An assessment of road-pricing measures on household travel demand in Germany using a computable general equilibrium framework"

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Abstract: We describe the modification of an Austrian computable general equilibrium (CGE) model in order to construct such a model and database for Germany. Our objective is to assess the impact of road pricing measures on household travel demand and some economic indicators. To account for the distributional effects of regulative policy instruments such as road pricing in the transportation sector, we introduce different household categories. Depending on the distribution of private households over different income categories, specific travel demand patterns and a revenue redistribution structure, an overcompensation effect of the road pricing charge can be observed in Germany for the lowest income category.

Keywords: Computable general equilibrium model, Passenger road travel, Road pricing

1 Introduction

Increased greenhouse gas emissions resulting from the excessive growth in the global fossil fuel consumption is seen as one of the major causes of catastrophic weather incidents as well as falling life quality in regions suffering from environmental pollution. Production sectors that rely heavily on the use of fossil fuels in their production processes create negative externalities on the rest of the economy. The transportation sector is an important example of such market failures, where prices do not correctly reflect the social costs imposed by its services.

In industrialized countries, the transportation sector contributes around 30 % to overall national carbon emissions. A significant share of it arises from motorized passenger travel. Nevertheless, intervening policy measures in the German transportation sector aiming at the reduction of fossil fuel consumption have been rather indirect, mostly being a mineral oil tax or road user charge applied in the freight transport sector. Other policy pricing measures, such as road use charging in the passenger car travel sector, tolling, or even the introduction of emission permit trading are subject to widespread discussion, but the still lack concrete realization plans. Probably the most important hindrance to broaden and diversify the scope of implemented road use charging measures is the low public acceptance of such instruments.

The degree of acceptance in the economy for the policy measure depends on the (potential) welfare gain of the majority of its agents affected by the reform. On the individual level, acceptance can be expected if individual utility is not diminished. The difficulty with individual utility preservation and the overall welfare increases is the uneven distribution of such gains (see Mayeres and Proost (2002), Farrell and Saleh (2005)). This is particularly the case where the implementation of policy instruments in the motorized passenger travel sector is concerned. In order to assess the impact of transport policies, e.g., distance dependent road pricing, on different households, distinguished according to income level and geographical region, in the German economy, we extend an existing computable general equilibrium (CGE) model. The original Austrian Road Pricing Model was introduced and implemented in Steininger and Friedl (2004) to assess the consequences of road pricing policies in Austria. We adjust this model and extend the underlying Social Accounting Matrix

(SAM) to account for specific characteristics of travel demand modelling.

The organisation of the paper is as follows. The main objective of this paper is the impact assessment of the introduction of road pricing in the German economy. We refer to different household classes and to those aspects of passenger travel, which are of main relevance to evaluate the effects from implementing policy measures in the overall economic context. Section 2 provides a description of the Austrian Road Pricing model. Section 3 discusses the main extensions to the model and to the underlying database to make the ARPM model suitable for application to the German economy. In Section 4 we introduce the results from applying the model to assess the impact of road pricing in different household classes distinguished according to income. Section 5 concludes.

2 General model structure

For information on CGE models, we refer to Shoven and Whalley (1992) or, more recently, to Ginsburgh and Keyzer (1997). We distinguish between multiregional CGE models, where the world is subdivided into multiple regions, and a single region GGE model, where only one region is studied.

2.1 The German Road Travel Policy Model (GRTPM)

The German Road Travel Policy Model (GRTPM) is based on the Australian Road Pricing Model (ARPM), introduced in Friedl and Steininger (2004).[1] We apply this model to German data. The model is a single country computable general equilibrium (CGE) model with 36 production sectors, among others agriculture (LAWI), coal (KOHLE), manufacture of refined petroleum products (OELBB), extraction of crude petroleum and natural gas (OELVER), electricity, ferrous and non ferrous metals, (EISEN), chemicals (CHEMIE), metal (METALL), machines (MASCH), electrical goods (ELEINR), transport equipment (FAHRZ), rubber and

[1] The ARPM has been developed and implemented by Prof. Steininger and his research fellows from the University of Graz. The authors would like to thank Professor Karl Steininger for making the ARPM model available.

plastic products (GUMMI), construction (BAU), distribution (HANDEL), land transport (VERK), water and air transport (SUL), supporting and auxiliary transport (SVERK), finance and insurance (GELD), other market services (SODIEN), and non market services (NMDIEN). We enumerate these sectors with *es* or *ss*. The GRTPM model is a static model, implying that goods are not distinguished by time. The model therefore represents the state of the economy at the date of its calibration.

The model contains three consumption households, one consumer household 'cons', a government household 'govt', and a household that refers to the intake of road pricing revenues 'rpa' or the road pricing agency. The consumer household represents private consumption and passenger transport demand while the government household represents public consumption in the economy. Labour and capital are the production factors. Furthermore, there exists a foreign exchange sector 'fx' referring to the import and export relations with the rest of the world. We consider private and public forms of transport, each represented by a production sector 'priv' and 'pub' respectively.

Functional forms

Each agent is modelled using either a representative microeconomic consumption household or production household (see Varian (1993)). A consumption household is characterized by a preference ordering over the obtainable goods described by a utility function, and by a budget set that is limited by his income. The consumer is assumed to choose that bundle of goods in his budget set that maximally satisfies his preferences, i.e., his behaviour can be described by utility maximization over his budget set. A production household is assumed to possess a production technology that transforms an input bundle consisting of all goods in the economy and of the production factors, into an amount of its output good. The producer is assumed to choose that production or input-output bundle that maximizes its profit, i.e., his behaviour can be described as profit maximization over the production set defined by his technology. Both agents are assumed to take the prices of the goods as given.

Calibration of a CGE model includes a choice on the functional form for the utility functions and the production technologies. Mainly, these functional forms are some kind of constant elasticity of substitution

(CES) function due to its advantageous properties with respect to flexibility, and its consequences on the assumptions with respect to the existence and uniqueness of equilibrium in this model. Depending on the degrees of freedom in choosing the elasticity of substitution, we distinguish a constant elasticity of substitution when the substitution elasticity is equal between all goods but its value is allowed to vary between 0 and infinity, a Cobb-Douglas function where the substitution elasticity is assumed to be equal to one, and a Leontief function where the substitution elasticity is assumed to be zero.

For computation reasons and to fit the data on which the CGE is calibrated, we prefer to write the CGE model in its dual form instead of aforementioned primal form. This means that we use the equivalence between expenditure minimization and utility maximization, and between cost minimization and profit maximization. Likewise, we can present each functional CES form in its calibrated dual form. We refer to the literature, such as Varian (1993) or Shoven and Whalley (1992) for details.

The substitution elasticity between goods usually varies over the pairs of goods. In order to obtain some more flexibility in calibrating a CGE model, one often resorts to a nested structure of CES functions, CD functions and Leontief functions. The input goods can be categorized into groups having similar substitution elasticity. Depending on this grouping, one can obtain composites using an appropriate functional form. Then, by grouping the composites further, some flexibility in the calibration to substitution elasticities is reached. In this way, we obtain a tree structure of composites where the root is given by a composite whose value represents total cost or expenditure, and the end nodes represent the single input goods (see Armington (1969)).

The production sectors

Each economic sector *es* is represented by a microeconomic production household that owns a constant returns to scale production technology. The sector produces x(*es*) units of its output good using g(*ss*,*es*) units of the other goods *ss* as intermediate inputs, k(*es*) units of capital and l(*es*) units of labour as primary inputs in such a way that the costs per unit of output are minimized. Total revenue equals total cost, following the nonzero profit assumption on a constant returns to scale technology. The total costs of production sector *es* are decomposed into the cost of obtaining g(*ss*,*es*) units each input good *ss* at a price of pg(*ss*) per unit, and the cost, of obtaining lk(*es*) units of the labour-capital composite ‘elk’ at a price of plk(*es*) per unit, using a Leontief production function. The latter costs are decomposed in the labour cost, pl (1+tl) l(*es*), and capital costs, pk (1+tk) k(*es*), using a CES function with elasticity of substitution elk. Here, the cost includes that ad-valorem tax tk resp. tl on capital resp. labour input.

The cost of the region’s total demand for composite good *es*, pg(*es*) g(*es*), is decomposed into the cost, of obtaining y(*es*) units of the domestically produced variant of this good at a price of py(*es*) per unit and the cost, of obtaining m(*es*) units of the imported variant of this good at a price of pm(*es*) per unit. We assume a finite elasticity of substitution telas(*es*) between the domestically produced variant and the imported variant. This is known as Armington’s Assumption.

The total revenue, px(*es*) (1+tix(*es*)) x(*es*), of a production sector *es*, including an ad-valorem output tax rate of tix(*es*), consists of revenue, py(*es*) y(*es*), obtained on the domestic market and the revenue, pex(*es*) ex(*es*), obtained on the export market. This decomposition uses a Constant Elasticity of Transformation (CET) function with elasticity of transformation telas(*es*).

Trade relations with the rest of the world are included into a single country CGE model through the introduction of an artificial production household. Through export, the country obtains foreign exchange while it pays with foreign exchange for its imports. Hence, the economy obtains a revenue pfx efx(*es*) on foreign exchange at the cost of pex(es) ex(*es*) on exports, and a revenue of pm(*es*) m(*es*) of imports at the cost of pfx mfx(*es*) on foreign exchange, on each production good *es*. Cost minimizing input quantities are given by ex and mfx at corresponding prices p. Output levels of the production sectors are given by efx and m again at corresponding prices p. This concludes the trade closure of the model.

The transport sector

The transport sector consists of car transport (‘priv’) and public transport (‘pub’). Private transport refers to car transport. We only refer to passenger transport, hence the demand for transport by the private household cons. Each of these sectors is modelled using a microeconomic production household possessing a constant returns to scale technology and striving to minimize costs per unit of output. Revenue p^{priv} priv of the private transport production sector is decomposed in the cost from obtaining oil, pg('OELVER') (1+trpa) g^{priv}('OELVER'), in the cost of car use, pg('FAHRZ') (1+trpa) g^{priv}('FAHRZ'), in the trade cost, pg('HANDEL') (1+trpa) g^{priv}('HANDEL'), and in the cost, pg('GELD') (1+trpa) g^{priv}('GELD'), using a Leontief production function. These costs contain the cost of road pricing in the form of an ad-valorem tax rate trpa.

Revenue p^{pub} pub of the public transport production sector equals the cost of obtaining g^{pub}('VERK') units of the goods from the transportation production sector 'VERK' at a price of pg('VERK') per unit.

The consumer household

This model assumes that the economy's production resources labour and capital are owned by the private consumer as are its endowment of foreign exchange. He does not own any endowment in the other goods. The consumer is supposed not to obtain any utility from holding the production factors and foreign exchange so he obtains his income M^C from selling his labour endowment L at a price of plinc per unit, his capital endowment K at a price of pk per unit, and his foreign exchange endowment FX at a price of pfx per unit. Furthermore, he obtaines a net transfer T at a price of pT per unit from the government and a road pricing refund RPR at an after tax price of p^{rpr} (1-tiv) per unit.

$$M^C = pl^{inc}\, L + pk\, K + pfx\, FX + pT\, T - pT\, (1-u)\, U + p^{rpr}\, (1-tiv)\, RPR.$$

This income provides the consumer with a budget with which he can obtain a welfare maximizing bundle of goods at minimal expenditure, given the market prices of the goods. Total expenditure on ucons units of utility at a price of pucons per unit by the consumer is decomposed into the expenditure on w units of a non-transport goods composite at a price of pw per unit, and the expenditure of v units on a transport goods composite at a price of pv per unit, using a CES functional form with elasticity of substitution equal to 0.9. On the one hand, the consumer household's total expenditure pw w on a non-transport composite is decomposed into the expenditure, pg(*es*) cons(*es*), on each good *es*, using a Cobb Douglas production function. The consumer household's total expenditure pv v on the transport composite is decomposed into the expenditure,

p^{priv} c^{priv}, on private transport, and the expenditure, p^{pub} c^{pub}, on public transport using a CES production function with elasticity of substitution equal to 1.6.

The government household

The government household is assumed to obtain his income from paying a net transfer T at a price of pT per unit, from collecting production taxes from the producers, labour and capital taxes from the producers, from the tax income tiv included in the road price refund, and from transport tax levied on the use of production goods in the private transport sector,

$$M^G = - pT\ T + pT\ (1\text{-}u)\ U + tiv{*}p^{rpr}\ RPR + \sum_{es} tix(es)\ px(es)\ x(es) + \sum_{es} tl\ pl\ l(es)$$

$$+ \sum_{es} tk\ pk\ k(es) + tiv\ (\ pg(\text{'OEVER'})\ giv(\text{'OEVER'}) + pg(\text{'FAHRZ'})\ giv(\text{'FAHRZ'})$$

$$+ pg(\text{'HANDEL'})\ giv(\text{'HANDEL'}) + pg(\text{'GELD'})\ giv(\text{'GELD'})\ ).$$

This income provides a government budget that can be spent on the purchase of consumption goods. Total public expenditure pu^{govt} u^{govt} of the government is decomposed into the expenditure $pg(es)$ $c^{govt}(es)$ on each composite good es, using a Cobb Douglas functional form. This represents the country's public expenditure. The use of the CD functional form implies that only a fixed proportion of the household's income M^G is used for each alternative.

The road pricing agency

This model introduces a consumption household called the road pricing agency 'rpa' which obtains his income M^S from collected road pricing refunds RPR at an after tax price of p^{rpr} (1 - tiv) including taxes tiv paid on transport

$$M^S = p^{rpr}\ (1\text{-}tiv)\ RPR.$$

Income is assumed to be a part of the income of the consumer household, M^C. This income, consisting of u^{rpa} units of utils at a price of p^{rpa} per util is therefore obtained as a part of the supply of private transport used by the production sector 'BAU', pg('BAU') c^{rpa}('BAU') and as a part of the supply of private transport used by the production sector 'VERK', pg('VERK') c^{rpa}('VERK') using a Cobb Douglas functional form. The use of the CD functional form implies that only a fixed proportion of the household's income M^S is obtained from each alternative.

Equilibrium

We assume that there is perfect competition on the markets. In this model, this means that the prices of all produced goods equal their marginal costs of production. The goods markets are then cleared by the output levels of the production sectors. The prices of the production factors, labour and capital, are determined as the market clearing price. We assume that both production households as well as consumption households are price takers. Many CGE models also include income conditions in the definition of an equilibrium, where total expenditure for each consumption household equals its total income.

This model distinguishes among three consumption households, each of them with a budget defined by its income, the consumer, government, and the road pricing agency. For the consumer, total private expenditure on the consumption of goods should equal this household's income M^C:

$$pu^{cons}\ u^{cons} = M^C.$$

For the government household, total public expenditure on its consumption of goods should equal this household's income M^G obtained from taxes, subsidies, and road pricing revenues:

$$pu^{govt}\ u^{govt} = M^G.$$

The road pricing agency obtains its income M^S from the after tax road pricing refunds and this income is completely spent in the transport sector:

$$p^{rpa}\ u^{rpa} = M^S.$$

On each production factor market, prices are such that total demand equals total supply. Each market is assumed to be regional, i.e., referring to the German market itself. Hence, on the labour market, the wage rate pl is such that:

$$\sum_{es} l(es) = L(1\text{-u}).$$

The capital market is cleared by the price pk, hence pk is such that:

$$\sum_{es} k(es) = K.$$

Then, on the foreign exchange market, supply of foreign exchange by the consumer and obtained through exports is met by demand for foreign exchange stemming from imports through the price pfx of foreign exchange:

$$\sum_{es} (\mathrm{mfx}(es) - \mathrm{efx}(es)) = \mathrm{FX}.$$

On each market for tradable composite good *es*, output level x(*es*) is such that total demand for good *es* is satisfied. For each composite *es* ∉{'BAU','VERK','OELVER','FAHRZ','HANDEL', 'GELD'}, production is such that it satisfies demand for this good as an input into the production sectors ss, and as consumption good by the consumer and the government:

$$g(es) = \sum_{ss} gx(es,ss) + c^{cons}(es) + c^{govt}(es).$$

The composite 'BAU' is also used as a consumption good by the road pricing agency, leading to extra demand on this market:

$$g(\text{'BAU'}) = \sum_{ss} gx(\text{'BAU'},ss) + c^{cons}(\text{'BAU'}) + c^{govt}(\text{'BAU'}) + c^{rpa}(\text{'BAU'}).$$

The composite good 'VERK' is also used as a consumption good for the road pricing agency, but it also serves as an input good in the public transport production sector:

$$g(\text{'VERK'}) = \sum_{ss} gx(\text{'VERK'},ss) + c^{cons}(\text{'VERK'}) + c^{govt}(\text{'VERK'}) + g^{pub}(\text{'VERK'}) + c^{rpa}(\text{'VERK'}).$$

The composite goods *es* ∈{'OELVER', 'FAHRZ','HANDEL','GELD'} are also used as inputs in the private transport sector. Hence:

$$g(es) = \sum_{ss} gx(es,ss) + c^{cons}(es) + c^{gov}(es) + g^{priv}(es).$$

Also on each transport market, prices are such that total demand equals total supply. We only consider passenger transport, which implies that the supply of public as well as private transport only needs to cover the demand for these transport means by the consumer. Hence, for the public transport market, the market clearing becomes:

$$pub = c^{publ},$$

while on the private transport market:

$$priv = c^{priv}.$$

3 The database extension

A proper assessment of the impact of regulative pricing policy measures implemented in the passenger travel sector requires an explicit consideration of the economic behaviour of private households with respect to travel choice, which in turn depends on individual or household-specific socioeconomic and sociodemographic attributes.[2] Obviously, some of these attributes not only determine the demand for travel, but they also influence households' reaction to changes in the supply conditions of travel, e.g., to the variation in prices of a kilometer traveled in a car. However, apart from a few exceptions (see Mayeres (1998, 2004), Broecker (2002), Mayeres and Proost (2002), Steininger (2002), Munk (2003), Steininger and Friedl (2004), Schaefer and Jacoby (2005, 2006)) most CGE models are somehow limited with respect to impact assessment of passenger travel pricing measures, basically because demand for passenger travel is not explicitly included, neither in the model database, nor in the model structure.

The primary objective of our CGE model is to account for this shortcoming for the case of Germany and include passenger travel demand into the model. We therefore extend the ARPM model described in the previous section with different private household types according to income categories and corresponding travel expenditure and travel behaviour parameters. This allows us to model the distributional effects emerging from household income specific travel demand patterns. The model distinguishes between the demand for private and public transport. Within the demand for private transport, we account for the household expenditure and investments in car travel. We include additional sectors into the model through the model specification. The new passenger travel demand related sectors integrated into the model are linked to already existing sectors, such as 'crude oil', 'vehicles' and 'trade', etc..

3.1 The introduction of different private household categories

[2] We refer to Hautzinger (1978), Dargay (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 modelling, car purchase, car ownership and car use modelling.

To optimize the suitability of the CGE model for the evaluation of the distributional effects from policy intervention over different income classes in the passenger road travel sector, the model distinguishes among multiple household categories. Each household category is characterized by a uniquely parametrized utility function, described for the consumer household in the ARPM model in Section 2, and specific endowments of capital and labour. Household category specific primary factor endowments determine its wage and capital income. Corresponding to differences in income distribution, notable variations in household specific travel demand patterns exist. A comparable relationship can be observed for different income categories and land use attributes. Thus, to account for different land use characteristics, three residential location attributes were defined. We differentiate between households living in urban, suburban and rural areas. Table 1 illustrates the correlation between household income and residential location for passenger car travel.

< insert here Table 1: Passenger car travel for different household income categories and residential location types >

For Germany we observe that private households falling into the highest income category (3,600 Euro per month) use the car four times more intensive than people in the lowest household income category, or almost twice the car use intensity of an average car user in Germany. In the agglomeration areas, where by definition the concentration of big cities is the highest, car use intensities as to annual vehicle kilometres driven per household are the lowest, even though the differences are not very pronounced. Table 2 depicts the distribution of public transport demand among different household income and residential location types.

< insert here Table 2: Public transport travel for different household income categories and residential location types >

The depicted travel activity patterns for households falling into different income categories as well as for households located in residential areas with different population densities clearly demonstrates existing variations in travel behaviour within the private household sector. These two aspects are of particular relevance for the assessment of the acceptability towards different road travel pricing measures, mainly because private households' price and income elasticities with respect to (road) travel demand depend to a great extend on income and also on the availability of substitution alternatives to the car, where the latter is proxied by the residential location (see Dargay and Gately (1999), Dargay (2001), Hanly et al. (2002), Giuliano and Dargay (2006)). Following these differences in travel behaviour among defined categories, we distinguish initially four household groups according to income. For the construction of household income-specific travel patterns different 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). To include household specific travel demand patterns into the model, we use travel activity parameters expressed in kilometers. Furthermore, we consider two different transportation modes: public transit and motorized individual car travel, where public transit contains local public transport as well as long distance public traffic. In addition to mobility parameters, we use household expenditure data on relevant transportation related goods and services within the classification of individual consumption by purpose (COICOP/ HICP 2000). Table 3 shows the remarkable differences in the distribution of household income and selected household consumption expenditures categorised by different income levels.

< insert here Table 3: Income and travel expenditure distribution by different household income categories>

Figure 1 shows a simplified structure of the model database modification by splitting the private household sector into different categories.

< insert here Figure 1: Schematic picture of SAM disaggregation by household income categories >

Through a specification of the road travel demand elasticities derived from micro-econometric modelling and partially adapted from secondary literature on travel demand research, we implicitly consider important results from behavioural analysis in travel demand modelling (for extensive literature survey see Goodwin (1992), Johansson and Schipper (1997), Graham and Glaister (2002a, 2002b and 2004), Goodwin et al. (2004), Blum et al. (1988)).

Finally, another important purpose of the household-categorical disaggregation within a CGE model framework is to allow for the assessment of (re-)distributional effects from a reallocation of collected revenues from, e.g., road pricing measures imposed on passenger cars. Fact is, that the final effect of a regulative pricing instrument on social welfare within an economy, i.e., economic growth, individual utility, and fiscal revenues depends on the use or transfer of monetary returns collected from the measure (see Small (1992), Meyers (2000, 2001), Mayeres and Proost (2002), Farrell and Saleh (2005)).

In the model used in this study, a separate sector represents the implementation of the road pricing measure. The road pricing institution collects and redistributes the revenues flowing back from the application of the policy measure. The road pricing measure can be implemented as a distance-dependent mark-up on the price of private transport in Cent per vehicle-km. The road pricing agency itself consumes 15 % of the revenues total. The consumption of the road pricing agency is considered as intermediary input flows from the sectors ‘insurance and banking’, ‘electronic devices’ and the factor ‘labour’. Other 50 % of the revenue flows go into public transport. The remaining 35 % of the revenues total from road pricing are redistributed within the private household sector. This revenue redistribution to the private household categories is effected in varying proportions in correspondence to the different private household income levels. As a result from defining different household income categories, it becomes possible to apply the model to assess equity effects from imposing road pricing policy by the government and respectively redistribute the fiscal revenues from the measure to, e.g., support households belonging to the lowest income category. Furthermore, the structure of revenue redistribution among the different sectors participating in the process can be chosen to meet different policy objectives.

3.2 The constructing the private transport sector

With the inclusion of private household categories differentiated to income and residential location, already one shortcoming as found in most of the existing CGE models as far as accounting for passenger travel is concerned has been tackled. When taking into account the representation of passenger road travel demand, input factors flowing into the household generation process of car travel need to be considered: we distinguish between two basic categories of inputs: consumptive factors and household investment expenditure on car travel.

The first category depends almost entirely on household specific car use patterns and combines expenditure on car fuels, fuel taxes and levies, car repair and maintenance costs, and different kinds of costs for parking. Correspondingly to these variable expenditures, we include another cost component, which contains different kinds of fixed costs related to car ownership and maintenance, such as households spending on newly purchased passenger vehicles and second-hand cars together with insurance expenditure and fixed annual road taxes. Figure 2 portrays the extensions and modifications carried out in the original database in order to account for the specifics of private car travel.

< insert here Figure 2: Schematic picture of SAM disaggregation by car-travel related sectors >

In the final step, the functional structure of the model and the model code will be adjusted in correspondence to the country specific database and in correspondence to the systematic approach for the nested structure of private household demand, including demand for travel activity and durable cars.

4 Results

We introduce two policy scenarios by varying the level of a distance dependent road pricing measure imposed on users of passenger cars between 5 Cent/km and 15 Cent/km.

Already the descriptive comparison of different household income categories with respect to their consumption of transportation goods and services as well as to their income proportions as illustrated in Table 4 and Table 5, gives important background-information for the interpretation of the effects from the implemented road pricing scenarios.

< insert here Table 4: Income distribution by different household income categories >

One remarkable quality that we observe when examining the proportion of the total household income accumulated in the lowest income category, is its relatively small volume. In Germany, households with an income level less than 1,300 Euro obtain only 3.2 % of the overall private household income volume from labour and only 2 % of the overall private household income volume from capital.

< insert here Table 5: Travel expenditure distribution by different household income categories >

The lowest income category merits again some attention, when comparing household specific expenditurestructures, since in this category all transport expenditure positions are by far the lowest. For instance, the share of the lowest household income group in the overall variable transport expenditures amounts to just 5.8 %.

In Table 6, the results for the two different road pricing levels and the different household income categories are summarized considering private transport demand bundle, car transport demand, public transport, and welfare including transport and without it.

< insert here Table 6: Results from introduction of different levels of road pricing on selected economic and travel behaviour indicators >

In general, overall private household transport demand as well as the demand for car travel both decrease gradually but degressively with rising road pricing levels. Welfare reduction for the different household income categories is by far more moderate, when transport is not included in t he consumption bundle. Households in the highest income category seem to react much less elastic to the implemented policy measure. They also experience the relatively lowest welfare losses, compared to the three other household classes. In contrast the household category with the lowest disposable income experiences the highest decline in demand for travel, mainly car travel. When looking at welfare effects considering transport, they also display the highest welfare reductions. When the welfare effect is considered without transport, households in the second lowest income categories experience the largest negative impact. It is interesting to observe, that despite the cost increase of car travel through the implementation of road use charges, household demand for public transport does not increase for all different household income categories. The opposite is the case; due to welfare increases, the relatively inelastic car travel demand against the background of its rising price, demand for public transport apparently also experiences a significant drop. This is in particular the case for the two lowest household income categories.

In our experiment with varying levels of the imposed road pricing charge we examined the macroeconomic effects caused by the policy measure implementation. Regarding the volume of revenues generated from the pricing policy measure, we observe a degressive raise in road charge revenues by increasing the amount charged per car-kilometre – from 17,570 mio. Euro in the case of a 5 Cent road-km use charge to 46,286 mio. Euro when 15 Cent per km of road use charge are imposed.

Gross domestic product (GDP) experiences a positive development as result from the measure implementation. Furthermore, the growth of economic activity induced by the introduction of road pricing takes place independently whether or not we consider sectors related to the passenger travel and the implementation of road pricing.

In line with the overall positive economic effects from the introduction of road pricing, the employment in the German economy also rises. Directly linked to this positive labour market effect, the absolute number of unemployed as well as the unemployment rate exhibit a slight decline with respect to the rising level of the road charge implemented on cars. Together with rising overall economic activity, also the demand of the government household shows an expanding tendency. In contrast to this, the overall welfare implies a negative change.

Results obtained for selected economic sectors as correspond to some of 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 road pricing. The most significant decline can be observed for the sectors 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 clearly exhibit a positive development, e.g., construction or non-market services. The most remarkable growth is yet revealed for the land transport sector. Nevertheless, also sectors linked to the economic activity of the road pricing collection agency display a positive upward trend, e.g., electrical goods or the banking and finance sector.

5 Concluding remarks

We implement a CGE model in order to properly assess the impacts that regulative policy measures have on agents' behaviour on one hand and on the entire economy on the other. 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 modelling literature, factors influencing individual or household behaviour 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 heterogonous 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 one as investment 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 passenger car travel sector. Depending on the distribution of private households between different income categories, specific travel demand patterns, and the revenue redistribution structure, different effects of the road pricing measure can be observed in Germany for different household categories. The organisation of the revenue collection and redistribution is basically decisive for the macroeconomic welfare as well as the sectoral impacts. Therefore it has a great impact potential for the acceptability of regulative road pricing instruments. Inclusion of other characteristics, which explain private household reaction to policy intervention will allow to better target observable effects from such measures. These extensions are household residential location and land use attributes or the endowment with durable (capital) goods, e.g., motor vehicles.

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Table 1: Passenger car travel for different household income categories and residential location types

Private car travel (as driver and passenger) per household (hh) in the category and per year in 2002										
Type of residential location as to population density and accessibility	Income category, in Euro per month									
	< 1,300		**1,300 to < 2,000**		**2,000 to < 3,600**		**>= 3,600**		**Total**	
	In 1,000 km	Number of hh in mio..	In 1,000 km	Number of hh in mio..	In 1,000 km	Number of hh in mio..	In 1,000 km	Number of hh in mio..	In 1,000 km	Number of hh in mio..
Agglomeration area	9.4	6.7	18.5	3.9	28.9	6.9	41.1	2.6	22.0	20.1
Urban area	11.5	4.7	23.2	2.5	33.9	4.5	47.1	1.4	25.2	13.0
Rural area	12.8	1.7	18.1	0.9	37.8	1.6	42.6	0.5	25.6	4.7
Total	10.6	13.0	20.1	7.3	31.7	12.9	43.1	4.5	23.5	37.7
Source: Survey MiD 2002, own calculations DIW Berlin.										

Table 2: Public transport travel for different household income categories and residential location types

Public transit travel per household (hh) in the category and per year in 2002										
Type of residential location as to population density and accessibility	Income category, in Euro per month									
	< 1,300		**1,300 to < 2,000**		**2,000 to < 3,600**		**>= 3,600**		**Total**	
	In 1,000 km	Number of hh in mio..	In 1,000 km	Number of hh in mio..	In 1,000 km	Number of hh in mio..	In 1,000 km	Number of hh in mio..	In 1,000 km	Number of hh in mio..
Agglomeration area	2.5	6.7	2.6	3.9	3.1	6.9	3.8	2.6	2.9	20.1
Urban area	1.4	4.7	1.9	2.5	2.3	4.5	3.0	1.4	2.0	13.0
Rural area	0.9	1.7	1.0	0.9	3.0	1.6	4.5	0.5	2.0	4.7
Total	1.9	13.0	2.1	7.3	2.8	12.9	3.6	4.5	2.5	37.7
Source: MiD 2002, own calculations DIW Berlin.										

Table 3: Income and travel expenditure distribution by different household income categories

Income and travel expenditure distribution by different household income categories, in % of overall total household income or expenditure volume									
Income categories	Number of households in mio.	Households in % of the total	Labour income	Capital income	Total transport exp.	Fix transport exp.	Variable transport exp.	Public transport exp.	Exp. on (new) car purchase
< € 1,300	7.7	19.8	3.2	1.9	5.2	3.9	5.8	12.8	1.5
< € 2,600	13.2	34.0	18.1	15.5	24.1	22.7	25.6	28.3	18.8
< € 3,600	7.3	18.8	20.2	19.0	22.1	22.0	23.2	18.1	22.0
>= € 3,600	10.7	27.4	58.5	63.6	48.7	51.4	45.4	40.8	57.7
Total	38.9	100.0	100	100	100	100	100	100	100
Source: EVS 2003, own calculations DIW Berlin.									

Table 4: Income distribution by different household income categories

Income distribution by different household income categories, in % of total German household income		
Household income category	Labour income	Capital income
less than € 1,300	3.2	1.9
less than € 2,600	18.1	15.5
less than € 3,600	20.2	19.0
more than € 3,600	58.5	63.6
Source: EVS 2003, own calculations DIW Berlin.		

Table 5: Travel expenditure distribution by different household income categories

Travel expenditure distribution by different household income categories, in % of total expenditure for a given transport category					
Household income category	Total transport exp.	Fixed transport exp.	Variable transport exp.	Public transport exp.	Exp. on (new) car purchases
less than € 1,300	5.2	3.9	5.8	12.8	1.5
less than € 2,600	24.1	22.7	25.6	28.3	18.8
less than € 3,600	22.1	22.0	23.2	18.1	22.0
more than € 3,600	48.7	51.4	45.4	40.8	57.7
Source: EVS 2003, own calculations DIW Berlin.					

Table 6: Results from introduction of different levels of road pricing on selected economic and travel behaviour indicators

Household income category	Effects from introduction of different levels of road pricing on selected economic and travel behaviour indicators, in %-change compared to the base line				
	5 Cent/km				
	Private transport demand bundle	Car transport	Public transport	Welfare including transport	Welfare excluding transport
less than € 1,300	-15.7	-16.1	-13.9	-14.6	-1.2
less than € 2,600	-11.1	-11.2	-10.0	-10.1	-3.3
less than € 3,600	-8.0	-8.1	-7.1	-7.4	-1.8
more than € 3,600	-2.7	-2.7	-2.4	-2.9	-0.4
	15 Cent/km				
less than € 1,300	-31.4	-31.9	-27.9	-29.2	-3.4
less than € 2,600	-25.6	-25.8	-23.3	-23.4	-8.8
less than € 3,600	-19.4	-19.6	-17.4	-17.9	-5.1
more than € 3,600	-7.5	-7.6	-6.6	-7.8	-1.3
Source: EVS 2003 and VGR 2001 German Federal Statistical Office, own calculations DIW Berlin.					

Figure 1: Schematic picture of SAM disaggregation by two-dimensional household categories as to income and residential location classification

Figure 2: Schematic picture of SAM disaggregation by car-travel related sectors

Figure 1

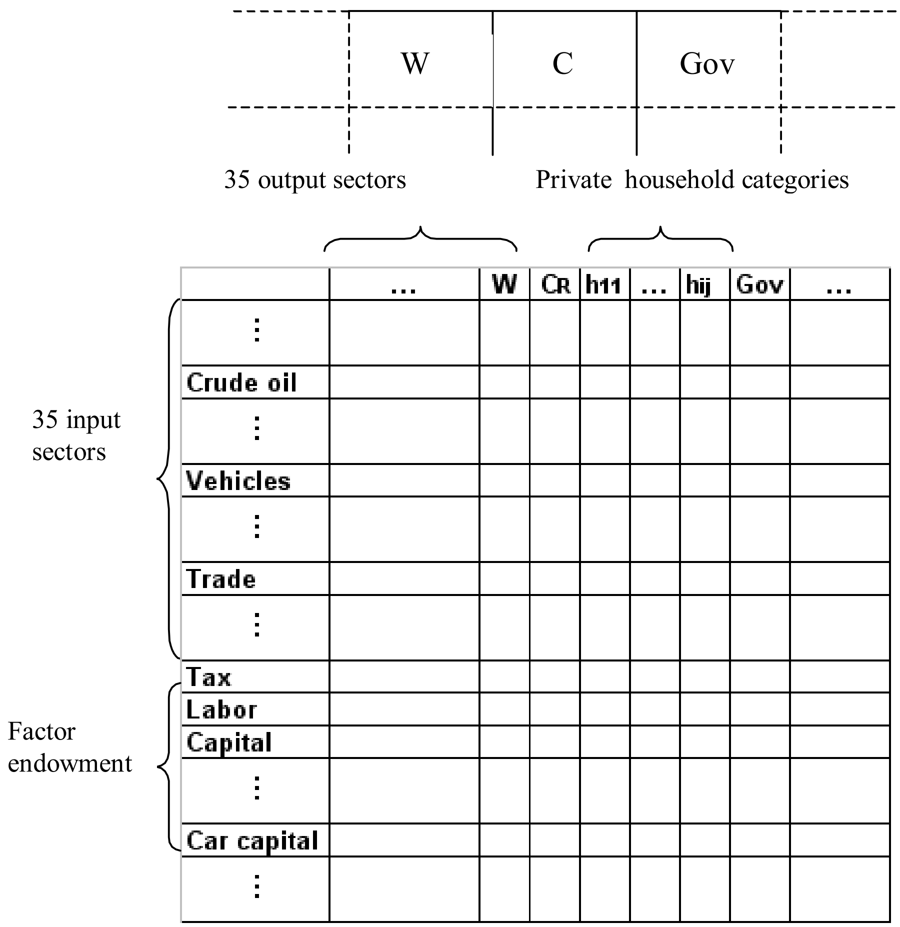
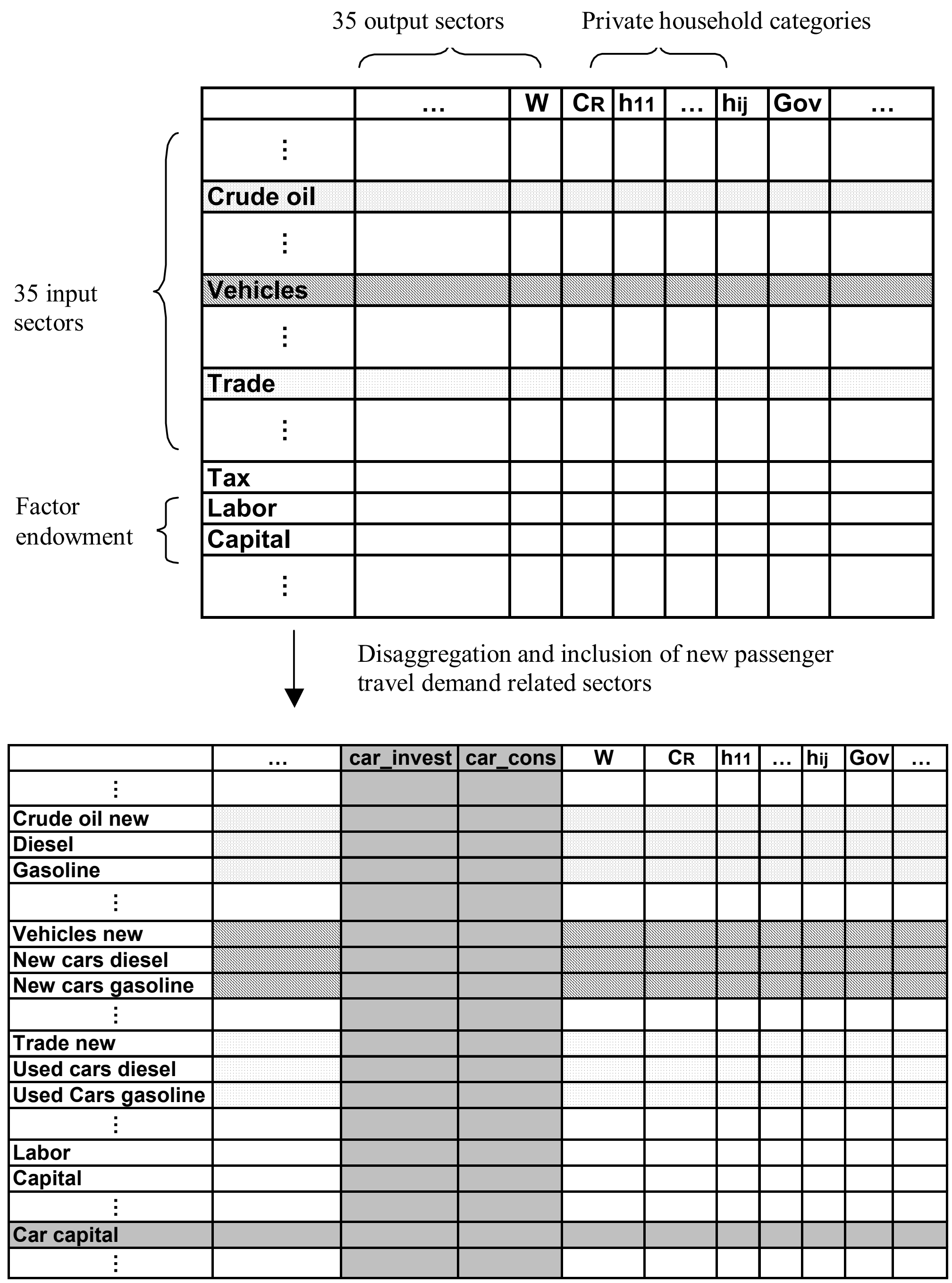

W
C
Gov
35 output sectors
Private household categories
...
W
CR
h11
...
hij
Gov
...
Crude oil
Vehicles
Trade
Tax
Labor
Capital
Car capital
35 input sectors
Factor endowment

Figure 2


35 output sectors
Private household categories
…
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hij
Gov
…
35 input sectors
Crude oil
Vehicles
Trade
Tax
Factor endowment
Labor
Capital
Disaggregation and inclusion of new passenger travel demand related sectors
car_invest
car_cons
Crude oil new
Diesel
Gasoline
Vehicles new
New cars diesel
New cars gasoline
Trade new
Used cars diesel
Used Cars gasoline
Labor
Capital
Car capital