Deutsches Institut für
Wirtschaftsforschung

DIW BERLIN

# Discussion Papers

907

Dominika Kalinowska • Karl W. Steininger

# Car Road Charging – Impact Assessment on German and Austrian Households

Berlin, July 2009

Opinions expressed in this paper are those of the author and do not necessarily reflect views of the institute.

IMPRESSUM

© DIW Berlin, 2009

DIW Berlin
German Institute for Economic Research
Mohrenstr. 58
10117 Berlin
Tel. +49 (30) 897 89-0
Fax +49 (30) 897 89-200
http://www.diw.de

ISSN print edition 1433-0210
ISSN electronic edition 1619-4535

Available for free downloading from the DIW Berlin website.

Discussion Papers of DIW Berlin are indexed in RePEc and SSRN.
Papers can be downloaded free of charge from the following websites:

http://www.diw.de/english/products/publications/discussion_papers/27539.html
http://ideas.repec.org/s/diw/diwwpp.html
http://papers.ssrn.com/sol3/JELJOUR_Results.cfm?form_name=journalbrowse&journal_id=1079991

# Car Road Charging – Impact Assessment on German and Austrian Households

Dominika Kalinowska[1]

Karl W. Steininger[2] [3]

**Abstract:** The authors apply a computable general equilibrium (CGE) modeling framework to carry out a two-country comparison for Austria and Germany assessing the impact of road charging (RC). The pricing policy measure is introduced for the private motorized transport mode and applies to the overall road network. To derive and compare distributional effects of passenger car RC, the mode-specific travel demand of private households is integrated into the CGE model. Furthermore, the modeling framework accounts for different household categories with respect to disposable net income and the corresponding travel demand profiles introduced in terms of behavioral mobility parameters as well as household travel expenditures. Comparing the country-specific results, we find country-specific differences in the impact of RC on household categories, as well as similarities. The differences that we find indicate the importance of particular parameters for the evaluation of infrastructure pricing policy reforms. We can relate differences to prevalent country-specific differences in socio-demographic characteristics, land use structure, territorial population distribution, as well as macroeconomic indicators. To add substance to the two-country impact assessment, a sensitivity analysis is carried out, introducing different RC revenue use schemes. We find differences in distributional effects under equity concerns to be closely related to the revenue use pattern as well as to country- and household-specific travel demand profiles.

**JEL Classification**: D58, H23, R48

**Keywords:** Computable general equilibrium model, redistributive effects, road charging

---

[1] Department of Energy, Transportation, Environment, German Institute for Economic Research – DIW Berlin, E-Mail: dkalinowska@diw.de, Tel.: +49 (0)30 89789 687, Mohrenstrasse 58; D-10117 Berlin.

[2] Department of Economics, University of Graz, Universitätsstraße 15, A-8010 Graz.

3 Wegener Center for Climate and Global Change, University of Graz, Lechgasse 25, A-8010 Graz.

# 1 Introduction

Main objective of this paper is the assessment and comparison of effects from the introduction of car road user charging occurring within the private household sector in Austria and Germany. But before discussing the implementation and the impact assessment of the policy measure introduced in the two countries of interest, an important aspect to be mentioned is the motivation for such an intervention. Road pricing or road charging, defined as the direct collection of user charges per km of infrastructure demand, recalls nearly a century of economic research and literature [Pigou, 1920, Knight, 1924]. It has been often discussed as a mechanism for the internalization of negative road transport externalities. Reduction of car travel after the introduction of an additional user charge implies positive social welfare effects not only through individual utility optimisation, but also through the abatement of adverse environmental effects from the use of motor vehicles. At the same time, RC has been also recognized as both, a mechanism for road use management to alleviate congestion in cases of excess infrastructure demand [Small, 1992; Lindsey and Verhoef, 2001] and an instrument for revenue generation for financing road transport infrastructure [Mohring and Harwitz, 1962; Keeler and Small, 1977]. In many economies, including Austria and Germany the question of infrastructure network financing has recently become a major challenge. The growing gap between rising motorized travel demand and shrinking budgetary sources for the provision of road capacity is an important cause for seeking alternative infrastructure investment resources. One reason for the melting away of traditional, primarily tax-based road infrastructure financing sources is the expected revenue shortfall from fuel taxes entailed by fuel consumption efficiency gains. However, despite technological improvements in fuel use efficiency, decreasing fuel consumption, and therefore stagnating or shrinking fuel tax revenues, car use, and with it infrastructure use, continues to grow and will require further financing. Hence, growing attention is turned to road charging as an alternative revenue source.

Charging road use in Austria and Germany is furthermore attractive due to its technical feasibility. In both countries freight vehicles have been charged for the use of the national primary road network – in Austria since January 2004 and in Germany since January 2005. Existing road charging implementation infrastructure can be easily extended to passenger cars, taking advantage of the existing revenue collection technologies.

Therefore, introduction of car road charging appears to be an efficient and feasible alternative to generate additional revenue as well as pursuing environmental objectives of reduced car use. The implementation of instruments other than RC or a mineral oil tax for revenue generation for infrastructure investment is likely to impose high implementation costs and create inefficiencies through distortionary effects, such as refuelling trips to border regions with lower gasoline prices due to lower energy taxes.

The main objective of this study is the assessment and the comparison of economic and environmental effects from the implementation of car road use charging in Austria and in Germany. Of focal interest are effects occurring within the private household sector that is differentiated by four household income categories.

The road user charge implemented in this study applies to car users. Its level is set according to marginal (social) cost pricing calculations, but does not explicitly account for the external cost component from congestion [Herry and Sedlacek, 2003; Infras/ IWW, 2000, 2004; RECORDIT, UNITE]. With reference to Dupuit (1962 [1849]), RC is implemented as an instrument to cover long-run costs of road construction and maintenance in the sense of a "funding toll" rather than to manage road use in terms of a "decongestion toll" [Clark, 1923; Peterson, 1932, 1950; 304; Ekelund and Hébert, 1999; Derycke, 1998].

The historical tradition and established theoretical reasoning in favor of RC have been of little help in gaining political acceptance of the measure among the broad public and in spreading its practice. Despite the (overall social) welfare-optimizing function of RC, hardly any car user values the pricing measure as improving society. The exception may constitute those with above average values of time. In general, the affected drivers also ignore the fact of public revenue generation. The prevailing negative individual perception is one reason for the general lack of public acceptance for RC. It is closely linked to the uncertainty about the negative distributional impacts resulting from the measure. In many cases RC is suggested to have a regressive impact, which means that it is more disadvantageous for the poorer drivers. This is often explained on the basis of the relative income shares that these households spend on transport, particularly on fuel consumption. Lower income categories are also assumed to have lower time values and, therefore, to profit less from possible congestion reduction.

So far, only a few implementations of RC exist, of which most are suboptimal solutions of indirect charging. Nevertheless, implementation of RC has been gaining interest, in part due to technological innovations and new electronic solutions that could remedy its existing shortcomings. In general, more sophisticated RC adjusted to specific time frames, road categories, or even user groups could be implemented efficiently, ensuring convenience and lower operating costs while also taking into account the controversial issue of data confidentiality.

This paper attempts to shed light on the interrelation between the effects of RC and selected macroeconomic indicators, as well as microeconomic, monetary and behavioral travel demand parameters for different private household income categories. Impacts from RC are therefore calculated within a computable general equilibrium modeling framework, accounting for different household categories with respect to disposable net income and the corresponding travel demand profiles introduced through behavioral mobility parameters as well as household travel expenditures.[4] Through the integration of micro-data based passenger travel demand patterns into the CGE model, the work combines a bottom-up and a top-down approach into an applicable instrument for the assessment of potential road pricing scenarios. The simulation of different RC scenarios illustrates different effects resulting from the variation of the model assumptions and parameters. Comparing the country-specific modeling results, national differences as well as intra-household-category similarities in the impact of RC can be observed. The different results can be largely explained through prevalent country-specific differences in land use structure, territorial population distribution, macroeconomic indicators, as well as socio-demographic characteristics. This shows the importance of the listed factors for the evaluation of infrastructure pricing policy reforms. When we do not account for the environmental benefits and reduction of other external effects by RC, and when a constant value of time is assumed, the direct effect from RC is negative across household categories. We do not depict the expected welfare-enhancing effect of the pricing measure across household categories, but we do show that it can be improved by the choice of RC revenue use. In particular, the design of the revenue redistribution scheme can be implemented to counteract welfare inequality concerns. This noted, based on results from standard neoclassical methods of welfare analysis and from equity assessment [Atkinson, 1970], sensitivity analyses of net benefit at the aggregate level and equity implications are carried out by introducing different RC revenue redistribution schemes. The results from this part of the study in turn provide valuable implications for the potential acceptability of such policy reforms. The modeling results for Austria and Germany lead to the conclusion that differences in distributional effects with respect to equity impacts are strongly related to the

[4] The modeling frame is based on the Austrian Road Pricing Model (ARPM), which was originally introduced and implemented in Steininger and Friedl (2004) to assess the consequences of road pricing policies in Austria. We extend the model for Germany and construct a German Social Accounting Matrix (SAM) underlying the model, including household specific travel demand parameters.

revenue recycling patterns as well as to country- and household-specific travel demand profiles.

The organization of the paper is as follows. Its objective is the overall economic impact assessment within the two-country comparison of effects evoked by road user charges imposed on private passenger cars using the overall road network in Austria and Germany, respectively. Section 2 sets out the model structure. Within the implementation of the country-specific models, the same scenarios are considered for the reallocation structure of the corresponding revenues, allowing extensive analysis of the effects of these. In Section 3, relevant features of the model structure, application and the underlying database are discussed. Emphasis is put on the specific incorporation of passenger travel demand into the economic modeling frame. Section 4 discusses the results obtained from model simulation and sensitivity analysis for different road charging revenue redistribution schemes to assess the impact of the pricing measure on different household categories in Germany and Austria, respectively. The two-country comparison is used to analyze the redistribution and equity effects of RC on different household income groups under varying revenue reallocation designs. Section 5 concludes.

# 2 Model and database description

## 2.1 Model structure

The intention to introduce a nationwide road charging scheme in the passenger car sector touches on a multitude of economic, ecological as well as social questions, uncertainties, and concerns that must be considered, often simultaneously.[5] A consistent and integrated assessment of the economic, environmental, and welfare distribution impacts of road charging implemented for private cars can be done more accurately when the overall interactions within the economy as well as the budgetary situation and travel choice behavior of private households are taken into account. Information referring to private household travel can be represented by activity parameters, such as mode choice, trip purpose, and distance traveled, as well as monetary measurements, such as travel expenditure in absolute terms and as a proportion of household dispensable income. Given the different types of mobility indicators, travel behavior in general and reactions to changes in travel costs – e.g., triggered by the increased price of car use due to a road charge – depend primarily on socio-demographic and socioeconomic attributes. One important attribute is disposable income.[6] This implies that the socio-demographic and socioeconomic profile of an individual or a household determines the effect that is triggered by transport policy in terms of price changes. The explicit consideration of different household income categories within the overall economic framework of a computable general equilibrium (CGE) model, allowing for the introduction of a policy reform such as RC, enables the investigation of general economic and ecological effects together with accompanying distributional and equity implications. The numerical property of an applied CGE model allows for a quantitative assessment of impacts from a policy measure such as RC. At the same time, the methodological consistency of the CGE approach gives the advantage of an integrated comparison of quantified effects in the overall context of “environmental quality, economic performance and income distribution" [Boehringer and Loeschel, 2006, pp. 50-51].

However, apart from a few examples [Mayeres, 1998 and 2004; Broecker, 2002; Mayeres and Proost, 2002; Steininger, 2002; Munk, 2003; Steininger and Friedl, 2004; Schaefer and

[5] In terms of sustainability impact assessment, the European Union (EU), for example, asks for "careful assessment of the full effects of a policy proposal [that] must include estimates of economic, environmental and social impacts" (EC, 2001).

[6] We refer to Hautzinger (1978), Dargay (2002), BMVBW/ IVT et al. (2002), Bresson et al. (2004), Kalinowska et al. (2005), Lipps and Kunert (2005), van de Coevering and Schwanen (2005), Giuliano and Dargay (2006), Johansson et al. (2006), Kalinowska and Kuhfeld (2006), Limtanakool et al. (2006), Naess (2006) for examples of passenger travel demand modeling, car purchase, car ownership and car use modeling.

Jacoby, 2005 and 2006], most CGE models are somehow limited with respect to – in particular – the social impact assessment of policies introduced with regard to passenger road travel. Prevailing uncertainties linked to equity and distributional impacts of RC set difficult-to-overcome barriers to the acceptability of the policy measure [Mayeres and Proost, 2001]. None of the existing CGE models that account for passenger travel demand have yet been applied to Germany. In CGE models applied to German data, the demand for passenger travel is not explicitly included, or the way that it is integrated into the model does not allow the evaluation of welfare distribution effects on a disaggregated household level [Meyer and Ewerhart, 1989; Broecker, 2001, 2002, 2004; Bach et al., 2001]. Also, no studies containing an international comparison of effects from road charging policies using an analogous methodological approach and data basis have so far been documented in the literature. To account for existing shortcomings, a CGE model including passenger travel demand for Germany – the German Road Travel Policy Model (GRTPM) – has been constructed based on the Austrian version – the Austrian Road Pricing Model (ARPM) – introduced in Steininger and Friedl (2004).[7] Thus, using the same methodological approach for both countries ensures comparability of results. Both models differentiate households according to income classes. We apply the standard, single country model for a small open economy to the respective databases for Germany and Austria.[8] Each model accounts for 35 production sectors, of which the following are directly linked to the representation of passenger travel demand: extraction of crude petroleum and natural gas, transport equipment, distribution, land transport, supporting and auxiliary transport, finance and insurance, as well as other market services. Agents are modeled using a representative microeconomic consumption or production function, respectively [Varian, 1993].

A consumer is characterized by a preference ordering over the obtainable goods described by a utility function and by a budget set that is limited by income. The representative consumer agent is assumed to choose that bundle of goods in his budget set that maximally satisfies his preferences; i.e., his behavior can be described by utility maximization over his budget set. The GRTP model basically distinguishes three agents: private households, the government, and the road pricing agency.

---

[7] The ARPM has been developed and implemented at the Economics Department of University of Graz; it is documented in Steininger et al. (2007).

[8] For information on CGE models, we refer to Shoven and Whalley (1992) or more recently to Ginsburgh and Keyzer (1997).

A production sector is assumed to use a production technology that transforms an input bundle consisting of all goods in the economy and the primary production factors into an amount of its output good. The producer is assumed to choose the production or input-output bundle so that it maximizes profit; i.e., producer behavior can be described as profit maximization over the production set defined by the available technology. All agents are assumed to take the prices of the goods as given. Prices in turn satisfy the market-clearing criterion, where total demand equals total supply.

Production of non-passenger-transport goods follows a nested constant elasticity of substitution (CES) structure, with capital and labor as primary inputs and intermediate inputs entering in a Leontief functional form with substitution elasticity equal to zero. The main equations underlying the model are summarized in the Appendix, where an overview of the model variables is also enclosed. The production of passenger travel consists of car travel and public transport and follows equations (3) to (6). In addition, household demand for car travel is satisfied by a combination of fixed and variable inputs, where the corresponding cost components follow a Leontief function with an elasticity of substitution set at zero. This implies that kilometer charges applying to the variable input cannot be substituted by other fixed input components; i.e., there are no technical means by which to avoid kilometer charges other than driving less. Private household demand is represented by a nested CES structure with unity elasticity of substitution for consumption of goods and services other than passenger travel. The demand between the bundles of non-transport and transport goods and services is governed by the calibrated elasticity of substitution of $\delta_h^C=0.275$. A calibrated elasticity of substitution $\delta_h^T=0.636$ is used to express the relationship of the demand for the two different passenger transport goods, i.e., demand for motorized individual car travel and for public transport (equations (10) to (12) provide the calibration of parameters given in Steininger et al., 2007).[9] Through the specification of elasticity of substitution parameters calibrated from country-specific micro-econometric travel demand modeling [Kriebernegg, unpublished; BMVBW/ IVT et al., 2002], we consider the quantitative extent of the reaction potential to changes in the price of car travel induced by RC. For extensive literature surveys of car use and ownership elasticities, see also Goodwin (1992), Johansson and Schipper (1997), Blum et al. (1988), BMVBW/ MiD 2002 (2002), Graham and Glaister (2002a, 2002b and 2004), Goodwin et al. (2004). To allow for a comparison of the implicit country-specific

[9] An elasticity of substitution between private and public transport with a value of 0.5, for example, means that a 1% price increase of car travel relative to public transport induces a 0.5% change in the modal split, here in favor of public transport.

household effects on reaction to car RC, the aggregated elasticities of substitution are assumed to be the same in Austria and Germany and are set uniform across household income groups. Moreover, by using uniform substitution elasticities, observed distributional effects of the RC measure are induced by household-specific travel profiles in terms of expenditure and activity parameters. Varying car travel expenditures imply different travel cost increases across the household categories after the introduction of a uniform RC. Differences in additional costs from car use imply differing reactions across income groups [Steininger and Friedl, 2004].

The model distinguishes between the demand for private and public transport. Private transport expenses consist of variable household expenditures on car use and of fixed household expenditures on car purchase and ownership. The first category depends almost entirely on household-specific car use patterns and combines expenditures on car fuels, fuel taxes and levies, car repair and maintenance costs, and different kinds of costs for parking. Private household demand for these inputs is satisfied by the corresponding sectors within the input-output table, such as the intermediate sectors 'crude oil', 'vehicles' and 'trade', etc.[10]

To improve the applicability of the CGE model for evaluating the distributional effects of policy intervention in the passenger road travel sector, the model distinguishes among different household income classes. Each household income category is characterized by a uniquely parameterized utility function as well as endowments of capital and labor. A household's primary factor endowment determines its wage and capital income. Household income category-specific travel demand patterns are included in the model through behavior-based mobility parameters (in km per mode) and travel expenditure coefficients (in €) from survey data on household budgets and expenditures. For the construction of German travel patterns for different household income groups, several data sources were used: the German Sample Survey of Income and Expenditure [Einkommens- und Verbrauchsstichprobe, EVS, 2003, StaBuA], the Continuous Household Budget Survey [Laufende Wirtschaftsrechnungen, LWR, 2003, StBuA], German Input-Output Matrix based on National Accounts [Volkswirtschaftliche Gesamtrechnungen, VGR, 2000] and finally survey data from Mobility in Germany [MiD, 2002] and The Car Mileage Survey [Fahrleistungserhebung, 2002].

Corresponding data on transport expenditures and on transport demand in terms of quantity (passenger and vehicle kilometers and mode per year) for Austria were obtained from an

[10] The Austrian database was available from Steininger and Friedl (2004). The German databases, in the form of a social accounting matrix, have been constructed based on the input-output table and other information available from the German Federal Statistical Office (StaBuA).

econometric merge of the Austrian mobility survey [Henry and Sammer, 1999], the Environmental Balance of Transport [Federal Ministry of Agriculture, Forestry, Environment and Water Management, unpublished] and the Austrian consumption expenditure survey [ST.AT, 2002].

Finally, foreign trade is subject to the Armington assumption of product differentiation. A change in the price relation between foreign and domestic goods is followed by a trade balance shift according to the sector-specific foreign trade elasticity.

The model is closed by a fixed foreign trade balance at the level of the reference year ("neoclassical closure", fixed foreign savings) such that investment is savings driven and the foreign exchange rate adjusts to achieve equilibrium.

### 2.2 Road charging and revenue redistribution

One purpose of the disaggregation of the private travel demand within a CGE model framework between different transport modes and household income categories is to enable the assessment of welfare and (re-)distributional effects of the car RC policy. The final effects of the pricing measure within the economy depend on the use or reallocation of the monetary returns collected from the road charge [Small, 1992; Meyers, 2000 and 2001; Mayeres and Proost, 2002; Farrell and Saleh, 2005; Hau 1998, 2005a, 2005b]. Road charging revenues are collected and redistributed within the CGE model structure, where 15% of the total revenues are retained for system-financing purposes and redirected to intermediary input sectors such as ‘insurance and banking’, ‘electronic devices’ and the factor ‘labor’.

The scenario analysis is carried out for Austria and Germany based on a 5 Euro-Cent per km distance-dependent road charge (mark-up on the variable car costs) imposed on private car drivers. The 5 Euro-Cent per km RC rate is a lower bound, averaged estimate drawn from a survey of Austrian, German as well as European studies on road infrastructure cost assessment as well as external average and marginal social cost calculations. More precisely, the rate of 5 Euro-Cent is set as one-half of the reference value from average external cost calculations for cars and is assumed to correspond to the lower bound from marginal external cost calculations. Therefore, one-half of the estimated marginal external costs without congestion externalities are internalized in our RC scenario [Herry and Sedlacek, 2003; Infras/IWW, 2000, 2004; RECORDIT, UNITE]. A road charge set at the level of 5 Euro-Cent per km would raise the price of a 100-km trip by 5 Euro, which on average paid for 4 to 5 liters of fuel in 2000 to 2002. Furthermore, two different scenarios of revenue use are specified: one without any direct redistribution to the private households and one where one-third of the RC revenue is refunded to the private household sector after deduction of the 15% allotted to self-financing system costs.[11] The remaining revenue flows in equal parts into the improvement of public transport services and road infrastructure investment. In the scenario where one-third of the RC revenue is transferred to the private household sector, it is further assumed that the refund is evenly divided among the four household income categories according to the corresponding number of households in each category. The sensitivity analyses of different RC revenue recycling schemes allow the assessment of the welfare and distributional impacts of the policy measure, where the choices of revenue redistribution reflect different policy objectives. The uniform redistribution structure of RC revenues among the four household categories illustrated in this paper does not result from welfare-optimizing assumptions. The simulation of different redistribution schemes of the RC revenue is rather used to provide a better understanding of the welfare and equity impacts of the RC measure in the context of an international comparison.

### 2.3 Descriptive data analysis

In the Austrian case, income categories are based on a quartile household distribution. The German data allowed the construction of a “close-to” division of the households into income quartiles, as is shown based on the percentage distribution of the total number of households in Table 1.[12,13]

Therefore, economic and mobility data for Austrian household income groups are based on an almost equal number of households in each category. The German household data refer to almost equal one-quarter shares for the lowest and the highest of the four income categories.

---

[11] The assumption about the transaction costs retained to finance the system operating the RC revenue collection and redistribution has often been subject to critical discussion, in particular when the cost is set as a share of the overall revenue. In this study, the approximate value or share of the system cost has been derived from existing road infrastructure cost assessment studies, given the charge level of 5 Euro-Cents per kilometer and corresponding revenues. The question of an optimal revenue share of the RC collector agency vs. changing road pricing levels is left to future discussion and is not further elaborated in this paper [Herry and Sedlacek, 2003; Infras/ IWW, 2000, 2004; RECORDIT, UNITE].

[12] For the German model database two different data sources – the German Sample Survey of Income and Expenditure and the Mobility in Germany national travel survey – were merged. Within the mobility survey households were asked to assign themselves to a given income category. Thus the German travel database contains only household income classes and not continuous household income information. This limited the construction of true household income quartiles as well as inhibited the calculation of household equivalent income. Due to the data restriction the household income category distribution was chosen that allowed the best possible comparison with the Austrian quartile distribution.

[13] Despite arguments - from an economic policy point of view - in favor of analyzing distributional and equity effects based on equivalent household income quintiles, in most studies carried out to assess effects from road charging “only” household income classes were used. This simplification is mainly due to the prevailing lack of the required continuous household income data to construct household equivalent income quintiles (see for just a few examples Giuliano, 1994; Murakami and Young, 1997; Pucher and Renne, 2003; Deka, 2004; Safirova et al., 2005; Elliasson and Mattsson, 2006).

The two remaining income categories in the "middle" of the four-group breakdown are somehow skewed toward the second lowest category.

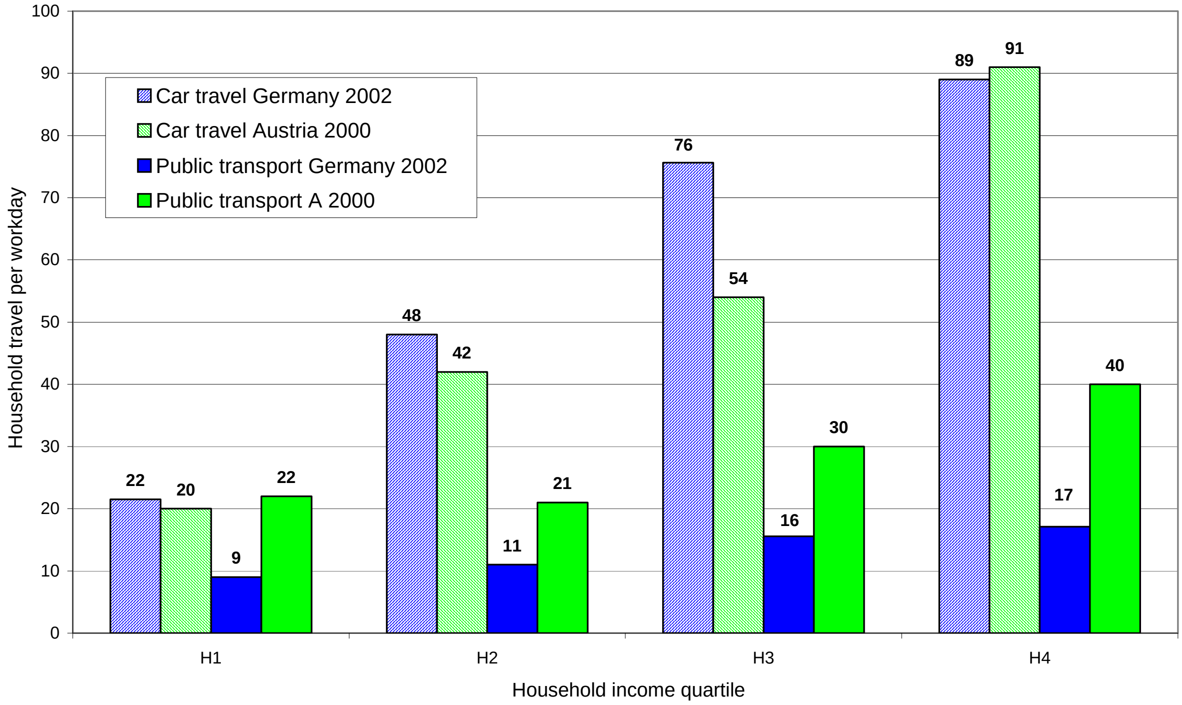
Nevertheless, as illustrated in **Table 1**, both the economic and mobility data for the two countries examined are well comparable. The economic and socio-demographic characteristics of the four household categories in particular provide substantial insight into the explanation of different mobility patterns and, later on in the analysis, of the varying effects of RC.

The illustrations of travel activity patterns per household and per workday disaggregated for different income levels of Austrian and German households shown in Figure 1 display considerable differences.

**Table 1 Basic household economic and travel data, Austria 2000 and Germany 2002**

| Household (HH) Group | Monthly household income in € | Total no of HH and distribution in % | Income distribution in % | Car km share in % | Public transport km share in % | $CO_2$ from passenger transport distribution in % |
|---|---|---|---|---|---|---|
| **Austria** | | | | | | |
| H1 | < 1,478 | 24.8 | 13.3 | 9.9 | 19.3 | 10.4 |
| H2 | < 2,311 | 25.1 | 21.8 | 19.9 | 18.9 | 19.9 |
| H3 | < 3,267 | 25.1 | 26.0 | 25.9 | 25.8 | 25.9 |
| H4 | >= 3,267 | 24.9 | 38.9 | 44.3 | 36.0 | 43.9 |
| All HH | | 100 | 100 | 100 | 100 | 100 |
| | | [in 1,000] | | [billion km] | [billion km] | [million t] |
| Total | | 3,241 | | 63.1 | 21.6 | 12.40 |
| **Germany** | | | | | | |
| H1 | < 1,500 | 25.8 | 11.9 | 9.7 | 17.9 | 10.0 |
| H2 | < 2,600 | 28.4 | 19.7 | 23.8 | 24.1 | 23.8 |
| H3 | < 3,600 | 19.2 | 27.8 | 25.3 | 23.0 | 25.2 |
| H4 | >= 3,600 | 26.6 | 40.6 | 41.3 | 35.0 | 41.1 |
| All HH | | 100 | 100 | 100 | 100 | 100 |
| | | [in 1,000] | | [billion km] | [billion km] | [million t] |
| Total | | 38,111 | | 460.2 | 104.1 | 92.86 |
| Sources: MiD 2002 (INFAS and DIW, 2002), EVS 2003 (StaBuA, 2005), Austria 2000 (Steininger et al, 2007), own calculations. | | | | | | |

**Figure 1 Household travel per workday and mode across income categories, Austria 2000 and Germany 2002**




Sources: MiD 2002 (INFAS and DIW, 2002), EVS 2003 (StaBuA, 2005), Austria 2000 (Steininger et al, 2007), own calculations.

In Germany, households in the top income group use their cars for 89 km per workday and thus four times more intensively than those of the lowest income group, where the mileage driven per workday per household reaches 22 km. In Austria, the relation between the car use intensity of the top and bottom income categories is even more pronounced at 91 km and 20 km, respectively, per workday per household. While the lowest, the second lowest, and the highest income groups are fairly similar across the two countries, the third household category exhibits clearly different car use profiles, with 76 km per workday per household in Germany and 54 km in Austria.[14]

In general, likely explanations for differences in car use between the different income groups are dissimilarities in household distribution according to the size or structure of the households, as well as differences in residential choices and therefore the degree of accessibility. To use Germany as an example, it can be observed that higher income categories – including the 2,600 € to 3,600 € category – mainly comprise households with numerous members, most of them children. This relationship also applies to Austria and is

[14] Motorization rates in Austria and Germany are fairly comparable, with 511 cars per 1,000 inhabitants in Austria and 541 cars per 1,000 inhabitants in Germany [EU energy and transport in figures, 2007/2008].

even more pronounced for the peripheral area, as can be seen in Table 2. This observation is in line with the variation in average daily distances traveled per household, in particular with reference to the top income group, as can be seen in Figure 1.

**Table 2 Average household size according to residential location and income category, Austria 2000 and Germany 2002**

| Average household size (persons/ HH) according to residential location and income group | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **A** | GR | **A** | GR | **A** | GR | **A** | GR |
| Household (HH) Group | **Periphery** | Rural regions | **Central regions** | Agglomerations | **Vienna** | Urban regions | **Total** | Total |
| H1 | **1.4** | 1.5 | **1.3** | 1.5 | **1.2** | 1.5 | **1.3** | 1.5 |
| H2 | **2.6** | 2.5 | **2.2** | 2.2 | **1.8** | 2.4 | **2.2** | 2.3 |
| H3 | **3.2** | 2.9 | **2.9** | 2.8 | **2.4** | 2.9 | **2.9** | 2.8 |
| H4 | **4.1** | 3.0 | **3.4** | 2.9 | **2.6** | 3.1 | **3.5** | 2.9 |
| All HH | **2.9** | 2.3 | **2.5** | 2.2 | **2.0** | 2.2 | **2.5** | 2.2 |
| Sources: MiD 2002 (INFAS and DIW, 2002), Austria 2000 (Steininger et al, 2007), own calculations. | | | | | | | | |

Households with children are in general more mobile than families without children. Table 3 shows overall daily household travel for different household types, with or without children. Hence, couples with children or single parents on average clearly display higher daily travel activities. Couples without children travel per day from 51 to 105 km depending on their employment status. However, couples with children travel between 136 and 140 km per day. Children are mobile and generate extra mobility since very often they need to be accompanied by older individuals or adults, who are in most cases other family or household members.

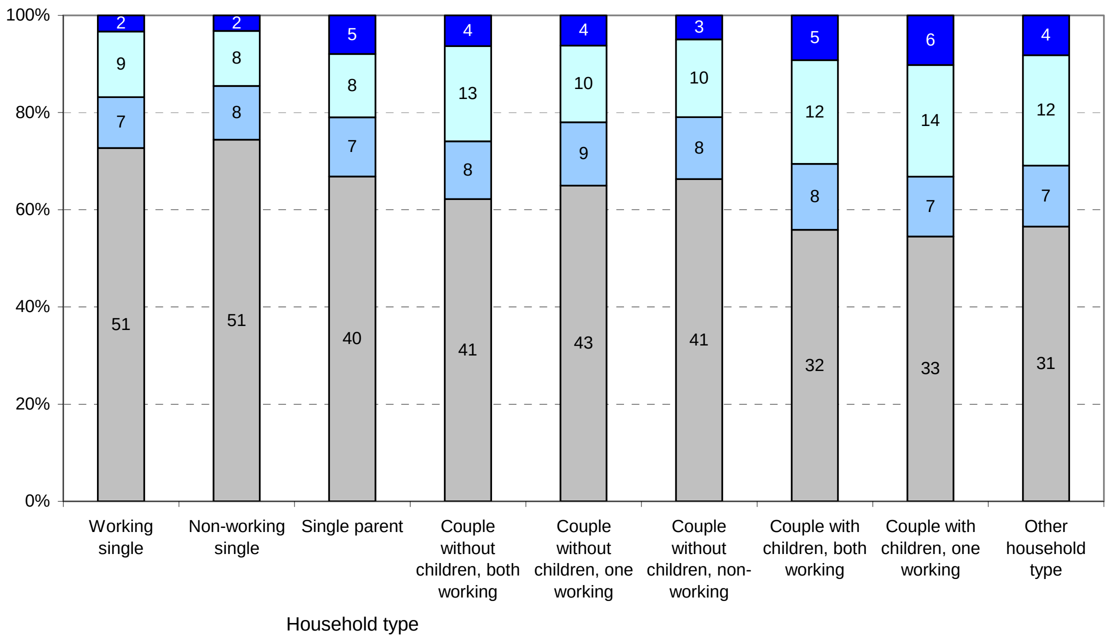
Furthermore, shown below for German data, families with one or more children tend to live in less accessible areas like suburbs or peripheral regions, where they have the opportunity to reside in a house rather than a flat. Figure 2 and Figure 3 show the distribution of households across residential area types by household size and by household type. Comparing household types with and without children, it can be seen that despite the overall dominating share of households living in population centers, families with children or multiple-member households have higher rates in suburban and peripheral regions.

**Table 3 Overall mileage in km traveled per day and per household by household type and residential area, Germany 2002**

| Household type | Type of residential area | | | | |
|---|---|---|---|---|---|
| | Centers | Agglomerations | Intermediate and suburb areas | Periphery | Average over all region types |
| | In km/ day/ household | | | | |
| Working single | 51 | 47 | 55 | 41 | 51 |
| Not-working single | 20 | 22 | 20 | 22 | 21 |
| Single parent | 87 | 59 | 98 | 157 | 88 |
| Couple without children, both working | 109 | 112 | 97 | 105 | 105 |
| Couple without children, one working | 73 | 86 | 92 | 86 | 77 |
| Couple without children, not working | 53 | 51 | 51 | 66 | 51 |
| Couple with children, both working | 146 | 174 | 151 | 170 | 149 |
| Couple with children, one working | 137 | 142 | 130 | 180 | 136 |
| Other household type | 148 | 150 | 154 | 152 | 151 |
| Average over all household types | 72 | 83 | 90 | 109 | 81 |

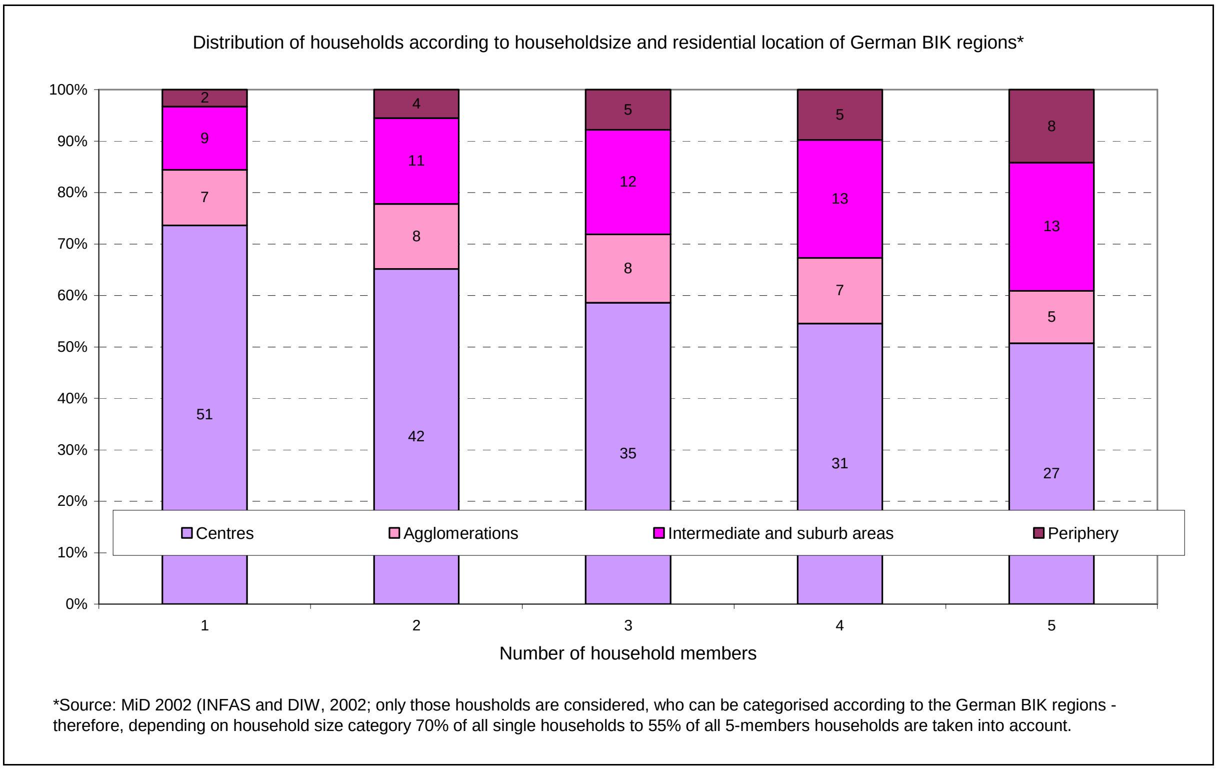
Source: MiD 2002 (INFAS and DIW, 2002).

**Figure 2 Household type and residential area, Germany 2002**




*Source: MiD 2002 (INFAS and DIW, 2002); only those housholds are considered, who can be categorised according to the German BIK-regions, therefore depending on household type category 70% to 55% of all households are taken into account.

**Figure 3 Household size and residential area, Germany 2002**




The somewhat limited use of public transport due to lower accessibility in less populated rural or suburban areas is reflected in the household travel intensities presented in Table 4. Moreover, the – relatively low – demand for public transport in remote areas such as suburbia or periphery is primarily driven by the demand of school children.

In summary, households in higher income categories, which tend to be multiple-member households with children in suburban areas, display higher car use intensities.

As shown in Figure 1, use of public transport in terms of daily distance traveled is almost twice as high for Austrian as for German households. This is mainly due to the significant share of the Austrian population accounted for by its largest city, Vienna (24.3% of households, see Table 5), and Vienna’s long-time public transport supply quality. It is also reflected in lower car ownership rates in Austria, as is given below. In Germany, almost one-fifth of the population lives in bigger cities with convenient public transportation infrastructure and services and this high rates of public transport use. Therefore, considering other larger cities in Austria as well, Austria has a higher proportion of its population in areas well served by public transport. Conversely, in sparsely populated areas with thin public transportation networks, high car use rates prevail.

**Table 4 Mileage in km traveled by car and public transport per day per household by household type and residential area, Germany 2002**

| Type of residential area | Centers | | Agglomerations | | Intermediate and suburb areas | | Periphery | | Average over all region types | |
|---|---|---|---|---|---|---|---|---|---|---|
| Household type | Individual motorized travel | Public transport | Individual motorized travel | Public transport | Individual motorized travel | Public transport | Individual motorized travel | Public transport | Individual motorized travel | Public transport |
| | In km/ day/ household | | | | | | | | | |
| Working single | 35 | 13 | 33 | 11 | 49 | 5 | 38 | / | 39 | 9 |
| Not-working single | 11 | 6 | 16 | 4 | 16 | 2 | 18 | / | 14 | 5 |
| Single parent | 66 | 15 | 43 | 9 | 86 | 9 | 104 | 43 | 69 | 12 |
| Couple without children, both working | 85 | 18 | 89 | 19 | 88 | 5 | 96 | / | 88 | 12 |
| Couple without children, one working | 55 | 12 | 70 | 9 | 79 | 10 | 74 | / | 60 | 11 |
| Couple without children, not working | 39 | 9 | 45 | 2 | 36 | 10 | 58 | / | 39 | 6 |
| Couple with children, both working | 112 | 26 | 146 | 20 | 124 | 21 | 156 | 6 | 123 | 18 |
| Couple with children, one working | 115 | 13 | 119 | 16 | 108 | 13 | 160 | 15 | 113 | 15 |
| Other household type | 109 | 30 | 119 | 25 | 128 | 21 | 126 | 20 | 121 | 22 |
| Average over all household types | 54 | 14 | 66 | 12 | 75 | 11 | 95 | 10 | 65 | 11 |
| Source: MiD 2002 (INFAS and DIW, 2002). | | | | | | | | | | |

The relatively less intense use of public transportation by German households seems to be compensated for by higher car use intensities. Obviously, German households have a stronger preference for automobile use than Austrian households. Table 6 underpins this assumption. Household distributions as to motorization and income level for Austria and Germany show that the share of non-motorized households is significantly lower in Germany than in Austria, and the difference is more pronounced for high income groups. Hence, there are more non-motorized households in Austria than in Germany. The shares for households with one vehicle within each of the four income groups are almost comparable for the two countries.

The differences within the multi-motorized households are notable. Their share is almost twice as high in Germany as in Austria, except for the top income group.

**Table 5 Household distribution as to income group and residential location, Austria 2000 and Germany 2002**

| % of households according to residential location and income group | | | | | | |
|---|---|---|---|---|---|---|
| | **A** | GR | **A** | GR | **A** | GR |
| Household (HH) Group | **Periphery** | Rural regions | **Central regions** | Agglomerations | **Vienna** | Urban regions |
| H1 | **26.1** | 12.9 | **47.4** | 51.2 | **26.5** | 35.9 |
| H2 | **25.7** | 12.3 | **50.3** | 53.5 | **24.1** | 34.2 |
| H3 | **26.8** | 12.5 | **48.6** | 53.0 | **24.6** | 34.4 |
| H4 | **29.2** | 11.1 | **48.9** | 57.9 | **22** | 31.0 |
| All HH | **26.9** | 12.4 | **48.8** | 53.2 | **24.3** | 34.4 |
| Sources: MiD 2002 (INFAS and DIW, 2002), Austria 2000 (Steininger et al, 2007), own calculations. | | | | | | |

**Table 6 Household distribution as to motorization level and income, Austria 2000 and Germany 2002**

| % of households according to motorization level and income group | | | | | | |
|---|---|---|---|---|---|---|
| Household (HH) Group | No car available | | 1 car | | 2 or more cars | |
| | **Austria** | Germany | **Austria** | Germany | **Austria** | Germany |
| H1 | **63.1** | 42.8 | **35.4** | 52.6 | **1.4** | 4.6 |
| H2 | **23.8** | 11.0 | **63.3** | 65.0 | **12.8** | 24.0 |
| H3 | **9.2** | 3.5 | **62.2** | 45.7 | **28.5** | 50.8 |
| H4 | **4.3** | 1.7 | **39.3** | 31.3 | **56.4** | 67.0 |
| All HH | **25.1** | 19.6 | **50.1** | 53.4 | **24.8** | 27.0 |
| Sources: MiD 2002 (INFAS and DIW, 2002), Austria 2000 (Steininger et al, 2007), own calculations. | | | | | | |

Another factor that partially explains the partially greater car use in Germany and higher public transport demands in Austria is the household structural distribution, or the proportion of single households, as presented in Table 7 and Table 8 within the specific residential location and household income groups. The shares of single households within each specific household income and residential location group are quite similar for Austria and Germany, being nearly 70% for the lowest income group, independent of the land use attribute. With few exceptions, the shares decrease progressively along with the income brackets within each residential location group. Except for the comparison of Vienna for Austria and urban regions for Germany, the shares of single households in the two top income groups are considerably higher for Germany than for Austria (see Table 7). The lowest shares of single households irrespective of income level can be found in both countries in rural and peripheral regions, respectively (see Table 7 and Table 8).

The two-country comparison between residential locations within the income category shows a more differentiated picture. Agglomerations in Germany display the highest single household rates, independent of the income level. In Vienna, serving as an example of the household structural distribution within urban areas in Austria, it is quite remarkable that the largest shares of single households can be found for the two highest income classes.

**Table 7 % shares of single households in household totals as to residential location and income group, Austria 2000 and Germany 2002**

| % shares of single HH in HH totals according to residential location and income group | | | | | | |
|---|---|---|---|---|---|---|
| | **A** | GR | **A** | GR | **A** | GR |
| Household (HH) Group | **Periphery** | Rural regions | **Central regions** | Agglomerations | **Vienna** | Urban regions |
| H1 | **67.3** | 66.2 | **74.9** | 70.8 | **84.8** | 66.5 |
| H2 | **17.7** | 17.6 | **33.2** | 31.5 | **51.9** | 21.4 |
| H3 | **2.6** | 3.4 | **5.8** | 12.0 | **14.5** | 6.3 |
| H4 | **1.1** | 7.4 | **2.7** | 8.8 | **11.9** | 5.6 |
| All HH | **21.5** | 31.6 | **28.9** | 38.4 | **42.3** | 33.4 |
| Sources: MiD 2002 (INFAS and DIW, 2002), Austria 2000 (Steininger et al, 2007), own calculations. | | | | | | |

**Table 8 Distribution of single households according to residential location within income groups, Austria 2000 and Germany 2002**

| Distribution of single HH according to residential location within income groups | | | | | | |
|---|---|---|---|---|---|---|
| | **A** | GR | **A** | GR | **A** | GR |
| Household (HH) Group | **Periphery** | Rural regions | **Central regions** | Agglomerations | **Vienna** | Urban regions |
| H1 | **23.2** | 12.4 | **47** | 52.8 | **29.7** | 34.7 |
| H2 | **13.4** | 8.2 | **49.5** | 64.0 | **37** | 27.8 |
| H3 | **9.9** | 4.8 | **40** | 71.1 | **50** | 24.1 |
| H4 | **7.2** | 10.7 | **31.3** | 66.7 | **61.5** | 22.7 |
| All HH | **19.2** | 10.9 | **46.8** | 57.0 | **34.1** | 32.1 |
| Sources: MiD 2002 (INFAS and DIW, 2002), Austria 2000 (Steininger et al, 2007), own calculations. | | | | | | |

In summary, implications derived from the single household structure and residential location-specific distribution of the population do not offer an unambiguous interpretation of the mobility demand or the household reaction to RC. One can argue that, in general, single households can react more elastically to price increases of car use by switching to public transport modes. The reasoning becomes less straightforward when we look at single households in high income categories, which can more easily buffer car use price increases. However, population distribution in terms of household structures is an important aspect in determining aggregated travel demand patterns and should be taken into account when analyzing household-specific reaction potentials to road use charging policies.

Higher motorization within specific household categories in Germany exists across residential locations, as implied by the non-motorization levels presented in Table 9. Thus, non-motorization is less frequent in Germany than in Austria, which likely explains the relatively low use of public transport observed for Germany.

**Table 9 Shares of non-motorized households in household totals by income group and residential location, Austria 2000 and Germany 2002**

| **% share of non-motorized HH in HH totals according to residential location and income group** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **A** | GR | **A** | GR | **A** | GR | **A** | GR |
| Household (HH) Group | **Periphery** | Rural regions | **Central regions** | Agglome-rations | **Vienna** | Urban regions | **Total** | Total |
| H1 | **61.0** | 39.0 | **57.4** | 48.4 | **75.6** | 35.9 | **63.1** | 42.7 |
| H2 | **16.5** | 8.2 | **18.8** | 13.9 | **42.1** | 7.3 | **23.8** | 11.0 |
| H3 | **4.5** | 1.9 | **8.0** | 4.6 | **16.7** | 2.2 | **9.2** | 3.5 |
| H4 | **2.9** | 1.4 | **4.5** | 2.3 | **5.5** | 0.5 | **4.3** | 1.7 |
| All HH | **20.6** | 17.5 | **21.9** | 22.3 | **36.5** | 16.0 | **25.1** | 19.6 |
| Sources: MiD 2002 (INFAS and DIW, 2002), Austria 2000 (Steininger et al, 2007), own calculations. | | | | | | | | |

The differences in car use in particular – not the use of public transport – across household income groups correlate with the differences in consumption budget shares for transport, as shown in Table 10. In general, household income-dependent transport expenditure patterns within each country seem fairly comparable between the two countries, even though they are not identical.

In line with findings of significantly positive income elasticities for car ownership and car use,[15] the fraction of household expenditures dedicated to travel compared to total household consumption expenditure increases in Austria from 9.6% for low income households to 18.6% for high income households and in Germany from 10.2% for low income households to 12.3% for high income households. Therefore Austrian households – except for the lowest income group – spend on average about 5% more of their disposable income on travel activities than German households. The income share spent on fixed car expenditure

[15] For further reading on income elasticities for car ownership and car use, see also Dargay and Gately, 1999; Dargay, 2001; Hanly et al., 2002; Johansson-Stenman, 2002; Pucher and Renne, 2003; Giuliano and Dargay, 2006; Kletzan et al., 2006.

components in Austria is on average about 3 % to 4 % higher than in Germany. In particular, high income households in Austria spend a significantly higher share of their income on car purchase than German households (both in absolute level and as share of income). The exception is the lowest income category (less than 1,500 euros per month), where the shares are almost the same in both countries. The reason for this difference in purchase expenditures (by some 2 % of income) is twofold: First, car taxes and duties for upper class vehicles are significantly higher in Austria [Kalinowska et al., 2005]. Second, fleet composition in Austria is characterised by a significantly larger share in larger cars (the category 1751-2000 $cm^3$ cylinder capacity accounts for 33 % in Germany, but for 40 % in Austria; the reverse is true for smaller cars). Note, that the last observation is consistent with a larger share of Austrians living in cities well served by public transport, where many of them live without any car. Once Austrians do own a car, however, the vehicle tends to be a larger and thus more expensive one. In the age-composition of the car-stock, older vintages are higher represented in Austria (Austrians thus drive their cars longer), consistent with a higher share of repair costs in Austria, also raising the fixed-cost component (by roughly 1 % of income).[16]

**Table 10 Transport expenditures across household income categories, Austria 2000 and Germany 2002**

| Income category and transportation expenditures in % of average monthly household income | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | H1 | | H2 | | H3 | | H4 | |
| | **Austria** | Germany | **Austria** | Germany | **Austria** | Germany | **Austria** | Germany |
| Car fixed costs | **5.97** | 6.15 | **11.00** | 7.71 | **12.39** | 8.31 | **14.57** | 9.52 |
| Car variable costs | **2.49** | 2.62 | **3.71** | 3.04 | **3.84** | 3.10 | **3.58** | 2.29 |
| Public transportation | **1.13** | 1.45 | **0.76** | 0.78 | **0.63** | 0.56 | **0.47** | 0.46 |
| Overall transportation | **9.58** | 10.23 | **15.47** | 11.54 | **16.87** | 11.97 | **18.61** | 12.27 |
| **In Euro per kilometre** | | | | | | | | |
| Overall variable transportation cost | **0.05** | 0.07 | **0.06** | 0.07 | **0.06** | 0.07 | **0.05** | 0.08 |
| Sources: Sources: MiD 2002 (INFAS and DIW, 2002), EVS 2003 (StaBuA, 2005), Austria 2000 (Steininger et al, 2007), own calculations | | | | | | | | |

[16] The information on household car travel expenditures was derived from the micro data of the German sample survey of income and expenditure. Due to survey design households with a monthly net income over 18,000 Euro are eliminated from the sample. This can be another possible explanation for the fact that fixed car expenditures in the highest income category are comparatively lower for German than for Austrian households.

Income shares spent on public transport across all four income categories are similar in both countries, with the exception of the lowest income group. In Germany, households belonging to this category spend 30% more on public transit services than the Austrian households in the same category. Nevertheless, one should keep in mind that in Austria as well as in Germany, a high share of private households exists –up to 50% in rural areas – whose spending on public transportation is close to zero. On the other hand, in some urban agglomerations, more than half of all households do not own a car.

Except for the lowest income category, Austrians tend to spend more of their disposable income on car fuel, which makes up the greatest proportion of variable car costs. The country-specific difference in car fuel expenditures is most pronounced for the highest income category.

Altogether, the structure of mode-specific household travel expenditures is in line with the results for the mobility parameters presented in Figure 1 and Table 1. The initial differences in household expenditure shares on mobility services and the corresponding travel activity parameters reveal the availability of reaction potentials to the pricing measure and are therefore relevant for the interpretation of the welfare and equity impacts from car RC in Austria and Germany.

# 4 Simulation results

For a comparative static impact assessment, a distance dependent and time invariant overall road network charge for car use is implemented at the level of 5 Euro-Cent/km. The implementation of RC changes the price of car travel and generates a shift in the modal split resulting in changing overall transport volumes, depending on the reaction parameters introduced in the model. In the policy simulation, two different variants of revenue redistribution are defined: 1) private households are not subject to a direct refund from RC revenues, and 2) private households receive one-third of the total refund, uniformly distributed among households. In both cases the remaining revenue is equally distributed between road infrastructure investment/maintenance and public transport enhancement.

Table 11 summarizes the overall transport, environmental and macroeconomic effects from the measure for Austria and Germany and for varying road charge revenue reallocation policies.

The volumes of revenues generated in Austria and Germany from charging car drivers using the national road network differ considerably in absolute terms, given the different sizes of the countries. In Germany, collected road charge revenues are almost seven times the Austrian total. This reflects primarily the difference in the population size and therefore in the number of car users and total car mileage driven between the two countries. In Austria, total car mileage amounts in the reference case to about 63 billion km. In Germany, car travel makes up 406 billion km per year and is therefore – in line with the difference in RC revenues – about seven times higher than in Austria. As shown in Figure 1, average workday car use of an Austrian household is –except for the highest income category – (considerably) lower than in a German household. Total use of public transportation in Germany is thus, at 104 billion km, only almost five times the annual Austrian volume of 22 billion km (“only” relative to its tenfold larger population) as Germans are more “reluctant” to use public transport on a daily basis, displaying lower average daily distances traveled by various modes of public transit (see Figure 1). After the introduction of RC, a reduction in car use accompanied by an increase in the use of public transportation can be observed in both countries. Both effects have different magnitudes depending on the region. According to the revenue reallocation scheme, motor vehicle travel falls between 5% and 5.4% in Germany and between 6.5% and 7% in Austria. The reduction in car use after the introduction of car RC is slightly higher in both countries when there is no direct revenue transfer from the RC fund to the private household sector. The reduction in auto mobility due to the distance-dependent cost rise in car use is (partially) compensated by the shift toward public transit. Therefore, in both countries, the kilometers traveled with public transport modes rise on average by 4.4% to 4.8% in Germany and 5.5% to 6.2% in Austria. The redistribution of an RC revenue share directly to private households lowers the negative effect of RC on car use in both countries. Moreover, RC revenue transfer to the private household sector promotes the switch from car travel to the use of public transportation. Taking the kilometers traveled in the car or in the modes of public transport as a homogenous “mobility” bundle, the net effect of RC on travel activity in general is negative. As a result, in Germany overall household mobility is reduced by 0.2% to 1% and in Austria by 0.3% to 1.5%. Due to the reduction in car travel, CO2 emissions generated in the motor vehicle sector decrease on average by about 9% in Germany and 10% in Austria. The positive environmental effect of CO2 reduction is based on the fact that the average CO2 emission per passenger-km ratio is far lower for public transport than for car travel [VDV-Statistik, 2006]. Therefore, because of the sizeable reduction in car use and despite the rise in the use of public transport due to the modal shift, overall CO2 emission levels decline.

Gross domestic product (GDP) in both countries experiences positive growth after the implementation of the policy scenarios. Since, with the introduction of the new service “environment”, this factor of production is now explicitly paid for, GDP increases. However, the consumption measure used in this study (see Table 12) includes only market goods. While the payment of a road charge actually increases the environmental consumption, the consumption of traditional market goods declines.

The aggregated welfare calculated within the model quantifies the social benefit from the reduction of negative externalities from car use. Its level is based on an average external costs per kilometer calculation as an approximation of marginal external transport costs.[17] Therefore, the net welfare benefit is higher in both countries for the scenario without the direct transfer of RC revenues to private households since the scenario with direct transfer also induces higher car use. As external transport costs in fact can be assumed to rise progressively with transport volume rather than linearly as we approximate here, the benefit quantification can be considered conservative [for more details, see Steininger et al., 2007].

[17] In the approximated external cost calculation, the following categories are taken into account: infrastructure costs, external accident costs, and environmental costs (noise, local pollutants, climate effects), each differentiated by type of street and user, and net of public revenues raised, e.g., from taxes on insurance, vehicle registration and fuels [Herry and Sedlacek, 2003; Infras/ IWW, 2000 and 2004].

**Table 11 Macroeconomic effects from different road charging schemes, Austria 2000 and Germany 2003**

| | | Overall effects from different road charging schemes for Austria and Germany | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Austria | | | | | Germany[1] | | | | |
| | | Reference | Scen. NO revenue redistribu-tion to private HH | Change % | Scen. revenue redistribution to private HH | Change % | Reference | Scen. NO revenue redistribution to private HH | Change % | Scen. revenue redistribution to private HH | Change % |
| Transport variables | | | | | | | | | | | |
| Level of road charge | Euro per km | - | 0.05 | - | 0.05 | - | - | 0.05 | - | 0.05 | - |
| Revenues total | Mill. Euro | 0 | 2,933 | - | 2,949 | - | 0 | 21,769 | - | 21,848 | - |
| Revenues (semi-public) | Mill. Euro | 0 | 2,493 | - | 1,671 | - | 0 | 18,504 | - | 12,381 | - |
| Car vehicle km | Mill. km | 63,068 | 58,653 | -7.0 | 58,983 | -6.48 | 460,163 | 435,371 | -5.39 | 436,967 | -5.04 |
| Public transport km | Mill. km | 21,614 | 22,799 | 5.48 | 22,949 | 6.18 | 104,148 | 108,727 | 4.40 | 109,180 | 4.83 |
| | | | | | | | | | | | |
| Environment | | | | | | | | | | | |
| CO2 | 1.000 t | 12,947 | 11,611 | -10.30 | 12,947 | -9.80 | 92,856 | 84,372 | -9.10 | 84,682 | -8.80 |
| CO2 diff | 1.000 t | - | -1,336 | - | -1,270 | - | - | -8,485 | - | -8,174 | - |
| | | | | | | | | | | | |
| Macroeconomic variables | | | | | | | | | | | |
| Welfare change | Mill. Euro | | 355 | | 329 | | | 1,996 | | 1,867 | |
| GDP | Mrd. Euro | 178 | 178 | 1.30 | 180 | 1.34 | 1,983 | 2,009 | 1.33 | 2,008 | 1.23 |
| Number of Employees | in 1,000 | 3,133 | 3,135 | 0.06 | 3,135 | 0.06 | 39,096 | 39,380 | 0.73 | 39,307 | 0.54 |
| Number of unemployed | in 1,000 | 194 | 192 | -1.01 | 193 | -0.70 | 4,061 | 3,777 | -6.99 | 3,850 | -5.19 |
| Unemployment rate | in % | 5.84 | 5.78 | - | 5.8 | - | 9.41 | 8.75 | - | 8.92 | - |
| Price of capital | in % | | | 0.09 | | 0.07 | | | -0.03 | | -0.02 |
| | | | | | | | | | | | |
| Budgetary effects | | | | | | | | | | | |
| Due to change in | | | | | | | | | | | |
| Revenues from direct taxes | Mill. Euro | 51,986 | 52,065 | 0.15 | 52,043 | 0.11 | 722,674 | 726,381 | 0.51 | 725,437 | 0.38 |
| Revenues from indirect taxes | Mill. Euro | 12,383 | 11,985 | -3.21 | 12,098 | -2.30 | 60,643 | 60,945 | 0.50 | 60,850 | 0.34 |
| Labor market expenditures | Mill. Euro | 1,926 | 1,907 | -0.99 | 1,913 | -0.67 | 43,710 | 40,657 | -7.0 | 41,440 | -5.19 |
| Government demand | Mill. Euro | 37,632 | 37,115 | -1.37 | 37,208 | -1.13 | 378,537 | 383,575 | 1.33 | 381,814 | 0.87 |

[1] Same elasticities were used for Austria and Germany.
Sources: GRTPM and ARPM, own calculations.

Results obtained for selected economic sectors in both countries correspond to the results presented above for transport-related variables and macroeconomic indicators. As one would expect, the economic activity in sectors related to car travel demand decreases with the introduction of car RC. The most significant decline can be observed for the sectors of car manufacturing (i.e., transport equipment), retail activity (i.e., trading), market services, and foremost, production of refined petroleum products. On the other hand, sectors related to the positively affected public transport demand and the use of road pricing revenues for qualitative improvement or a quantitative extension of the road infrastructure supply or public transport services exhibit upward development, e.g., construction, non-market services, or the land transport sector. Also, sectors linked to the economic activity of the road pricing collection agency exhibit an upward trend, e.g., electrical goods or the banking and finance sector.

The positive effect on indirect taxes experienced in Germany results from the more positive labor market effect and the more moderate effect on private household welfare (see Table 12). In summary, shrinking public tax revenues are compensated for by the (semi-public) net revenues collected from car road pricing.

The introduction of an overall RC at the level of 5 Euro-Cent per km means a significant increase in the unit price of car travel compared to the variable car km cost for Austrian and German households shown in Table 10. The resulting effects vary considerably across household income groups and between the two countries (see Table 12).

**Table 12 Distributional impacts across household income groups and RC revenue reallocation schemes, Austria and Germany**

| Distributional impacts across road pricing policy scenarios and household income groups<br>Transport expenditure impacts from car road charging in % change relative to the reference scenario | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Austria[1)] | | | | Germany[2)] | | | |
| | Scen. NO revenue redistribution to private HH | | Scen. revenue redistribution to private HH | | Scen. NO revenue redistribution to private HH | | Scen. revenue redistribution to private HH | |
| Income category | Car | Public transport | Car | Public transport | Car | Public transport | Car | Public transport |
| H 1 | 17.9 | 7.3 | 19.3 | 8.6 | 12.4 | 5.0 | 13.3 | 5.9 |
| H 2 | 13.1 | 5.4 | 13.9 | 6.1 | 12.2 | 5.1 | 12.7 | 5.6 |
| H 3 | 11.8 | 4.9 | 12.4 | 5.4 | 11.8 | 4.9 | 12.2 | 5.3 |
| H 4 | 13.1 | 5.4 | 13.5 | 5.8 | 7.7 | 3.2 | 7.9 | 3.4 |

| Consumption impacts from car road charging in % change relative to the reference scenario | | | | |
|---|---|---|---|---|
| | Austria[1)] | | Germany[2)] | |
| | Scen. NO revenue redistribution to private HH | Scen. revenue redistribution to private HH | Scen. NO revenue redistribution to private HH | Scen. revenue redistribution to private HH |
| H 1 | -1.78 | -0.56 | -1.16 | -0.34 |
| H 2 | -2.14 | -1.41 | -1.35 | -0.91 |
| H 3 | -1.97 | -1.46 | -1.67 | -1.33 |
| H 4 | -2.30 | -1.95 | -1.34 | -1.12 |

[1)] For Austria slightly different income categories are valid, see Table 1.
[2)] Elasticities as in Austria
Sources: GRTPM and ARPM, own calculations.

Irrespective of the policy scenario the greatest increase in household expenditure for car travel is experienced in both countries by the lowest income group. In Austria the increase varies between 12% and 19% depending on the income group and the revenue use policy. For Germany, the corresponding figures are lower, at 8% to 13%. The lowest relative increases for car travel and public transport expenditures are experienced in Germany by the highest income group. In general, expenditures for public transport and car travel increase regressively across income groups in both countries. The policy scenario without a private household refund brings about a slightly different picture in Austria. The bottom income group experiences the greatest expenditure increase and welfare decrease when no RC revenue is transferred back to the households. As can be further seen in Table 12, where we do not account for the environmental welfare improvement but measure only the change in traditional marketed goods consumption across households, the welfare change of individual household categories is negative for each of them, but it varies significantly with the RC revenue redistribution scheme and is different for the two countries.[18] Comparing with the scenario including the household refund, the negative welfare change seems more moderate for the German than for the Austrian households. This effect is most pronounced for the two lowest income groups. In general, a progressive consumption and, therefore, household group-specific welfare effect is observed for Austria but not for Germany. In Germany, the upper middle income group experiences the highest welfare losses, irrespective of the RC revenue reallocation scheme. In Austria, it is instead the highest income category. This observation is important for the design of possible refund policies with the introduction of car road charging. It basically indicates that in Germany, the increase of car use with rising income is less pronounced than in Austria.

The distributive effects illustrated in Table 12 reflect on the whole the pre-policy mobility profiles of the different household income categories in the two countries and therefore their "vulnerability" to the RC measure. In both countries, the negative welfare effect from RC can be best compensated by revenue redistribution directly to households. The relatively highest benefit from revenue redistribution is allocated to the bottom income category. An important implication of this result is that the welfare or equity effect, and therefore the social acceptance of RC, policies is clearly linked to the redistribution scheme of the RC revenues. As shown in the sensitivity study, the redistribution of only a small part of the RC revenue to the private households will induce a rather moderate positive effect on their (car) travel demand and therefore not counteract the environmental objectives of the measure. However, a differentiated household refund structure can significantly absorb the negative welfare effect of the rising cost of car use.

[18] The welfare change is measured by the Hicksian equivalent variation, which gives the amount of income necessary to compensate an individual (in the pre-policy situation) in order to reach equality with the post-policy utility level [Just et al., 2004]. Thus, in the present analysis, the lowest income households in Austria would be willing to pay a fraction of 1.8% of their income to avoid the implementation of road pricing (scenario without household refund, table 12).

## 5 Discussion – concluding remarks

We implemented a CGE model in order to properly assess the impacts that regulative policy measures have on agents' behavior on one hand and on the entire economy on the other and apply it to a country comparison between Austria and Germany. When assessing pricing policy measures imposed in the area of passenger road travel, heterogeneous reaction potentials within the private household sector need to be taken into account. From findings documented in the travel demand modeling literature, factors influencing individual or household behavior responding to pricing measures are identified and assessed. In the database extension of our CGE model, we partially consider these factors through the specification of heterogeneous household categories. Furthermore, we account for aspects relevant in the process of car travel generation. We therefore differentiate between car purchase or ownership and car use, treating the former as a fixed expenditure on the purchase of a durable good. Finally, we implement the model to calibrate effects of different distance-dependent policy pricing measures implemented in the private passenger car travel sectors in Austria and Germany. The results show that there are considerable differences in the effects found in Austria versus those in Germany after the implementation of the policy measure. The two countries' respective travel patterns for the four income categories yield substantial variations in the impact of the RC scenarios. One interesting result is that welfare losses in terms of traditional consumption are more moderate in Germany than in Austria. Austrians are more sensitive to RC since they exhibit higher car use intensities than Germans. This is also reflected by a higher budget share of private households in Austria bounded in overall car travel expenditures, thus restricting the options for reallocating household spending.

Moreover, independent of the revenue redistribution scenario introduced in this paper, RC introduced in Germany does not have a consistently progressive impact across household income categories. In contrast, when RC is introduced in Austria together with a revenue redistribution scheme that transfers part of the revenue back to the households, the measure works in a progressive way; households in the highest income category bear the highest burden from the measure implementation. In conclusion, the design of the revenue redistribution scheme and consideration of pre-policy travel patterns are fundamental for the macroeconomic effects and household-specific welfare distribution. The specific design thus has a significant impact on the public acceptability of such a regulative road pricing instrument.

## References

Armington, P. (1969): A theory of demand for products distinguished by place of production, IMF Staff Papers, 16, 159-178.

Arnott, R., A. De Palma and R. Lindsey (1994): “The Welfare Effects of Congestion Tolls with Heterogeneous Commuters”. Journal of Transport Economics and Policy, 28, 139-161.

Bach, S., Bork, Ch., Ehrenheim, V., Kohlhaas, M., Schumacher, K., Lutz, Ch., Meyer, B., Praetorius, B. and Welsch, H. (2001) Die ökologische Steuerreform in Deutschland: Eine modellgestützte Analyse ihrer Wirkungen auf Wirtschaft und Umwelt. Veröffentlicht von Birkhäuser, 2001.

BASt, Bundesanstalt für Straßenwesen (2005) Fahrleistungserhebung 2002, Berichte der Bundesanstalt für Straßenwesen, Heft V 120, Bergisch–Gladbach.

Blum, U. C. H., Foos, G., Gaudry, M. J. I. (1988) Aggregate time series gasoline demand models: Review of the literature and new evidence for West Germany, Transportation Research Part A: General, Vol. 22, Issue 2, pp. 75-88.

Boehringer, C., Loeschel, A., 2006. Computable General Equilibrium Models for Sustainability Impact Assessment: Status quo and Prospects. Ecological Economics 60 (1), 49-64.

Bresson, G., Dargay, J., Madre, J.-L., Pirotte, A. (2004) Economic and structural determinants of the demand for public transport: an analysis on a panel of French urban areas using Shrinkage estimators, Transportation Research Part A: Policy and Practice, Vol. 38, Issue 4, pp. 269-285.

Broecker, J. (2001) Spatial Effects of Transport Infrastructur: The Role of Market Structure. In: J. Roy and W. Schulz (editors), Theories of Regional Competition. Nomos, Baden-Baden, 2001, pp. 181-193.

Broecker, J. (2002) Passenger Flows in CGE Models for Transport - Project Evaluation, Institute for Regional Research Christian-Albrechts-Universitaet Kiel, paper to be presented to the ERSA Congress 2002, August 2002, Dortmund.

Broecker, J. (2004) Computable General Equilibrium Analysis in Transportation Economics. In: D.A. Hensher, K. J. Button, K. E. Haynes, P. R. Stopher (editors), Handbook of Transport Geography and Spatial Systems. Elsevier, Amsterdam, 2004, pp 269-292.

Bundesministerium für Verkehr, Bau- und Wohnungswesen (Edit.) (2003) Verkehr in Zahlen 2003/2004, Bearb.: Sabine Radke, DIW Berlin, Deutscher Verkehrs-Verlag, Hamburg.

Bundesministerium für Verkehr, Bau- und Wohnungswesen (Edit.) (2002) Analyse von Änderungen des Mobilitätsverhaltens – insbesondere der Pkw-Fahrleistung – als Reaktion auf geänderte Kraftstoffpreise, Schlussbericht zum Forschungsprojekt Nr. 96.0756/2002/, Bearb.: Institut für angewandte Verkehrs- und Tourismusforschung e.V. (IVT) Heilbronn / Mannheim (Federführung), Progtrans AG Basel, Steinbeis-Transferzentrum Angewandte Systemanalyse (STASA) Stuttgart, Bonn.

Clark, J. Maurice (1923) Studies in the Economics of Overhead Costs. Chicago & London: University of Chicago Press.

Coevering van de, P., Schwanen, T. (2006) Re-evaluating the impact of urban form on travel patterns in Europe and North-America, Transport Policy, Vol. 13, Issue 3, pp. 229-239.

Conrad, K. (1983) Cost prices and partially fixed factor proportions in energy substitution, European Economic Review, Vol. 21, Issue 3, pp. 299-312.

Conrad; K. and Schroeder, M. (1991) Demand for Durable and Nondurable Goods, Environmental Policy and Consumer Welfare, Journal of Applied Econometrics, Vol. 6, No. 3, pp. 271-286.

Dargay, J. and Gately, D. (1999) Income's effect on car and vehicle ownership, worldwide: 1960–2015, Transportation Research Part A: Policy and Practice, Vol. 33, Issue 2, pp. 101-138.

Dargay, J. (2001) The effect of income on car ownership: evidence of asymmetry, Transportation Research Part A: Policy and Practice, Vol. 35, Issue 9, pp. 807-821.

Dargay, J. (2002) Determinants of car ownership in rural and urban areas: a pseudo-panel analysis, Transportation Research Part E: Logistics and Transportation Review, Vol. 38, Issue 5, pp. 351-366.

Deka, D. (2004) Social and Environmental Justice Issues in Environmental Transportation, in: Hanson, S., Giuliano, G. (Eds.), The Geography of Urban Transportation, Guilford Press, New York, pp. 332-255.

Derycke, Pierre-Henri (1998) Road Pricing-Analysis and Policies (Historical Perspective). Recherches Economiques de Louvain 64(1), pp. 63-74.

Dupuit, J. (1849) Des Péages. Annales des Ponts et Chaussées: Mémoires et Documents, 2nd ser., 17(1), 207-248. Trans. Elizabeth Henderson, On Tolls and Transport Charges. International Economic Papers, 1962, 11, pp. 7-31.

EC (European Commission) (2001) A sustainable Europe for a better world: a European Union strategy for sustainable development. Commission's Proposal to the Gothenburg European Council, COM (2001)264 Final, Brussels, 15 May 2001.

EC (2006) Directive 2006/38/EC amending Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures. Brussels, 17 May 2006.

Ekelund Jr., Robert E., and Robert F. Hébert (1999) Secret Origins of Modern Microeconomics: Dupuit and the Engineers. Chicago and London: University of Chicago Press.

EC, Directorate-General for Energy and Transport (2008) EU energy and transport in figures, 2007/2008. Statistical Pocket Book.

Elliasson, J. Mattsson, L.-G. (2006) Equity Effects of Congestion Pricing: Quantative Methodology and a Case Study for Stockholm. Transportation Research. Part A 40, pp. 602-620.

Farrell and Saleh (2005) Road-user charging and the modelling of revenue allocation, Transport Policy, Vol. 12, Issue 5, pp. 431-442.

Ginsburgh V. and Keyzer M. (1997) The Structure of Applied General Equilibrium Models, MIT Press, Cambridge, Massachusetts.

Giuliano, G. (1994) Equity and Fairness Considerations of Congestion Pricing, in: Committee for Study on Urban Transportation Congestion Pricing (Ed.), Curbing Gridlock: Peak Period Fees to Relieve Traffic Congestion. Transportation Research Board Special Report 242. Vol. 2, National Academy Press. Washington, D.C., pp. 250-279.

Giuliano, G., Dargay, J. (2006) Car ownership, travel and land use: a comparison of the US and Great Britain, Transportation Research Part A: Policy and Practice, Vol. 40, Issue 2, pp. 106-124.

Goodwin, P. (1992) A review of new demand elasticities with reference to short and long run effects of price changes, Journal of Transport Economies and Policy, 26, pp. 155-169

Goodwin, P., Dargay, J. and Hanly, M. (2004) Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review, Transport Reviews, Vol. 24, No. 3, pp. 275-292.

Graham, D. and Glaister, S. (2002a) The Demand for Automobile Fuel: A Survey of Elasticities, Journal of Transport Economics and Policy, 36, pp. 1–26.

Graham, D. and Glaister, S. (2002b) Review of Income and Price Elasticities in the Demand for Road Traffic. London: Department for Transport.

Graham, D. and Glaister, S. (2004) Road Traffic Demand Elasticity Estimates: A Review, Transport Reviews, Vol. 24, No. 3, pp. 261-274.

Hanly, M., Dargay, J. and Goodwin, P. (2002) Review of Income and Price Elasticities in the Demand for Road Traffic. London: Department for Transport.

Hau, T. D. (1998) Congestion Pricing and Road Investment. In Road Pricing, Traffic Congestion and the Environment: Issues of Efficiency and Social Feasibility, ed. Kenneth J. Button and Erik T. Verhoef. Cheltenham, UK: Edward Elgar, pp. 39-78.

Hau, T. D. (2005a) Economic Fundamentals of Road Pricing: A Diagrammatic Analysis, Part I-Fundamentals. Transportmetrica 1(2), pp. 81-115.

Hau, T. D. (2005b.) Economic Fundamentals of Road Pricing: A Diagrammatic Analysis, Part II-Relaxation of Assumptions. Transportmetrica 1(2), pp. 119-149.

Hautzinger, H. (1978) Travel demand elasticity with respect to socio-economic variables: The multinomial logit case, Transportation Research, Vol. 12, Issue 5, pp. 355-356.

Herry, M. and Sammer, G. (1999) Mobilitätserhebung österreichischer Haushalte 1995, Rohdaten (Mobility Survey of Austrian Households 1995). Vienna.

Herry, M., and Sedlacek, N. (2003) Österreichische Wegekostenrechnung für die Straße 2000. Austrian Ministry of Transport, Innovation and Technology, Vienna.

Infras/ IWW (2000) Maibach, M. u.a.: External Costs of Transport, Infras, IWW, im Auftrag der International Union of Railways (UIC), Paris.

Infras /IWW (2004) External Costs of Transport - Update Study, im Auftrag der International Union of Railways (UIC), Final Report, Zürich/Karlsruhe.

International Energy Agency/ OECD (2006) World Energy Outlook 2006.

Johansson, M. V., Heldt, T., Johansson, P. (2006) The effects of attitudes and personality traits on mode choice, Transportation Research Part A: Policy and Practice, Vol. 40, Issue 6, pp. 507-525.

Johansson, O. and Schipper, L. (1997) Measuring the long run fuel demand of cars: separate estimations of vehicle stock, mean fuel intensity, and mean annual driving distance, Journal of Transport Economics and Policy, 31, pp. 277-292.

Johansson-Stenman, O (2002) Estimating Individual Driving Distance by Car and Public Transport Use in Sweden, Applied Economics, Taylor and Francis Journals, vol. 34(8), pp. 959-67, May.

Just, R.E., Hueth, D.L., Schmitz, A., (2004) The Welfare Economics of Public Policy: A Practical Approach to Project and Policy Evaluation. Edward Elgar, Cheltenham.

Kalinowska, D., Kloas, J., Kuhfeld, H., Kunert, U. (2005) Aktualisierung und Weiterentwicklung der Berechnungsmodelle für die Fahrleistung von Kraftfahrzeugen und für das Aufkommen und für die Verkehrsleistung im Personenverkehr (MIV), Gutachten im Auftrag des Bundesministeriums für Verkehr, Bau- und Wohnungswesen. Berlin, Projektnummer 19.0005/2002.

Kalinowska, D., Kuhfeld, H., Kunert, U., Rülicke, O. (2005), Die Abgaben auf Kraftfahrzeuge in Europa im Jahr 2005. Forschungsprojekt im Auftrag des Bundesministeriums der Finanzen. DIW Berlin: Politikberatung kompakt 12, Berlin.

Kalinowska D., Kuhfeld, H. (2006) Motor Vehicle Use and Travel Behaviour in Germany – Determinants of Car Mileage, DIW Berlin Discussion Papers 602, Berlin.

Keeler, T.E. and Small, K.A. (1977) Optimal peak-load pricing, investment and service level on urban expressways. Journal of Political Economy 85, pp. 1-25.

Kletzan, D., A. Köppl, K. Kratena, S. Schleicher, and M. Wüger (2006) Towards sustainable consumption: Economic modelling of mobility and heating for Austria, Ecological Economics, Volume 57, Issue 4, 1 June 2006, pp 608-626.

Knight, F. (1924) Some fallacies in the interpretation of social cost, Quarterly Journal of Economics 38 (1924), pp. 582-606.

Limtanakool, N., Dijst, M., and Schwanen, T. (2006) The influence of socioeconomic characteristics, land use and travel time considerations on mode choice for medium- and longer-distance trips, Journal of Transport Geography, Vol. 14, Issue 5, pp. 327-341.

Lindsey, C.R. and Verhoef, E.T. (2001) Traffic congestion and congestion pricing. In: Hensher, D.A., Button, K.J. (Eds.), Handbook of Transport Systems and Traffic Control, Handbooks in Transport 3. Elsevier, Amsterdam, pp. 77–105.

Lipps, O. and Kunert, U. (2005) Measuring and Explaining the Increase of Travel Distance: A Multilevel Analysis Using Repeated Cross Sectional Travel Surveys, DIW Berlin Discussion Papers 492, Berlin.

Meyer, B. and Ewerhart, G. (1998) Multisectoral Policy Modelling for Environmental Analysis. In: Uno, K. / Bartelmus, P. (Hrsg.): Environmental Accounting in Theory and Practice. Amsterdam, pp. 395-406.

Mayeres, I. (1998) The Distributional Impacts of Policies for the Control of Transport Externalities - An Applied General Equilibrium Model, Center for Economic Studies - K.U.Leuven.

Mayeres, I. (2000) The Efficiency Effects of Transport Policies in the Presence of Externalities and Distortionary Taxes, Journal of Transport Economics and Policy, Vol. 34, Part 2, pp. 233-260.

Mayeres I. and Proost S. (2001) Reforming Transport Pricing: an Economic Perspective on Equity, Efficiency and Acceptability, Chapter 6. In J. Schade and B. Schlag (2003), Acceptability of Transport Pricing Strategies, Elsevier Science.

Mayeres, I. (2001) Equity and Transport Policy Reform, ETE Discussion Paper 2001-14, CES, K.U.Leuven, Leuven.

Mayeres, I. and Proost, S. (2002) Reforming transport pricing: an economist's perspective on equity, efficiency and acceptability, Energy, Transport and Environment Working Papers Series ete0212, Katholieke Universiteit Leuven, Centrum voor Economische Studiën, Energy, Transport and Environment.

Mayeres, I. (2004) Testing alternative transport pricing strategies: A CGE analysis for Belgium. Paper to be presented at the Conference on Input-Output and General Equilibrium: Data, Modelling and Policy Analysis, Brussels, 2-4 September 2004.

INFAS, DIW Berlin (2002) Survey Mobilität in Deutschland (MiD 2002), http://www.mobilitaet-in-deutschland.de/engl, (12/10/2006).

Mohring, H., Harwitz, M. (1962) Highway Benefits. Northwestern University press, Evanston, IL.

Munk, J. K. (2003) Assessment of the introduction of road pricing using a Computable General Equilibrium mode, Institute of Economics, University of Aarhus.

Murakami, E., Young, J. (1997) Daily Travel by Persons with Low-income. Paper submitted for the National Personal Transportation Survey Symposium. Bethesda, MD. October 29th - 31st., 1997.

Naess, P. (2006) Accessibility, Activity Participation and Location of Activities: Exploring the Links between Residential Location and Travel Behavior, Urban Studies, Vol. 43, No. 3, pp. 627-652.

Paltsev S.V. (1999): Moving from Static to Dynamic General Equilibrium Economic Models: Notes for a beginner in MPSGE, Colorado, 1999.

Peterson, Shorey (1932) Highway Policy on a Commercial Basis. Quarterly Journal of Economics 46(3), pp. 417-443.

Peterson, Shorey (1950) The Highway from the Point of View of the Economist. In Highways in Our National Life, ed. Jean Labatut and Wheaton Joshua Lane. Princeton, Princeton University Press, pp. 190-200.

Pigou, 1920 A.C. Pigou, Wealth and Welfare, MacMillan, London (1920).

Pucher, J. Renne, J.L. (2003) Socioeconomics of Urban Travel: Evidence from the 2001 NHTS. Transportation Quarterly 57/3 (Summer 2003), pp. 49-77.

Richardson, H.W. and C.B. Chang-Hee (1998) The Equity Impacts of Road Congestion Pricing. In K.J. Button and E. Verhoef (eds.), Road Pricing, Traffic Congestion and the Environment, Issues of Efficiency and Social Feasibility. Edward Elgar, Cheltenham, pp. 247-262.

REal COst Reduction of Door-to-door Intermodal Transport (RECORDIT), http://www.recordit.org/, (10/03/2008).

Safirova, E., Gillingham, K., Harrington, W., Nelson, P., Lipman, A. (2005) Choosing Congestion Pricing Policy: Cordon Tolls vs. Link Based Tolls. Transportation Research Record: Journal of the Transportation Research Board. No. 1932. Transportation Research Board of the National Academies, pp. 169-177.

Schaefer, A. and Jacoby, H. D. (2005) Technology detail in a multisector CGE model: transport under climate policy, Energy Economics, Vol. 27, Issue 1, pp. 1-24.

Schaefer, A. and Jacoby, H. D. (2006) Vehicle technology under CO2 constraint: a general equilibrium analysis, Energy Policy, Vol. 34, Issue 9, pp. 975-985.

Shoven, J. and Whalley, J. (1992) Applying General Equilibrium, Cambridge Surveys of Economic Literature, Cambridge University Press.

Small, K. (1983) “The Incidence of Congestion Tolls on Urban Highways”. Journal of Urban Economics, 13, 90-111.

Small, K.A. (1992) Using the Revenues of Congestion Pricing, Transportation, Vol. 19, No. 4, pp. 359-381.

Small, K.A., 1992. Urban Transportation Economics. Harwood Academis, Switzerland.

StaBuA, Statistisches Bundesamt (2004) Input-Output-Rechnung 2000, Volkswirtschaftliche Gesamtrechnungen, Fachserie 18, Reihe 2, Wiesbaden.

StaBuA, Statistisches Bundesamt (2005) Einkommens- und Verbrauchsstichprobe - Einnahmen und Ausgaben Privater Haushalte 2003, Wirtschaftsrechnungen, Fachserie 15, Heft 4, Wiesbaden.

StaBuA, Statistisches Bundesamt (2005) Einkommens- und Verbrauchsstichprobe - Aufwendungen privater Haushalte für den Privaten Konsum 2003, Wirtschaftsrechnungen, Fachserie 15, Heft 5, Wiesbaden.

StaBuA, Statistisches Bundesamt (2005) Einnahmen und Ausgaben Privater Haushalte 2003, Wirtschaftsrechnungen, Fachserie 15, Reihe 1, Wiesbaden.

StaBuA, Statistisches Bundesamt (2006) Inlandsproduktsberechnung: Detaillierte Jahresergebnisse 2005, Volkswirtschaftliche Gesamtrechnungen, Fachserie 18, Reihe 1.4, Wiesbaden.

Steininger, K. (2002) Environmentally Counterproductive Support Measures in Transport: A CGE Analysis for Austria, University of Graz, Department of Economics, submitted to the 2002 World Congress of Environmental and Resource Economists.

Steininger, K. and Friedl, B. (2004) Economic and Distributional Impacts of Nationwide Car Road Pricing: A CGE Analysis for Austria, paper submitted to the Thirteenth Annual Conference of the European Association of Environmental and Resource Economists, Budapest, June 2004.

Steininger, K., Friedl, B., and Gebetsroither, B. (2007) Sustainability impacts of car road pricing: A computable general equilibrium analysis for Austria. Ecological Economics, Volume 63, Issue 1, 15 June 2007, pp 59-69.

UNIfication of accounts and marginal costs for Transport Efficiency UNITE, http://www.its.leeds.ac.uk/projects/UNITE/, (10/03/2008).

Varian, H. (1992) Microeconomic Analysis, 3rd edition, Norton, New-York.

Verband Deutscher Verkehrsunternehmen (VDV) (2006) VDV-Statistik 2006, http://www.vdv.de/module/layout_upload/st2006_online.pdf, (10/03/2008).

# 1 Appendix

**List of Core Model Equations** (Source: Steininger and Friedl (2004))

Production

(1) $X_j = \min\left(H_j / A_j, X_{ij} / a_{ij}\right)$ *for* $j = 1, \ldots, 35$

(2) $H_j = \left(\delta_j L_j^{(\sigma_j - 1)/\sigma_j} + \left(1 - \delta_j\right) K_j^{(\sigma_j - 1)/\sigma_j}\right)^{\sigma_j / \sigma_j - 1}$ *for* $j = 1, \ldots, 35$

(3) $T^p = \min\left(T^{pf} / A^{pf}, T^{pv} / A^{pv}\right)$

(4) $T^{pf} = \min\left(X_i / A_i^{pf}\right)$

(5) $T^{pv} = \min\left(X_i / A_i^{pv}, km^p / A^{kmp}\right)$

(6) $T^u = \min\left(X_i / A_i^u\right)$

Foreign Trade

(7) $EX_j = EX_j^o \left(P_j^w / P_j\right)^{\varepsilon_j}$ *for* $j = 1, \ldots, 35$

(8) $M_j = M_j^o \left(P_j / P_j^w\right)^{\varepsilon_j}$ *for* $j = 1, \ldots, 35$

Labour Market

(9) $\dfrac{w}{p_p} \geq \overline{w_{low}} \perp u$

Household Demand

(10) $C_h = \left(\delta_h^C \; X_h^{C^{\left(\sigma_h^C - 1\right)/\sigma_h^C}} + \left(1 - \delta_h^C\right) T_h^{\left(\sigma_h^C - 1\right)/\sigma_h^C}\right)^{\sigma_h^C / \left(\sigma_h^C - 1\right)}$ *for* $h = h_1, \ldots, h_4$

(11) $X_h^c = \left[\sum_i \left(\delta_{h,i}^X X_{h,i}^{c^{\left(\sigma_h^X - 1\right)/\sigma_h^X}}\right)\right]^{\sigma_h^X / \left(\sigma_h^X - 1\right)}$ *with* $\sum_{\mathrm{i}} \left(\delta_{h,i}^X\right) = 1$ *for* $h = h_1, \ldots, h_4$

(12) $T_h = \left(\delta_h^T T_h^{p^{\left(\sigma_h^T - 1\right)/\sigma_h^T}} + \left(1 - \delta_h^T\right) + T_h^{u^{\left(\sigma_h^T - 1\right)/\sigma_h^T}}\right)^{\sigma_h^T / \left(\sigma_h^T - 1\right)}$ *for* $h = h_1, \ldots, h_4$

## Variables

Source: Steininger and Friedl (2004)

| | |
|---|---|
| **Factor demand** | |
| L | Total labour demand |
| K | Total capital demand |
| | |
| **Production** | |
| $X_j$ | Gross production of sector j |
| $K_j$ | Capital input in sector j |
| $L_j$ | Labour input in sector j |
| $H_j$ | Factor aggregate in sector j |
| $A_j, a_{ij}$ | Leontief-input -output -coefficients in sector j |
| $\delta_j$ | CES-distribution parameter in sector j |
| $\sigma_j$ | Elasticity of substitution in production between labour and capital in sector j |
| | |
| **Foreign trade** | |
| $EX_j$ | Export of sector j |
| $M_j$ | Import of sector j |
| $P_j$ | Production price of goods aggregate X in sector j |
| $P^w_j$ | World market price of goods aggregate M in sector j |
| $EX^0$, $M^0$ | Export and import quantities in sector j in the reference year |
| $\varepsilon_j$ | Foreign trade price elasticity of demand in sector j |
| | |
| **Labour Market** | |
| w | Nominal wage rate |
| $W_{low}$ | Lower bound on the real wage rate |
| $P_p$ | Paasche index of the aggregate price level |
| u | Rate of unemployment |

| | |
|---|---|
| **Transport** | |
| $T^p$ | Private car passenger transport |
| $T^{pf}$ | Private car passenger transport production fixed input |
| $T^{pv}$ | Private car passenger transport production variable input (directly kilometre dependent) |
| $T^u$ | Public passenger transport |
| $A^{pf}$, $A^{pv}$, $A^{pf}_i$, $A^{pv}_i$ | Leontief-input -output -coefficients in private car passenger transport |
| $A^{kmp}$ | Kilometre input coefficient in private car passenger transport |
| $A^u_i$ | Leontief-input -output -coefficients in public transport |
| $km^p$ | Vehicle kilometres driven in private car transport |
| | |
| **Consumption** | |
| $C_h$ | Total Consumption of household type h |
| $X_h^C$ | Consumption of non-transport goods of household h |
| $T_h$ | Transport consumption of household h |
| $\delta_h^C$ | CES-distribution parameter in consumption for household h |
| $\delta_h^T$ | CES-distribution parameter in transport consumption for household h |
| $\delta_{h,i}^X$ | CES-distribution parameter in non-transport consumption for household h |
| $\sigma_h^C$ | Elasticity of substitution between transport and non-transport demand for household h |
| $\sigma_h^T$ | Elasticity of substitution between private car transport and public transport demand for household h |
| $\sigma_h^X$ | Elasticity of substitution between non-transport goods in household h consumption |