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Macroeconomic Assessment of Vehicle Carbon Policies

Using a Transport-CGE-Model for Germany

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- DRAFT -

1. Introduction

The transport sector is a significant contributor to EU greenhouse gas emissions and therefore in focus of substantial climate policy regulation in Germany and the EU. Carbon dioxide (CO₂) emissions in road transport alone have been steadily rising during the past years. Currently, it contributes about one-fifth to the EU's total CO₂ emissions. In this regard, especially the reduction of CO₂ emissions from passenger cars is a major focus of climate policy regulation. In Germany, there are two policies in place aiming at the reduction of CO₂ emissions from passenger cars: the CO₂ oriented vehicle tax for car owners and the CO₂ emission performance standards for car producers (fleet targets).

In this paper we quantify the macroeconomic implications of these carbon policies. Two main questions drive our analysis: (1) which mechanisms do these policies trigger in private transport? (2) How do these policies perform concerning their macroeconomic impacts?

The paper is organized as follows. Chapter 2 gives an overview of vehicle carbon policies in the EU and Germany. Chapter 3 describes the methodology and modeling approach in the CGE-Framework. Chapter 4 describes the dataset. Chapter 5 entails the scenario analysis and model calculations. Chapter 6 concludes and discusses further research issues.

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2. Vehicle carbon policies in the EU and Germany

Transport is responsible for around a quarter of EU greenhouse gas emissions making it the second biggest greenhouse gas emitting sector after energy. More than two thirds of transport-related greenhouse gas emissions are from road transport, which makes up one-fifth of the EU's total emissions of carbon dioxide (CO₂). Passenger cars alone are responsible for around 12%. While emissions from other sectors are generally falling, those from road transport have continued to increase since 1990.³

In this regard, the EU has adopted a comprehensive strategy to reduce CO₂ emissions from new passenger cars sold in the EU. Due to its mobile and local emissions, the transport sector is difficult to regulate within an emissions trading scheme, as is done in the energy sector, i.e. mainly electricity generation. As the major regulatory measure, the EU therefore focuses on CO₂ emission performance standards for new passenger cars. The Regulation (EC) No. 443/2009 sets the average CO₂ emissions for new passenger cars at 130 g CO₂/km, by means of improvement in vehicle motor technology.⁴ A further reduction of 10 g CO₂/km, or equivalent if technically necessary, is to be delivered by other technological improvements and by an increased use of sustainable biofuels. The regulation officially comes into effect in 2012. There is a phasing-in from 65% in 2012 until 100% in 2015. From 2020 onwards, the Regulation sets a target of 95 g CO₂/km. Figure 1 shows the historic and projected evolution of CO₂ emissions from new passenger cars, as monitored by the European Environment Agency (2010).

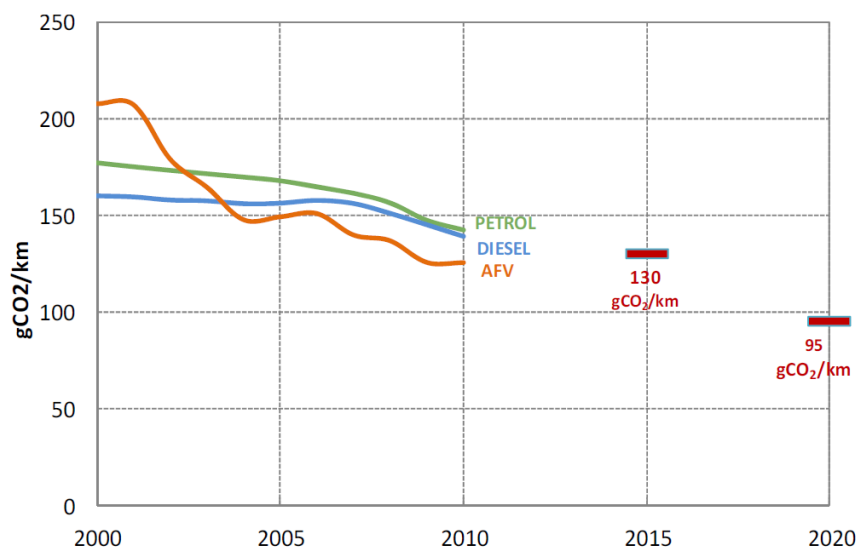
If the average CO₂ emissions of a manufacturer's fleet exceed its limit value in any year from 2012, the manufacturer has to pay an excess emissions premium for each car registered. The directive implements additional innovation incentives: given the use of environmental friendly innovations, manufacturers' specific targets are reduced by up to 7 g CO₂/km. The European approach allows pooling of manufacturers, i.e. manufacturers are allowed to jointly fulfill their average specific emission targets. Therefore, it imposes some flexibility of carbon mitigation but full flexibility using tradable permits is not achieved.⁵

³ However, from 2000 this mainly attributes to goods transport.

⁴ In 2010, average CO₂ emissions of new passenger cars in the EU amount to 140.3 g/km (EU10: 147.9). Slovakia is the only country where the CO₂ emissions increased from 2009 to 2010 (+ 2%). Germany, in the second place, has made the lowest progress in reducing CO₂ emissions (- 2.5%). European Environment Agency, 2011.

⁵ Cf. Abrell (2010).

Figure 1: Evolution of CO₂ emissions from new passenger cars by fuel (EU27) ⁶



Although not mandatory, several Member States have amended their car taxation schemes and introduced a CO₂-related element to complement the emission performance standards for passenger car production by more cause-oriented instruments such as differentiated car and energy taxes. In this regard, Germany has implemented a CO₂-oriented vehicle tax, which tackles car ownership. It is raised annually per vehicle and consists of two parts:

- (a) a fee for cubic capacity (gasoline: 2€ per 100 ccm, diesel: 9,50€ per 100 ccm)
- (b) a fee for CO₂ emissions (2€ for each g CO₂/km above 120 g CO₂/km).

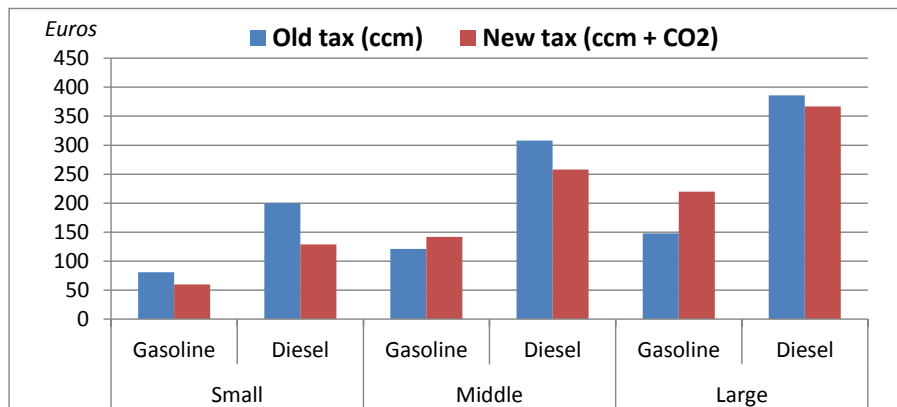
The new tax is valid for new car registration from 2009. Existing cars keep being taxed according to the old scheme. They will be smoothly phased-in until 2013. For further information see Jochem et al. (2008), UBA (2011) as well as Bundesfinanzministerium (2009).

Figure 2 illustrates the variation between the old and new tax scheme exemplary for the six car classes included in our Model (further description in chapter 3 and 4). The comparison builds upon the tax calculator on the homepage of the German Federal Ministry of Finance (BMF).⁷ As you can see, small car as well as Diesel car owners benefit from the new tax.

⁶ European Environment Agency (2011), Monitoring the CO₂ emissions from new passenger cars in the EU - summary of data for 2010, p. 5. AFV = Alternative fuel vehicles.

⁷ Cf. Bundesfinanzministerium (2012).

Figure 2: Comparison of old and new vehicle tax



Both supply-side and demand-side approaches are supposed to contribute to the reduction of CO₂ emissions from passenger cars by influencing consumer choice and behavior via the costs of purchasing and operating a vehicle. From an economic point of view, however, it is disputable whether mandatory standards are advisable, since they do not allow equal marginal abatement cost of carbon across the economy, i.e. they do not implement carbon reduction at lowest cost. Furthermore, the challenge in designing an appropriate CO₂-oriented vehicle tax lies in the definition of the underlying tax rate. Setting such vehicle carbon policies also yields uncertainties regarding their macroeconomic consequences, i.e. concerning the competitiveness of manufacturers, the direct and indirect costs imposed on business and the benefits that accrue in terms of stimulating innovation and reducing energy consumption.

3. Methodology and modeling approach

To assess private transport demand and macroeconomic impacts of vehicle carbon policies within a closed income circle we develop a modified version of the static small open economy Computable General Equilibrium (CGE) model for Germany established in Abrell (2010). The model entails a detailed disaggregation of the transport sector. CGE models represent the interactions of economic agents on markets in terms of price-induced production and consumption decisions. Due to their total-analytic framework, CGE models are especially suited to capture feedback effects between one agent (or sector) and the rest of the economy.

In general, consumer's welfare is not generated from flows of goods and services as measured in national accounts, but by consumption of services that are generated by a combination of flows with a specific capital stock (Kratena et al., 2006). In our model, therefore, households derive utility from the consumption of transport services (person-kilometers), and not from the purchase of vehicles,

energy or vehicle services separately. Vehicles are purchased, but not consumed at the same time. By providing utility over their lifetime, they are comparable to investment goods that depreciate over time. These so called durable goods are stocks that provide utility by providing recurrent service flows. Energy and services are non-durable goods as they are consumed in one instance. The decision of purchasing a durable good is made upon user cost prices (Conrad, 1983; Conrad & Schröder, 1991), rather than market prices, meaning the price of a vehicle plus its costs of using it. This involves expenditure for fuel as well as operation and maintenance services.

Our strategy for modeling household transportation is similar to Paltsev et al. (2004) who create a household production activity that combines goods purchased from industry to produce an own-supplied transportation service that represents use of personal automobiles. Figure 3 shows our approach to include transport demand into a standard CGE model framework. The passenger transportation activity is differentiated into work and leisure trips, which enter consumption and labour supply respectively. Consumers can satisfy their transport demand by choosing between different transportation modes, i.e. public modes and private cars. Public transport distinguishes air, rail and local public transport. Private car technologies are differentiated by engine size and fuel used.

Figure 3: Including transport demand in a standard CGE framework

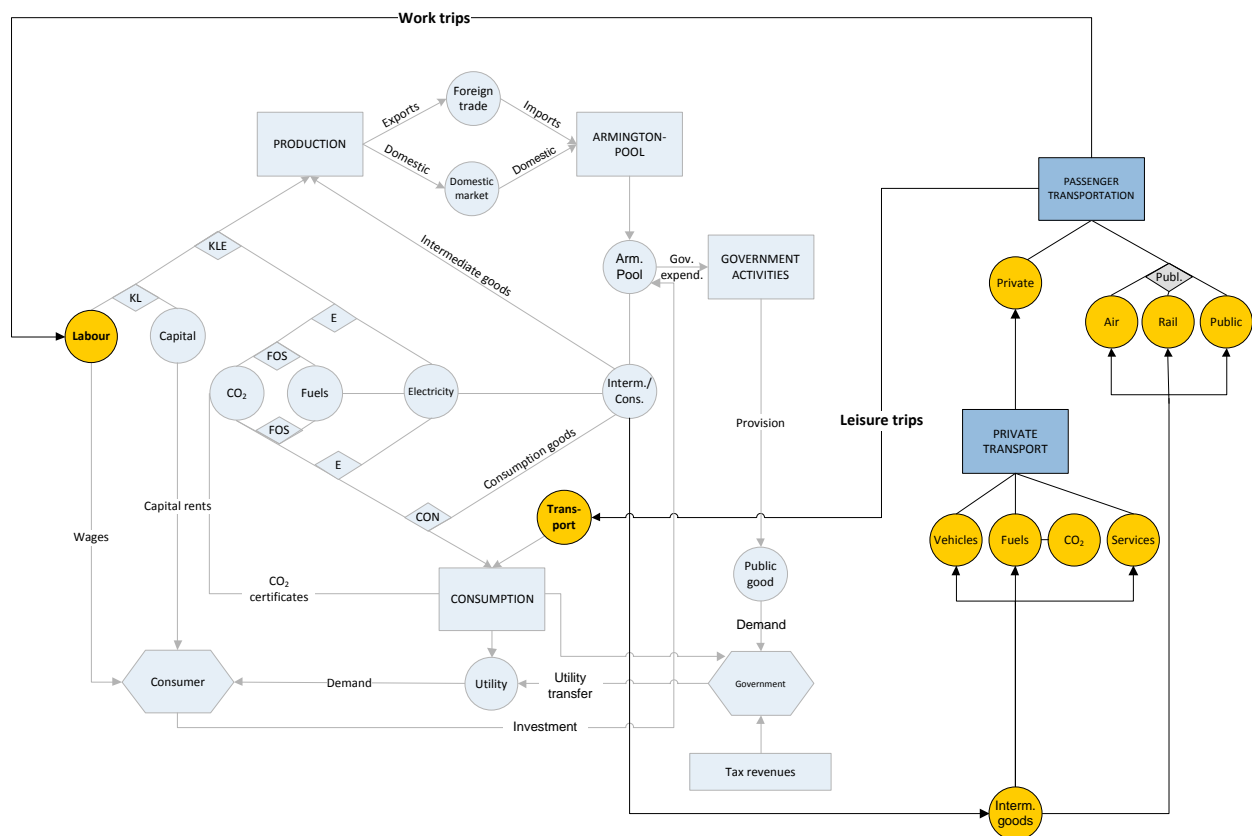
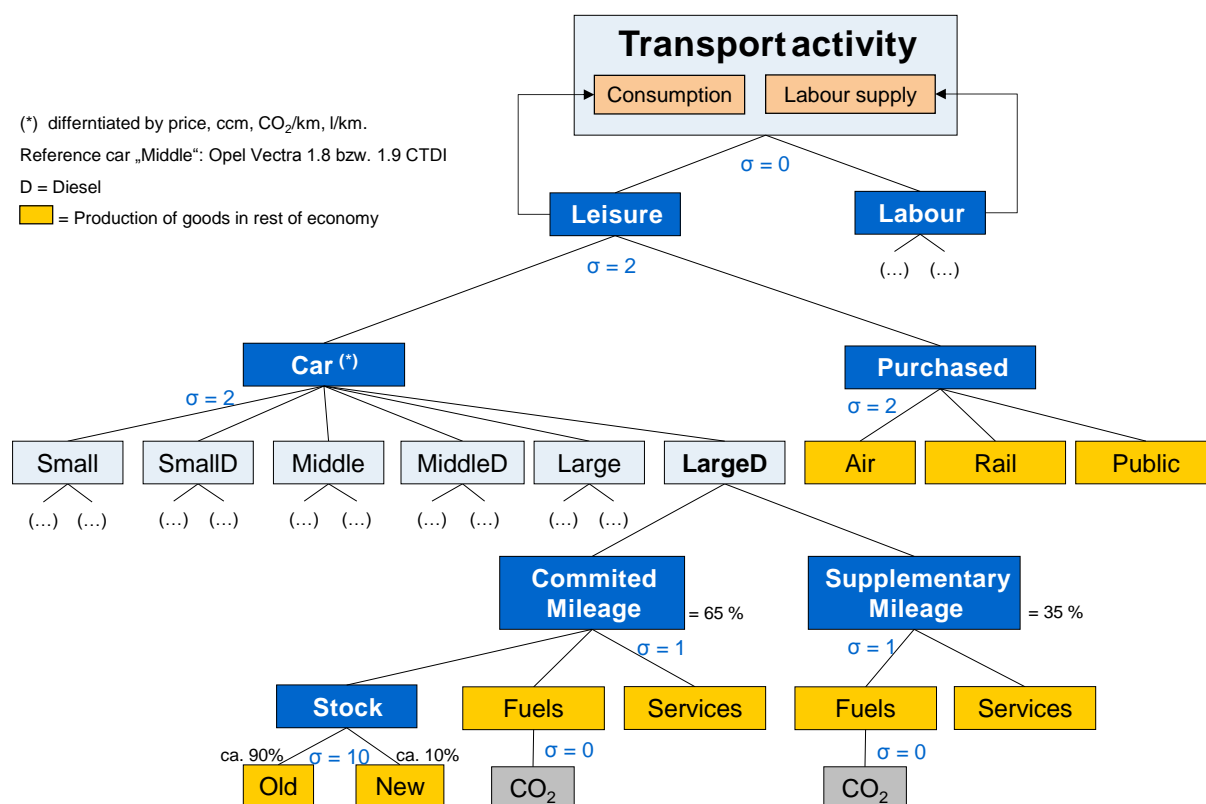


Figure 4 illustrates the nesting structure of producing the transport activity. Substitution elasticities are based on a literature review (Berg, 2007; Koopman, 1995; Munk, 2003, 2005; Paltsev et al., 2005; de Ceuster et al., 2007).

Figure 4: CES Modelling



Following the approach of Koopman (1995) in the EUCAR model, we distinguish between committed and minimum mileage of cars expressing the fact that consumers can react in two ways to rising fuel prices. First, reducing supplementary mileage to save the variable cost and keeping the number of available cars constant. Second, the consumer can reduce the number of car purchases reducing committed mileage. The approach is based on the assumption that buying an automobile implies a certain minimum of kilometers driven per year. Consequently, the committed mileage is characterized by the rental cost for the car and the variable cost implied by minimum kilometers driven. In addition, it is possible to drive more kilometers – the supplementary mileage – which are only characterized by variable cost. According to de Jong (1991) the share of committed mileage in observed kilometers driven is around 65%.

The CO₂ oriented vehicle tax is implemented as an increase of the circulation tax on new cars (see chapter 5). The existing cars within the vehicle stock are taxed according to the old tax scheme.

Emission performance standards are modeled as a separate good which constitutes a joint output and additional input in vehicle production both at the same, varying in the degree of the CO₂

performance of each car technology (cf. Thorpe, 1997). Each new car purchase requires input of efficiency certificates depending on the car specific efficiency value measured in g CO₂/km. Moreover, each purchase has an output of these certificates in the magnitude of the imposed standard. Consequently, cars with an efficiency exceeding the standard, i.e. the g CO₂/km undercut the standard supply permits purchased by those car manufactures falling short on the standard.

4. Dataset

The data base is the German Input-Output-Table (VGR) as well as the Physical Input-Output-Table (UGR) from 2004 provided by the Federal Statistical Office of Germany (Destatis).

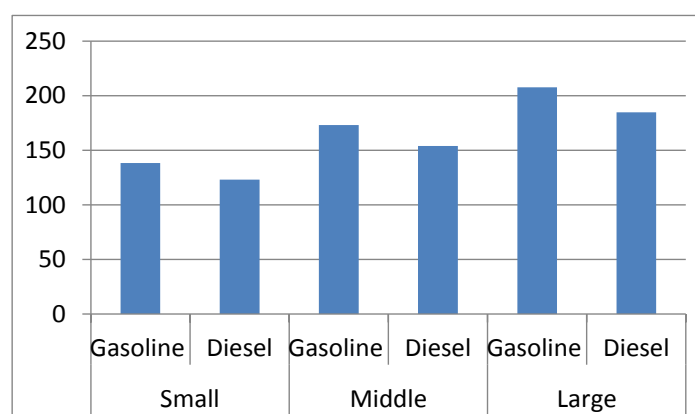
Transport and vehicle specific data has been gathered by different sources: DIW (German Institute for Economic Research (DIW), 2006, Verkehr in Zahlen 2006/2007, Deutscher Verkehrsverlag, Hamburg, 2006), car catalog 2008 (Auto Katalog, Nr. 51, Modelljahr 2008, Motorbuch Verlag) and KBA (Federal Motor Transport Authority). For a full description of the construction of the underlying database refer to Abrell (2010). Table 1 summarizes the characteristics of the six vehicle types.

Table 1: Characteristics of the six vehicle types

| Type | Small | | Reference car | | | |
|----------------------------|----------|--------|--------------------------|-----------------------------|----------|--------|
| | Small | | Middle | | Large | |
| Fuel | Gasoline | Diesel | Gasoline (Vectra 1.8) | Diesel (Vectra 1.9 CDTI) | Gasoline | Diesel |
| Price (€) | 17300 | 18580 | 24710 | 26540 | 32120 | 34500 |
| Gasoline (l/km) | 6.5 | - | 7.2 | - | 8.6 | - |
| Diesel (l/km) | - | 5.1 | - | 5.7 | - | 6.8 |
| ccm | 1200 | 1300 | 1796 | 1910 | 2200 | 2500 |
| gCO₂/km | 138 | 123 | 173 | 154 | 208 | 185 |
| No. in stock (Mio.) | 10.702 | 2.607 | 19.931 | 4.979 | 5.548 | 1.445 |

Figure 5 illustrates distribution of the specific CO₂ emissions per car type. The fleet average amounts to 164 gCO₂/km. In this dataset, only small diesel cars lie below the 130 gCO₂/km threshold.

Figure 5: Illustration of the specific CO₂ emissions per car type (gCO₂/km)



5. Scenario analysis and results

Having implemented the vehicle carbon policies into the model, we conduct scenario analyses, setting the CO₂-oriented vehicle tax, in line with the imposition of the emission performance standards. We are interested in the mechanisms that these policies are supposed to trigger in transport demand as well as their macroeconomic performance and whether the implementation of supply and demand side policies both at the same time is complementary or conflicted.

The new vehicle tax penalizes middle and large gasoline cars and favors small gasoline as well as all diesel cars. To simulate this process, we double the tax for middle gasoline cars and triple it for large gasoline cars. Furthermore we simulate a fleet target decrease from the baseline value of 164 gCO₂/km to the proposed 130 gCO₂/km, which is a 20% reduction. We implement 3 scenarios: two for each policy and one for the combination of both:

Our scenario definition looks as follows:

- 1) Single implementation of a CO₂-oriented vehicle tax (scenario *TaxG*, see figure 6)
 - Penalize gasoline cars (doubling the tax for middle and tripling it for large gasoline cars)
- 2) Single implementation of emission performance standards (scenario *Eff130*, see figure 7)
 - Impose a fleet target of 130 gCO₂/km
- 3) Combined implementation of both policies (scenario *Eff130TaxG*)

Figure 6: Vehicle tax variation

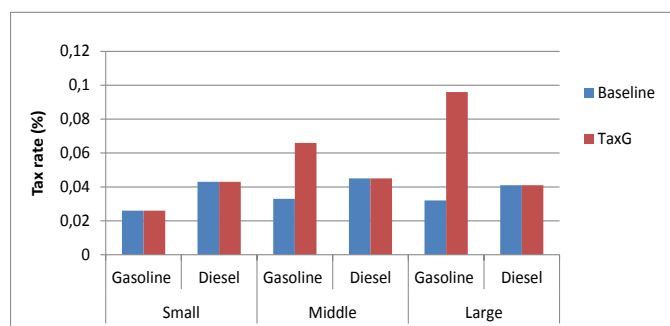
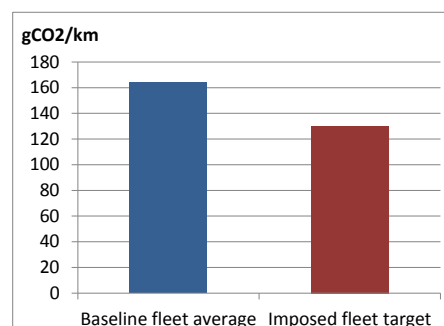


Figure 7: Imposing emission performance standard



The goal of this scenario definition is to simulate the current policies, both individually as well as in combination and assess its impacts on the composition of the vehicle stock, private transport demand and tax revenues generated. Due to the disaggregated representation of private transport alternatives and car technologies, the model determines the change in the modal split of private transport as well as the composition of the vehicle fleet. This indicative numbers are used to assess the consequences of the emission performance standards as well as the increased vehicle tax in order to gain more insights into the rational of these policies.

The first results of our calculations are summarized in figures 8 to 12. On a first glance you can see that the TaxG scenario involves little changes only, whereas the Eff130 scenario as well as the combined scenario Eff130TaxG impacts more severely.

In the TaxG scenario the vehicle stock attributes more small and diesel cars and less middle and large gasoline cars. The demand for transportation modes as well as their relative prices show only little variation. A slight price increase for car demand leads to a small demand shift towards purchased transport. The increased vehicle tax leads to more tax revenues mainly for middle gasoline cars, which leads to total tax revenue increase by 20%. The tax revenues are redistributed to the consumer via lump-sum utility transfers compensating for the tax payments.

The Eff130 scenario as well as the combined Eff130TaxG scenario yield similar results, indicating that the emission performance standard sets a stronger constraint to the economy than the CO₂-oriented vehicle tax. In the vehicle stock there is a massive shift from middle and large gasoline cars towards small cars, especially diesel. This forced substitution raises the cost for private transport by almost 40% and leads to an increased demand for purchased transport relative to car use by almost 8%. The distribution among the purchased transportation modes remains relatively stable with a marginal advantage for rail services (ptrain). The reduction of new car purchases in the vehicle stock leads to lower vehicle tax revenues by 15% compared to the baseline and 30% compared to the TaxG scenarios. Therefore the lumpsum transfer from the government to the consumer decreases.

Figure 8: Composition of vehicle stock

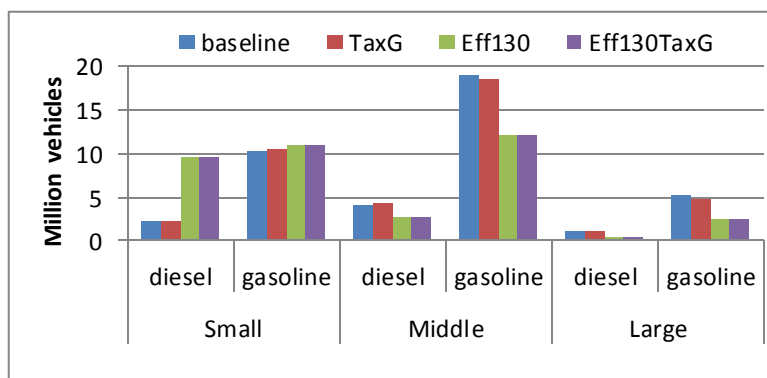


Figure 9: Relative price of transportation modes

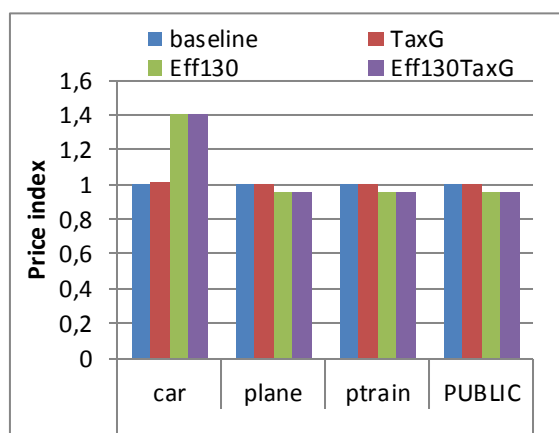


Figure 10: Demand for purchased transport relative to car

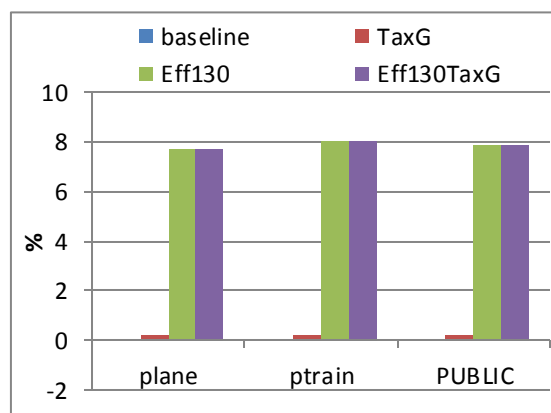


Figure 11: Vehicle tax revenues (by vehicle type)

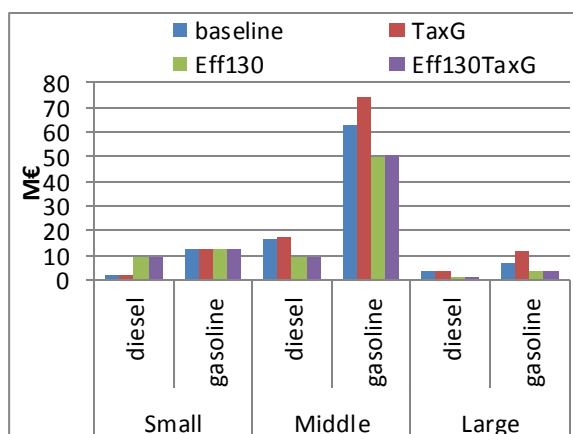
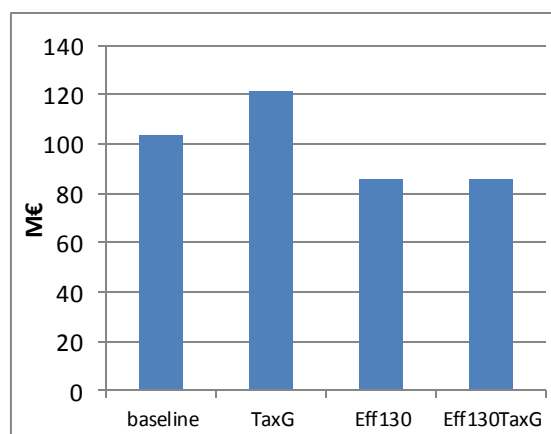


Figure 12: Vehicle tax revenues (total)



6. Conclusion and discussion

This draft paper contains the outcome of our first calculations using a modified version of the static small open economy Computable General Equilibrium (CGE) model for Germany established in Abrell (2010).

We isolated the effects of two different policy approaches as well as the combination of the two. In reality there is a variety of policies in place at the same time. Therefore it is important not only to look at isolated effects of a single policy but to take into account possible interactions and feedback effects of a combination of these. Our results indicate that the CO₂ emission performance standard of 130 gCO₂/km (-20%) is a heavy constraint to Germany's 2004-economy, where the average specific CO₂ emissions of the vehicle stock amount to 164 gCO₂/km. The CO₂-oriented vehicle tax, however, shows only little effects in the structure of transport demand, but rather results in higher tax revenues for the government. This implies that the finance function of the tax is greater than its steering effect.

The examination of our results, however, raises further points of discussion. Firstly, the analysis of the new CO₂-oriented vehicle tax has shown that diesel cars, especially large ones benefit from the new scheme. This raises the question whether it may be appropriate to also tax diesel cars more effectively. On the one hand they emit less CO₂ per km, but on the other they have other emissions such as particulate matter.

Secondly, the emission performance standard is an average fleet target. It neither impacts the absolute level of stock, nor the absolute numbers of each vehicle class and consequently not the total CO₂ emissions coming out of the vehicle stock as a combination of the average vehicle used and the level of private transportation activity. CO₂ emissions may increase if people switch from middle gasoline to large diesel cars or if people drive more kilometers in response to a decrease in unit cost per km. For further insights into this issue see studies on the *rebound effect*, such as Frondel et al. (2007) or Breakthrough Institute (2011).

Thirdly, the dynamic development of an economy is driven by innovation, which is able to substitute for labor, energy and material. An economy can respond to an efficiency target not only by substituting existing vehicles by each other, but also by improving the efficiency of the vehicles. This implies shifts in the combination of inputs for the production of a certain level of output. For example, increased use of light aluminum instead of heavier steel products reduces specific energy use and CO₂ emissions. This implies that there are structural shifts that transform the value chain of the economy, which can also be strongly expected by the increased production of electric vehicles (Fraunhofer 2010). From a life-cycle point of view, it is debatable whether the reduction of specific CO₂ emissions leads to a proportional decrease in overall CO₂ emissions as intermediate production (e.g. aluminum) entails higher CO₂ emissions as before (so called *carbon footprint*). In addition, more efficient cars need less fuel and therefore may cost less per km leading to an increase in transport demand (again the rebound effect). This is reason enough for us to pursue the goal of implementing

marginal abatement cost curves to better capture the substitution possibilities in vehicle production following dynamic and innovative shifts.⁸

The extension of our modeling work therefore includes the implementation of marginal abatement cost curves, the assessment of the ecological effectiveness of the vehicle carbon policies as well as deeper insights into overall macroeconomic cost efficiency of the policies.⁹

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⁸ Marginal abatement cost curves have been provided by different sources, inter alia McKinsey&Company (2007) or CE Delft (2009).

⁹ For a detailed discussion on assessment criteria of policies in environmental economics, see Wiesmeth (2012).

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