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Abstract

The objective with this study is to analyze the role of energy taxes for energy efficiency in the Swedish transport sector. In particular we analyze how large share the Swedish energy tax will contribute to the overall Swedish target for energy efficiency set by the EU directive for energy efficiency. To obtain the objective a dynamic demand model for gasoline and diesel is estimated, based on Swedish time series data from 1976 to 2012. The results from the demand model shows that a higher tax on gasoline results in lower gasoline demand, but leads to an increase in diesel consumption, and vice versa. A removal of the energy and CO2 tax, lowering both the gasoline and diesel consumer price, leads to an overall increase in energy use, but also to an increase in the share for diesel in fuel use. Concerning energy savings the simulation results show that the current Swedish energy and CO2 taxes are sufficient for achieving the EU stipulated target, and hence no additional measures has to be taken.

Key words: energy efficiency, gasoline, diesel, cointegration

1. Introduction and previous literature

The objective with this study is to analyze the role of energy taxes for energy efficiency in the transport sector. In particular we will analyze how large share the Swedish energy tax will contribute to the overall Swedish target for energy efficiency set by the EU directive for energy efficiency. To obtain our objective we estimate a dynamic demand model for transport fuel in Sweden (gasoline and diesel), based on time series data from 1976 to 2012.

The background to this particular objective is the EU Climate and Energy Package that stipulates, among other things, a 20% increase in energy efficiency in 2020, compared to 2009. The overall targets in the package were set by EU leaders in March 2007, when they committed Europe to become a highly energy-efficient, low carbon economy, and were enacted through the climate and energy package in 2009.[1] Concerning energy efficiency, what specific target to be met and how, was stipulated 2012 in the Energy Efficiency Directive (EED, Directive 2012/27 EU). According to Article 7 of the EED, all member countries of the EU have to carry out annual energy efficiency measures over the period 2014 – 2020 representing 1.5% of the annual volume of energy sold to end users. Each member country is then responsible to present a plan of how this target will be met. For Sweden the Swedish Energy Agency (Statens Energimyndighet) have been commissioned by the Swedish government to both detail what this target implies for Sweden concerning the specific energy efficiency target over the stipulated period, and to present a plan of how to reach the target. According to the presented plan (see Statens Energimyndighet ER 2013:04) the Swedish target is that measures should be presented amounting to an energy efficiency improvement of 75 TWh, accumulated over the whole period 2014-2020. According to the EED the transport sector is excluded from this target, since other EU directives handle it. On the other hand the interpretation of the EED is that effects on energy use in the transport sector due to broader policy instruments that are not specific for the transport sector can be counted in, and that such policy instruments that already is in use should be included. Among other things this means that the part of the general energy tax on transport fuels and the CO2 tax on gasoline and diesel that are above the EU minimum tax rates can be considered as a policy instruments in use, and not specific for the transport sector, and should hence be accounted for. The

[1] see http://ec.europa.eu/clima/policies/package/index_en.htm for a description of the package.

specific purpose here, then, is to analyze what contribution to the target of 75 TWh the current energy and CO2 tax have.

The strategy used here to reach the objective this is simply to estimate consumer demand functions for gasoline and diesel, and then use the estimated functions to obtain a reference scenario for gasoline and fuel consumption under ”business as usual”, and compare this with the outcome from a scenario where the energy and CO2 tax is lowered to the EU minimum level. The difference in energy use between the two scenarios is then the energy savings due to the taxes. The paper contributes to the literature in at least two different ways. The first is that we explicitly take substitution possibilities between gasoline and diesel into account. The second being that we explicitly use the estimated model for policy evaluation.

Basically fuel demand models can be classified into two different types; the first being models using aggregated time series data, the second using micro data, usually on the household level.

Concerning the first type they include, among others, static and dynamic models as well as different kinds of vehicle stock models. The data used in these types of models are usually time series data for individual countries, or panels consisting of aggregated time series for several countries. Earlier dynamic models using time series was most often in the form of lagged dependent variable type of models with no specific attention to the underlying data generating process. More recently, starting with Bentzen (1994), more explicit dynamic models have been used, taking the time series properties into account, such as error correction and structural time series models. An example of the former is Bentzen (1994), Eltony and Al-Mutairi (1995), Samimi (1995), Ramanathan (1999), and Polemis (2006). Examples of the latter type are Broadstock and Hunt (2010), and Karimu (2011). All these types of models have almost exclusively focused price and income elasticities. By now there exists a vast number of studies using these types of models (see Dahl, 2012 for the most recent survey). Interestingly, the majority of the studies concern either gasoline only, or some aggregate of motor fuels. In other words, fairly few studies do not explicitly take substitution possibilities between fuels, such as gasoline and diesel, into account. One of few exceptions is Polemis (2006), who estimate gasoline and diesel demand in Greece using a cointegration approach.

The second type of models, those who use micro data, have usually not been focusing price elasticities, but rather welfare effects and distributional effects due to changes in prices and/or taxes. Examples of such models can be found in Archibald and Gillingham (1980), Schmalensee and Stoker (1999), Yatchew and No (2001), West and Williams (2004) and (2005), Brännlund & Nordström (2004), and Wadud et al. (2010). In those studies where a price elasticity is estimated it tend to be higher than in models based on aggregate time series.

As a result of the vast amount of studies there exists several surveys of fuel demand studies over time, such as Dahl (1986), Dahl and Sterner (1991), Sterner and Dahl (1992), Espey (1998), Graham and Glaister (2002), Goodwin et.al (2004), Brons et.al. (2006), and Dahl (2012). Overall, the main conclusion that can be drawn from these surveys is that the price elasticity for gasoline demand is on average -0.2 in the short run, and -0.7 in the long run, but with a large variation between studies. In Polemis (2006), where diesel demand is included, the short run own price elasticity for diesel in Greece is -0.07, and the corresponding long run elasticity -0.44. Surprisingly, gasoline and diesel appear to be complements (negative cross price effect) in Polemis (2006). Brons et.al. (2006) perform a meta analysis on gasoline demand elasticities, in which they also decompose the elasticity into its three basic components; fuel efficiency, mileage per car, and number of cars. They find that the average elasticity is -0.53, and that the largest contribution comes from fuel efficiency and number of cars. Not surprisingly they also find that cross section and long run studies show a higher price elasticity (more negative). Interestingly they also find that the price elasticity have been stable over time.

The modeling approach in this study is mostly in the spirit of Polemis (2006), although focus is not on the modeling per se, but rather on policy evaluation.

The rest of the paper is structured as follows. In the next section, section 2, the modeling framework is outlined. The econometric model and the data that is used are presented in section 3. The results from the estimation of the econometric model are presented in section 4, while the simulation of the tax changes are presented in section 5. The paper ends with some concluding comments in section 6.

2. Modeling framework

The modeling framework used here is based on standard consumer theory. That is, consumers are assumed to attain utility from transport services and consumption of other goods and services. It is then assumed that they choose the amount of transports and other goods and service consumption in order to maximize utility, subject to their budget constraint. As a result, demand for transports will become a function of the price of transport services, price of other goods and services, and income. The price of transports is of central interest here since it includes the price of fuels, the energy efficiency of the vehicle, and the user cost (apart from fuel cost) of the vehicle. Since fuel demand is a derived demand through the transport service that fuel enables, and that it is directly connected to a specific type of capital we can alternatively decompose fuel demand into its components (see Johansson and Schipper, 1997). That is, we can express fuel demand as the product of fuel consumption per kilometer (*E*), driving distance per car (*D*), and number of cars (*K*). This latter approach of expressing fuel demand have the advantage that it enables us to disentangle the effects, from say a price increase on fuels, on the various components, hence making it possible to explicitly separate short run effects from long run effects. The downside is that it is very data demanding, and also that the final fuel demand may be very sensitive to the specification of each component. Formally we can then express fuel demand as:

$$q = E(p,y) \cdot D(p,y) \cdot K(p,y), \qquad (1)$$

where, *p* is fuel price, and *y* income.

The expression in (1) is general in the sense that all components may be dependent on fuel price and income. The approach taken here is a reduced form approach, mainly due to lack of data, which means that we write the fuel demand equation as:

$$q = q(p,y) \qquad (2)$$

The price and income elasticity is then

$$\begin{aligned} \frac{\partial q}{\partial p}\frac{p}{q} &= \varepsilon_p = \varepsilon_p^E + \varepsilon_p^D + \varepsilon_p^K \\ \frac{\partial q}{\partial y}\frac{y}{q} &= \varepsilon_y = \varepsilon_y^E + \varepsilon_y^D + \varepsilon_y^K \end{aligned} \qquad (3)$$

It is reasonable to believe that the short run price elasticity is smaller (in absolute value) than the long run elasticity, mainly because it is plausible that the effect of a fuel price change on the choice of car, and number of cars in a household, is small in the short run. Concerning changes in income it is less clear what the effects on fuel demand will be. An increase in income is usually expected to lead to an increase in fuel demand, through longer driving distances, more cars, and maybe bigger cars. On the other hand it can’t be ruled out that higher income increases the depreciation rate in the car fleet, i.e. old fuel inefficient cars are replaced at a faster rate by newer cars that are more fuel efficient. That is, it can't be ruled out that e_Y^g is negative and even outweigh the two other positive effects. Here we do not estimate the individual components of the price and income elasticity, but rather the total price and income elasticities, ε_p and ε_Y.

The modeling framework that we use can more formally be expressed as follows. We assume that individuals, or households, in principle employ a multistage decision process[2]. In the first stage the consumer maximizes utility by allocating his/her budget for consumption on aggregates of goods, such as food, clothes, and transport fuels[3]. This gives us then the unconditional demand functions for these main aggregates. More formally we can express this as:

$$\begin{aligned}&\max_{q^g,q^d,q^o} U(q^g,q^d,q^o)\\ &s.t.\; p^g q^g + p^d q^d + p^o q^o \le y\end{aligned} \tag{4}$$

where the superscripts *g*, *d*, and *o*, stand for gasoline, diesel, and the aggregate of other goods. The price of the aggregate good, p^o, is then a aggregate price index for other goods. In this study we use the consumer price index as the price of other goods.

Solving (1) gives us then the unconditional demand functions for gasoline, diesel, and other goods as:

$$q^g = q^g(p^g, p^d, p^o, y) \tag{5}$$

$$q^d = q^d(p^g, p^d, p^o, y) \tag{6}$$

$$q^o = q^g(p^g, p^d, p^o, y) \tag{7}$$

Since the demand functions (5) – (7) are homogenous of degree zero in all prices and income, we can divide through by the price of other goods, p^o, and get demand for gasoline and diesel as a function of real prices and real income, that is:[4]

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[2] This means, among other things, that we assume that preferences are weakly separable (see for example Edgerton, 1997). That is, the quantity consumed of, say, transport fuel (gasoline and diesel) does not affect the marginal rate of substitution between other goods (for example meat and fish).

[3] Here it is simply assumed that the saving-consumption choice has already been made.

[4] Since focus is on fuel consumption, we do not consider demand for other goods, although we can in principle retrieve the demand function for other goods from the adding up property.

$$q^g = q^g(P^g, P^d, Y) \tag{8}$$

$$q^d = q^g(P^g, P^d, Y) \tag{9}$$

Where $P^i = p^i/p^o$ and $Y = y/p^o$.

Given consumption on each specific fuel type, total energy use from transport fuel can be expressed as:

$$Q^E = \theta_g \cdot q^g + \theta_d \cdot q^d \tag{10}$$

where θ_g and θ_d are conversion factors, from volume units to energy units.

The effect on total energy use as a result of a change in the energy tax is then:

$$\frac{\partial Q^E}{\partial \tau} = \theta_g \left(\frac{\partial q^g}{\partial P^g}\frac{\partial P^g}{\partial \tau} + \frac{\partial q^g}{\partial P^d}\frac{\partial P^d}{\partial \tau} \right) + \theta_d \left(\frac{\partial q^d}{\partial P^g}\frac{\partial P^g}{\partial \tau} + \frac{\partial q^d}{\partial P^d}\frac{\partial P^d}{\partial \tau} \right)$$

A higher energy tax rate will give rise to higher consumer prices on both gasoline and diesel. Due to the own price effect, consumption of each type of fuel will decrease. But since gasoline and diesel are substitutes the cross-price effects are positive, counteracting the own-price effect. The total effect on energy use of a tax increase will however be negative for normal goods, i.e. for goods with a positive income elasticity, due to the income effect.[5] Furthermore, the effect on total energy use also depends on the energy content in each of the fuels.

3. Data and econometric model

The data that is used are aggregated time series data for Sweden, spanning over the period 1974 – 2012. Before estimation of the demand functions we normalize aggregate consumption and GDP with the population, meaning that we can think of this as demand for a representative Swedish consumer.

The data used in this study is retrieved from two main sources, the Swedish Petroleum and Biofuel Institute, and Statistics Sweden. Data on fuel consumption and fuel prices, gasoline

[5] The sum of the demand elasticities for each good (own and cross price) equals the negative of the income elasticity for the same good, i.e. $e_{gg} + e_{gd} = -e_{gy}$, and $e_{dg} + e_{dd} = -e_{dy}$, where the e's denote elasticities. (Henderson and Quandt, 1980).

and diesel, is taken from the Swedish Petroleum and Biofuel institute (www.spbi.se), and data on GDP (y), the consumer price index (CPI), representing the price index of other goods (p^o), and population is taken from the Statistics Sweden. Gasoline and diesel consumption is in cubic meters, and prices and GDP in SEK. Nominal prices and GDP are converted to real prices and real income by dividing with the CPI.

A graphical description of the data is found in appendix A. From the graphical description one may suspect non-stationarity of the variables, whereas the first difference appear stationary. To formally test this we employ standard Dickey-Fuller (DF) tests (augmented) in which the null hypothesis is a unit root versus stationarity.[6] The results from these tests are presented in appendix B. For the standard DF test we find a positive test statistics for all variables but the price of diesel. This may indicate that there is a deterministic trend and/or drift in the data. This is also confirmed by the DF tests in which a constant, trend, and/or a lag are included. An exception though is the DF value for gasoline consumption, which is still positive even in the case with a constant and a trend. A closer examination of the gasoline consumption series (in logarithms) reveal a sharp downward shift in gasoline consumption in 2007, indicating some kind of structural break at that time period. To check for this a DF test was run for the time period 1976 – 2006, i.e. the five last years were deleted. The results from this indicate clearly that we can't reject the null of a unit root when we also account for a deterministic trend. In summary all this means that we can't reject the hypothesis of unit roots in the individual time series, at least if we take into account a time trend and a structural break in 2007 for gasoline consumption.

Given the property of unit-root time series the Engel and Granger (1987) two step approach may be appropriate. The main advantage with this approach is that it is simple, transparent and conforms well to economic theory. This also provides additional tests of cointegration through Grangers representation theorem.

Equations (8) and (9) forms the basis for the econometric model. We follow a fairly standard approach by specifying (8) and (9) as log-linear functions. The experience from the literature is that the log-linear functional form seems to work well. In addition it is simple, and the results are easy to interpret and comparable to other studies. Following from the inspection of

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[6] See Dickey and Fuller (1979), Mckinnon (1994), and Maddala and Kim (1998) for an exposition of these tests.

the individual time series an exogenous time trend will be appended, as well as a dummy variable which takes the value of one for the period 2007-2012. Given all this the econometric model that will be used can be written as:

$$\ln q_t^i = \alpha_{i0} + \sum_{j=g,d} \alpha_{ij} P_t^j + \alpha_{iY} \ln Y_t + \alpha_{iT} t + \alpha_{iD} D_t + \varepsilon_t^i, \quad i = g, d, \alpha_{dD} = 0 \qquad (11)$$

$$\Delta \ln q_t^i = \beta_{i0} + \sum_{j=g,d} \beta_{ij} \Delta \ln P_t^j + \beta_{iY} \Delta Y_t + \theta_i \varepsilon_{t-1}^i + u_{it} \qquad (12)$$

where t denotes time, D a dummy variable that takes the value of one for the period 2007-2012, zero otherwise, and ε_{it} is a random term. Given this particular functional form, the parameters can be interpreted as elasticities. Given the error correction approach equation (11) is the long run relation, and ε can hence be interpreted as deviations from equilibrium. However, there may be temporary deviations from such long run equilibrium, due to some stochastic shock, and due to temporary price and income changes. This is captured in the second step, the short run dynamic relations, specified in equation (12). Equation (12) is the dynamic, or short run, relation where Δ denotes the first difference. The parameter θ is the error correction parameter that shows how short run consumption changes as a result of deviations from the long run, i.e. the speed of adjustment. Given that the variables are cointegrated, this parameter should be negative since a positive deviation from the long run relationship should result in a downward adjustment in consumption. Thus we can test for cointegration by first testing if the residuals in (11) are stationary, but also through Grangers representation theorem by testing if the error correction terms are significantly negative. For the former test we use the same tests as for the individual series, whereas for the latter we use a standard t-test.

4. Econometric results

The results from the estimation of (11) and (12) are shown in table 1 and 2. Since all variables are in logarithmic form they can be interpreted as elasticities.

The results in table 1 shows expected signs of the estimated coefficients. The own price elasticities are negative, whereas the cross price elasticities are positive. Concerning the income elasticity it is positive but lower than 1. Furthermore most of the parameters are highly significant. An exception, though, is the income elasticity for diesel, which is not significant different from zero. One possible explanation to the latter is that there is a strong correlation between income (GDP) and *t*, the deterministic trend, which means that the income effect is captured by the trend variable. The parameter corresponding to the deterministic trend (*t*) is negative in the gasoline equation, which may be explained by technological development in the sense that both gasoline and diesel propelled cars have become more energy efficient. The positive trend effect for diesel cars is not however an effect of less energy efficient cars, but is rather an effect of more consumer friendly and efficient diesel cars, which contributed to a positive trend over time in the substitution towards diesel cars, i.e. the trend captures both changes in technology and preferences.

Table 1. Estimates of long run equation (equation (11)).

	Gasoline		Diesel	
	Coef	t-value	Coef	t-value
C	-2.05	-0.95	-4.71	-1.83
P^b	-1.09	-9.19	0.40	3.35
P^d	0.45	6.13	-0.40	-5.19
Y	0.51	2.78	0.25	1.18
T	-0.01	-2.36	0.02	4.01
D	-0.13	-4.90	-	-
R2	0.92		0.96	
DW	1.38		1.34	
NOBS	37		37	
DF test[1]	-4.22*		-4.16*	

[1] Dickey-Fuller test: $\Delta\varepsilon = (\rho-1)\varepsilon_{t-1}$

* Significant different from zero, 1% level

Concerning cointegration we use the Dickey-Fuller test on the residuals, and according to this test we can't reject the hypothesis of a unit root in the residuals. As a result we may interpret the results in table 1 as long-run elasticities.

Table 2 shows the results from the second step, that is the short run elasticities. As can be seen, also here have the estimated parameters the expected signs. They are also smaller in magnitude, which also is expected. Furthermore, the error correction parameters are both negative and significant, which supports the modeling approach and further supports cointegration.

Table 2. Estimates of short run equation (equation (12)).

	Gasoline		Diesel	
	Coef	t-value	Coef	t-value
Konstant	-0.009	-1.75	0.01	2.06
Δp^b	-0.58	-5.09	0.12	0.71
Δp^d	0.18	2.63	-0.17	-1.82
ΔY	0.26	1.57	0.30	1.11
$EC_{(t-1)}$	-0.43	-2.79	-0.61	-3.71
R2	0.51		0.34	
DW	0.66		1.99	
NOBS	36			

To summarize, the results shows that a higher price of a specific fuel reduces consumption of the same fuel, but increases consumption of the other one. In other words, gasoline and diesel seems to be substitutes, as expected. These effects are stronger in the long run, as also expected. The results concerning price effects are summarized in table 3. Table 3 also shows the effect on energy use as a result of price changes.

Table 3. Effects on fuel consumption and energy use in percent from changes in prices.

	Percentage price change		
	$\Delta P^g = 10$ $\Delta P^d = 0$	$\Delta P^g = 0$ $\Delta P^d = 10$	$\Delta P^g = 10$ $\Delta P^d = 10$
Δq^g short run	-5.8	1.8	-4.0
Δq^g long run	-10.9	4.5	-6.4
Δq^d short run	1.2	-1.7	-0.5
Δq^d long run	4.0	-4.0	-0.0
ΔE short run	-1.6	-0.3	-1.9
ΔE long run	-1.9	-0.6	-2.6

$$\Delta E \text{ short run} = (\alpha_{gg} + \alpha_{dg})\Delta p^g \cdot s^g + (\alpha_{gd} + \alpha_{dd})\Delta p^d \cdot s^d$$

$$\Delta E \text{ long run} = (\beta_{gg} + \beta_{dg})\Delta p^g \cdot s^g + (\beta_{gd} + \beta_{dd})\Delta p^d \cdot s^d$$

s^g and s^b are the shares of total (gasoline and diesel) energy use for gasoline and diesel respectively.

Conversion factors from gasoline and diesel to energy are 9 004 KWh/m^3 and 9 960 KWh/m^3 respectively.

From table 3 we see that a 10% gasoline price increase leads to a reduction of energy use by 1.9% in the short run, and 2.6% in the long run. However, if the price of diesel increases by 10%, everything else unchanged, we see that the reduction in energy use will be very small. The reason being that the substitution towards gasoline counteracts the own price effect. More interestingly is the effect of a change in both the gasoline and diesel price, for example due to an increase in the energy tax for these fuels. From table 3 it is clear that this will lead to a fairly sharp decrease in gasoline consumption, whereas diesel consumption remains almost unchanged. The net effect on energy use is however negative.

5. Simulations

The result presented above will be used to simulate the effects on fuel consumption and energy use from a change in consumer prices resulting from an adjustment of the Swedish energy tax to the EU minimum tax rates.

The principle for the simulations is straightforward. From equation (11) we get:[7]

$$\varepsilon_{t-1}^{i} = \ln q_{t-1}^{i} - (\alpha_{i0} + \sum_{g,d} \alpha_{ij} \ln P_{t-1}^{j} + \alpha_{iY} \ln Y_{t-1} + \alpha_{iT}(t-1)), \qquad (13)$$

which then is substituted into equation (12). Solving for q gives us:

$$\ln q_{t}^{i} = \tilde{\alpha}_{i0} + \sum_{g,d} \left(\beta_{ij} \ln P_{t}^{j} - (\beta_{ij} + \theta_{i}\alpha_{ij}) \ln P_{t-1}^{j} \right) + \beta_{iY} Y_{t} + (\beta_{ij} + \theta_{i}\alpha_{iY}) \ln Y_{t-1} + (\theta + 1) \ln q_{t-1}^{i} \quad (14)$$

Then we use the estimated parameters in equation (14) and assume that we are in a steady state, or long run equilibrium, the year before the start year (2013) that corresponds to actual consumption of gasoline and diesel that year. Next we construct a reference scenario concerning real price and income (GDP) development, and two policy scenarios. In all scenarios real prices when taxes are excluded are assumed to be unchanged over the period 2014 to 2020. Concerning income we may consider alternative reference scenarios. In our base scenario here we assume that the real income is unchanged, i.e. no economic growth. We have considered a second in which we assume a 2% annual growth rate. The results from the latter is not presented here, but the interested reader can get upon request. Fuel taxes in the reference scenario are assumed to be at the same level as 2013 over the whole period, whereas

[7] The dummy effect is suppressed to save notational clutter. It can be seen as included in the constant.

in the alternative scenarios fuel taxes are adjusted to the EU minimum level. The basic scenario assumptions are displayed in table 4.

Table 4. Basic scenario assumptions

		Real consumer price SEK/liter		Change in consumer price %	
		gasoline	diesel	gasoline	diesel
Ref	2014-2020	14.26	14.09	0	0
Sc 1	2014-2020	8.27	9.01	-42	-36

At least two things should be noted. Firstly, it may seem unimportant what we assume concerning economic growth since we are comparing two scenarios with the same growth rate. This is correct as long as we only are interested in percentage changes of volumes. If we are interested in units of energy this no longer holds true since the levels will be higher in a growth scenario and that the different fuels have different energy content. Secondly, it may seem sufficient to just use the long run elasticities presented above to calculate the effect since there is a single permanent price change. This, however, will overestimate the accumulated effect since such a calculation assumes that consumption in each period have adjusted to the steady-state level. This motivates to some extent the explicit dynamic simulations here.

The results from the simulations are presented in table 5. As is shown in table 5, the short run, or first year, effect on total energy use is a 10% increase, while the effect the last year is 14.8%. We also see that a tax adjustment to the EU minimum level would imply an accumulated effect of 80 TWh over the period 2014-2020. Another way to put it is that the Swedish tax on motor fuels will contribute to an energy saving of 80 TWh during this period, which corresponds to approximately a 10% energy saving compared to the reference case. Furthermore, essentially the entire effect on energy use can be attributed to the change in gasoline consumption. The first year, 2014, is the energy saving from reduced gasoline use due to the change in tax approximately 7.5 TWh, while the saving from diesel is 1.3 TWh. As time goes and further adjustment takes place, the savings from gasoline increases, whereas the savings from diesel decreases.

Table 5. Effects on gasoline consumption, diesel consumption, and total energy use due to adjustment of energy taxes to the EU minimum level.

År	Δgasoline %	Δdiesel %	Δgasoline TWH	Δdiesel TWh	Δenergy TWh	Δenergy %	Δenergy TWh Accumulated	Δenergi % Accumulated
2014	21.5	2.5	7.5	1.31	8.8	10.1	8.8	10.1
2015	28.2	0.6	9.9	0.31	10.2	11.6	19.0	10.9
2016	32.1	0.2	11.3	0.09	11.4	12.9	30.4	11.6
2017	34.4	0.1	12.1	0.04	12.1	13.8	42.5	12.1
2018	35.7	0.1	12.5	0.03	12.5	14.3	55.1	12.6
2019	36.4	0.1	12.8	0.03	12.8	14.6	67.8	12.9
2020	**36.8**	**0.1**	**12.9**	**0.03**	**12.9**	**14.8**	**80.8**	**13.2**

In conclusion one can say that it seems as if the Swedish target of a 75 TWh energy saving during the period 2014 – 2020 can be reached by keeping the taxes at the current level. No further measures have to be taken, according to the results presented here.

6. Concluding remarks

The main objective with this study is to investigate how much the current Swedish tax on motor fuels may contribute to fulfill the Swedish target on energy saving mandated by the EU. According to this target Sweden is supposed to reach a reduction of energy use amounting to 75 TWh the period 2014-2020. Although the energy efficiency directive does not include the transport sector, the interpretation is that effects on energy use in the transport sector due to broader policy instruments, such as the general energy tax and the CO2 tax, can be counted in. The purpose here, then, is to analyze what contributions to the target of 75 TWh the current energy and CO2 tax on motor fuels have.

To accomplish this we estimate dynamic demand functions for both gasoline and diesel, and use these as the basis for the simulations. Concerning the results from the estimation of the demand equations one can conclude that they are in line with previous results in the literature. The price elasticity is slightly above the average found in the literature. Specific in this study is that we explicitly take substitution effects between gasoline and diesel into account, and this can probably explain the higher than average gasoline elasticity. Not surprisingly the results show that own price elasticity for gasoline is higher than the own price elasticity for diesel, both in the short and in the long run. A likely explanation to this is that a larger share of diesel consumption is used by the commercial sector, which is less sensitive to price changes than private households. Furthermore, gasoline and diesel are substitutes, both in the short and long run, implying that a price change in one of the fuels tend to increase the use of the other. An interesting result is that income elasticity is relatively low, indicating a shrinking budget share for fuels over time as income goes up. To some extent this probably reflects that car transports is a necessity, and to some extent that higher income leads to a faster turn around of the car fleet, which improves car efficiency.

Concerning the main objective, energy savings, it is clear that the tax contributes significantly. According to the results the annual savings due to the tax is almost 15% (in steady state). The main conclusion then is that the current tax on motor fuel, above the EU minimum rates are sufficient to fulfill the target mandated by the EU directive. Most of these savings are due to reduced gasoline consumption. Apart from contributing to overall energy savings, this means that the tax have contributed to a substantial substitution from gasoline to diesel.

The conclusion from a policy perspective is rather self evident, and perhaps not very surprising. That is, if we for some reason want to save energy a tax on energy will do the job, and there is no need for any further measures. This, however, does not mean that the price and income is the only determinants to fuel consumption, nor that the elasticities themselves are bound to be fixed and independent of a context. Here we have simply assumed that the price elasticity is stable over time, as well as unaffected by changes in prices and incomes. Alternatively it is not far fetched to believe that how consumers reacts to changes in price and income changes over time, due to changes in norms, preferences, and new information. Karimu (2011) estimates a time varying parameter model for gasoline demand in Sweden and UK and finds that there is some variation in the parameters, but that the variation is not significant on a yearly basis. An alternative approach is proposed by Ghalwash (2008) and Brockwell (2012). They are testing if the effect of a change in a tax, for example a gasoline tax, affects consumption different than a change in the producer price. The basic idea is that the tax may have a signaling effect, i.e. it may provide new information about the properties of the good to the consumer, which in turn may affect the consumer's preferences for the good. The results in both Ghalwash (2008) and Brockwell (2012) are though not conclusive concerning the signaling effect, and it is therefore an interesting subject for further empirical research.

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Appendix A

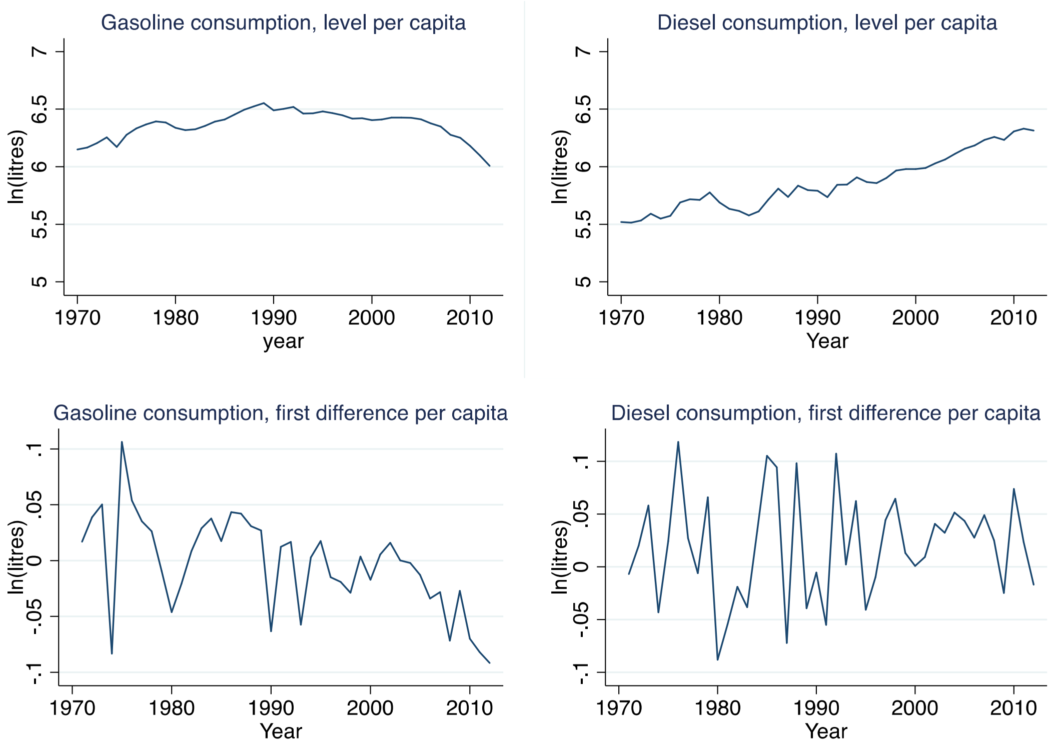

Figure A1. Gasoline consumption (logarithm of litres per capita).

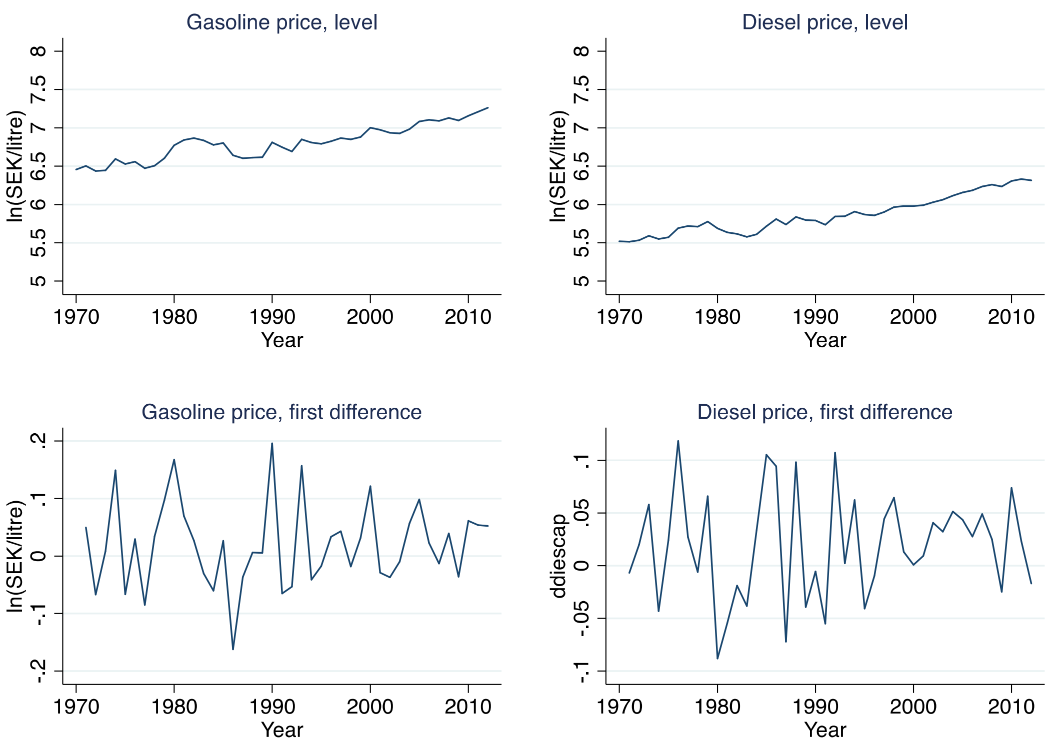

Figure A2. Gasoline and diesel price (logarithm of SEK per litre).

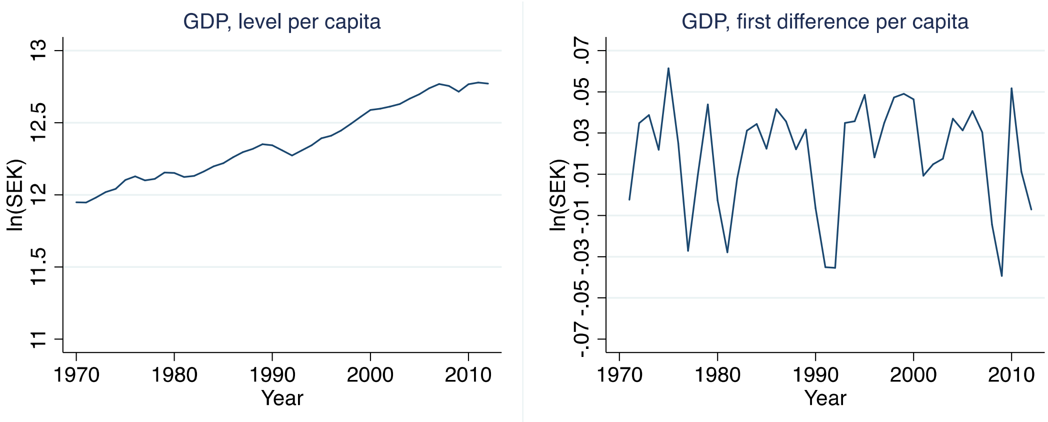

Figure A3. GDP (logarithm of SEK per capita).

Appendix B.

Table B1. Unit root test (H0 = unit root)[1]

	DF	$DF_{constant}$	$DF_{constant,trend}$	$ADF_{one\ lag}$
q^b (1976-2012)	1.91	2.57	1.80	1.012
q^b (1976-2007)	-0.29	-1.46	-0.92	-1.18
q^d	-1.97	0.187	-2.49	-2.54
P^b	1.58	-0.64	-2.24	-2.60
P^d	2.04	-1.44	-2.71	-4.08
Y	4.00	0.133	-0.64	-2.53
Critical value (1%)	-2.64	-3.68	-4.28	-4.29

[1] $\Delta y_t = c + dt + (\rho + 1)y_{t-1} + \varepsilon_t$, test statistica is t-value for ρ.