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INTEGRATING ECOLOGICAL COMPONENTS IN KILOMETRE-BASED ROAD TOLL SYSTEMS

Some member states of the European Union (e.g. Germany, the Czech Republic) have already included ecological components in their pricing systems of kilometre-based road tolls for road freight transport on the motorway-net. This means that vehicles with very modern emission standards have to pay less per kilometre in contrast to older trucks with a higher volume of exhaust-emissions. Austria implemented a kilometre-based road toll system in 2004, but without an ecological component. The goal of the paper is to evaluate the effects of considering EURO emission standards in the price systems of road tolls in Austria with the help of the scenario technique. Consequences as the shift in total travelled vehicle kilometres on the Austrian motorway net are discussed as well as hypothetical changes in the behaviour of the road freight forwarding industry to purchase and/or rent modern clean-exhaust vehicles.

1. Introduction

In general road user charges help to finance the road infrastructure and serve as an instrument in the fields of transport policy. This seems to be of utmost significance with regard to its potential for allocating social cost according to the polluter pays principle and reducing negative effects of road traffic on the environment.

The model for calculating toll rates and emissions which is presented in the course of this paper acts on the basic assumption that raised toll rates for heavy-duty vehicles with higher emission factors lead to a shift in the number of total travelled vehicle kilometres. This is because of an alteration in the investment structure of the road freight transport industry towards cleaner trucks and busses resulting in an increased number of modern fleets with the latest emission standards. However, the dimension of a reduction of or an increase in vehicle kilometres is dependent on the specific amount of the toll rates charged for clean exhaust and heavily emitting trucks and buses. Here the price is seen as the general indicator for creating incentives to use or invest in cleaner vehicles.

The modification of the current road toll system to a more ecological one is more and more discussed. Especially the amendment of the directive 1999/62/EC by the European Parliament and the Council in May 2006 emphasises the need for ecologically differentiated toll systems.

2. Theoretical background

2.1 Price differentiation and the internalisation of negative externalities of road traffic in connection with road user charges

In the context of using road infrastructure there exist many different concepts for differentiating prices, but not all of them lead to an optimal allocation of resources. The most important advantage of toll rates being differentiable is found in their ability to take the individual circumstances of road users and the road infrastructure itself into account. In the technical literature though there is no coherent definition of the term "*price differentiation*" [1]. A useful typology of approaches for varying prices was created by Pigou (1920) who distinguishes between three levels of price differentiation [2]. The technical literature offers various forms of differentiating prices [3]: (a) individual-oriented, (b) regional, (c) temporal, (d) utilisation-oriented or (e) vehicle-oriented. Following the recognition of ecological aspects as possible price differentiation criteria could be classified as vehicle-oriented.

On the one hand the above listed approaches rarely pursue the aim of an optimal allocation of resources, but try to maximise revenues or to achieve politically desired benefits for special groups of individuals. On the other hand an optimal pricing of road infrastructure does not automatically lead to an efficient pricing with regard to the financing of the actor operating the road infrastructure.

External costs are a result of individuals' negative influence on the production or consumption function of third parties without getting paid compensation and lead to a situation, where the marginal private cost of an activity diverges from the accruing marginal social cost [4]. In the case of marginal social cost being less than marginal private cost we speak about positive external effects, where third parties benefit from activities of other individuals [5]. Negative external effects, however, accrue from marginal private cost being less than marginal social cost with the differing amount representing the external costs [6]. Without an internalisation of these adverse effects the activity causing the negative externality will be over-performed, because the party acting in his or her own interest only confronts his or her marginal private utility with the correlative marginal private cost, but not with the marginal social

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cost. Thus, the additional social cost is passed along to third parties whose welfare deteriorates as there are no compensating payment flows [7]. The party causing the negative effect, however, has no reason to consider the extra social cost in his or her individual decision (Fritsch/Wein/Ewers 2005).

The emergence of external costs can be integrated in the standard model of road pricing which dates back to studies by Pigou (1920), Knight (1924), Walter (1961) or Johnson (1964). The model basically explains the occurrence of social marginal cost caused by the addition of marginal congestion cost to the sum of private marginal cost of the road user. The road users are characterised by a varied level of willingness to pay. Consequently, the introduction of a road toll which aims at the internalisation of the accrued social marginal cost will lead to a situation where road users who are not willing to pay the increased price will abandon the journey. The aim is to raise the price for using the road infrastructure as long as it is necessary to achieve an optimal deployment level of the road infrastructure.

In addition to the internalisation of marginal congestion cost road tolls can also integrate external costs accruing from transport activities or traffic in general. Road traffic leads to serious negative consequences for humans, the natural environment, materials and surfaces. These costs partly accrue from the existence of road infrastructure itself, but mainly from operating means of transport on it like costs of air and noise pollution, of accidental implications or congestion [8].

2.2 Analysing the EU legislation with regard to an ecological differentiation of road toll systems

The legal framework for the introduction of the kilometre-based truck road in Austria in 2004 is set by the European Parliament and the Council and is valid for all member states within the European Union. Therefore, in the next section the EU legislation with regard to an ecological differentiation of road toll systems will be analysed first to continue with the actual situation in Austria.

In the directive 1999/62/EC, “directive on the charging of heavy goods vehicles for the use of certain infrastructures”, the European Parliament and the Council created a framework for introducing road toll systems. This regulation was amended though in May 2006 by the directive 2006/38/EC. The comparison of the two directives has shown that the variation of toll rates by ecological, vehicle-oriented components as well as the internalisation of external environmental cost becomes more and more important.

According to Article 7, passage (10), point (a) of the amended directive each member state of the European Union is generally allowed to vary toll rates for the purpose of preventing environmental damage, congestion or infrastructural damage, for optimising the use of infrastructure or for road safety. Moreover, the variation of toll rates must be proportionate, transparent, non-discriminatory and should not be intended to generate additional toll revenues. When it comes to a variation of toll rates by EURO emission classes the amended directive sets new limits for the variation of toll rates. The old regulation states that the highest toll rate is not allowed to exceed 50 % of the rate for an equivalent vehicle meeting the strictest emission standards. However, according to the amended directive, Article 7, passage (10), point (b) varied toll rates may exceed the rate for an equivalent vehicle meeting the strictest emission standards by 100 %. Thus, the new regulation concerning the variation of toll rates by EURO emission classes sets an upper limit for raising toll rates, which is also considered in the model for calculating toll rates and emissions.

3. Model for estimating effects of an ecologically differentiated road toll system

A deliberate control of the price system for the use of the Austrian motorway net shall create incentives for an intensified deployment of clean-exhaust trucks and buses and simultaneously for a reduction of the number of vehicles heavily exhausting air pollutants. In such a scenario vehicles with a maximum loaded weight over 3.5 tons that fulfil the newest emission standards (EURO IV and V) are charged reduced toll rates in contrast to those which are emitting high volumes of pollutants (EURO 0 and I). In connection with pricing systems for the use of road infrastructure the only question is at what level prices must be set so that controlling effects are evolved.

Therefore, a model for calculating toll rates, volumes of exhaust-emissions and external costs was established which serves as a tool for creating the above pictured scenario theoretically. On the basis of an intensive data collection and various assumptions scenarios with varied toll rates were elaborated in order to measure the effects of varied toll rate amounts on:

- the total toll revenues collected by the ASFINAG;
- the volume of airborne exhaust-emissions of heavy-duty vehicles;
- the level of external cost caused by airborne exhaust-emissions of heavy-duty vehicles.

Another goal of the model is to generate realistically enforceable toll rates which lead to a maximal possible impact in the sense of reduced volumes of exhaust-emissions. Moreover, it is about testing whether a system which only subsidises clean-exhaust vehicles is sufficient for achieving a maximal reduction of exhaust-emissions or whether a combined system is needed. In the latter case vehicles with low or no emission standards are additionally penalised with increased toll rates. Each scenario of the model is elaborated in a way that it always shows these two different possibilities, a bonus-system and a bonus-malus-system.

3.1 Methodology

The scenario technique is applied in the model for projecting scenarios where a maximal reduction of exhaust-emissions in the future becomes possible and following a decline of external costs caused by road traffic with heavy-duty vehicles on the Austrian motorway net. The general advantage of the scenario technique lies in its ability to project future development paths and to derive adequate action from the gained results. Therefore, scenarios must be generated which can be understood as reasonably formulated, hypothetic future images of a delimited problem. They help to consider different variants and possibilities for developing and serve as a tool for preparing decisions.

In the model three model scenarios were designed. The decision for the different toll rate levels included a complex task of finding amounts which are "realistically enforceable", "overpriced" or "understated" with regard to the Austrian situation. It was necessary to set up assumptions which represent the impact of changed/varied toll rates on the total travelled vehicle kilometres on the Austrian motorway net and on the investment structure of the road freight transport industry in clean-exhaust vehicles in the most realistic way.

The model produces a multitude of results for each price system in each scenario which then needs to be evaluated for an effective decision-making. To sum up, the methodology of the whole model is summarised in *Fig. 1:*

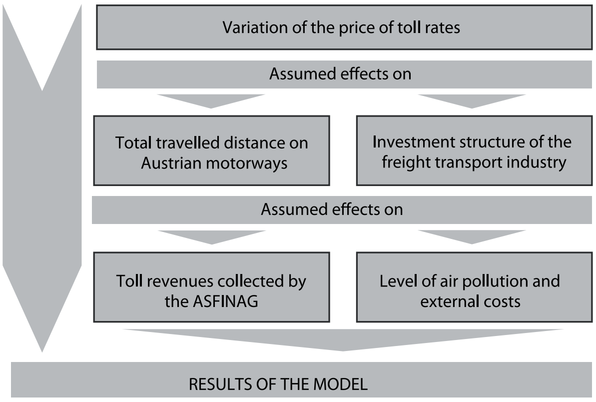

Fig. 1 Methodology and parameters used in the model (Individual design)

3.2 Calculation methods

3.2.1 Characteristics of the total travelled vehicle kilometres

In a first step it is necessary to collect data concerning the total travelled heavy-duty vehicle kilometres on the Austrian motorway and to distinguish them first by nationality of the vehicles, second by axle category and third by EURO emission class. For finding out the nationality of the travelled vehicle kilometres for the year 2005 the ASFINAG is consulted as they are continuously assessing various characteristics of the trucks and buses which are using the Austrian motorway net. The nationality of the vehicles is of great importance, because in a next step the statistics of all registered trucks and buses of each country can be consulted to evaluate axle categories and EURO emission classes which are needed to calculate the total toll revenues and second the reduction potential for exhaust-emissions and external costs.

As a matter of reducing complexity only for the first six countries in the ranking which hold the greatest proportions of the total travelled vehicle kilometres further inquiries concerning axle categories and EURO emission classes are undertaken. These countries are Austria, Germany, Hungary, Italy, the Czech Republic and Slovenia and represent 81.42 % of the total travelled vehicle kilometres (starting with the country holding the greatest proportion of travelled vehicle kilometres). For the remaining 59 countries an average is calculated for indicating vehicle category and EURO emission class.

After the total travelled vehicle kilometres are differentiated by nationality, axle category and EURO emissions class the shift of travelled vehicle kilometres can be calculated for the three scenarios with the help of the above explained assumption concerning the reduction of the total travelled vehicles kilometres. Therefore, the assumed percentages must be weighed for each country depending on their proportion of travelled vehicle kilometres in the three axle categories. This calculation method guarantees a more precise result concerning the shift of total travelled vehicle kilometres.

With the newly generated vehicle kilometres per axle category it is possible to calculate the toll rate revenues for each scenario.

3.2.2 Calculating the reduction potential of the volume of road traffic air pollutants

The model also evaluates the effects of a road toll with ecological components on the total volume of emitted air pollutants. An ecologically differentiated toll rate could lead to a reduction of road traffic exhaust-emissions because of a decreased number of heavily emitting vehicles on the Austrian motorway net. Calculations are carried out for a number of air pollutants: Carbon dioxide (CO2), Nitrogen dioxide (NOx), Hydrocarbon compounds (HC), Particle emissions, Sulphur dioxide (SO2) and Carbon monoxide (CO). The aim of the calculations was to indicate the reduction potential in tons of each pollutant. Therefore, data was obtained from the Austrian Federal Environmental Agency indicating the volume of exhaust-emissions for a reference vehicle with the following characteristics:

Characteristics of the reference vehicle for calculating the reduction potential of the volume of exhaust-emissions (Individual design) Table 1

	Number of axles	Max. loaded vehicle weight	Deadweight	Vehicle load capacity
Tractor trailer	2	18 tons		
Road semi-trailer	3	32 tons		
Articulated lorry	5	40 tons	14 tons	26 tons

The exhaust-emission data was derived for an articulate diesel lorry with a maximal loaded vehicle weight of 40 tons, an average loading of 15 tons with a constant driving style and an average speed of 75 km/h. With regard to the quality of the road, the degree of the road inclination and meteorological conditions ideal road conditions were assumed as well as a steady flow of traffic. Thus, the Austrian Federal Environmental Agency calculates emission volumes for a selected number of air pollutants in g/km. In a last step these numbers were first multiplied with the actual vehicle kilometres in each EURO emission class of the axle category ≥ 4 travelled in 2005, then with the number vehicle kilometres calculated in the scenarios. The generated tons of particular air pollutants in the year 2005 and in the model scenarios can then compared with each other to find out the most effective scenario in terms of reducing exhaust-emissions.

3.2.3 Projecting the external costs of road traffic air pollutants

All data needed for undertaking the calculations in the model refer to the calendar year 2005. In the case of collecting data concerning external costs caused by exhaust-emissions of road traffic in Austria though the study being most up to date dates back to the year 2000. Hence, the numbers given for the year 2000 are projected for the year 2005 via the increase of the real GDP in Austria in percentages. The individually designed formula is given below:

$$ExCost_{\,air\ pollutent\ `05} = ExCost_{\,air\ pollutent\ `00} \times \Delta GDP_{real}$$

where:

$ExCost_{\,air\ pollutent\ 2005}$	External costs of a specific air pollutant in the year 2005
GDP_{real}	Alteration of the Austrian real GDP in %

$$= \frac{GDP_{real`05} - GDP_{real`00}}{GDP_{real`00}}$$

Thus, the particular external costs for a selected number of different air pollutants in Austria can be calculated for the year 2005. They are listed in following table:

Particular external costs of selected air pollutants in Euro per ton per pollutant in 2005 (Source: [9]) Table 2

	CO_2	NO_x	HC	Particles	SO_2	CO
[€/t]	88.08	10,228.44	21,575.60	4,628.24	4,813.38	46.31

3.3 Results

In the model which is set up for the calendar year 2005 three different scenarios with varied premiums and surcharges are created. Depending on the scenario the model starts either with realistic, minimal or maximal amounts of toll rates as it is described below:

In scenario I clean-exhaust vehicles are granted a premium amounting 16 % of the basic toll rate of 13 Cent per kilometre. The surcharge for heavily emitting trucks and buses accounts for an additional 20 % of this basic toll rate. The percentages for the premium and the surcharge are chosen in a way so that the new generated rates represent amounts with realistic chances of being enforced.

In scenario II the price reduction for clean-exhaust vehicles as well as the surcharge for heavily emitting ones is calculated in a way so that the new toll rates will probably evolve a minimal possible effect. Following, vehicles with modern emission standards only get a price reduction of 10 %, whereas heavily emitting ones are charged plus 12 % of the basic toll rate. With regard to the achievement of the aim of maximal controlling effects through differentiated toll rates lower amounts than these minimal toll rates are not recommendable.

In scenario III it is important to bear in mind the upward limit set in the amended directive 2006/38/EC which is not allowed to exceed 100 % of the toll rate charged for an equivalent vehicle fulfilling the strictest emission standard. Thus, the price reduction for clean-exhaust vehicles amounts to 24 % in the model, whereas strongly polluting trucks and busses have to pay an extra fee of 32 %.

The model has shown that the bonus-malus-system with maximal toll rates as hypothesised in scenario III represents the most powerful effects. The results are summarised below:

- *Shift in total vehicle kilometres*

The result of the calculations is that a differentiation of the existing toll rates by EURO emission classes leads to a reduction of the total travelled vehicle kilometres which amounts to 2,756,337,788 km on the Austrian motorway net. The reduction potentials range from −1.13 % in scenario II (bonus-system) to − 3.54 % in scenario III (bonus-malus-system).

- *Shift in total revenues collected by the ASFINAG*

Four out of six scenarios lead to a loss of revenues for the ASFINAG. The minus ranks between −3.14 % (scenario III bonus-system) and −0.27 % (scenario II bonus-malus-system). In the case of a bonus-malus-system with maximal price reductions and surcharges a slight surplus in total toll revenues amounting to 0.53 % is possible. The worst impact for the financial situation of the ASFINAG, a decrease of −3.1 %, is calculated for the same scenario only with a bonus-system.

- *Shift in the volume of air pollutants emitted by trucks and busses*

Here a combined bonus-malus-system and toll rates being as high or low as hypothesised in scenario III represent the best opportunity as the volume of each air pollutant declines. The air pollutants which show the most substantial reduction potential are particle and NO_x emissions (−11.13 % and −10.67 %). In such a scenario CO_2 emissions for example can be reduced by −10.38 % which equals 152,791 tons.

- *Reduction of external cost caused by road traffic exhaust-emissions*

Also with regard to the external cost of air pollution caused by road traffic a combined bonus-malus-system with toll rates as being set in scenario 3 would be recommendable, because it leads to the highest decrease of cost compared with the other scenarios.

4. Conclusion

A lot of European countries have introduced kilometre-based road toll systems for road freight transport on the motorway-net or intend to implement it in the next years. The goal of the paper is to find out the effects of considering the different quantities of pollutants in Austria in the price systems of road tolls. Different approaches like a bonus-system, a malus-system or a combined bonus-malus-system are subject to this paper. Using the scenario methodology premises are discussed concerning changes on the overall driving kilometres on motorways and on changes concerning the behaviour to purchase respectively rent new environment-friendly vehicles.

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