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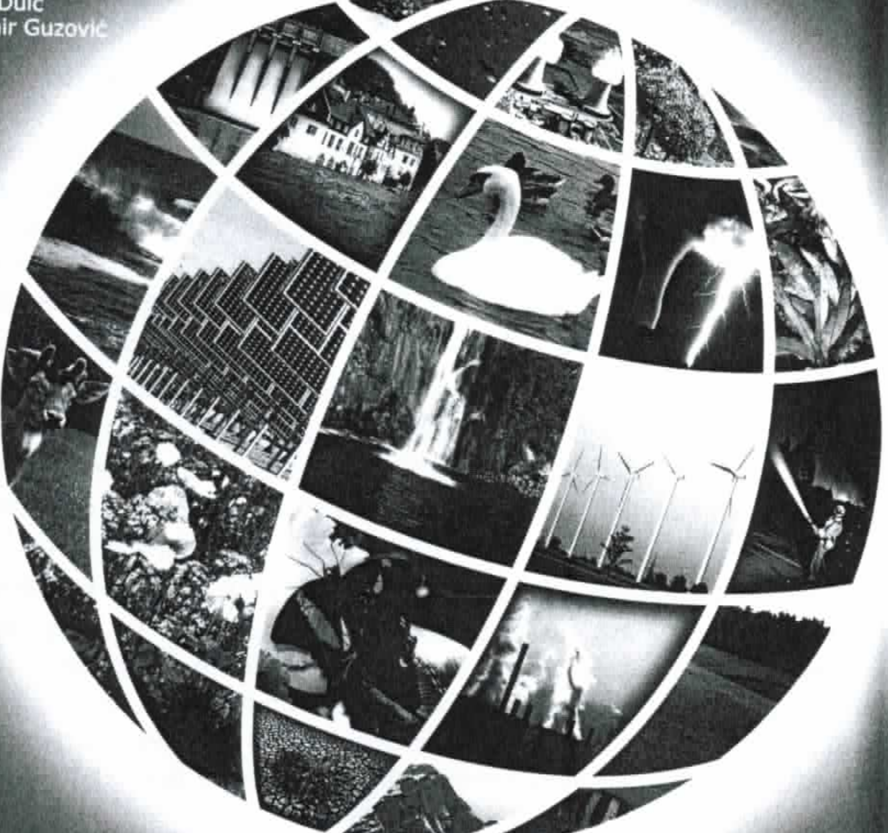

The impact of more efficient new passenger cars on energy consumption in EU-15 countries

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ABSTRACT

The core objective of this paper is to analyze the impact of fuel intensity changes on energy demand of new passenger cars in EU-15 countries. Of special relevance in this context is how the rebound effect due to the change in car fuel efficiency and car size (average engine power) affects the energy conservation effect.

A specific aspect of our investigations is to find out how changes in fuel intensity and car size interact. This is especially important to get an appraisal of the rebound effect due to a lower fuel intensity or lower fuel cost. Lower fuel intensity reduces the cost of car travel, and may lead to further growth in vehicle kilometre driven and car size, while higher fuel prices may offset this effect to some extent.

The preliminary results of our analysis based on an econometric analysis of data for the EU-15 vehicle stock and for new cars in EU-15: Rebound due to increase in vehicle kilometre driven in EU-15 is about 40% and rebound due to increase in car size is about 15%.

INTRODUCTION

The current problems arising from motorized individual transport lead to an urgent need for implementing efficient policy measures. Currently, in the EU standards e.g. for CO_2 emissions per km are discussed as a policy tool of priority. To get a reliable appraisal of the effects of standards it is important to identify the overall impact of the corresponding parameter fuel intensity on energy consumption.

This issue is addressed frequently in the scientific literature see e.g. [1], [2], [3] or [4] for some recent work.

The core objective of this paper is to analyze this impact of fuel intensity changes on energy demand of new passenger cars in EU-15 countries. Of special relevance in this context is how the rebound effect due to the change in car fuel efficiency and car size (average engine power) affects the energy conservation effect.

The method of approach is based on an econometric analysis of the EU-15 countries. We focus on analyzing the demand for energy (e.g. litre of gasoline and diesel), as well as the demand for service for the stock of cars. With respect to service we consider long-term service demand (kW of cars) as well as short-term service demand (vkm - vehicle km driven). The usage of new cars is derived from the use of the average of the entire fleet of gasoline and diesel cars by using service price elasticity and different service prices.

A specific aspect of our investigations is to find out how changes in fuel intensity and car size interact. This is especially important to get an appraisal of the rebound effect due to a lower fuel intensity or lower fuel cost. Lower fuel intensity reduces the cost of car travel, and may lead to further growth in vehicle kilometre driven and car size, while higher fuel prices may offset this effect to some extent.

This basic principle of the rebound effect is depicted in Figure 1. Point 1 shows the initial situation (E_1 –energy consumption, η_1 –fuel efficiency, S_1= vkm_1*kW_1). With the increasing energy efficiency from η_1 to η_2 theoretically energy consumption could be reduced from E_1 to E_2^{th}. Due to the higher efficiency, service price is lower, which causes increase in service demand to S_2= vkm_2*kW_2. Due to the increase in energy efficiency from η_1 to η_2 and the rebound effect energy consumption will be reduced only to E_2^{pr} instead to E_2^{th}.

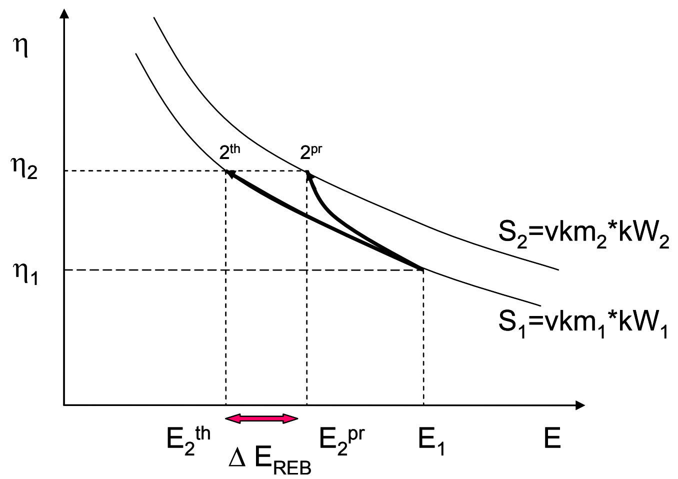


Figure 1. The rebound effect: increase in vkm driven and car size if efficiency is improved

The data used for these analyses are mainly taken from:

- ALTER-MOTIVE database & Country review report, see Ajanovic (2009) [5]; www.ALTER-MOTIVE.org
- Schipper et al. (1995) [6];
- IEA, Energy prices & taxes [7];
- OECD, National accounts [8];
- ODYSSEE database [9];
- ACEA statistics [10];
- EC monitoring report [11].

We calculated service prices based fuel prices (from IEA - Energy Prices and Taxes) and fuel intensities of the stock (based on ALTER-MOTIVE database). We weighted fuel prices (of 2000) by vehicle km driven (vkm).

Figure 2 depicts the development of vehicle km driven (vkm), energy consumption and the fuel intensity of the stock of vehicles in EU-15 from 1990 to 2007. It can clearly be seen that energy consumption is stagnating since about 1998. Yet, vkm has still increased almost continuously. Figure 3 depicts the same development for normalized figures, setting the values of 1990 equal to 1.

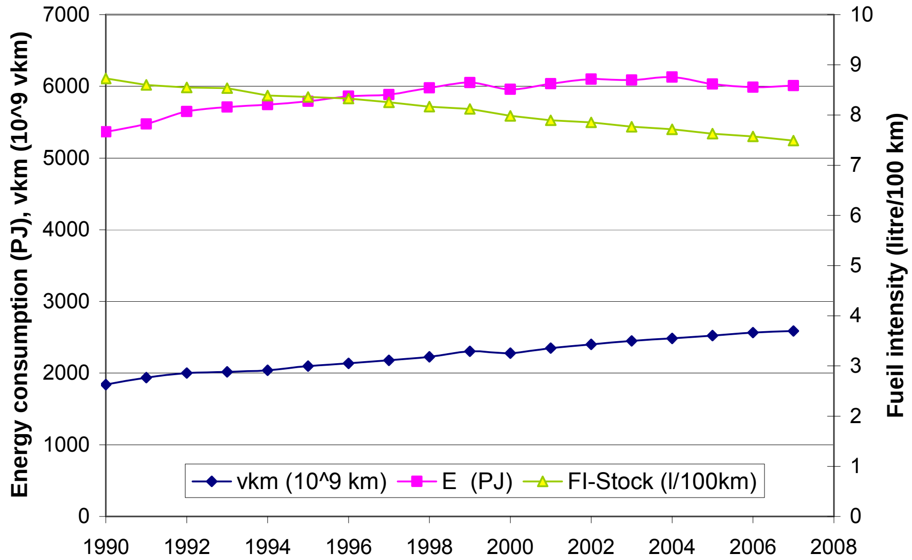


Figure 2. Development of vehicle km driven (vkm), energy consumption and the fuel intensity of the stock of vehicles in EU-15 from 1990 to 2007

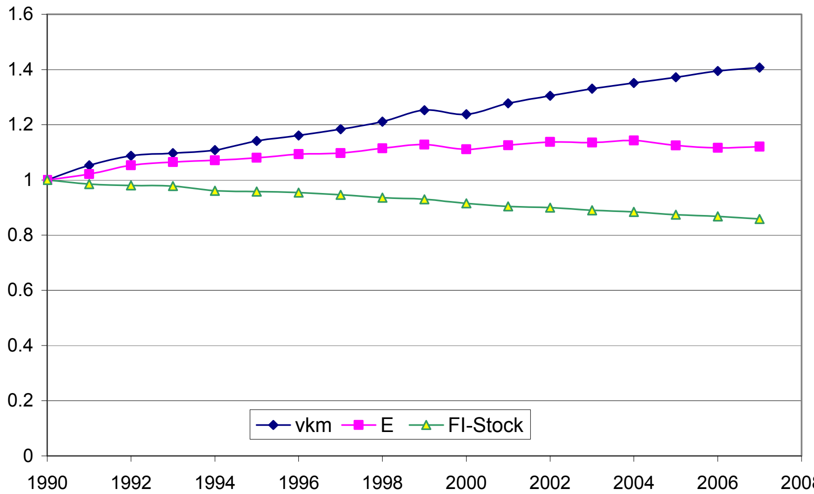


Figure 3. Normalised development (1990=1) of vehicle km driven (vkm), energy consumption and the fuel intensity of the stock of vehicles in EU-15 from 1990 to 2007

In the figures 2 and 3 we have described features of the stock of vehicles. In the next figures 4 and 5 we show now features of new vehicles. It is important to note that in this paper we use for some analyses – e.g. regarding vkm – the data of the stock and for some other analyses – e.g. kW – the data of new vehicles. The major reason for this is that for the stock no kW-related data are available and for new vehicles no vkm-data are available. So we try to squeeze from every of the two data sets the information out that is possible but we do not mix the two data sets!
So regarding power in this paper we only look at new vehicles. We will compare for new vehicles at how their increase in power (kW) compared to the power in the starting year have (1990) affected the change in fuel intensity of new cars and straightforward what was the rebound (less energy saved due to the switch to larger vehicles) for new cars.

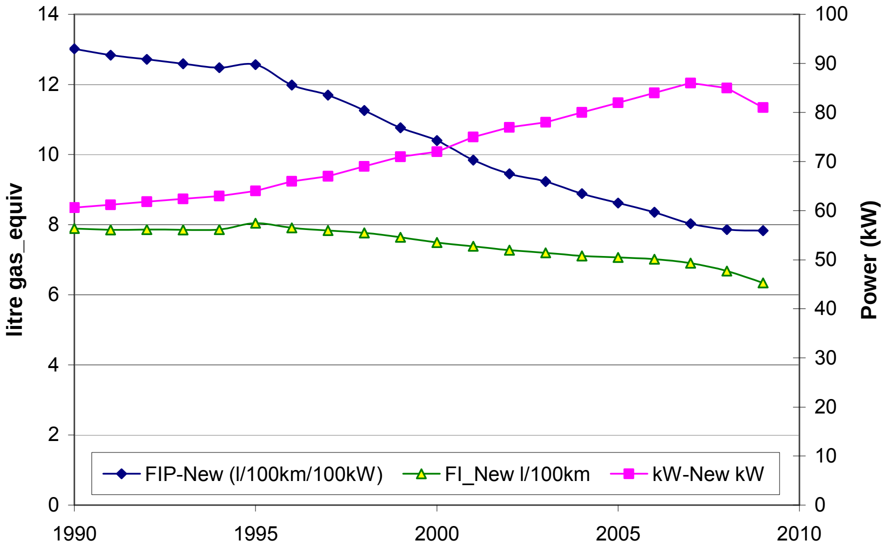
Figure 4 shows the development of fuel intensity, power-specific fuel intensity and power (kW) of new vehicles in EU-15 from 1990 to 2009. Fuel intensity (FI) in Fig. 4 and Fig. 5

does not reflect the real efficiency improvement because it is distorted by the switch to larger cars. To correct for this we define a power-specific fuel intensity (FIP):

$$FIP = \frac{FI}{vkW} \qquad (l/(100km\ kW)) \qquad (1)$$

vkW….vehicle power

It can clearly be seen from Fig. 4 and Fig. 5 that the decrease in FIP from 1990 to 2009 was virtually twice as high as the decrease of FI.



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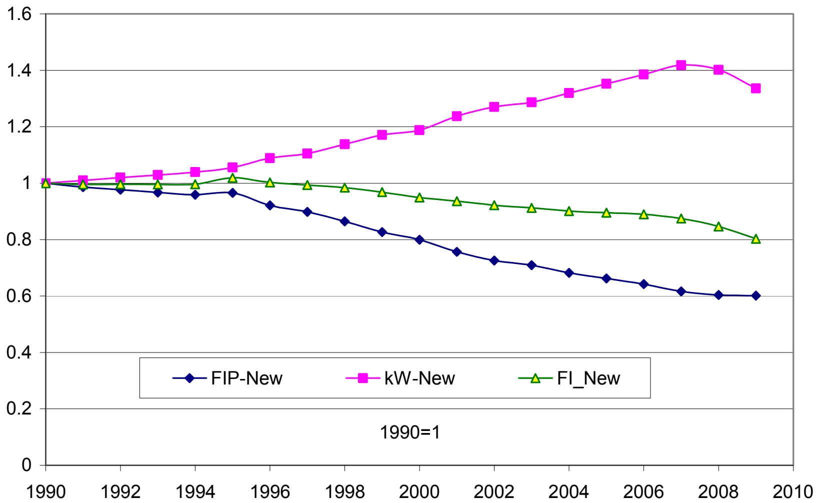

Figure 5. Normalised development (1990=1) of fuel intensity, power-specific fuel intensity and power (kW) of new vehicles in EU-15 from 1990 to 2009

THE IMPACT OF FUEL INTENSITY VS FUEL PRICE

The basic relationship for the following analyses is that energy consumption is the product of demand for services and fuel intensity.

$$E = S \cdot FI \tag{2}$$

The analysis in this paper builds on Ajanovic/Haas (2011a) [12]. They have analyzed the rebound effect due to improvements in fuel intensity FI (l/100 km driven). Fuel intensity was used as a proxy for the reverse of efficiency.
However, this analysis has been distorted because the used FI has been diluted by more powerful cars leading to lower FI reduction than the kW-related FIP, see Figure 4 and Fig. 5.

Ajanovic/Haas (2011a) have conducted an estimation of the following effects: (i) the effect of changes in fuel intensity including a saving effect and a rebound effect because of increases in vehicle km driven and (ii) the price effect[1] [12]. The level of service demand S of e.g. a household with respect to km driven depends on available income Y and the price of energy service P_S:

$$S = f(P_s, Y) = f(P \cdot FI, Y) = C(P \cdot FI)^{\alpha} Y^{\beta} \tag{3}$$

Using derivations the change in service demand (dS) can be split up into the price, the efficiency and the income effects:

$$dS = \frac{\partial f}{\partial P} dP + \frac{\partial f}{\partial FI} dFI + \frac{\partial f}{\partial Y} dY \tag{4}$$

In this paper we are further on interested in the change of service demand due to a change in the fuel price and the fuel intensity. We do not look at the income effect.

We proceed further using this equation and we obtain for the change in energy consumption:

$$dE = SdFI + FIdS \tag{5}$$

The change with respect to price is:

$$\frac{dE}{dP} = \frac{SdFI}{dP} + \frac{FIdS}{dP} \tag{6}$$

The change in energy demand (if dFI/dP=0)[2] due to the direct price effect is:

$$\frac{dE}{dP} = \frac{FIdS}{dP} \tag{7}$$

The change in service demand vehicle km driven caused by the price effect and using equ. (12) is:

[1] For better reading and following the arguments we repeat part of this formal analysis here.
[2] In the long run, lasting price changes will have an impact see e.g. Walker/Wirl (1993) [13].

$$\frac{dS}{dP} = \frac{\partial f}{\partial P} = \alpha (P\,FI)^{\alpha-1} FI \frac{P}{P} = \alpha \frac{S}{P} \tag{8}$$

where α is the elasticity of vehicle kilometres driven with respect to service price P_S. Straightforward, the change in energy demand due to a change in the fuel price is:

$$\frac{dE}{dP} = FI \frac{dS}{dP} = FI\alpha \frac{S}{P} \tag{9}$$

and the total energy change from a price change is

$$dE(dP) = FI\alpha\ S \frac{dP}{P} \tag{10}$$

Next the effect of an exogenous aggregated fuel intensity change is analyzed. Note that this FI also encompasses the switch to larger cars!

$$\frac{dE}{dFI} = FI \frac{dS}{dFI} + S \frac{dFI}{dFI} = \alpha FI (P\,FI)^{\alpha-1} P + S = S(\alpha+1) \tag{11}$$

and the total energy change from a change in FI is:

$$dE(dFI) = S(1+\alpha)dFI = SdFI + \alpha SdFI \tag{12}$$

To depict the actual numbers for the derivation presented above we use results from an econometric analysis conducted in Ajanovic (2011b) [14]. For the econometric analysis in this paper we used only 10 EU-countries from which we had sound data for vkm, price and fuel intensity.

Figure 6 shows the two effects due to changes in fuel intensity from equ. (12). The first effect is change in demand from driving more fuel efficient vehicles the same number of miles (SdFI). In Figure 6 we see that in 2007 the total change in FI led to total energy savings dE(dFI) of about 700 PJ. The second effect is the energy change from driving more kilometers, (α S dFI) called the rebound effect due to more driving. An example to explain the rebound effect in detail:

Assume FI old is 60 kWh/100 km and service price elasticity is (-0.4). If is improved by 10 % and we have 10000 km driven, we calculate theoretical savings of (60/100)· 0.1· 10000 = 600 kWh. Yet due to the rebound - now we drive 400 km more because we use FI and not FIP. So this is 10400 km - we now save only 360 kWh. Note, that this rebound is too small because it is curtailed by the switch to larger cars! The rebound effect led to an additional energy consumption of about 300 PJ.

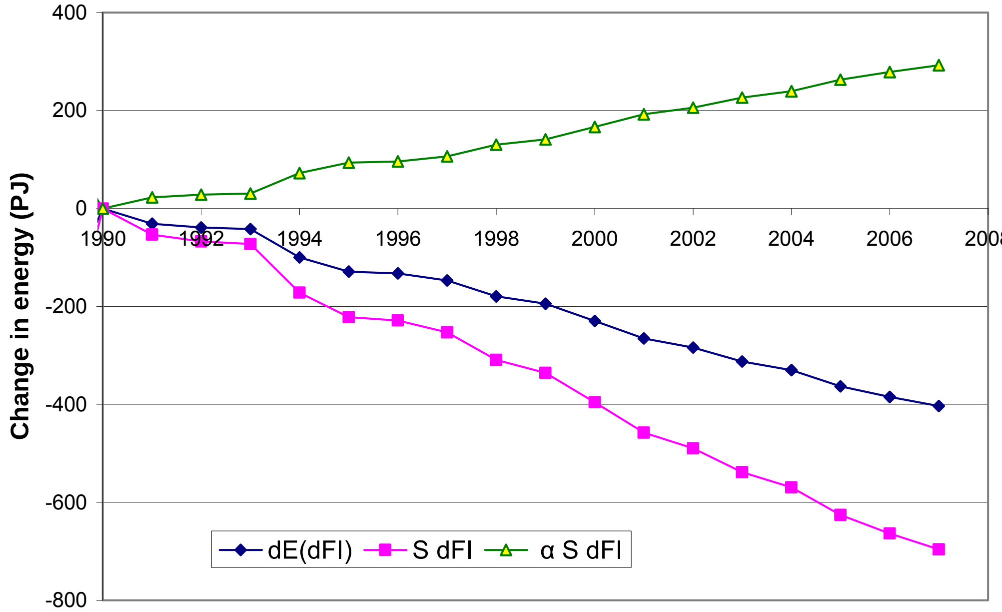

Figure 6. The change of energy consumption due to changes in fuel intensity for EU-15, base 1990

Figure 7 compares the overall effect due to a change in fuel intensity (dE(dFI)) and the price effect (dE(dP)). As shown in Figure 7, due to the volatility of the fuel price, the price effect can lead to higher or lower energy consumption. With respect to the fuel intensity effect savings in 2007 compared to the base year are about 400PJ, see Figure 7.
At the end of the investigated period in 2007, there was a price effect of about 600 PJ energy savings compared to 1990. In total the price and the FI effect brought about energy savings dE of about 1000 PJ.

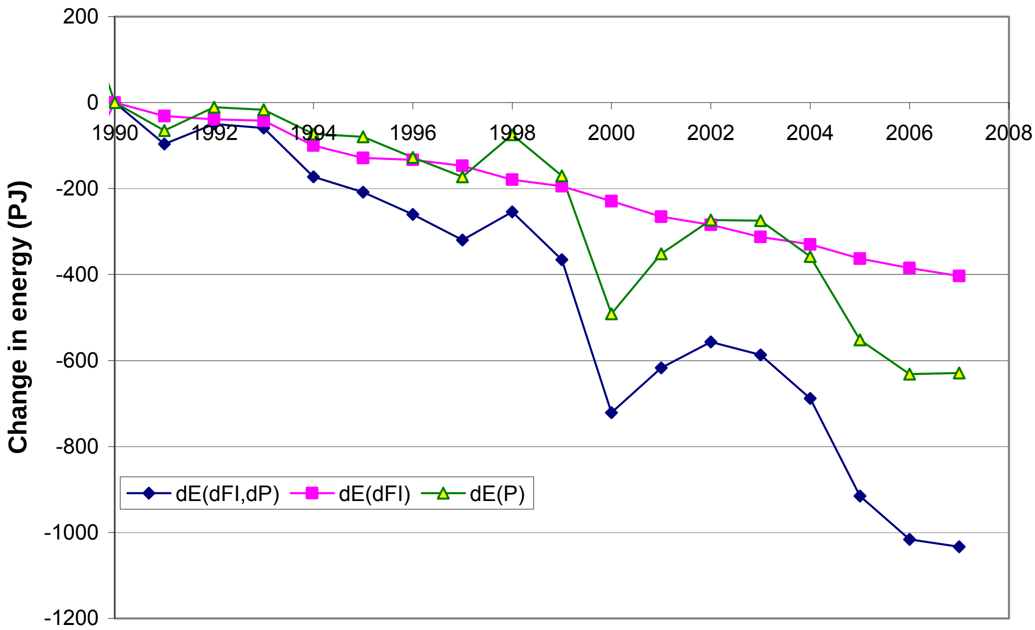

Figure 7. The change of energy consumption due to changes in fuel intensity and fuel price for EU-15, base 1990

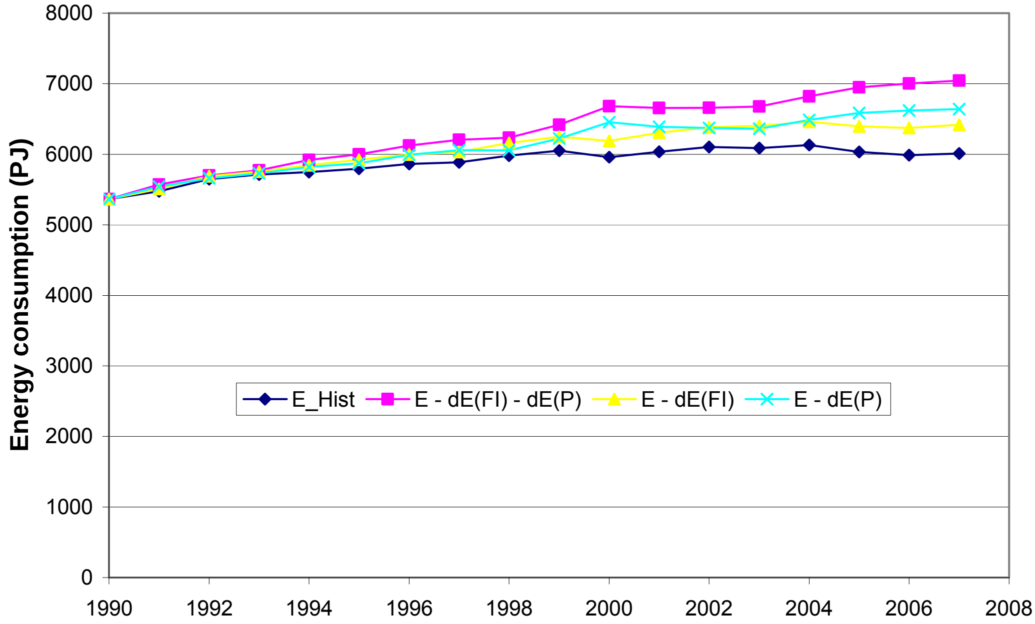

Figure 8. Historic development of total energy consumption in comparison to the impact of fuel intensity and the fuel price for EU-15, base 1990

THE IMPACT OF SIZE

Next we analyse the impact of vkm driven and the increase of average car capacity (kW) explicitly.

To do so, service demand in equation (2) is extended to a short-term and a long-term component (see also Ajanovic/Dahl/Schipper (2011) [15]):

$$E = S_{ST} S_{LT} FIP = vkm \cdot kW \cdot FIP \tag{13}$$

$$E = FIP \cdot vkW \cdot vkm \tag{14}$$

And for the change in energy consumption dE we obtain:

$$dE = dFIP \cdot vkW_0 \cdot vkm_0 + dvkW \cdot vkm_0 \cdot FIP_1 + dvkm \cdot FIP_1 \cdot vkW_1 \tag{15}$$

To calculate dvkW and dvkm we use the definition of service price elasticity. For constant fuel price –which is not subject to this investigation – we obtain:

$$\alpha = \frac{\dfrac{d(vkm \cdot vkW)}{vom_0 vkW_0}}{\dfrac{dFIP}{FIP}} \tag{16}$$

For holding power (vkW) const we obtain for dvkm:

$$dvkm = \alpha_{vkm} vkm_0 \frac{dFIP}{FIP} \tag{17}$$

For holding vkm constant we obtain for dvkW:

$$dvkW = \alpha_{kW} vkW_0 \frac{dFIP}{FIP} \tag{18}$$

And finally for the change in energy consumption:

$$dE = vkm_0 vkW_0 dFIP + \alpha_{vkW} vkW_1 vkm_0 dFIP + \alpha_{vkm} vkW_1 vkm_1 dFIP \tag{19}$$

In this equ. the first term (vkm_0 vkW_0 dFIP) refers to the savings due to the technical efficiency improvements. The term (α_{vkW} vkW_1 vkm_0 dFIP) is the additional energy consumption because of the rebound due to the switch to larger cars. And the last term (α_{vkm} vkW_1 vkm_1 dFIP) is the additional energy consumption because of the rebound due to more km driven with the more efficient car.

Note that for simplicity and currently lacking data we have assumed the same price elasticity for changes in vkm and changes in vkW.

CONCLUSIONS

The major perception of this analysis is: Due to pure efficiency improvements in the EU-15 about 50% more energy would have been saved (including vkm driven rebound) between 1990 and 2007 if no switch to larger cars would have been achieved.

In other words, due to increase in size of cars the saving effect because of efficiency improvement has been reduced to the half!

This leads to the major conclusion that policies that strive only for efficiency improvements for passenger cars will have very limited success. Hence it is necessary to introduce proper additional fuel taxes (to curb the increase in vkm) and size-dependent registration taxes (to avoid excessive increases in car size) to finally harvest the full benefits of better car efficiency.

REFERENCES

1. Görlich, R., Wirl, F., 2011. Interdependencies between Transport Fuel Demand, Efficiency and Quality: An Application to Austria, Energy Policy 2011 (forthcoming).

2. Schipper, L., 2009. Automobile Fuel; Economy and CO2 Emissions in Industrialized Countries: Troubling Trends through 2005/6, (mimeo)

3. Schipper, L., Hedges E., 2011. Perils of Prognoses: Lessons from the European Experience with Diesel Automobile Technology. Energy Policy.2011 (forthcoming).

4. Sprei, F. 2010. Energy Efficiency Versus Gains In Consumer Amenities. Examples from passenger cars and the Swedish building sector. Phd. Thesis. Gothenburg, Sweden: Chalmers University.

5. Ajanovic A. ed., 2009. Country review report. www.ALTER-MOTIVE.org

6. Schipper, L., 1995. Determinants of Automobile Energy Use and Energy Consumption in OECD Countries: A Review of the Period 1970-1992. Annual Review of Energy and Environment, 20.

7. IEA Statistics, Energy prices and taxes, 2010

8. OECD, National Accounts Statistics, 2010

9. Odyssee database, Energy Efficiency Indicators in Europe, www.odyssee-indicators.org

10. ACEA Statistics. http://www.ACEA.org

11. EU, 2010: Progress report on implementation of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles, COM(2010) 656 final

12. Ajanovic A, R. Haas, 2011a: The role of efficiency improvements vs price effects for modeling passenger car transport demand and energy demand – Lessons from European countries, Energy Policy, 2011 –forthcoming

13. Walker, I. O., F. Wirl, 1993. Irreversible Price-Induced Efficiency Improvements: Theory and Empirical Application to Road Transportation. The Energy Journal 14(4), 183-205

14. Ajanovic A, R. Haas, 2011b: On the effectiveness of standards vs taxes for reducing CO_2 emissions in passenger car transport Europe, Proc. RISÖ international conference, Roskilde, Denmark. 2011.

15. Ajanovic, A., Dahl C., Schipper L., 2011. Modeling Transport (Energy) Demand and Policies – an introduction. Energy Policy 2011 (forthcoming)