( \frac{\partial L_{m,v}}{\partial M_{m,v}} < 0 \). We approximate this relation through the number of vehicle kilometres, \( L_{m,v} = L_{m,v}(X_{m,v}) \), \( \frac{\partial L_{m,v}}{\partial X_{m,v}} < 0 \)

Note further that we unrealistically assume that total transport demand remains unchanged (demand elasticity equals zero). For the present analysis of the potential welfare gains of differentiated fees this assumption is not crucial.

3 SCENARIOS AND RESULTS

3.1 The practical evaluation

We calculate results of scenario by assuming that demand is perfectly elastic so that any price difference implies that demand for the expensive vehicle type or road type declines to zero and is completely exchanged to demand for the cheapest vehicle type or road type.

In the calculations above this implies that \( X_j^1 = 0 \) if \( j \) is the most expensive vehicle type. From this we can calculate the changes in vehicle kilometres for vehicle type \( i \), which is now the cheapest and similarly for all the other vehicle types.

Our information about the external costs on different road types is limited. We are therefore not able to distinguish between road types except for wear and tear costs. We can further not distinguish between transport in and out of urban areas. This is very important with respect to the external costs, which are much higher in urban areas. However, we do not consider the problem to be of large importance for the results because only a small fraction of the vehicle kilometres are driven in urban areas (even though a larger part of the vehicle kilometres driven by small trucks is in urban areas).

We assume that \( T_{m,v} = 0 \) for all vehicle types. Hence, we assume that all trips can be replaced by trips made in other vehicle types. With this we obtain a way to measure the maximal potential for a given instrument (e.g. a tax working in a given direction).

Of course, this is not realistic, but we do not have information to set the lower limit of vehicle trips higher than zero. This assumption makes it even more important to adjust the average load. Unfortunately our data cannot be used
to make such an adjustment either. The limitations all influence our results similarly such that the results overestimate the “true” potential of reductions. However, we believe that the mistakes are consistent across the various scenarios. We are thus able to compare the outcomes of the scenarios relatively, remembering that we are not directly interested in the absolute values of the cost changes.

When we introduce a scenario we evaluate the cost function by changes in the vehicle kilometres by the different vehicle types. When other vehicle types are used to convey the goods there is a possibility that the new vehicle can have a higher pay load. This will obviously reduce the demand for vehicle trips and thus the number of vehicle kilometres. We take this into account by assuming that the use of vehicles is independent of the actual pay load they convey in total. This implies for example that there will always be enough goods to be conveyed to fill up the largest vehicles. The average load will thus remain the same for all vehicle types disregarding the practical obstacles that may prevent this (small amounts of goods being delivered at a remote place, which will always be delivered by a small vehicle). In our analysis this will lead to overestimation of the reduction in vehicle kilometres.

We assume that the average load per vehicle trip is fixed, which allows us to write $T_{m,v} = \bar{L}_m \bar{X}_{m,v}$. Using this in the constraints we get

$$\begin{align*}
\text{Min} & \sum_{m,v} \alpha_{m,v} \bar{X}_{m,v} + \sum_{i,m,v} \beta_{i,m,v} \bar{X}_{m,v} + \sum_{i,m,v} \gamma_{i,m,v} \bar{X}_{m,v} + \sum_{i,m,v} \lambda_{i,m,v} \bar{X}_{m,v} \\
\text{s.t.} & \sum_{m,v} \bar{L}_m \bar{X}_{m,v} = \sum_{m,v} \bar{L}_m \bar{X}_{m,v}^0
\end{align*}$$

The assumption implies that for any $i$ different from $j$, and $k$ different from $i$ and $j$:

$$\begin{align*}
\Delta T = 0 \iff T_i^0 + T_j^0 + \sum_{k \neq i,j} T_k^0 = T_i^1 + T_j^1 + \sum_{k \neq i,j} T_k^1 \\
\implies \bar{L}_i \bar{X}_i^0 + \bar{L}_j \bar{X}_j^0 + \sum_{k \neq i,j} \bar{L}_k \bar{X}_k^0 = \bar{L}_i \bar{X}_i^1 + \bar{L}_j \bar{X}_j^1 + \sum_{k \neq i,j} \bar{L}_k \bar{X}_k^1 \\
\implies X_i^1 = X_i^0 + \frac{\bar{L}_j}{\bar{L}_i} (X_j^0 - X_j^1) + \sum_{k \neq i,j} \frac{\bar{L}_k}{\bar{L}_i} (X_k^0 - X_k^1)
\end{align*}$$

Or in other words that the changes in vehicle kilometres is found by the relative average load.

3.2 Data

Various data elements characteristic for transport by trucks in Denmark has been compiled and organised in a database for the purpose of the analysis. A basis demand table describing year 2003 transports (tons) and associated traffic (vehicle kilometres) has been established segmented by 48 vehicle types and by the impact on two infrastructure categories (“main-road” or “other road”). The data of the demand table covers and include internal transports in
Denmark, and the part of international (differentiated by Danish or foreign operator) transports (exports, import, and transit) with impact on the Danish infrastructure. The demand table has been constructed and assembled by the TetraPlan A/S from data collected by “Centralregisteret for Motorkøretøjer” and Statistics Denmark supplemented by data and model run results from two national freight traffic models addressing the Danish national (LDK) and international (SENEX) transport.

The 48 vehicle types of the analysis are characterized by type of vehicle and total weight, \( s \):

- Solo truck (between 6 and 12 tonne)
- Solo truck (between 12 and 18 tonne)
- Solo truck (between 18 and 26 tonne)
- Solo truck (more than 26 tonne)
- Truck and semi-trailer (less than 40 tonne total weight)
- Truck and semi-trailer (more than 40 tonne total weight)
- Truck and trailer (less than 40 tonne total weight)
- Truck and trailer (more than 40 tonne total weight)

Furthermore these vehicle types are distinct and classified by the number of axles on the road, \( a \), (2, 3, 4, 5, 6), and by Euro-norm, \( e \), (0, 1, 2, 3, 4, and 4+).

In order to calculate external costs each vehicle type is associated with a marginal cost per kilometre for each of the externalities. The externalities addressed in this work include:

- Emissions, \( \beta_{m,v} \) (CO2, NOx, SO2, CO, HC, and particles)
- Road maintenance, \( \alpha_{m,v} \)
- Noise, \( \gamma_{m,v} \)
- Accidents, \( \lambda_{m,v} \)

The values of the marginal costs for these externalities are based on a previous Danish survey/review and compilation of official Danish values (Danish Ministry for Transport and Energy, 2006). The official values are in general average values for all HGV’s, and in this work they are further adjusted and differentiated according to the vehicle types of the present analysis.

The official marginal costs of air emissions are provided in DKK per gram pollutant. The vehicle differentiated marginal cost of air emissions are determined combining these with emissions per vehicle kilometres differentiated by Euro-norm and 3 vehicle weight categories from the TEMA database (Ministry for Transport and Energy, 2000).

The official value for the marginal cost of road maintenance is a general value for all HGV’s and needs be differentiated for the present analysis. Each vehicle type is associated with an appropriate “10 ton equivalent” based on the number of axles and average load. Values for the vehicle differentiated marginal costs of road maintenance is then scaled proportional the “10 ton
equivalent" and adjusted to maintain the original average marginal cost for all HGV's based on the demand table traffic data.

Similar, the official value for the marginal cost of noise is a general value for HGV's. The relative noise level of trucks has previously been measured (Ellebjerg Larsen, Bendtsen, and Mikkelsen, 2003) for 2 categories (2 axles and more than 2 axles). The intensity of noise and associated marginal cost is assumed proportional to number of axles on the road. The value for the marginal cost of noise is thus for each vehicle type scaled proportional to the estimated noise intensity of the appropriate axle category (the number of axles) and adjusted to maintain the original average marginal cost for all vehicles based on the demand table traffic data.

The available data material enabling a vehicle type differentiation of the official value for the marginal costs of accidents is rather uncertain and insufficient, and slightly outdated. The Danish data from 1995 provides numbers for accidents involving trucks by six different types. This provides a relative measure of the accident risk for the vehicle types, however associated with the 1995 vehicle type traffic. Ignoring this discrepancy, the values for the vehicle differentiated marginal costs of accidents is constructed scaled proportional the 1995 accident risk and adjusted to maintain the original average marginal cost for all HGV's based on the demand table traffic data.

Having established the marginal cost per km. associated with each of the externalities differentiated on the 48 vehicle types, the contributions to the external cost is simply calculated by multiplication of a given vehicle type differentiated demand table traffic (vehicle kilometres), e.g. the demand table basis of year 2003, by the appropriate marginal costs.

3.3 Scenarios

It is possible to calculate a large number of scenarios with the model and the data we have obtained. However, our interest in the present paper is to evaluate the maximal potential changes. We analyse this by calculating the changes in external cost when we introduce fees aimed at one or two dimensions simultaneously. We further assume perfect elastic demand such that all trips are transferred to the cheapest vehicle category within the dimension on which the fees are differentiated. Finally, we ignore the practical constraints related to trips that cannot be exchanged to other vehicle types.

These assumptions leave us with four primary scenarios:

1. Differentiate on environmental class. *Environmental friendly vehicles* or highest Euronorm class.
2. Use of smallest vehicles, *Fair pricing*, higher fees on larger vehicles
3. Use of largest vehicles, *undifferentiated fees*, small vehicles are relatively more expensive to use
4. *Use of large environmental friendly vehicles*, higher fees on small (inefficient) vehicles and vehicles with lower environmental standard (Euronorm class)
3.3.1 Environmentally friendly vehicles
We use this scenario to evaluate the expected maximal effect that can be obtained through a change to the best environmental classification type – the Euronorm 4+ (or in some cases 4). We maintain the vehicle size and road type in this scenario, which implies no changes in the total amount of vehicle kilometres within each size class of vehicles: \[ \sum_v x_{s,e,v}^1 = \sum_v x_{s,e,v}^0 \].

The change in external costs is approximately 168 million DKr (Danish Krone) compared to the total external costs in the base situation on 3.500 million DKr. The cost savings are thus equal to approximately 4.8 %. The savings differentiated on externality type are illustrated in Figure 1. The main changes are found in NOx and Particles, which are also those categories that are in specific focus in the Euronorm classifications. No changes are found in CO\(_2\), which is not a parameter in the classification. It is not surprising that no changes are found in noise, accidents and infrastructure, which are only related to the vehicle size (and number of axles).

![Figure 1. Size of savings in external cost (1000 DKr) per category of externality by changes in traffic towards highest environmental class](image)

3.3.2 Fair pricing, using small vehicles
By fair pricing we mean that larger vehicles must pay a higher fee, because they are more polluting, higher wear on the infrastructure etc. Our assumption about perfect elastic demand implies that demand within each environmental class shifts to the smallest vehicle category: \[ T_{e,s,v}^1 = 0 \] when \( s \) is not equal to (solo trucks between 6 and 12 tonne gross weight, trucks and trailers less than 40 tonne or trucks and semi-trailers less than 40 tonne). Traffic is undertaken on the same road type, \( v \), as in the base case. The change in vehicle size induces large changes in vehicle kilometres (an increase of 1.4 billion ve-
Use of smaller vehicles lead to lower external costs per kilometre, but the huge increase in kilometres outweighs this benefit completely. The external costs increase by 1.4 billion DKr (corresponding to a 38 % increase). The increase is dominated by the changes in noise, accidents and infrastructure maintenance as illustrated in figure 2. The environmental externalities all increase, but only by a small margin. The change in vehicle size for these external costs generate benefits larger that the increases induced by the increasing number of vehicle kilometres.

3.3.3 Undifferentiated fees, use large vehicles

This scenario is the reverse of the small vehicle scenario above. We have chosen to denote it the undifferentiated fee scenario. If all vehicles irrespective of size must pay the same fee this implies that large vehicle become relatively cheaper to use compared to small vehicles. Our assumption of perfect elastic demand induce all trips to be undertaken in the largest vehicles and leaving the distribution between environmental Euro class unchanged:

\[ T_{e,s,v}^1 = 0 , \text{when } s \text{ is different from solo trucks larger than 26 tonne, trucks and trailers larger than 40 tonnes, and trucks and semi-trailers larger than 40 tonne.} \]

As noted above this scenario ignore the practical problems related to maintaining the same average load in the large vehicles after a shift of all trips (including distribution trips with e.g. very small parcels). The scenario does not take into account the influence this shift has on the marginal external costs – the marginal external costs for larger vehicles are based on where these trucks normally drive (outside large urban and heavily populated areas), where a large number of the trips shifted to these vehicles are undertaken.

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\[ ^1 \text{Our data does not show any difference in the user (direct) costs between different environmental vehicle classes.} \]
within these urbanised areas. Our results thus overestimate the potential changes in external costs.

The external costs savings found in this scenario are driven by large changes in vehicle kilometres, which outweigh the increases induced by the higher marginal external costs for larger vehicles. The total cost savings are more than 350 million DKr corresponding to a 10 % decrease.

Figure 3 shows that the results are based on a trade of between larger environmental costs and huge savings in noise, accident and road maintenance costs.

3.3.4 Large environmental friendly vehicles
A large part of the discussion about distance dependent vehicle fees is related to reductions in the environmental costs of transport and the possibility of reducing these consequences. This scenario is intended to illustrate the potential of fees differentiated with respect to environmental standard without further differentiation on e.g. vehicle size. The scenario is thus a combination of scenario 1 and 3. The scenario shows that there is an extra external environmental cost saving that can be obtained. The total potential savings are 530 million DKr (which corresponds to a 15 % percent reduction). The savings now arise from the externalities as illustrated in figure 4.
The increase in CO$_2$ costs is as in the undifferentiated scenario caused by the larger energy use in the larger vehicles. All other external costs are decreasing. The accident costs savings are again far larger than any other external costs component and are driven alone by the reduction in vehicle kilometres. The reductions in NOx and particles are driven by the Euronorm differentiation.

### 3.4 Comparison of scenarios

The results of the analysed scenarios are compared in figure 5, where two additional scenarios are included (detour scenarios) that are included to evaluate the consequences of trucks making detours to avoid paying the fees on the primary motorway and highway network. Without taking other considerations into account it does not seem to be a large problem in relation to external costs that detours are made. According to the marginal maintenance costs we have used, these are lower for the secondary roads compared to the main roads. However, the larger the vehicles using the smaller secondary roads the larger the damage and thus maintenance costs as the final scenario illustrates.
Our results show that there are significant external cost savings that can be obtained. However, the differentiated fees do not necessarily result in large additional gains. It appears that a fair pricing, where the fees increase with marginal external costs per kilometre lead to increases in total external costs contrary to what would be expected. The largest gains can potentially be obtained by reducing the number of vehicle kilometres e.g. by using larger vehicles or by increasing the load on all vehicles (the latter effect is not analysed here).

Our results show a relatively large potential in differentiating on environmental classes (Euro classifications). However, it should be mentioned, that the gains obtained here will come irrespective of differentiated fees because all new vehicles by EU regulation belong to higher Euro classes. Introduction of fees differentiated with respect to Euro class can lead to an immediate effect that will gradually be reduced. A differentiation with respect to emission standard will most likely have higher fees for larger vehicles, which have higher emission per kilometre. This will lead to usage of smaller vehicles. Our results indicate that the external costs related to such a scheme will increase.

4 CONCLUSION

The findings in the present paper are important contributions to the knowledge base on effects of distance dependent heavy goods vehicle taxes currently under debate in many countries. The results provide further insight into the potential expected welfare gains of introducing differentiated heavy vehicle fees.

We find that undifferentiated fees show the largest potential contrary to most economic theory. Differentiating on e.g. environmental performance only has a potential of half the potential of undifferentiated fees measured in absolute savings in external costs. In contrast a “fair fee” differentiation on e.g. vehicle size shows a large increase in external costs. The basic driver behind these results is changes between small and large vehicles, which changes the number of vehicle kilometres. An increased use of larger vehicles thus reduces
vehicle kilometres to an extent that out-weighs the increasing emissions and road damage per vehicle kilometre.

We do find an improved welfare induced by environmentally differentiated taxes. However, most of these welfare gains will be obtained over time even without vehicle fees, because they are part of the requirement for new vehicles made by the EU. We must also remember that our findings are the maximal potential reactions, which in most cases are far beyond what would be achieved in reality.

- The rather limited potential external cost savings indicate that for Denmark, it may not be reasonable to introduce more complex taxation systems for road use. The overall potential gains can be compared to estimates of the operation (transaction) costs of a system. Our analysis has only considered heavy goods vehicles and the conclusion thus only concerns the relation between potential gains of HVF and the transaction costs of such a system. The relative size of the costs and benefits may change dramatically if passenger cars are included in the system. We may also find additional benefits from especially those scenarios that influence vehicle kilometres. We have not included congestion as this is not a very important question on those parts of the networks where HGV’s undertake most of their traffic. However, the reductions we find are of a magnitude that can have a significant impact on congestion in e.g. the Greater Copenhagen area with large time savings for passenger cars. As such this would further strengthen our conclusion that undifferentiated fees are a rather effective instrument.

5 LITERATURE


