THE EFFICIENCY OF FUEL TAXES IN COMPARISON TO TAXES INCLUDED IN THE RETAIL PRICE OF A VEHICLE

TERM PAPER – ENERGY ECONOMIC AND POLICY

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1. Introduction

Apart from grey energy, the main source of carbon dioxide—the main greenhouse gas which leads to the anthropogenic climate change—are fossil fuels and fossil gas.

In addition to the yearly energy consumption in Switzerland of liquid fuels of 496 170 tera-joules (2008) and of fossil gas of 110 760 tera-joules (2008), notably, there is only coal with a yearly energy consumption of only 6720 tera-joules (2008) (SFOE 2010). The main source of carbon dioxide, liquid fuels, can be divided into three types of fuels, which is defined by the final purpose of use (see Figure 1). The consumption of motor fuels is still increasing whereas the consumption of fuels for heating has been decreasing since the 1970s; in fact, it has recently fallen below the level of motor fuels. The main reason as to why it is difficult for Switzerland to reach the Kyoto-target is traffic (SFOE 2010). According to SFOE (2010), 37% of all greenhouse gas emissions of Switzerland are caused by transportation. As we can see in Figure 2, private cars are the main cause of CO2 emissions in the transportation sector as they are responsible for about two third of these CO2 emissions. This fact underlines the importance of further government measures.
Since there are already technologies available, which cause less greenhouse gas emissions, the following questions arise: How can the state promote efficient vehicles so as to dramatically reduce the above described greenhouse gas emissions in the transport section. Most notably, two promising energy-efficiency technologies - electric vehicles and hybrid vehicles – will be taken into consideration.

A very important question is how governments or policy makers can turn Switzerland’s car pool fleet into a more sustainable one.

I will be comparing two different ways of taxing drivers of conventional, inefficient vehicles in order to be able to evaluate the efficiency of each taxing systems. The aim of this paper is to show how taxes on either gasoline or vehicles can make electric or hybrid vehicles as competitive as conventional cars. So as to provide a very rough estimation of taxes to be implemented on either gasoline or on vehicle purchase prices, I integrate three exemplary cars available on the market - one conventional, an electric and a hybrid car - into a choice model. To be able to gain any output at all within the given timeframe, I am forced to determine all vehicle attributes as constant except for fuel prices and purchase prices. This in turn lowers the accuracy of the output considerably. However,
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this paper will enable the reader to gain qualitative insight into the matter of concern here.

The following step will consist of an evaluation of the efficiency of each taxing system and the attempt to find possible causes for the differences in efficiency.
2. Taxes Based on Fuel

One possibility to increase costs for conventional vehicles is to raise fuel prices. If car drivers have to pay more for fuel, the overall costs per driven kilometre will increase for conventional cars, whereas the costs for electric cars remain stable. As we can see in Figure 3, the fuel supply curve is influenced by the installed tax. As a result, there is a new equilibrium where the supply curve with tax meets the demand curve. The amount of saved gasoline $\Delta Q = Q_{\text{without tax}} - Q_{\text{with tax}}$ depends on the slope of the demand curve, which is represented by the price elasticity of demand $E_d = \frac{\% \text{ change in quantity demanded}}{\% \text{ change in price}} = \frac{\Delta Q_d/Q_d}{\Delta P/P}$ (Gillespie 2007). In Figure 3, it is schematically shown, how a tax influences the price and the demand of a certain good. Worthy of mention is the fact that a distinction must be made between price elasticities in the short and in the long run. Car users are considered to primarily adjust car utilization in the short run, whereas in the long run, they are also able to replace their inefficient cars by more efficient models, or in our case, by electrical and hybrid cars (Pock 2010). Many studies came up with very low or almost no elasticities in the short run, whereas a higher number of alternatives in the long run leads to a increased elasticity (Pock 2010).
In this paper it is only the capacity to compete at the stage of purchasing a new vehicle, which is of interest. This is why I will focus on the long-run price elasticity exclusively. Pock (2010) found short-run elasticities of -0.106, whereas long-run elasticities were calculated at -0.360 for Europe. Although the long-run effect is evidently stronger than the short-run effect, an absolute value for elasticity lower than one is considered to be inelastic.

However, since the total cost of a vehicle also includes future fuel costs, it seems obvious that an increase in fuel costs automatically shifts the benefits towards electrical and hybrid vehicles, too.

3. Taxes Based on Car Purchases

A more direct way to convince car buyers to switch to more sustainable vehicles consists in charging buyers of conventional, unsustainable vehicles a fee included in the retail price of a new vehicle. Purchase prices of inefficient cars would thereby rise, whereas those of efficient cars would remain constant. This fee should be brought to such a level that electrical or hybrid vehicles become competitive. However, one should be aware of the fact that such taxes do not have any impact in the short-term.

4. Estimation of Taxes

Many studies have found relations between chosen cars and vehicles attributes, purchase prices and fuel costs. In order to be able to determine the needed taxes such that electric or hybrid vehicles are bought with the same frequency as conventional ones, I use a simple model with variables estimated for the UK. For the sake of simplicity, I kept all attributes constant except for the purchase prices and fuel costs. As a result, the output includes many limitations. Low driving ranges for electric cars as well as the limited availability of refilling infrastructure are also major factors, which discourage car buyers from investing in electric vehicles. On the other hand, consumers may actually be willing to pay a certain amount for environment-friendly technology. This, too, is not taken into consideration in these models.
A qualitative insight into consumer preferences can be obtained by matching similar sized cars equipped with different engine types. I took the same car models used in a previous study (Figliozzi, Boudart et al. 2010) and applied current Swiss prices.

<table>
<thead>
<tr>
<th>Model</th>
<th>Engine Type</th>
<th>Purchase Price (CHF)</th>
<th>Fuel Consumption per 100 km</th>
<th>Fuel Price (CHF)</th>
<th>Fuel Price per 100 km (CHF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toyota Yaris¹</td>
<td>Conventional</td>
<td>19,750 (Toyota 2011)</td>
<td>5.1 l/100 km (Toyota 2011)</td>
<td>1.78 /l²</td>
<td>9.078</td>
</tr>
<tr>
<td>Honda Insight³</td>
<td>Hybrid</td>
<td>29,800 (Honda 2011)</td>
<td>4.4 l/100 km (Honda 2011)</td>
<td>1.78 /l²</td>
<td>7.832</td>
</tr>
<tr>
<td>Nissan Leaf</td>
<td>Electric</td>
<td>49,950 (Nissan 2011)</td>
<td>76,500 kJ/km (Congress 2011)</td>
<td>0.0767 /kWh</td>
<td>2.2695</td>
</tr>
</tbody>
</table>

Table 1: Purchase prices, fuel consumption and prices (in Swiss Francs)

¹ 5-doors, 1.0 VVT-i 5- Gear, manual, Linea Terra
³ Insight Hybrid,1.3l, 4, 'S' 
4.1. Estimation using the EFTEC model

Table E4.1: Parameter estimates for vehicle attributes (other parameters not presented) from a fixed-effects nested logit model of demand for new cars

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameter Estimate</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost Attributes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(scaled by avg. income)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purchase Price</td>
<td>1.0165</td>
<td>0.000</td>
</tr>
<tr>
<td>Resale Price</td>
<td>0.7046</td>
<td>0.000</td>
</tr>
<tr>
<td>Fixed Cost</td>
<td>-1.9170</td>
<td>0.003</td>
</tr>
<tr>
<td>Fuel Cost per 100km</td>
<td>-0.3850</td>
<td>0.000</td>
</tr>
<tr>
<td>Physical Attributes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automatic</td>
<td>0.0808</td>
<td>0.000</td>
</tr>
<tr>
<td>Num Gears</td>
<td>0.0371</td>
<td>0.000</td>
</tr>
<tr>
<td>Size (width x length)</td>
<td>0.0010</td>
<td>0.000</td>
</tr>
<tr>
<td>Brake Horsepower</td>
<td>0.0020</td>
<td>0.000</td>
</tr>
<tr>
<td>Acceleration (secs to 100km/h)</td>
<td>-0.0097</td>
<td>0.000</td>
</tr>
<tr>
<td>Number of Airbags</td>
<td>0.0201</td>
<td>0.000</td>
</tr>
<tr>
<td>Air Conditioning</td>
<td>0.0087</td>
<td>0.203</td>
</tr>
<tr>
<td>Allay Wheel Rims</td>
<td>0.0239</td>
<td></td>
</tr>
<tr>
<td>Anti-Lock Braking System</td>
<td>-0.0724</td>
<td>0.000</td>
</tr>
<tr>
<td>Doors</td>
<td>0.0039</td>
<td>0.134</td>
</tr>
<tr>
<td>N</td>
<td>70,875</td>
<td></td>
</tr>
<tr>
<td>Num Fixed Effects</td>
<td>735</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within</td>
<td>0.9133</td>
<td></td>
</tr>
<tr>
<td>Between</td>
<td>0.1512</td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>0.3257</td>
<td></td>
</tr>
</tbody>
</table>

Economics For The Environment Consultancy Ltd (eftec) estimated a logit model for car attributes and their demand for the department of transportation of the United Kingdom. Keeping all attributes fixed except for purchase price and fuel cost per 100 km and assuming that demand for electric vehicles equals demand for conventional vehicles, we get

$$
\beta_1 \cdot \log(PP_{conv}) + \beta_2 \cdot \log(FC_{conv}) = \\
\beta_1 \cdot \log(PP_{EV}) + \beta_2 \cdot \log(FC_{EV}),
$$

whereas PP is the purchase price and FC the fuel cost of a certain car. The life expectation and the annual driving distance of all vehicle types are assumed to be 10 years and 10,000 kilometres, respectively.

The related fuel cost, including taxes, for conventional fuel can be estimated by

$$
FC_{conv} = FC_{EV} \cdot \exp\left[\frac{\beta_1}{\beta_2} \cdot (\log(PP_{EV}) - \beta_1 \cdot \log(PP_{conv}))\right]
$$

and the purchase price, including tax for a conventional car

$$
PP_{conv} = PP_{EV} \cdot \exp\left[\frac{\beta_1}{\beta_2} \cdot (\log(FC_{EV}) - \beta_1 \cdot \log(FC_{conv}))\right].
$$

For hybrid competitive taxes on fuel, the model is formulated as if the new tax were just applied for fuel used for conventional cars, whereas there were no additional taxes installed on fuel used for hybrid cars. Since the fuel used for hybrid and conventional cars are the same, however, this distinction is not easy to realise in the real world.
With the above assumption, the equation derived for electric cars can be applied to hybrid cars, as well.

### 4.2. A Model and Its Limitations

As already mentioned in Section 2, the model used exhibits a series of limitations. Firstly, taxes are calculated as if there were no differences in terms of physical attributes of the three car types, such as maximal driving range, top speed and so on. Furthermore, it seems obvious that consumers are also concerned about the availability of refilling station and the time needed to refill the vehicle. These two aspects, too, are not included in the model. Fuel prices are considered to be constant over the entire lifespan of a vehicle and uncertainties with regards to future prices are equally excluded. Other maintenance costs as well as registration taxes are not included, either. It must be noted, too, that there are only three vehicles included in this model. It is therefore clear that the output of this model is not useable for direct tax implication. However, this model can still be helpful to gain a deeper insight into the efficiency or limited effects of certain fuel taxes and purchase taxes.

However, a more sophisticated model with more than just one vehicle per engine type is likely to gain more accurate values for taxes.
4.3. Results and Discussion

<table>
<thead>
<tr>
<th></th>
<th>Feul costs /100km</th>
<th>Purchase Price</th>
<th>Total costs without taxes</th>
<th>fuel costs incl. Fuel taxes</th>
<th>total cost with fuel tax</th>
<th>purchase with purchase tax</th>
<th>total cost with purchase tax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>9.078</td>
<td>19750</td>
<td>28828</td>
<td>26.29</td>
<td>46044.89</td>
<td>29546.42</td>
<td>38624.42</td>
</tr>
<tr>
<td>E-Mobile</td>
<td>2.2695</td>
<td>49950</td>
<td>52219.5</td>
<td>2.27</td>
<td>52219.50</td>
<td>49950.00</td>
<td>52219.50</td>
</tr>
<tr>
<td>Hybrid</td>
<td>7.832</td>
<td>29800</td>
<td>37632</td>
<td>7.83</td>
<td>37632.00</td>
<td>29800.00</td>
<td>37632.00</td>
</tr>
</tbody>
</table>

Table 3: Estimated total cost if the matched vehicle were competitive at the same level taxes with variables from Table 2 and prices from Table 1 (in Swiss Francs)

By examining the total costs of a conventional vehicle and an electric vehicle in Table 4 when taxes are implemented, one can clearly see that either in the case of fuel taxes or in the case of taxes based on purchase, the electric cars costs exceed by far the costs of a conventional car. It is likely that the assumed annual driving distance as well as the lifespan of the vehicles were chosen at a too low level.

Contrary, by assuming that hybrid vehicle demand is equal to the demand for a conventional one, it was possible to show that an implemented tax on purchase prices led to almost identical total costs for those two vehicle types. The conventional car however will cost considerably more in the course of its lifespan than a hybrid car if fuel taxes are implemented.
As Table 4 shows, the costs of fuel taxes accumulated over the entire, assumed lifespan of a vehicle amount to more than double the price if fees were implemented on conventional vehicles in order to bring sustainable vehicles to a competitive level. It is clear that the assumed life expectation is critical in terms of accumulated costs of fuel taxes. By having a closer look at actual lifespans of vehicles and the mean annual driving distance of a privately owned car in the UK, the region for which the variables were estimated, it turns out that the assumption taken for the above model are too low. In 1999, the mean lifespan of a car in the UK was 13.95 years and on average privately owned vehicles were driven for distances of 13550.7 km a year (CFIT 2010; DfT 2010).

In the case of hybrid competitive fuel taxes, the question imposes itself as to why consumers are willing to pay significantly more for fuel-inefficient vehicles even if there are more economical vehicles available, at least if long-term calculations are made. Here, it is worth mentioning that in economic theory, future benefits are considered to have a lower value in the present.

### 5. The Value of Time and the Present Value Model

For money, which is not invested but deposited in a bank account, one is paid interest. It is obvious then that a distinction needs to be made between investments resulting in benefits, which lie in the future on the one hand and investments with
immediate benefits on the other. The neoclassical theory of rational choice holds that rational human beings favour the option with the highest net value. If benefits and costs are constant over time, market actors will prefer immediate benefits over longer-term benefits (Pannell 2008). There exists a widely used and simple model, the so-called ‘Net Present Value Model’, which accounts for the time delay (Magni 2009). The net present value $PV[B_n]$ of a benefit $B_n$, which takes effect in $n$ years is

$$PV[B_n] = \frac{B_n}{(1+r)^n} \text{ (Tietenberg and Lewis 2008)}.$$ 

The present value for a benefit gets smaller with every additional year by the rate of $r$, the so-called discount rate. If there are benefits located in more than just in a certain year, the benefits needs to be summed up. This can be described using the following equation:

$$PV[B_0, ..., B_n] = \sum_{i=0}^{n} \frac{B_n}{(1+r)^n}$$

It is well worth noting that the actual economically reasonable discount rate should be higher than the interest of a bank account, due to risks (Pannell 2008).

However, even if one calculated the cost for fuel with this net present value model and by applying economically reasonable interest rates, one is not able to explain the willingness to pay for fuel inefficient vehicles when fuel taxes are implemented. I derived the discount rate from the cost of fuel, which would need to be implemented in order to bring the hybrid vehicle to a competitive level by assuming that the total costs per vehicle equals

$$TC = PP + \sum_{n=0}^{13} \frac{FC_{\text{per year}}}{(1+r)^n}$$

The annual fuel costs for each vehicle is calculated using the fuel cost indicated in Table 3 and the actual annual driving distance of a car in the UK in 2009 of 13305.7 kilometres.
Based on the assumption that the demand of a hybrid car equals the demand of a conventional car and its maintenance costs, following equation can be derived:

$$PP_{HV} + \sum_{n=0}^{13} \frac{FC_{per\ year, HV}}{(1+r)^n} = PP_{conv} + \sum_{n=0}^{13} \frac{FC_{per\ year, conv}}{(1+r)^n}$$

The above equation is only valid if $r=0.2645$. This means, that car buyers have to discount the future with a rate of 26.45%, which is a considerable higher value than one would expect by comparing this rate to interest rates found on the market.

Dreyfus and Viscusi (1995) estimated discount rates applied by car buyers in the U.S.. They came up with rates set somewhere between the values of 10.7% and 17.4%, which are lower than the above estimation, but still significantly higher than interest rates available on markets.

It is therefore likely that there are other factors influencing car buyers’ cost-saving awareness at a low level.

Greene (1983) argues that apart from highly subjective discount rates, which, according to him, are caused by bounded rationality, the following factors contribute considerably to the fact that improved fuel economy is not adequately taken into account for by car buyers:

- Imperfect information about future savings due to better efficiency
- Loss aversion: Consumer tend to valuate losses more than gains (Gal 2006)
- Uncertainty most notably with regards to future gasoline prices

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5 Higher purchase prices of efficient cars are there considered as losses and the saved amount of fuel costs in the future are considered to be gains
6. Conclusion

As we have seen in Section 2, fuel taxes do not strongly influence fuel consumption in the short-run because of extremely low demand elasticity. An improved utilization by way of high gasoline prices is therefore not likely to have a significant effect on green-house gas emissions. Making the car pool fleet more energy-efficient can have a considerably higher impact on greenhouse gas emissions caused by transportation.

In order to achieve that target, I estimated taxes to be implemented on either gasoline or on vehicle purchases. To do so, I took three exemplary, comparable cars available on the market, one conventional, an electric and a hybrid car, and integrated those into a choice model. Since I held all vehicle attributes constant except for the fuel and purchase prices, the output cannot be considered to be 100% realistic. However, the result is still useable to discuss possible effects of such taxes. It was possible to show that consumers react much more sensitive to taxes connected to the purchase of a car. Therefore, to achieve a certain rise in demand for more energy-efficient vehicles, taxes installed on fuel and accumulated over the whole lifespan of a vehicle need to be much higher than taxes connected to purchase. As a result, taxes on purchases can be considered to be more efficient as taxes on fuel. This is why I argue that it is better if new taxes or fee bates policies have an instant effect by the time of a purchase decision rather than anytime later in the lifespan of a car.

However, one should be aware of the fact that taxes based on purchase do not have any effect on the car utilization after a car is bought. Therefore, a fuel tax might still be a feasible measure to improve car utilization.

In order to estimate purchase taxes more accurately, more sophisticated models as well as more data of different vehicle types are needed. Furthermore, all different car attributes also need to be taken into account.
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