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Abstract

One of the most remarkable developments in passenger car transport in recent years was the rapid gain of market shares of diesel vehicles – especially in some European countries. The major reasons for this development were a better fuel economy – about 20% to 30% compared to gasoline – and lower fuel price (to some extent due to considerable tax benefits) which led to lower service prices per vehicle km driven of about 30% for diesel cars comparing to gasoline cars, as well as other well-known characteristics of diesel cars such as reliability and durability.

The crucial question from energy policy makers point-of-view and the core objective of this paper is: Did the switch to more efficient diesel cars also lead to effective energy savings on the aggregate level? In this paper we analyse whether this effect was achieved and whether the switch to diesel really led to over-all energy savings.

To answer this question we analyse the development of service demand (vehicle km driven) in passenger car transport in ten European countries – Austria, Denmark, France, Italy, Germany, Sweden, Spain, Portugal, The Netherland and United Kingdom –over the time period 1980-2007 by means of results of an econometric analysis.

The major conclusion is sobering: The major savings over time were brought about by over-all efficiency improvements for both gasoline and diesel cars. Due to better efficiency of cars in general between 1980 and 2007 about 9% of energy was saved of which about an eighth – 1 % – was saved due to the switch to diesel. Given this very moderate result we can conclude that the fuel tax incentives provided of about 10% to 50 % lower taxes for diesel than for gasoline were not at all justified.

So summing up better fuel intensities due to diesielisation did not lead to a remarkable energy conservation effect. The major saving effect was clearly due the general technical efficiency improvements of passenger cars.

Keywords: dieselization, efficiency improvement, rebound effect, energy conservation

1. Introduction

One of the most remarkable developments in passenger car transport in recent years was the rapid gain of market shares of diesel vehicles in many European countries. This gain of market shares was – among other reasons – probably caused by incentives for using diesel like significantly lower fuel taxes. One reason for these lower taxes was that diesel was considered to bring about environmental benefits because of lower fuel intensities and – as assumed – straightforward energy saving effects.

The crucial question from energy policy makers point-of-view is: Did the switch to more efficient diesel cars also lead to effective energy savings on the aggregate level? The core objective of this paper is to analyse whether this effect was achieved and whether the switch to diesel really led to over-all energy savings. This analysis is conducted in comparison to the energy savings due to over-all efficiency improvements for all passenger cars. In this paper we continue and extend the analysis of the impact of switch to diesel introduced in Ajanovic/Haas (2011a) and compare the over-all effects of fuel intensity
reductions with those due to the switch to diesel. We conduct the analysis for ten European countries for which data for the service vehicle km driven were available at least for the period 1980 to 2007.

2. Background

The share of diesel cars in the total vehicle stock in EU-15 increased from 3.3% in 1980 to 32% in 2007 (Ajanovic ed, 2009). In some EU countries (e.g. Austria, Belgium, France) diesel consumption in passenger car transport is higher than gasoline consumption. In 2009 about 49% of vehicles sold in EU-15 were diesel. In Belgium and France that figure is even significantly higher – about 75% (ACEA, 2010; Schipper, 2011).

The increase of the share of diesel on the stock of cars in some European countries like France, Austria, Italy, Germany, Denmark and Sweden is depicted in Figure 1.

![Figure 1. Increase in the share of diesel on stock of cars in some EU countries](image)

The increasing share of a new diesel cars and total stock of diesel cars in ten analysed European countries (Austria, Denmark, France, Italy, Germany, Sweden, Spain, Portugal, The Netherland and United Kingdom) is shown in Figure 2.
Figure 2. Increase in the share of diesel new cars (SHD_NEW) as well as in stock of diesel cars (SHD_ST) in the ten EU-countries investigated.

The major reasons for this development are a better fuel economy of diesel cars – about 20% to 30% compared to gasoline cars – and lower fuel price (to some extent due to considerable tax benefits, see Figure 4 and 5) which led to lower service prices per vehicle km driven of about 30% for diesel cars comparing to gasoline cars. Figure 3 shows the ratio of service price of gasoline Psg (EUR/100 km) and the service price of diesel Psd (EUR/100 km) for the average of all cars on the road. Figure clearly depicts the economic benefit of diesel with service prices of gasoline being between 32% (IT) to 46% (DK) higher in 2007.

Figure 3. Development of the ratio of service prices gasoline / service price diesel in some European countries (Ajanovic/Haas (2011a))
Along with better fuel efficiency, the other well-known characteristics of diesel cars are reliability and durability.

At the moment, taxes on gasoline in Europe is in the range from 49% to 60%, and taxes on diesel from 42% to 63% of the pump price. However, the total tax on gasoline is higher in all investigated countries, see Figure 4.

![Figure 4. Excise taxes on gasoline and diesel (Data source: Europe's Energy Portal, effective March 2, 2011)](image)

In Figure 5 the percentage is shown to which gasoline is taxed higher than diesel. As shown, the biggest difference between the tax on gasoline and diesel is in The Netherlands and lowest in United Kingdom.
Figure 5. Percent of which gasoline is taxed higher than diesel

Having better fuel economy in comparison to gasoline cars of about 20% to 30%, diesel cars of same size have in average also lower carbon dioxide emissions per kilometre driven.

Figure 6. Targets and average CO₂ emissions from new passenger cars by fuel (EU27) (COM 2010, 656)

The evolution of average CO₂ emissions from new gasoline and diesel passenger cars is shown in Figure 6. The figure shows also European targets till 2020 regarding the reduction of CO₂ emissions from new passenger cars.
3. Method of approach

The method of approach applied in this paper builds on the seminal contribution by Greene (1997) using:

\[ E = S \cdot FI \tag{1} \]

with \( S \) is vehicle km driven and \( FI \) is fuel intensity in e.g. litre/100km. For the change in energy consumption due to changes in \( FI \) \(^1\) we obtain:

\[ dE = SdFI + FIdS \tag{2} \]

To extract the rebound effect in this paper we use the results obtained in Ajanovic/Haas (2011b) for service price elasticity (for the same set of 10 EU-countries as investigated here) for the service vehicle km driven of (-0.42) over the time period 1980-2007 by means of an econometric analysis. This figure is used to further on calculate the energy savings based on equ. (2) including the rebound effect.

This analysis is applied to identify the impact of the overall decrease of \( FI \) and to the diesel-specific \( FI \)-effect.

4. The over-all savings due to reductions in fuel intensity

In this chapter we analyze the impacts of total changes in fuel intensity for gasoline and diesel cars on energy consumption. That is to say we look at the total energy savings due to efficiency improvements of passenger cars. In the context of analysing the energy savings due to efficiency improvements one of the most critically discussed issues is the rebound effect, see e.g. Greene (1997) and Ajanovic/Haas (2011a).

In the following, we conduct an estimation of the effect of changes in fuel intensity including a saving effect and a rebound effect because of increases in vehicle km. This analysis is based on the investigation in Ajanovic/Haas (2011a). The definition of service demand \( S \) used is:

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

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 intensity. We do not look at the price and income effect.

Next we analyse this effect of an exogenous fuel intensity change using equ.(3) :

\[ \frac{dE}{dFI} = FI \frac{dS}{dFI} + S \frac{dFI}{dFI} = \alpha FI(P \cdot FI)^{-1} P + S = S(\alpha + 1) \tag{5} \]

\(^1\) See also the detailed derivation in Ajanovic at al (2011)
and the total energy change from a change in FI is:

\[ dE(dFI) = S(1 + \alpha)dFI = SdFI + \alpha SdFI \]  

(6)

Figure 7. The change of energy consumption due to changes in fuel intensity for EU-10, base 1980

Figure 7 shows the two effects due to changes in fuel intensity from equ. (6). The first effect is change in demand from driving more fuel efficient vehicles the same number of miles (SdFI). In Figure 7 we see that since 1984 the total change in FI led to total energy savings \( dE(dFI) \) of about 950 PJ in EU-12. The second effect is the energy change from driving more kilometres, \( (\alpha SdFI) \) called the rebound effect. The rebound effect led to an additional energy consumption of about 400 PJ, see Figure 7.

5. The impact of the increasing use of diesel

So we have identified now the overall savings due to reduction in aggregated fuel intensity. Next we analyse what was the specific impact of the switch to diesel.

The difference in the development of fuel intensities of gasoline and diesel cars is depicted in the following Figures 8 and 9 in litres per corresponding fuel (litre gasoline/100 km and litre diesel/100 km) for EU-10 from 1980 to 2007. While per litre there can be seen a remarkable difference, see Figure 8. However, the energy–corrected figures showing diesel consumption also in gasoline units is much less impressing, see Figure 9.

Note that it is very important to consider that the lines in the Figures 8 and 9 also include changes in sizes. So part of the slow decrease of the fuel intensity for diesel cars is due to the switch to larger cars.
Yet, we can extract the fuel intensity effect in a similar way to that in the preceding chapter. In this chapter we were interested in the effects of changes of fuel intensities over time. Now we are interested in the effects of the differences in fuel intensity between the fuel mix and gasoline. The change in this mix is caused by the switch to diesel.

So we are interested in the change of the difference $\Delta FI$ of the fuel intensity between the fuel mix and gasoline over time due to the switch to diesel. That is to say, of interest is how much better weighted average fuel intensity $FI$ (see equ. (7)) is than fuel intensity of gasoline cars $FI_g$ in a specific year, see Figure 10.
\[ FI = \frac{FI_g \cdot S_g + FI_d \cdot S_d \cdot \frac{LHV_d}{LHV_g}}{S_g + S_d} \]  

(7)

where
- \( FI_g \).........average fuel intensity of gasoline cars (L/100 km)
- \( FI_d \).........average fuel intensity of diesel cars (L/100 km)
- \( S_g \).........vehicle km driven by gasoline cars
- \( S_d \).........vehicle km driven by diesel cars

This difference \( \Delta FI \) is:

\[ \Delta FI = FI_g - FI \]  

(8)

To extract the fuel intensity impact of the switch to diesel we use equ. (2). We look at the impact of a change in \( \Delta FI \) and we obtain

\[ \frac{dE}{d(\Delta FI)} = FI \frac{dS}{d(\Delta FI)} + S \frac{dFI}{d(\Delta FI)} \]  

(9)

Equivalently to equation (5) \( dS \) is:

\[ dS = \alpha \frac{S}{FI} d(\Delta FI) \]  

(10)

and finally we obtain for the total change in energy consumption due to a change in \( \Delta FI \):

\[ dE(d(\Delta FI)) = S \ d(\Delta FI) + \alpha \ S \ d(\Delta FI) \]  

(11)
The two components of equation (11) as well as the total change of energy consumption depending on $\Delta FI$ - the lower fuel intensity of diesel - are depicted in Figure 11.

![Figure 11](image1)

**Figure 11.** Impact of changes in fuel intensity due to a switch to diesel for EU-10, (base 1980) on total energy consumption

In Figure 12 finally a comparison of energy savings due to over-all energy efficiency improvements of passenger cars and the effect of the lower fuel intensity of diesel is provided. It can clearly be seen that the effect of diesel is small compared to the general saving effect. So summing up better fuel intensities due to dieselsation did not lead to a remarkable energy conservation effect. The major saving effect was clearly due the general technical efficiency improvements of passenger cars.

![Figure 12](image2)
6. Conclusions

In this paper we have analysed, how the switch to diesel cars with presumed considerably lower fuel intensity in European countries has influenced over-all energy consumption in road passenger car transport.

The major conclusion is sobering: The largest part of savings over time was brought about by over-all efficiency improvements for both gasoline and diesel cars. Due to better efficiency of cars in general between 1980 and 2007 about 9% of energy was saved of which about an eighth – 1 % – was saved due to the switch to diesel. Given this very moderate result we can conclude that the fuel tax incentives provided of about 10% to 50 % lower taxes in different European countries for diesel than for gasoline were not at all justified. Moreover, this analysis did not yet takes into account the increase in energy consumption due to the price effect for cheaper diesel. Considering this additional aspect is left for analysis in a further paper.

References

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