THE IMPACT OF FISCAL POLICIES ON PASSENGER CAR TRANSPORT ENERGY DEMAND IN OECD COUNTRIES

Amela Ajanovic, Energy Economics Group, Vienna University of Technology, Phone +43 58801 373 64,
E-mail: ajanovic@eeg.tuwien.ac.at
Reinhard Hass, Energy Economics Group, Vienna University of Technology , Phone +43 58801 37352,
E-mail: haas@eeg.tuwien.ac.at

Abstract

Continuously rising CO_2 emissions are still a major problem of transport activities world-wide. Although most developed countries have introduced a broad portfolio of policy measures to reduce greenhouse gas emissions, they continue to increase virtually all over the world. Passenger car transport contributes the largest share to this problem.

The core objectives of this paper are: (i) to provide a survey on fiscal policies for car passenger transport in major OECD countries; (ii) to analyze their corresponding impact on energy consumption, service demand (vkm driven), and fuel intensity in passenger car transport, and (iii) to extract to what extent which tax policies are a promising instrument to reduce energy consumption and GHG emissions.

With respect to the future development of car passenger transport the major perception of this analysis is that only a broad portfolio of policy instruments with a core focus on standards and taxes will be necessary to reduce fuel intensity, energy consumption as well as GHG emissions significantly.

1. INTRODUCTION

Passenger cars contribute the largest share of CO_2 emissions in transport. Although most developed countries have introduced a broad portfolio of policy measures to reduce greenhouse gas emissions, they continue to increase virtually all over the world. The already applied policy measures such as voluntary agreements between car manufactures in Europe and energy labeling for new cars have so far not shown significant reduction of greenhouse gas emissions.

Another important option for reducing CO_2 emissions are several kinds of fiscal policy measures. They could force car users to change behavior – to reduce travel activity, to buy smaller cars with higher energy efficiency or to switch to other transport modes if possible.

The fiscal policy measures across the OECD countries are very different and many tax regimes have been designed with revenue generation rather than environmental enhancement as a primary motive (Sterner, 2007).

Regarding the attitude of countries to fiscal policies measures there are at least four major different reasons for introducing fiscal policy measures. The first and oldest reason for taxation is to generate general tax income, to increase the government income. Second reason for taxation is to finance existing or new infrastructure. Third and currently very important reason is reduction of greenhouse gas emissions, which could be reduced for example through the taxation of the CO_2 emissions. Forth, due to implementing fiscal policies like road tolls congestion can be reduced.

The most important fiscal policies measures in passenger road transport are:

- tax on acquisition/registration: fixed taxes paid once when purchasing or registrating a car (incl. a value added tax (VAT));

- tax on ownership: periodical fixed taxes paid independent of the amount of kilometers driven;
- value added tax (VAT): VAT is based on the before tax sale price of the car
- motoring taxes/taxes on fuels: excise duties and VAT on fuel.

The core objectives of this paper are: (i) to provide a survey on fiscal policies for car passenger transport in major OECD countries; (ii) to analyze their corresponding impact on energy consumption, service demand (vkm driven), and fuel intensity in passenger car transport, and (iii) to extract to what extent which tax policies are a promising instrument to reduce energy consumption and GHG emissions.

In this analysis we focus on the following OECD-countries, from which data are available for longer time series: From the EU the countries analyzed are: Austria, Germany, Denmark, France, Spain, Sweden, Italy and The Netherlands. Outside from Europe we analyze Australia, Canada, Japan and United States,

The fiscal policies analyzed in this paper are fuel taxes and registration taxes. In the next sections we provide a survey on tax policies and the major historical development in different OECD countries. Then the impacts of fuel taxes and registration taxes on travel activity, car ownership level, new car registration, fuel intensity and energy consumption in individual passenger transport are analyzed using econometric analyses.

2. SURVEY ON TAX POLICY MEASURES IN PASSENGER CAR TRANSPORT IN SELECTED OECD-COUNTRIES

In this section we give a brief survey of tax policies in passenger road transport in selected European and non-European OECD countries.

In the EU road transport produces over 70% of transport CO_2 emissions, of which passenger cars make up more than half and these emissions continue to grow strongly. The European strategy of CO_2 reduction encompasses voluntary agreements with the car manufactures, consumer information and fiscal policies measures.

At present in the European Union there is little Community legislation or efforts towards harmonization of fiscal policies applied by the Member States in the area of passenger car taxation. Therefore, it is for each Member State to lay down national provisions for the taxation of these cars.

As shown in Table 1, the criteria for registration taxes are quite different across the European Union. The major parameters the taxes are based on fuel consumption, on cylinder capacity, CO_2 emissions and price. Taxes on ownership for passenger cars are mostly based on kilowatt, cylinder capacity, CO_2 emissions, fuel consumption and weight.

The range of Value Added Tax (VAT) in EU-27 is between 15% (United Kingdom) and 25% (Denmark and Sweden). The European average of the VAT is about 20 %.

Table 1. Taxes on acquisition and ownership (Data source: ACEA, 2009)

Country	VAT	Registration tax	Ownership tax
Austria	20%	Based on fuel consumption Maximum 16% + bonus/malus	kW
Germany	19%	None	Cylinder capacity, exhaust emissions CO2 emissions (as from July 2009)
Denmark	25%	105% up to DKK 79,000 180% on the remainder	Fuel consumption, weight
Spain	16%	Based on CO2 emissions From 0% (up to 120g/km) to 14.75% (above 200g/km)	Horsepower
France	19.6%	Based on CO2 emissions From € 200 (161 to 165g/km) to € 2,600 (above 250g/km)	None
Italy	20%	IPT + PRA + MCTC	kW, exhaust emissions
The Netherlands	19%	Based on car price + CO2 emissions 40% - € 1, 394(petrol) 40% + € 290 (diesel)	Weight, province
Sweden	25%	None	CO2 emissions, weight
United Kingdom	15%	None	CO2 emissions, cylinder capacity

The by far highest registration tax is implemented in Denmark. The lowest automobile taxation – registration tax as well as fuel tax – is applied in the USA (see e.g. Schipper, 1995). Compared to European countries there is virtually an absence of taxation.

In Japan auto-related taxes includes car tax, car weight tax and car acquisition tax:
1. Car Acquisition Tax - Levied based on the acquisition price of the vehicle at the time of purchase.
2. Car Weight Tax - Fixed amounts of tax are levied according to vehicle weight for each type of automobile at the time of inspection.
3. Car Tax - Fixed amounts of taxes are levied each year according to total engine displacement and according to type of vehicle, as well as the purpose of the car's use.
The level of car taxation in Japan is similar to the European average.

In Europe a major share of fuel price are taxes – VAT and excise tax. The share of tax on fuel is very different in Europe, approximately in the range from 43% to 63% for gasoline, and 37% to 58% for diesel. As shown in Figure 1, in all selected European OECD countries share of fuel tax in the total gasoline price is over 50%. Tax on diesel compared to gasoline is about 10% lower.

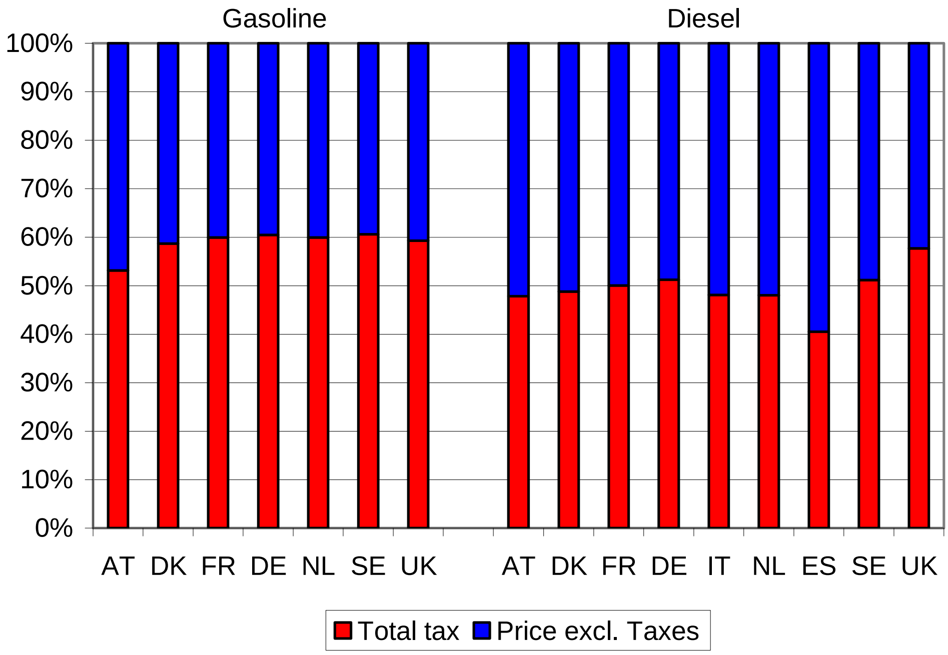

Figure 1. Share of tax in total fuel price in the selected EU countries, 2008

Comparing Figure 1 and 2 it is obviously that fuel taxes are much lower in non-EU countries and lowest in the United Stated (see also Figure 4 for the absolute magnitude and the development over time). Fuel tax in Canada can be different across the country, but on average, about one quarter third of the total gasoline price at the refueling station is tax.

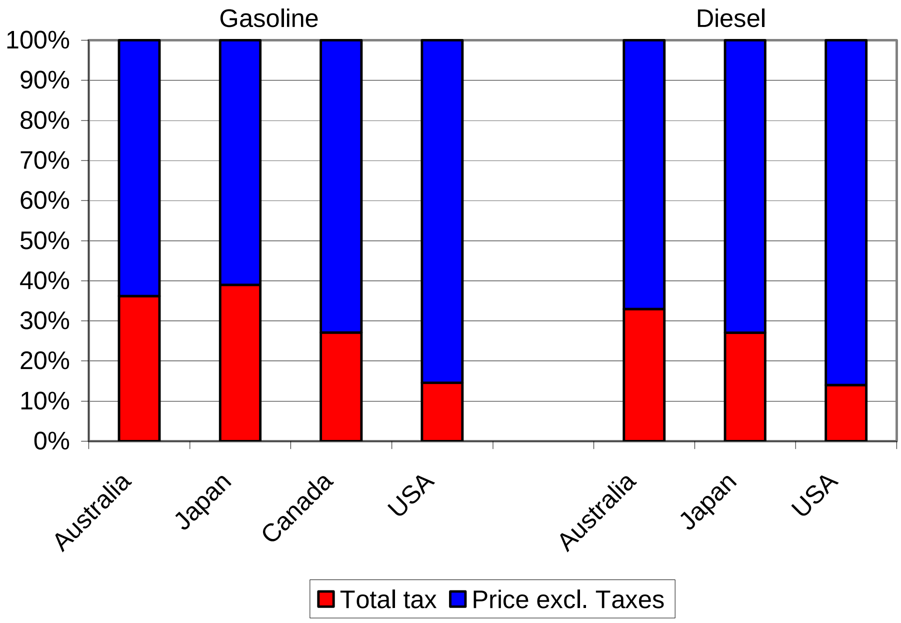

Figure 2. Share of tax on total fuel price in the selected non-European OECD countries

3. HISTORICAL DEVELOPMENTS IN PASSENGER CAR TRANSPORT

In this section we show the major historical developments in passenger car transport in selected OECD countries which are affected by tax policies.

3.1 Fuel prices and fuel taxes

Figure 3 depicts historical development of fuel price (in real terms, including taxes). Fuel prices contain a significant percentage of taxes, especial in Europe, as shown in Figure 1 and Figure 2. Fuel prices have a significant impact on car fuel intensity and distance traveled. In countries with higher fuel prices – Europe and Japan – lower fuel intensities can be noticed, see Figure 5. As also shown in Figure 5 in EU countries and Japan fuel intensity is significantly lower than in the USA, Australia and Canada.

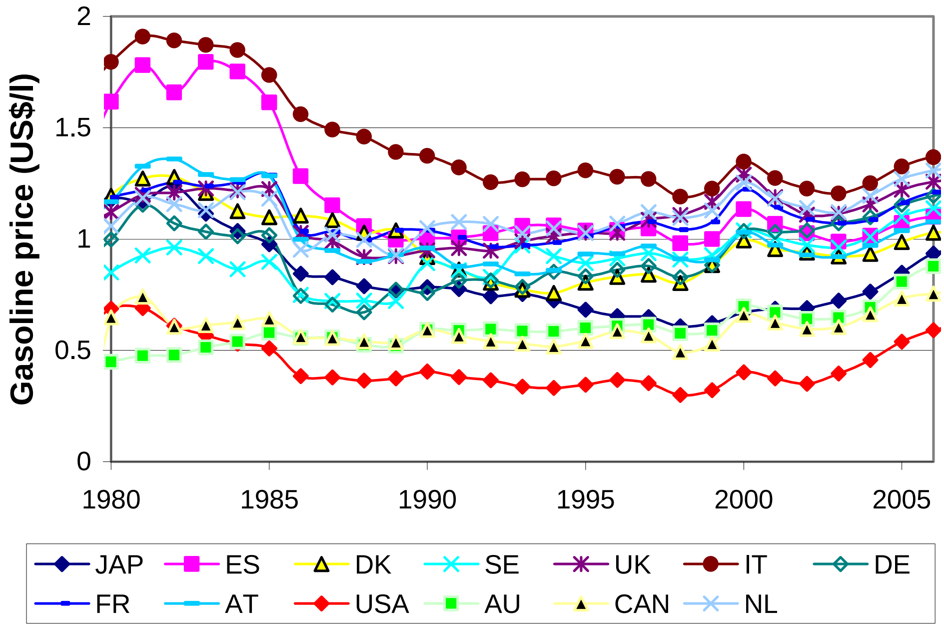

Figure 3. Historical development of fuel price (in real terms, including taxes)

A very impressing insight in the differences of the magnitude of fuel taxes and their changes over time provides Figure 4. Most remarkable is that in some countries like Germany, Sweden and UK are almost 1 US$ (2000 PPP) per litre gasoline equivalent while in others like the USA they are close to zero. These European countries also had the steepest increases in fuel taxes in recent years. It is also of interest that there is a very broad variety of patterns which are virtually different for every country. Moreover, fuel taxes in European countries are currently higher than in all other countries analysed.

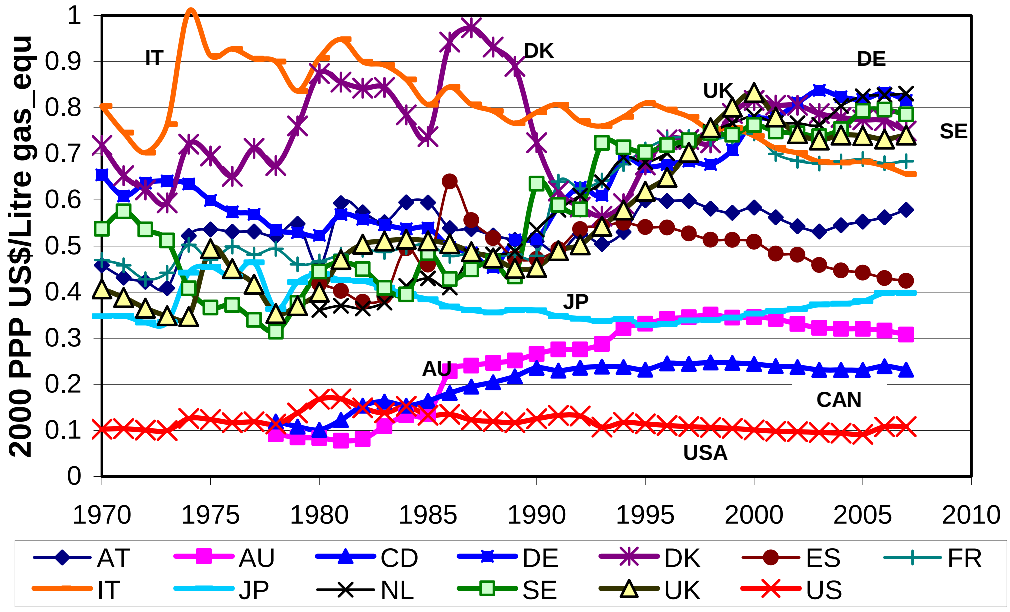

Fig. 4. Development of the magnitude of fuel taxes in investigated OECD countries from 1970 and 2007

3.2 Fuel intensity

Figure 5 depicts that higher fuel prices have triggered improvements in car efficiency. The steepest decreases in fuel intensities took place in the period of high oil prices in the late 1970s and the 1980s (including also some delay effects for bringing the efficiency increases from the labors to the roads). Hence, fuel taxes could be an effective tool to further increase car energy efficiency and to promote the use of alternative fuels.

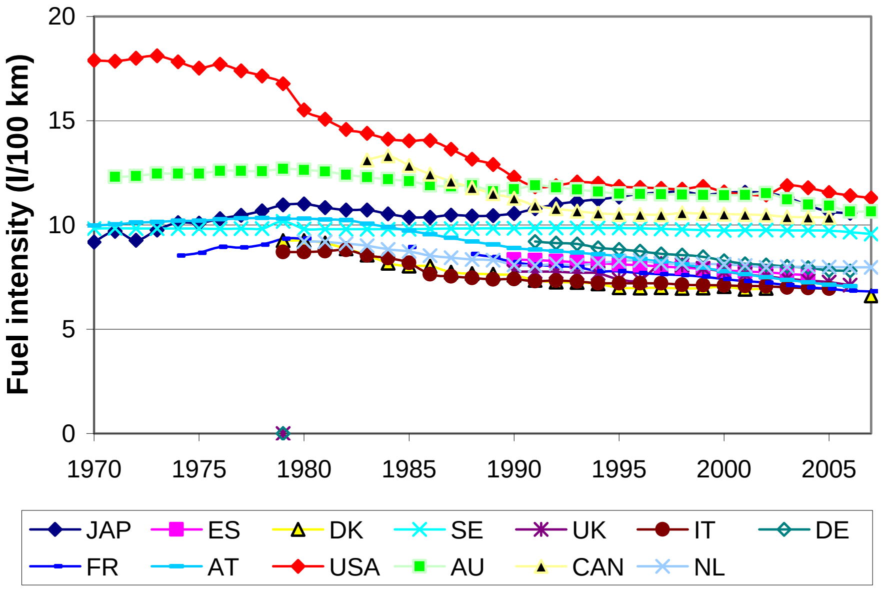

Figure 5. Historical development of fuel intensity

3.3 Vehicle stock

Increasing car ownership is an important driver of energy consumption in car passenger transport. As shown later car ownership level is strongly correlated to income and to investment costs. Hence, policy measures like registration taxes may have a significant impact on vehicle stock as well as a number of new car registrations per year. Figure 6 compares these features and shows car prices, registration taxes and car ownership per capita in some EU-countries.

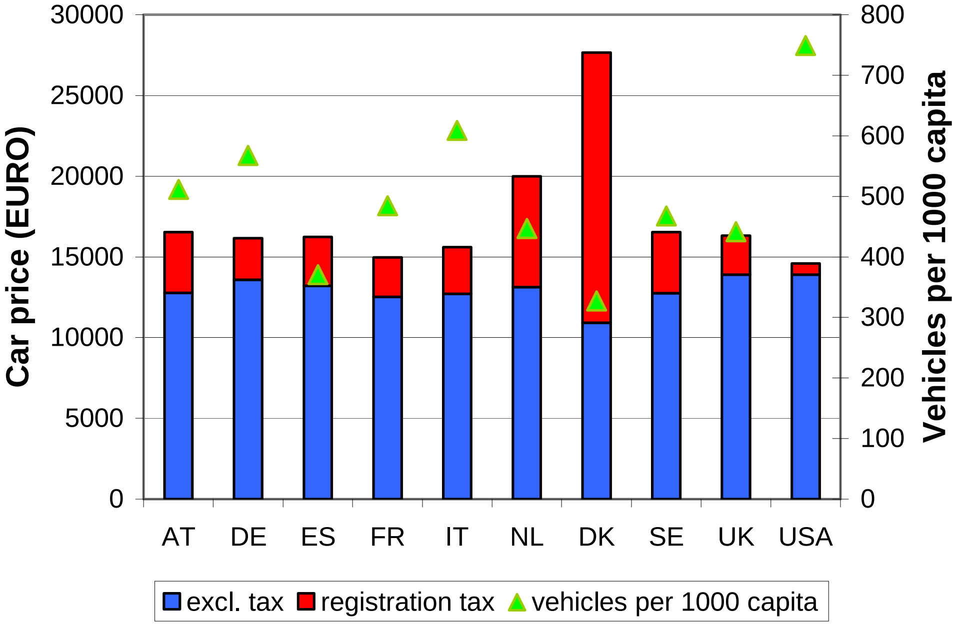

Figure 6. Car prices (incl. and excl. registration taxes) in EU countries and the USA in 2007 (Data sources: Ajanovic ed.,2009: EU, 2007)

The most interesting country in this figure is Denmark. Denmark has a relatively high GDP per capita and a low car ownership level. This can be explained by much higher vehicle registrations taxes in Denmark compared to other EU countries as well as the USA with a virtual absence of taxations. Denmark has tried to influence car drivers to buy cars which are more energy efficient –with lower CO_2 emissions – by means of introducing high registration and car owners' taxes as well as high fuel taxes.
The differences in car taxation help to explain the different historical development of car ownership level across the investigated countries, see Figure 7.

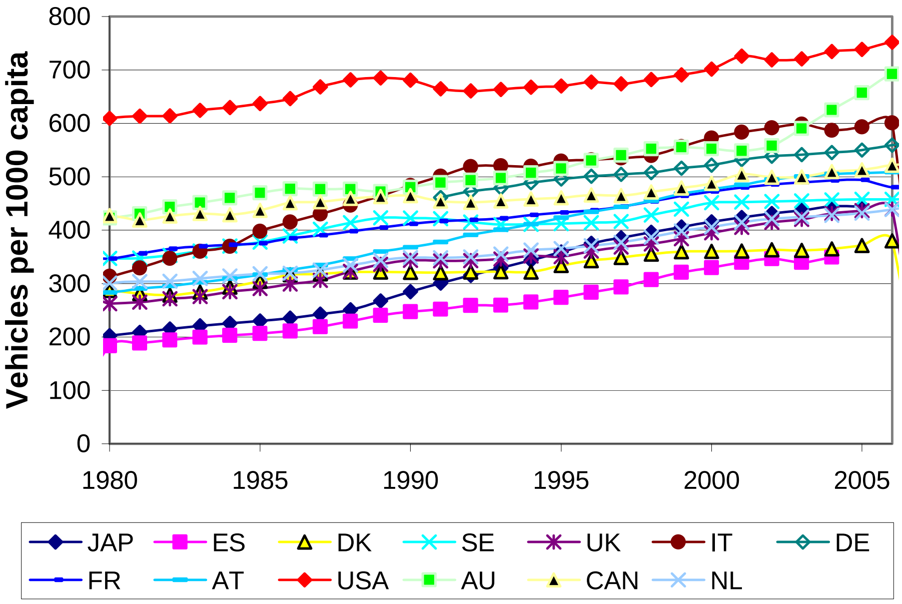

Figure 7. Historical development of vehicle stock

3.4 Share of energy consumption of investigated countries

What is of special interest for this analysis looking at the world-wide effects of taxes and their relevance is how the countries with higher and the countries with lower taxes contribute to energy consumption. Figure 8 depicts these shares of passenger car energy consumption in investigated countries in 1970 and 2007 and the most impressing fact is of course the share of the USA. It was about 75% in 1970 and it decreased slightly to about 68% in 2007 in our country sample.

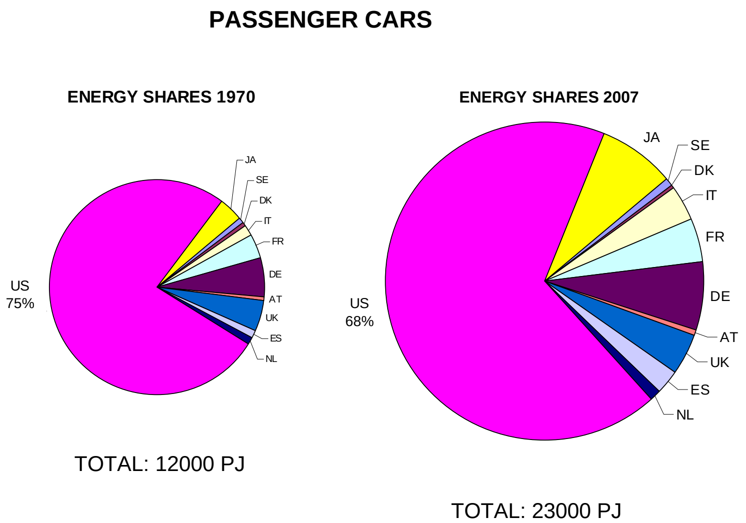

Figure 8. Share of energy consumption of investigated countries in 1970 and 2007

4. METHOD OF APPROACH AND DATA USED

The method of approach applied in this paper is based on fact the energy consumption is caused by demand for service and the efficiency of conversion FI:

$$E = vkm \cdot FI \tag{1}$$

In the following we use econometric approaches to extract the impact of taxes on the energy consumption, vkm driven, total vehicle stock (VST), the number of new vehicles (VNEW) and fuel intensity (FI).
We conduct a pooled model approach with data for eleven OECD countries: Austria, Germany, Denmark, France, Spain, Sweden, Italy, The Netherlands, United Kingdom, Japan and United States, ideally available from 1970 to 2007.

Data used are taken from:

- ALTER-MOTIVE database (see Ajanovic 2010)
- Schipper et al (1995),
- IEA Energy prices & taxes;
- http://www.ODYSSEE.org;
- http://www.ACEA.org;
- http://www.eia.doe.gov
- http://ec.europa.eu/competition/sectors/motor_vehicles/prices/report.html

Note, that unfortunately not the same and complete time series were available for all parameters and countries!

5. SETBACK OF TAXES ON PRICES

Firstly, to get a sound appraisal of the effects of taxes it is important to know whether there is a reduction of the basic prices of the product without taxes due to their introduction (and due to a decrease in the marginal production costs due to the reduction of the good consumed) or not. We investigate this aspect in the following for fuel taxes and registration taxes. For ownership taxes this effect cannot exist because there is no related base product price.

5.1 Setback of fuel taxes on energy prices

If there is no setback the total fuel price after tax should be:

$$P_{F\_Tot} = P_{F\_no\_tax} + 1 \cdot \tau_{FUEL}$$

We analyse whether the coefficient of τ_{FUEL} is really equal to 1 by running the following regression:

$$P_{F\_Tot} = a + b \cdot \tau_{FUEL}$$

If b=1 then there is no setback.

The result of the regression is (t-Stat. in parentheses):

$$P_{F\_Tot} = \underset{(20.4)}{0.43} + \underset{(22.7)}{0.93} \cdot \tau_{FUEL}$$

This result is ambiguous. So we also test whether (1-b) is significantly different from zero and with a t-Statistic of 1.84 no significance at the 5%-level is proven.

Note, that for this analysis we used data from European countries as well as the USA and Japan.

5.2 Setback of registration taxes on car purchase prices

If there is no setback the total investment costs (IC) after tax should be:

$$IC_{Tot} = IC_{no\_tax} + 1 \cdot \tau_{REG}$$

We analyze whether the coefficient of τ_{REG} is really equal to 1 by running the following regression:

$$IC_{Tot} = a + b \cdot \tau_{REG}$$

If b=1 then there is no setback.

The result of the regression is (t-Stat. in parentheses):

$$IC_{Tot} = \underset{(103)}{11895} + \underset{(41.77)}{0.85} \cdot \tau_{REG}$$

This result is rather clear indicating that there is an impact of taxes on car prices. But we also test whether (1-b) is significantly different from zero and with a t-Statistic of 8.38 we get the confirmation that it is. This result implies that from 100% of a registration tax only 85% of the impact coefficient of investment costs on other variables remains.
This also underlines the observation of Figure 6 where e.g. Denmark with the highest registration tax shows the lowest investment costs.

Note, that for this analysis only data from European countries were available.

6. RESULTS FOR IMPACTS OF TAXES ON ENERGY CONSUMPTION AND VEHICLE KILOMETER DRIVEN

Next we analyse the impacts of taxes on energy consumption and vehicle km driven. For these estimates we had to split our database into two subsets: one subset consisting of the parameters which were available for (almost) all years and all countries for the whole period 1970-2007.
For another subset, which also includes investment costs, registration taxes and new vehicles data are available mainly from 2000 to 2007.

Table 1 shows the results of the analyses for estimating energy consumption.

Table 1. Estimates for energy demand (E) 1970-2007 (t-Statistics in parentheses)

Model:	**1**	**2**	**3**	**4**	**5**	**6=5**	**7**	**8=7**
α (long-term price elasticity)	-0.77 (-17)	-0.8	-0.49 (-11.2)	-0.51	0.14 (1.0)		0.05 (0.44)	
β (long -term income elasticity)	1.04 (97)	1.06	1.02 (109)	1.01	1.00 (17)		1.02 (72)	
γ (long -term fuel intens elasticity)			0.83 (12.5)	0.85			0.57 (3.3)	
δ (long -term car investment cost elasticit	N.A.	N.A.	N.A.	N.A.	-0.5 (-7.3)		-0.44 (-6.25)	
λ (Lag)		0.30 (11.5)		0.22 (9.2)		0.004 N.S		0.004 N.S
A (short -term price elasticity)		-0.56 (-12.9)		-0.4 (-9.5)				
B (short -term income elasticity)		0.74 (26)		0.79 (31)				
Γ (short-term fuel inten elasticity)				0.66 (10.3)				
R² korr	0.975	0.981	0.98	0.985	0.994	--	0.995	--

*) Calculated from: α=A/(1-λ) , β=B/(1-λ), γ= Γ/(1-λ)

In the columns 1 to 4 the estimates for the first subset (without investment costs) are documented for variations of including and excluding lags and fuel intensity using the basic equation:

$$E_t = C \cdot P^{\alpha} GDP^{\beta} FI^{\gamma} E_{t-1}^{\lambda} \qquad (2)$$

The major results of the estimates in Table 1 (models 1-4) are that the price elasticity is highly significant and of high magnitude. Including fuel intensity improves the quality of estimates (R^2) and the corresponding coefficient γ is also highly significant.
The lag is moderate and smaller if fuel intensity is included which is plausible (because the long term effect of prices and fuel taxes on efficiency) and long term price elasticity is smaller when fuel intensity is included because $\alpha_{LT} = f(FI)$. That is to say, if fuel intensity is not included in the estimates the long-term price elasticity covers part of this effect.

In the columns 5 to 8 we show the results for estimates with the second (smaller) subset where registration tax and car investment costs were available. The following equation was used:

$$E = C \cdot P^{\alpha} GDP^{\beta} FI^{\gamma} IC^{\delta} \qquad (3)$$

Again, we conducted the analyses for variations of the basic equation (3) including and excluding lag and fuel intensity. However, the lag was not significant in any estimation. Indeed, car investment costs also had a significant impact of about -0.44 in the best model (column 7 in Table 1).

Summing up, on an international level fuel taxes posing a high share of fuel prices – see Figure 1, 2 and 4 – have a significant impact on energy consumption. One remark is important: While for the European countries we can assume quite harmonized conditions and habits this might not apply in comparison to the USA and Japan and, hence, the estimated impact will not be equal in all areas considered.

Also for registration taxes we got significant numbers but we have to concede that these were only applicable to European countries.

Table 2 shows the results of the analyses for estimating vehicle km driven.

Again in the columns 1 to 4 the estimates for the first subset (without investment costs) are documented for variations of including and excluding lags and now vehicle stock using the basic equation:

$$vkm = C \cdot P_S^{\varphi} GDP^{\beta} VST^{\chi} vkm^{\lambda} \qquad (4)$$

In Table 2 (model 1-4) the service price already captures fuel intensity. This justifies the smaller price elasticity. The values for the quality of estimates (R^2) are even better as the already very good values obtained for energy.
Including vehicle stock (VST) in the estimates provides highly significant values. Yet, it has to be taken into account that $VST = f(GDP)$.
There is multicollinearity between these two variables which explains the lower income elasticity.
Regarding the lag: There is no reason for a lag with respect to VST and in price elasticity because no difference between short- and long-term price elasticities is expected. Only for income a lag might be reasonable. The results of very small lags underline this argument.

Table 2. Estimates for service demand (vkm) 1970-2007 (t-Statistics in parentheses)

	1	2	3	4	5	6=5	7	8=7
φ (long -term service price elasticity)	-0.32 (-9.5)	-0.34	-0.26 (-7.7)	-0.26	-0.53 (-3.32)		-0.11 (1.67)	
β (long -term income elasticity)	1.08 (169)	1.08	0.5 (17.1)	0.47	1.05 (48.2)		0.43 (9.14)	
χ (long -term VST elasticity)			0.54 (20.2)	0.55			0.56 (12.7)	
δ (long -term car IC elasticity)					-0.35 (-3.3)			
λ (Lag)		0.17 (7.83)		0.09 (6.37)		0.04 N.S.		0.012 N.S.
Φ (short -term service price elasticity)		-0.28 (-8.7)		-0.24 (-10)				
B (short -term income elasticity)		0.9 (39)		0.43 (14.6)				
X (short -term VST elasticity)				0.5 (19.3)				
R² korr	0.988	0.989	0.994	0.995	0.986	--	0.999	--

*) Calculated from: φ=Φ/(1-λ) , β=B/(1-λ), χ=X/(1-λ)

In Table 2 (model 5-8) estimates are presented for the subset of data where registration tax and car investment costs were available using the equation:

$$vkm_t = C \cdot P_{S_t}^{\varphi} GDP^{\beta} VST^{\chi} IC^{\delta} vkm_{t-1}^{\lambda} \qquad (5)$$

Again, car investment costs have a significant impact of about -0.35. In the estimates with vehicle stock again we have to consider multicollinearity with GDP. Note, that there is also multicollinearity expected between IC and VST so estimates using all three of these parameters do not lead to any useful results. So in column (5) and (7) of Table 2 we used IC and VST alternatively!

The lag was not significant in any estimation.

7. RESULTS FOR IMPACTS OF TAXES ON FUEL INTENSITY

Next we analyse the impacts of taxes on fuel intensity. As can be seen from Figure 9 a relatively clear correlation between higher fuel prices and lower fuel intensity is expected. For example, the United States and Japan have highest fuel intensity and lowest fuel prices. Italy has high fuel prices and relative low fuel intensity (also due to smaller cars).

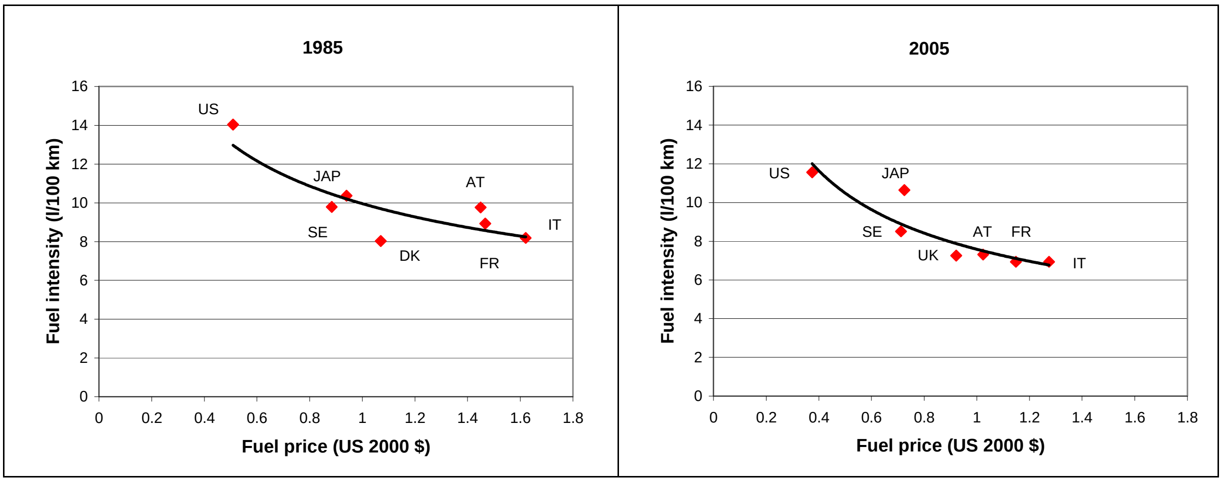

Figure 9. Car fuel intensity versus average fuel price, 1985 and 2005
The cost of diesel is included in the average price according to its proportion of total fuel used in the year shown

The dependence of FI on the price is depicted using the equ:

$$FI_t = C \cdot P_t^{\alpha} \qquad (6)$$

The result is a value of -0.4 (-15.9) for the coefficient α and hence a significant dependence of FI from fuel price.

Our estimates of FI on registration tax did not show unambiguous results. One reason might be that over the period of data availability – from 2000 to 2007 – not really remarkable decreases in FI took place and, hence, also the effect was difficult to extract. In this context it is also important to point out the problem of estimating lags in pooled models, see e.g. also Johansson/Schipper (1997).

8. CONCLUSIONS

The major conclusions of our analysis are:
There are huge differences between countries regarding the implemented tax policies like fuel and registration taxes. Our analysis provides sound evidence that fuel taxes have a clear impact on vehicle km driven and straightforward, on energy consumption simply because of

less km driven. Yet, looking at history it must be stated that this saving effect occurred mainly in the investigated European countries with higher fuel taxes. But, worldwide, especially in comparison with the USA this effect has been rather moderate.

With respect to the effect of taxes on the price of the underlying product, the following perceptions are important. Regarding fuel taxes there is only a moderate set-back effect of the taxes on the fuel price which is not significant on a world-wide level due to our analyses. This implies that the introduction of a fuel tax leads to a linear price effect. With respect to registration taxes at least for Europe we can find a setback of about 15%. That is to say, the introduction of this tax reduces the price effect on energy consumption to about 85%.

From the analyses conducted also clear evidence is provided that fuel taxes have a significant effect on improving the energy efficiency of cars. Aside from the simple fact that fuel intensities are higher in countries with very low fuel taxes and vice versa the results of our econometric analyses identify a significant and rather high impact factor of 0.4.

Yet, due to different economic, socio-demographic and geographical characteristics of regions as well as the fact that the "cultural value" of the car addressing "values" like freedom, status, masculinity etc., it is likely that effectiveness of fiscal policy measures will be different by countries and region.

An important aspect that remains for future research work is that, car taxation also increases the difference in price between larger and smaller, more efficient vehicles. Therefore, car taxation may also affect the size of new cars and the chosen technologies (e.g. electric vehicles in the smaller size categories) In the long run this might lead to a completely different average size and size distribution of the total car stock.

With respect to the future development of car passenger transport the major perception is that only a broad portfolio of policy instruments with a core focus on standards and taxes will be necessary to reduce fuel intensity, energy consumption as well as GHG emissions significantly.

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