DESIGN OF A USER CHARGE FOR HEAVY-DUTY VEHICLES ON GERMAN MOTORWAYS CONSIDERING THE OBJECTIVES OF EFFICIENCY, FAIRNESS AND ENVIRONMENTAL PROTECTION

– Findings from the EU Research Project DESIRE* –

Werner ROTHENGATTER, Dr., Prof.
Institute for Economic Policy Research (IWW)
University of Karlsruhe
Karlsruhe, Germany

Claus DOLL, Dipl. Wirtsch.-Ing.
Institute for Economic Policy Research (IWW)
University of Karlsruhe
Karlsruhe, Germany

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The German government plans to introduce a kilometre charge on motorways for heavy duty vehicles >12t, beginning in the year 2003. According to an EU Directive the charge has to be orientated to the average infrastructure costs and can be differentiated according to the environmental performance (“EURO Standard”) of the vehicles. Based on the possible differentiation of the user charge this paper analyses the probable impacts on the transport market and on basic environmental indicators. Three scenarios are constructed: first, a modest user charge only on motorways; second, a higher user charge on the whole network of federal roads with a given level of service of the railways; and third, the previous scenario combined with an improved level of service of the railways. The result is that only in the case of the third scenario the hope of environmental policy is realistic that road transport can be reduced and environmental quality significantly improved through a road user charging scheme.

Key Words: Road freight transport, User charges, Directive 62/1999/EC of the European Community, Environmental effects, Efficiency and equity

1. INTRODUCTION

The German Federal Government plans to introduce a user charge for heavy-duty vehicles on German motorways beginning in the year 2003. This will include all road freight vehicles and buses exceeding a tonnage of 12 tons. The first objective is to improve the use of capacity, which includes the use of infrastructure (of the different transport modes), the loading of vehicles and the optimisation of logistic patterns. The second objective is to allocate the total cost of the infrastructure in a fair way to the users and to avoid distortions of competition through a balanced cost allocation or subsidisation. Third, the pricing scheme should provide incentives to use the best environmental technology and to reduce the environmental costs of freight transport.

The European Commission published a White Paper in 1998 in which the pricing scheme of social marginal cost pricing was strongly recommended to the member countries to achieve the objectives mentioned[1]. However, these suggestions have been subject to some criticism by member countries, in particular, because the assumptions for deriving this so-called “first-best”– solution of welfare theory are very rigid and far from the real world[2]. Before the background of the criticism of the concept of social marginal cost pricing the European Parliament has modified a Directive of the European Commission for the road user charging of heavy-duty vehicles in a way that prices should be in principle based on fully distributed costs, but can be modified according to the time of day in congested network parts and to environmental characteristics of the vehicles.

The principles of price setting according to this European Directive look very simple, as they include three issues:

(1) The full infrastructure cost should be allocated to the users;
(2) Prices on highly congested network sections can be higher than on low congested parts; and
(3) Prices for environmentally cleaner vehicles can be lower than for old technology vehicles.

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However, the reactions of the demand side can be manifold such that the design of an optimal charging system for heavy-duty vehicles on the motorways subject to the three issues results in a complex optimisation calculation.

In this paper we will give very brief theoretical treatment of fair and efficient pricing in the transport sector. The legal requirements of European Directives constrain the possible pricing schemes and we will focus in this paper on the remaining possibilities to stimulate efficient behaviour and environmental protection. Emphasis is paid to analyse the possible reactions of the demand side to the pricing schemes and the development of modelling approaches for simulating such reactions in a quantitative way. Finally three scenarios for heavy-duty vehicles pricing schemes on German motorways are presented and their possible impacts on road freight traffic in Germany are discussed. This leads to particular conclusions with respect to the environmentally motivated differentiation of user charges and to the appropriate design of a road-pricing scheme.

2. THEORETICAL BACKGROUND OF EFFICIENT AND FAIR PRICING

The European Commission proposed to introduce a scheme as a social marginal cost pricing in the European transport sector. “Marginal costs are those variable costs that reflect the cost of an additional vehicle or transport unit using the infrastructure. Strictly speaking they can vary every minute, with different transport users, at different times, in different conditions and in different places”[1]. With this definition, the Commission has determinedly committed itself to the short run marginal costs, which means that all cost components that do not react to minor changes of usage are excluded from the calculation. In particular all fixed costs of the infrastructure or of the administration are eliminated by this way. Social marginal costs only comprise operating cost, cost of wear and tear of the infrastructure, congestion and scarcity cost, ecological cost and accident costs, caused by additional transport unit using the infrastructure.

It is well known from the theory of welfare economics that social marginal cost pricing is efficient under certain conditions in the sense that it leads to an optimum capacity utilisation of given infrastructure network. This old insight, which dates back to Pigou[3] and has been periodically revived for academic purposes, is linked to a number of very rigid basic premises. Therefore several branches of pricing theory have been developed to generate pricing schemes which provide economic efficiency subject to constraints of the real world. Examples are the Ramsey pricing or the multi-part tariff rules.

While the above mentioned pricing schemes are orientated to efficiency (maximising welfare subject to constraints) the fully distributed cost (FDC) schemes also include fairness issues. People often regard a pricing system to be fair if the price reflects the full costs, which have been caused by a user. But there is still a deeper rationale for FDC schemes. Assume that the transport infrastructure belongs to a club of users and that the state only plays the role of an arbiter. As the club does not exist for one period only, and the demand of the club members for infrastructure capacity and quality develops over time, it is obvious that the cost of capacity has to be included in the pricing scheme. An allocation scheme according to the club principle then has to meet some efficiency and fairness principles[4].

Efficiency issues are:

(1) The infrastructure club management (state administration or state-regulated company) should receive incentives to build the optimal size of the infrastructure; it should just break even.

(2) There should be no cross subsidisation in the sense that a user group pays more than the costs would be to accommodate this group alone.

(3) All infrastructure users should receive enough incentives to use the capacity economically.

These issues are paired with fairness requirements:

(4) Smaller (lighter) vehicles pay less than larger (heavier) vehicles.

(5) The amount by which the charge to a larger (heavier) vehicle exceeds that for a smaller one does not exceed the difference in cost of providing capacity for the two types.

Contrasting the information given in the textbook literature FDC schemes can be highly differentiated. The cost allocation scheme can show a very detailed structure and link cost blocks to the appropriate lever points of decision making of user groups (members of the club).

In the German motorway cost allocation study which is presently undertaken to derive cost figures as a basis for setting user charges the cost allocation procedure comprises three levels:

- Allocation of the cost of deterioration of the infrastructure according to the causality principle (e.g., applying the modified AASHO-road tests).

- Allocation of parts of the construction costs according to the “investments specificity principle”. This means that particular user groups have specific investment requirements, such for instance heavy duty vehicles need a greater thickness of layers or a higher stability of bridge construction while cars need a motorway design with low curvature and more consumption of space because of the high speed. These cost differentials can be allocated in a structured way.
- Allocation of the remaining common costs according to fairness principles of Game Theory. The first allocation principle set above corresponds with the marginal cost issue. The second allocation principle is motivated by the fact that every item of the road construction has to be replaced in the future and that the user groups which express demand for this particular item should pay a fair amount into the cash of the club of users such that the replacement of this construction item can be financed. After applying these two principles there will still remain some common costs which have to be allocated to the users as they have to be paid by the whole club. Game Theory has developed interesting solutions to this problem such that this final step of cost allocation does not have to be performed by an arbitrary rule of thumb but can be based on clear axioms of fairness (e.g., Shapley-value; Nucleolus allocation; Disruption Nucleolus allocation*).

3. THE LEGAL REQUIREMENTS OF A PRICING SCHEME FOR HDV ON EUROPEAN MOTORWAYS

The principles of price setting according to European Directive 1999/62/EG from June 17th 1999 are threefold:

(1) The average cost of the transport infrastructure, which can be allocated to a user group, is the benchmark for the user charge. This means that the overall revenues from user charging should exactly equal the cost of infrastructure provision and operation. Further costs (external costs) of transport should not be internalised through the infrastructure user charge**.

(2) It is possible to differentiate the user charges by time of the day (peak hours – off peak hours). The difference between the lowest and the highest charge should not exceed 100%. The differentiation of the charges has to be conforming to the underlying objective, which is a more balanced use of the infrastructure capacity over the time of the day.

(3) The user charges can be differentiated according to vehicle emission categories. The emission categories which are presently relevant are Euro 0, Euro 1, Euro 2, Euro 3 (presently obligatory for newly licensed vehicles), Euro 4 (obligatory beginning in the year 2006) and Euro 5 (obligatory beginning in the year 2008). Note that Euro 4 technology is already available and that Euro 5 technology will be available in the medium term. The Directive fixes the ranges between the lowest and the highest charge according to the environmental differentiation to maximally 50%.

The rules stated by the Directive 1999/62/EG state, furthermore, that these charging principles apply to motorways and roads of similar construction type only. Further roads can be included as soon as they are highly affected through motorway charging (diversion of traffic from motorways to secondary roads) such that the security level of these roads is negatively affected. Finally the Directive excludes a double pricing of the road users, for instance it does not allow for combining a time dependent charge (Vignette system) with a kilometre dependent charge (a user charge according to the Directive). This means that the motorway vignette which is presently existing for heavy duty vehicles in Germany and some other European countries has to be abandoned as soon as the kilometre charge is introduced.

Contrasting the clear devices which the Directive is giving with many respects it leaves the problem of definition and valuation of infrastructure cost completely open. What concerns the definition of infrastructure cost it is unclear to which extent the overhead costs of public administration can be included and whether compensatory measures for environmental protection can be considered or not. When it comes to the valuation of infrastructure cost a variety of different methodologies are possible from the scientific point of view. In a current

* See Rothengatter, 2001: Flexible cost estimation for transport infrastructure provision as a base for user charging schemes (including a game theoretical appendix). Paper presented to the WCTR in Seoul.

** The member countries are free to internalize external cost of transport through fuel taxes or ecological taxes or regulations within the ranges of the European directives.

motorway cost allocation study, for instance, the consulting institutes to the Ministry of Transport, Prognos (Switzerland) and IWW (Germany) have discussed three possible departures for the valuation of infrastructure costs:

1) Public administration approach;
2) Public enterprise approach; and
3) Private enterprise approach.

Very roughly speaking and not anticipating the final results of this study the range between the lowest and the highest evaluation could be between 0.125€ and 0.25€ per truck kilometre (>12t). This means that the lack of guidelines for defining and valuing infrastructure costs leads to a wide range of possible cost values.

4. POSSIBLE REACTIONS OF THE DEMAND SIDE AND MODELLING APPROACHES FOR THEIR SIMULATION

The kilometre based user charges will be introduced in Germany in the year 2003 for all road freight vehicles between 12 and 40 tons. The government has already decided that there should be a differentiation of the charges according to the environmental performance of the vehicles but not according to the time of the day (or the level of congestion). On the base of the a priori settings by the European Directive and the decision of the German government, the German Environmental Agency has launched a study on the possible differentiation of the user charges and their impacts on the transport market and on the environment as well[5]. The following results refer to this study. Four types of reactions have been analysed:

- Diversion of traffic from the motorways to the secondary network;
- Diversion from road to rail;
- Strategic adjustments of logistics, roundtrips and loading factors in the road haulage industry; and
- Change of the vehicle fleet.

It is evident that the simulation of the reactions of the demand side requires to apply a series of models which describe the particular behaviour of hauliers and shippers in the segments mentioned. It would be inappropriate to estimate the demand reactions by using average elasticities as this is often done to roughly calculate the reactions of demand.

Altogether five different models have been applied to study the different impacts:

1. *Road haulage cost model*
   The cost structure for German trucking operations has been taken from the records of the road haulage association. Relating this cost to the units of weight and distance (ton kilometres) one results in six major influencing effects for the cost per ton kilometre: transport distance, transport time, vehicle type, vehicle loading, product category and parcel size. The influence on these factors varies in the three transport segments: regional transport, domestic transport and international transport. On the base of this differentiated model for the cost of hauliers it was possible to derive the relative impact of a road user charge on the road haulage costs in the different market segments.
2. *Social cost model*
   As the impacts of road user charging schemes are partly welfare enhancing but also partly reducing welfare it was necessary to construct an indicator for the social valuation of different pricing schemes. This has been done on the basis of a social cost evaluation of road freight transport activities[6].
3. *Freight transport network model*
   IWW has developed a European transport model including the road and rail networks[7]. Freight transport matrices have been generated in other projects for the European Commission and the network models have been finally categorised on the basis of traffic counts. Therefore the model estimations meet the actual observations with sufficient accuracy. This network model could be used to simulate traffic diversion from motorways to secondary networks in case of introducing a user charge on motorways and the shift of free traffic from road to rail (change of modal split).
4. *Logistic model*
   The main reaction to road user charging is not the diversion from road to rail rather than internal adjustment of road freight traffic. This consists in changing the vehicle roundtrips, changing the loading of vehicles and changing the logistic structure. The logistic model EUNET, developed by IWW, has been applied to simulate the possible change of logistics.
5. *Vehicle fleet model*
   As soon as road user charges are differentiated with respect to the environmental performance of road vehicles, incentives will arise to purchase new and environmentally better technology. This leads to change in the structure of the vehicle fleet. IWW has developed a system dynamics model for the assessment of

the OECD scenario EST (Environmentally Sustainable Transport)[8]. One module of this system dynamics model is a cohort model for the trucking fleet in Germany. This model has been made sensitive to environmental charging using the cost information of the road haulage cost model (see model 1). This means that it has been assumed that the road haulage industry changes to new technology as soon as net cost savings can be expected. As there is presently and in the next years a large market for used trucks in Central and Eastern Europe one can follow that the reaction to a high differentiation of user charges according to environmental parameters is relatively high, because the industry can most probably sell the used vehicle stocks.

5. SCENARIOS TO STUDY THE IMPACTS OF DIFFERENT PRICING SCHEMES ON THE ENVIRONMENT

Three scenarios have been constructed to study the impacts of motorway user charging for heavy duty vehicles. The basic characters of these scenarios are summarized in Table 1.

For scenario I it is assumed that only the motorways are priced while the secondary network is free of charge. The average user charge is 0.125€ for the years 2003-2010 in a constant value. For the different weight classes between 12t and 40t a differentiation is assumed in so far as trucks with a weight higher than 18t pay 0.025€ more than average while the remaining trucks pay less.

In scenario II it is assumed that the road pricing is applied to motorways and primaries. The average user charge starts with 0.125€ in the year 2003 and is increased in constant steps such that it reaches 0.2€ in 2010. The weight related additional charge starts with 0.025€ in 2003 for the heavy loads with a higher weight than 18t and ends with 0.05€ in 2010.

Table 1 Basic definition of scenarios

	Priced Network	User Charge Average > 12t	Weight Related Add. Charge > 18t
Scenario I	Motorways	0.125€ (2003–2010)	0.025€ (2003–2010)
Scenario II	Motorways and Primaries	0.125€ (2003) 0.2€ (2010)	0.025€ (2003) 0.05€ (2010)
Scenario IIa	Constant level of service for railways		
Scenario IIb	Improved level of service for railways		

For a more detailed analysis of the possibilities of diverting freight traffic to the railways, it has been assumed in scenario IIa that the level of service of railways is kept constant over the time range considered, while in scenario IIb it has been assumed that the level of service of the railways will be considerably improved in the future. The background of this assumption is that the government plans to spend a part of the revenues from road user charging for investing in better railway networks.

A remark should be added with respect to the average cost value of 0.125€ per truck km. The Ministry of Transport, Housing and Construction has in 1999 established a high level Commission to study the possibilities for the future financing of the transport infrastructure (the so-called Pällmann Commission)*. The main outcome of the Commission's work was the suggestion to the Ministry to change the finance of transport infrastructure from tax finance to finance by user charging. The Commission suggested furthermore to establish companies of private law, owned by the state, for the Federal roads, the Federal railways and the Federal inland waterways. These companies should be responsible for designing, planning, building, financing and operating the infrastructure networks. For the German motorways the Commission has calculated that the price of 0.3DM (this equals roughly 0.15€) would be appropriate to collect enough revenues to finance the cost of motorways which are allocated to heavy duty vehicles. According to the Commission the trucks are contributing already 0.05DM (0.025€) to the motorway finance through the fuel tax, their final suggestion was to introduce a motorway charge for heavy duty vehicles of 0.25DM (0.125€).

As a differentiation of the user charges according to the environmental performance is considered it is important to list the existing Euro standards, the time of introduction and the limit values for different types of exhaust emissions. This is shown in Table 2.

Figure 1 gives the shares of the different Euro standards in the vehicle stock from 2003-2010 according to a reference scenario (development without incentive effects of user charging).

The dynamics of this structure change of the vehicle fleet has been forecasted by using the fleet cohort model of IWW. While in 2003 there are trucks of all emission standards on German roads this reduces to three standards

* This name refers to the Chairman of the Commission, Wilhelm Pällmann, former Chairman of the Deutsche Telecom and former member of Managing Board of the Deutsche Bahn.

Table 2 Time of introduction and emission limit values for the single Euro standards (in g/kWh)

Norm	Euro 0	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5
Introduction	1990	1993	1996	2001	2006	2008
HC	2.60	1.23	1.10	0.66	0.46	0.46
CO	12.30	4.90	4.00	2.10	1.50	1.50
NOx	15.80	9.00	7.00	5.00	3.50	2.00
Particulate Matter	—	0.40	0.15	0.10	0.02	0.02

Table 3 Correction factors according to emission categories (%)

Emission Category	NOx Limit Value (g/kWh)	Relevance 2003	Relevance 2010	Factor (%) 2003	Factor (%) 2010
Euro 0	16.8	x		50.0 %	50.0 %
Euro 1	9.0	x		22.4 %	50.0 %
Euro 2	7.0	x	x	14.2 %	50.0 %
Euro 3	5.0	x	x	6.1 %	30.0 %
Euro 4	3.5	x	x	0.0 %	15.0 %
Euro 5	2.0		x	0.0 %	0.0 %

only in 2010 (Euro 3, Euro 4, Euro 5). Evaluating this result one has to consider that presently no further Euro standards (Euro 6, 7, etc.) are known and there is also no information available on their possible introduction time. The figure shows furthermore that the speed of structure change is higher for the heavy load categories, or, in other words, their average life time is lower.

Remembering the regulation of the European Directive 1999/62/EC, which allows for a maximum differentiation of tariffs of 50% between the best and the worst environmental category one results in the correction factors of Table 3. As can be seen from this table the degree of differentiation is diminishing in the time from 2003 to 2010.

On the basis of these preliminary considerations one can derive that the patterns of the user charges for road freight vehicles for the different scenarios and the years 2003 and 2010. The magnitude of the user charges are exhibited in Table 4. The cost values have been derived after repeatedly employing models 1–5 which were introduced in the previous chapter. The complexity of this modeling is caused by the fact that by definition a full cost recovery has to be guaranteed. The share of total infrastructure cost which is allocated to heavy duty vehicles is dependent on the number of such vehicles and their axle loads. The number of vehicles, the axle loads and the kilometres traveled are dependent on the user charge and the various reactions of shippers and hauliers to different magnitudes of user charges. The summary of the impact analyses, which is given in the following, gives some insight to the complexity of this interactive modeling scheme.

It can be seen from Table 4 that in the year 2003, when the charges will be introduced, there is little differentiation between the standards Euro 3, 4 and 5, while the differentiation between Euro 0, 1 and 2 is comparatively high. This structure completely changes up to the year 2010. There will be only a very small share of vehicles with Euro 0, 1 and 2 standards such that a differentiation between these standards does not make sense any more. Now the categorization into Euro 3, 4 and 5 has matters which result in a considerable range of the

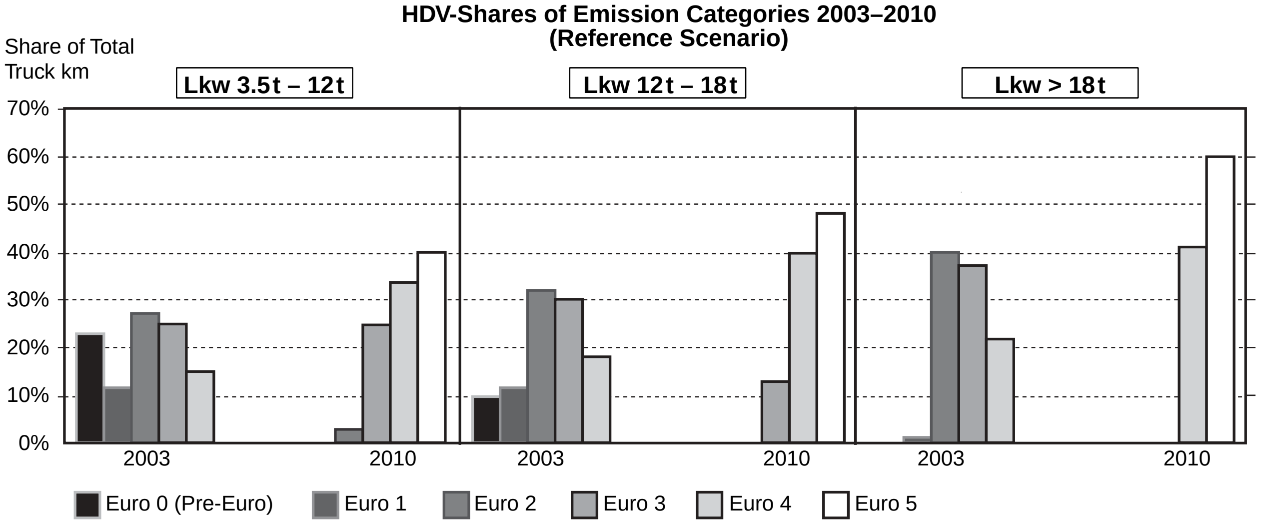


Fig.1 Fleet structure according to emission categories in Germany from 2003-2010

Table 4 User charges in the scenarios I and II for the years 2003 and 2010

Categories	(Euro/Truck km) 2003		(Euro/Truck km) 2010	
	Scenario I Motorways	Scenario II All Federal Roads	Scenario I Motorways	Scenario II All Federal Roads
HDV 12t - 18t				
Euro 0	0.15	0.15	0.15	0.19
Euro 1	0.12	0.12	0.15	0.19
Euro 2	0.11	0.11	0.15	0.19
Euro 3	0.10	0.10	0.13	0.17
Euro 4	0.10	0.10	0.11	0.15
Euro 5	0.10	0.10	0.10	0.13
HDV >18t + Art. HDV				
Euro 0	0.18	0.18	0.19	0.27
Euro 1	0.15	0.15	0.19	0.27
Euro 2	0.14	0.14	0.19	0.27
Euro 3	0.13	0.13	0.16	0.24
Euro 4	0.12	0.12	0.14	0.20
Euro 5	0.12	0.12	0.13	0.18
Average				
All weight classes	0.13	0.13	0.13	0.18
HDV 12t – 18t	0.12	0.12	0.11	0.14
HDV >18t + Art. HDV	0.13	0.13	0.13	0.19

user charges. It can also be seen that all the constraints which have been set a priori (average values, weight related add-ups, maximum spread between the environmentally best and worst categories) are met.

6. TRAFFIC DIVERSION TO THE SECONDARY NETWORK

The introduction of user charges on the motorways can have two impacts on route choice. Firstly the users might partly or completely divert from the motorways to the secondary networks which are not priced. Secondly – in particular if also the secondary networks are subject to road pricing – users might prefer shorter routes i.e., they prefer to reduce transport distance rather than transport time. Distance/time trade off. This effect has been qualified in two steps:

In a first step for every HDV-category a prototype vehicle has been defined – using the information on cost and load characteristics – and routed optimally from each origin to each destination under the scenario conditions. The route search is done for an uncongested network such that this computation generates the maximum potential of users, who might consider changing the route, because this could bring a net cost saving.

In a second step the network is loaded with traffic through the transport model VACLAV and the propensity to divert is checked again under the condition of realistic congestion in the secondary network (in particular in urban areas). As many benefits from route diversion are eaten up by congestion the second step gives a more realistic picture on the actual behaviour of users.

It is often argued that users prefer to stay on a motorway because in this case they need less information on the right route and feel more certain. But in particular for heavy duty vehicles this cannot be expected in the future as most of the vehicles will be equipped with digital travel assistance.

Table 5 gives the result of the calculation. The typical results are:

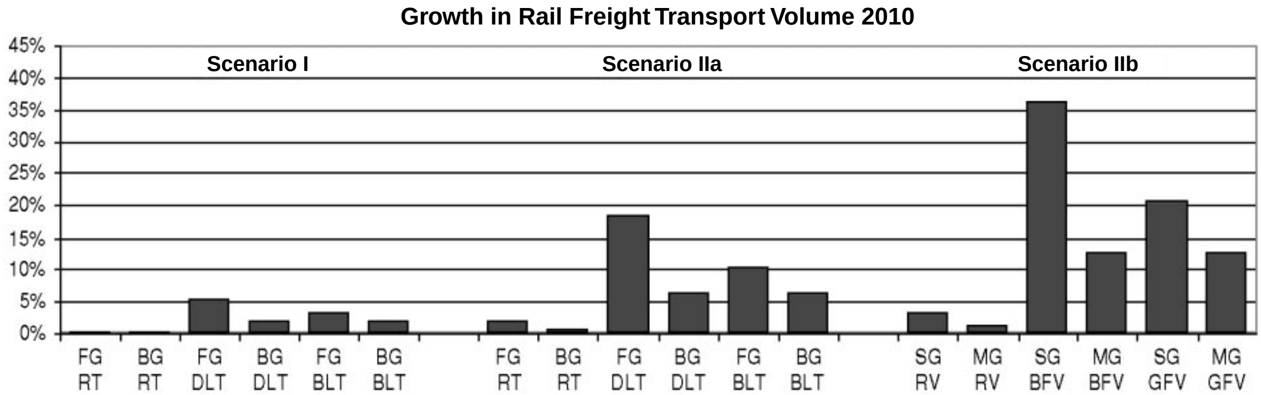
- The magnitude of freight traffic diversion to secondary networks is decreasing with increasing distance.
- The magnitude of diversion is decreasing with increasing Euro Standard.
- The magnitude of diversion is decreasing with increasing weight.
- If the whole Federal road network is priced the diversion effects are substantially lower compared to pricing the motorways only.

7. FREIGHT TRAFFIC DIVERSION FROM ROAD TO RAIL

Applying the transport model and enriching this model with detailed expertise from European and Swiss scenarios (projects PETS, SOFTICE, Transalpine Transport studies), it was possible to derive a differentiated picture for the possibilities of modal shift of freight transport. Figure 2 gives the aggregate result in terms of the comparison between the scenarios and the reference case. It can be seen that in the scenario I case of modest pricing of the motorways, only, the resulting effects on modal shift are very low, better to say negligible. In scenario IIa it is assumed that the road user charges are higher and apply to the whole Federal road network. In this case one can derive a significant shift from road to rail which is, however, modest in magnitude. Only 4% of domestic traffic and about 7% of international traffic can be shifted from road to rail under these conditions. Only if there is a substantial upgrading of the level of service of railways in Germany, which is assumed in scenario IIb, can one expect

Table 5 Route diversions in scenarios I and II

Scenario	Vehicle Type	Regional Transport (< 150km)	Long Distance			Total Long Distance
			150 to 300km	300 to 500km	> 500km	
I	Articulated HDV, Euro 0	7.8%	6.1%	3.7%	2.1%	3.9%
0.125€	Articulated HDV, Euro 5	5.2%	4.1%	2.6%	1.3%	2.6%
on	HDV, Euro 0	8.4%	6.5%	3.4%	2.4%	4.0%
Motorways	HDV, Euro 5	5.2%	4.2%	2.1%	1.4%	2.5%
II	Articulated HDV, Euro 0	5.2%	4.1%	2.3%	1.2%	2.4%
0.175€	Articulated HDV, Euro 5	3.3%	2.3%	1.6%	0.8%	1.5%
on	HDV, Euro 0	6.5%	4.8%	2.6%	1.7%	3.0%
Motorways	HDV, Euro 5	4.1%	3.0%	1.3%	0.8%	1.7%



FG = Forwarder goods, BG = Bulk goods, RT = Regional traffic (<150 km), DLT = Domestic long-distance traffic, BLT = Border-crossing long-distance traffic, SG = Goods with logistic requirements, MG = Bulk cargo, RV = Regional transport, BFV = Domestic transport, GFV = International

Fig. 2 Effect of traffic shift from road to rail, 2010

a shift from road to rail, which comes closer to the political expectations. The gain in transport performance of the railways is between 12% and 35% in the market segments of domestic and international transport. As expected there is little effect in regional and local freight transport.

8. INTERNAL ADJUSTMENTS AND IMPROVEMENT OF LOADING FACTORS

While environmental policy usually expects that the major reaction of pricing road transport is a shift from the road to environmentally more friendly modes, in reality the main reaction is an internal adjustment within the road freight transport sector. However, it is very hard to model the manifold reactions of hauliers and shippers to reduce the companies' transport cost and by this to partly compensate for the user charges.

There are different forms of rationalization of transport operations and the adjustment of the vehicle fleet. This includes for instance the optimization of round trip tours, the formation of vehicle pools or the co-operation between transport haulage firms. An adjustment of the vehicle fleet can consist in using a higher share of vehicles with a weight less than 12t which are not priced or the use of very heavy vehicles to improve on the loading efficiency of the vehicles. Besides such standard forms of adjustments one can also observe cost saving activities which are beyond legal forms of competition but not severely penalized in Europe. This concerns the employment of drivers from east and south-east European countries, the overloading of vehicles, the violation of regulations and social dumping practices. It can be expected that a higher cost pressure through road user charges has also an impact on illegal practice. This does not necessarily mean that road user charging tends to increase the illegal operations in the haulage market. There are also clear indications that employment of low cost drivers or cabotage practice of firms located in low wage and environmentally less regulated countries is reduced. This is due to the fact that cabotage and dumping freight traffic activities imply to go longer distances on the road network. As soon as there are distance-related charges introduced this incentive is reduced.

Based on a micro-economic model for road haulage and reactions observed in other countries (in particular, in Switzerland after the introduction of HDV charges) an estimation of these internal adjustments has been performed. The aggregate result of the estimations is that the road hauliers would be able to compensate for about 15% of the cost increase which is induced by road user charging through easy-to-implement and legal internal adjustments.

9. EFFECTS ON LOGISTIC PATTERNS

The effects on logistic patterns can be studied by using an extended warehouse location model developed by Eberhard[9] at IWW. Figure 3 gives an example for a logistic distribution system with a central port for processing imported goods (here, Hamburg and three delivery warehouses). The model gives a clear tendency for the change of logistic strategies depending on road user charging. The number of distribution warehouses tends to increase while the average distances for goods delivery will decrease.

Figure 3 presents the transport flows from a distribution network with a single origin import harbor of goods and three warehouses in Germany. In the left part of the picture only the transport flows from the warehouses to the final customers are shown, while in the right part the goods supply from the port of Hamburg to the warehouses is added. The comparison shows that transport flows resulting from warehouse supply are very significant and thus the optimal design of a goods distribution system must take into account the transport costs to and from the warehouses. An increase of the number of warehouses surely decreases the average distance to the customer, but at the same time increases the average distance traveled by goods from the import harbor (or production site) to the warehouses. It should be clear that this looks different if the number of ports or production sites increases.

10. EFFECTS OF THE USER CHARGES ON THE FLEET STRUCTURE

We assume that over the time range considered between 2003 and 2010, vehicles of all Euro classes Euro 0 to Euro 5 are available. For newly licensed cars the Euro 3 standard is obligatory from 2001, Euro 4 from 2004 and Euro 5 from 2008. It has been observed in the past that three years before introduction of a new standard already 20% of vehicles correspond to this standard. Two years before introduction this share is already 60% and one year before introduction it is 95%. In Germany the change to environmentally new technology is fostered through a reduction of the vehicle tax and a reduced vignette charge for the motorways. A typical result is that in the year 2010 the share of Euro 0, Euro 1 and Euro 2 is practically negligible. Also the share of Euro 3 is already drastically diminished while Euro 4 and Euro 5 are clearly the dominating environmental technologies.

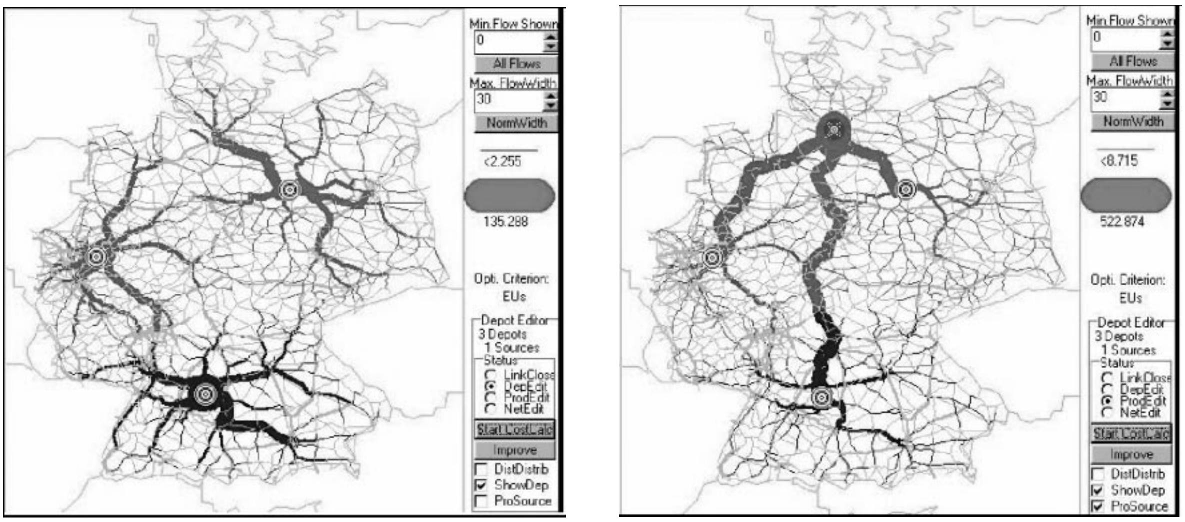


Fig. 3 Example for a logistic distribution system (Sea port: Hamburg)

Assuming a life time of 8 – 9 years for heavy duty vehicles, a yearly mileage of 80,000 km and an additional cost for Euro 4/Euro 5 standard of about 15.000€ one can easily calculate the break-even-point for switching from old to new technology. According to the calculation, this is reached if the environmental share of the user charge exceeds 0.03€ per vehicle kilometre. This break-even-point is easily achieved by many haulage companies and – assuming that they can sell the used vehicles for the rest value (eventually to companies in central and east Europe) they will heavily react to an environmental differentiation of the user charge.

11. SUMMARY AND EVALUATION OF THE RESULTS

The different results of the computations for the scenarios I, IIa and IIb can be compared to the reference scenario on the base of aggregated external cost for accidents, noise, exhaust emissions and CO_2 emissions. This gives a rough evaluation for the environmental performance, which can be expected (Figure 4).

Evaluation of Scenario I: Scenario I (user charge of 0.125€ per vehicle km for HDV only on motorways) does not lead to a change of the environmental position in freight transport. The main positive effects for this scenario are a slight decrease of motorway use by heavy duty vehicles and a shift of the vehicle structure towards environmentally better technology. While the quantitative impact of structure change of the vehicle fleet is substantial, its impact on the environmental indicators is comparatively low. This is mainly caused by the fact that already in the reference scenario the 2010 vehicle fleet predominantly consists of Euro 4 and Euro 5 vehicles. The accelerated shift from Euro 4 to Euro 5, induced by the user charges, does not lead to a very large environmental impact. Therefore the negative impacts of this scenario, which stem from the diversion of motorway traffic to the secondary road network, tends to offset the positive results completely. Although this diversion from the motorways to other roads seems to be rather modest (about 3.5%) it leads to a much higher percent increase on the links of alternative routes on which the specific accident and environmental costs of trucking are much higher than on the motorways. The shift to the railways is very low and cannot contribute to a better environmental balance as the railways according to the assumptions set continue to use old transport technology.

Evaluation of Scenario IIa: In scenario IIa the average user charge is higher (0.2€ per vehicle km) and the user charge applies to all roads of the Federal road network. As a consequence the overall effects of this scenario is significantly positive for the environment. The main effect is a substantial rationalisation within the road haulage industry, improving on their logistics and operations such that the overall use of roads is reduced. The traffic diversion to the railways is rather modest as – according to the assumptions set – the railway technology does not change the environmental advantage and traffic diversion is limited.

Evaluation of Scenario IIb: In scenario IIb it is assumed that the quality of railway service is improved through investments in the network and better organisation. As a result not only the "push effects" of higher prices in road transport are at work, but also the "pull effects" of better railway services. Altogether this leads to a reduction of road transport of about 4% for some market segments as for instance international freight traffic, this change can be about 10%. The reduction of traffic load on the motorways is quite significant (about – 8%) and, again, much higher in some market segments like international transport (– 12%) which presently show the most active dynamics.

Compared to other studies the results of these analyses on impacts of user charges of a modest magnitude are comparatively low. The main reason is that it can be shown that there are still many ways for the shippers and road hauliers to adjust to the user charge and save costs without basically changing their logistic routines. A fur-

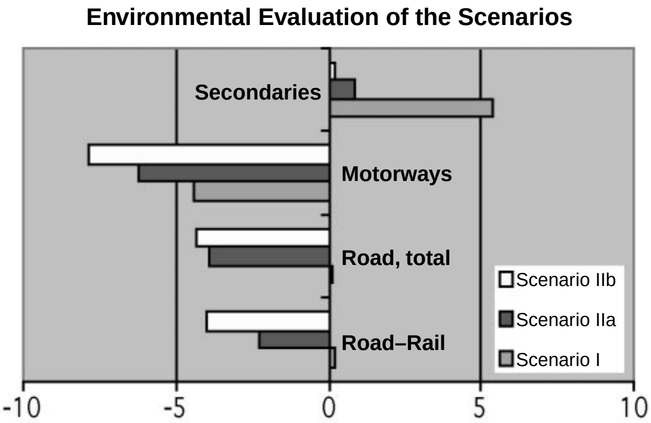


Fig. 4 Environmental evaluation of the scenarios (in % compared with the Reference Scenario; " — " means reduction and " + " means increase of environmental costs)

ther insight is that one can expect indeed a rapid change of the environmental technology used as soon as there is a differentiation of charges according to the environmental standards. However, as there are already high incentives in the market to change to environmentally more friendly truck technology a comparison of the environmental impacts for the year 2010 shows that the environmental benefits stemming from a better technology are significant but not very large. A diversion of a higher shares of the freight transport markets from road to rail can only be expected if the logistic quality of railway service becomes much better than it is today.

What has not been analysed in this study is the long-term feedback effects which can be expected if the push and pull effects persist or are increased over time. In this case the long-term effects on change of logistic routines and the change of location after 2010 choices can lead to different patterns of freight traffic. Bundling effects can occur such that a share of railway and inland waterway traffic will be increasing and a change of production and warehouse locations can contribute to a reduction of distances of road freight traffic. This means that a rational political strategy could be to start with the modest scenario I and to change after a medium term to scenario IIb. After 2010 scenario IIb could be developed further to generate the long-term feedback mechanisms which can effect a multiplication of the medium term effects exhibited in this study.

12. CONCLUSION

It has been shown by combination of micro-economic and macro-economic analyses that user charges on German motorways for heavy duty vehicles, which are differentiated according to environmental performance, can bring positive results for the environmental quality. However, if a pricing scheme is incomplete and includes only the motorways but not the secondary road network then also detrimental effects can occur in so far as a traffic diversion from motorways to the secondary network can be induced. Even if this diversion comprises only a small percentage of motorway traffic the negative consequences on alternative routes in the secondary network can be quite relevant. In the worst case, the positive effects of motorway charging can be eaten up completely by such negative impacts of traffic diversion.

Once the user charging comprises the whole long distance road network the negative effects diminish. But small impacts still can be identified because once user charges reach higher magnitudes they effect a change of the trade-off between time and distance minimisation. A clearly positive effect enters the scheme if the railways are assumed to be able to improve considerably on their level of service. If shippers and forwarders can allocate consignments to railway companies without a major loss of service quality, then a shift of traffic from road to rail can be achieved which helps to reduce the environmental load of freight transport.

Summing up the results show that in the medium term there cannot be expected an environmental bonanza stemming from a road pricing policy which only applies to heavy duty vehicles greater than 12t and only to motorways. An extension of road pricing to light duty vehicles and cars and the secondary network would multiply the effect and a continuity of pricing policy over time and would contribute to create long-term feedback mechanisms towards a sustainability path for freight transport.

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