GOVERNMENT OFFICES OF SWEDEN

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Directorate-General for Energy
1049 Brussels
Belgium

Plan for implementation of Article 7 of the Energy Efficiency Directive

This memorandum gives an account of how Sweden intends to implement Article 7 of Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. The report has been prepared pursuant to the provisions of Article 7(9) and point 4 of Annex V to the Directive.

Section 1 presents an assessment of the cumulative energy savings that must be achieved during the period 2014-2020. Section 2 describes the instruments planned to achieve the savings. Section 3 presents an account of the method used to calculate the energy saving based on the planned instruments, in addition to an assessment of the anticipated savings.

1. Cumulative energy saving for the period 2014-2020

Pursuant to Article 7(1) of the Directive, Member States must achieve a certain cumulative end-use energy saving by 31 December 2020. The cumulative energy saving shall be at least equivalent to new savings each year from 1 January 2014 to 31 December 2020 of 1.5 % of the annual energy sales to final customers in Sweden of all energy distributors in Sweden or all retail energy sales companies in Sweden averaged over the three-year period 2010-2012.

Pursuant to the second paragraph of Article 7(1), the sales of energy, by volume, used in transport may be partially or fully excluded from the calculation of the cumulative energy saving that is to be achieved. In accordance with Article 7(2) and (3), Member States may use various methods to reduce the cumulative end-use energy saving that must be achieved among final customers by up to 25 %.

1.1 Supporting data

The data used to calculate the cumulative energy saving have been obtained from official Swedish energy statistics. Both annual and quarterly energy balances for Sweden have been used as a basis, in addition to statistics for the annual energy consumption of manufacturing industry[1]. Table 1 presents an account of the amount of energy sold in different sectors during the period 2010-2012.

Fuel that is sold and used for non-energy purposes has not been included. The same applies to electricity consumption by district heating plants for internal purposes, the consumption of electricity that is generated by refineries and industrial back-pressure production for industries, coal and coke that is used in the blast furnaces of the iron and steel industry and biofuel produced within industry (e.g. the paper and pulp industry, sawmills and the wood products industry). In addition, the coal and coke used for energy purposes in the iron and steel industry are imported directly and are therefore not supplied by Swedish energy suppliers. To ensure that the system boundaries are the same as if ‘white certificates’ had been introduced, these energy quantities have not been included. Sweden intends to include the energy sold and used in the transport sector in the basis used to calculate the energy saving.

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[1] Quarterly energy balances for the 4th quarter and for the years 2011 and 2012, EN20SM1302; Annual Energy Balance Sheets 2010-2011, EN20SM1206; Annual energy balances 2009-2010, EN20SM1203; Energy use by the manufacturing industry 2012, provisional data, EN23SM1302; Energy use by the manufacturing industry 2011, final data, EN23SM1301; Energy use by the manufacturing industry 2010, final data, EN23SM1201.

Table 1. Energy sales 2010-2012 [TWh/year]

	2010	2011	2012	Average 2010-2012
Electricity	**123.9**	**120.3**	**121.0**	**121.7**
Homes, etc.	74.8	70.1	72.7	72.5
Industry	46.7	47.6	45.3	46.5
Transport	2.4	2.6	3.0	2.7
District heating	**54.7**	**47.1**	**53.8**	**51.9**
Homes, etc.	49.2	42.7	47.9	46.6
Industry	5.4	4.4	5.9	5.3
Oil products	**112.1**	**107.2**	**103.6**	**107.6**
Homes, etc.	14.0	13.1	9.1	12.1
Industry	14.4	12.5	12.2	13.0
Transport	83.7	81.5	82.3	82.5
Natural gas	**6.6**	**6.7**	**6.5**	**6.6**
Homes, etc.	2.5	2.2	2.0	2.2
Industry	3.8	4.2	3.9	3.9
Transport	0.4	0.4	0.6	0.5
Biofuel	**29.0**	**30.9**	**33.9**	**31.3**
Homes, etc.	15.3	16.2	18.8	16.8
Industry	8.7	8.7	8.1	8.5
Transport	5.0	5.9	7.0	6.0
Total	**326.2**	**312.2**	**318.9**	**319.1**
Homes, etc.	155.8	144.3	150.6	150.2
Industry	79.0	77.4	75.3	77.2
Transport	91.4	90.5	93.0	91.6

1.2 Calculation of the cumulative energy saving

The Directive gives Member States the option of using various methods to reduce the new end-use energy savings that must be achieved among final customers by a maximum of 25 %.

Sweden intends to apply the method specified in Article 7(2)(c), i.e. to use values of 1 % for 2014 and 2015; 1.25 % for 2016 and 2017; and 1.5 % for 2018, 2019 and 2020 in the calculation of the cumulative energy saving. This will result in a reduction of 20.8 %, which is less than the 25 % permitted by the Directive.

Collectively, this means that **the cumulative energy saving that Sweden intends to achieve during the period 1 January 2014 to 31 December 2020 inclusive is estimated to amount to 106 TWh.** This assessment is provisional, as it is not yet clear whether the methods Sweden intends to use to calculate the effects of instruments (see Section 3) may be used. The final position on the total cumulative energy saving will be adopted by the Swedish government when it is certain of the calculation methods that may be used.

1.3 Distribution of the cumulative energy saving over intermediate periods

Pursuant to Article 7(10)(a), Member States that intend to achieve the cumulative energy saving in ways other than through an obligation scheme for energy saving must divide the period 2014-2020 into at least two intermediate periods.

As stated in Section 2, Sweden intends to achieve the cumulative energy saving using instruments other than an obligation scheme for energy saving. **Sweden intends to divide up the entire period 2014-2020 into two intermediate periods, with the first period covering the years 2014-2016 and the second period covering the years 2017-2020.** A checkpoint will therefore be introduced following the end of the first period.

To assess how the total cumulative energy saving to be achieved during the entire period 2014-2020 should be divided up between the two intermediate periods, consideration must be given to the energy savings that the intended instruments will generate from year to year. Table 11 (Section 3) shows that a third of the cumulative energy saving arising from the instruments has been calculated as having been achieved after three years. On the basis of this, it is proposed that the cumulative energy saving that must be achieved be divided in a corresponding way between the two intermediate periods. **Therefore, the total cumulative energy saving during the first intermediate period (2014-2016) will amount to 35 TWh. The remaining 71 TWh should then be achieved during the period 2017-2020.**

2. Instruments for energy efficiency

Article 7 states that Member States may opt to achieve the cumulative energy saving through an energy efficiency obligation scheme ('white certificate') or by using other instruments. A combination of an obligation scheme and other instruments may also be used.

2.1 The Swedish energy efficiency policy

In the 2009 energy bill, the Swedish government stated that 'a successful policy for energy efficiency is characterised by millions of decision-makers also taking energy efficiency into consideration in an integrated way with other decisions on a daily basis' (Prop. 2008/09:163, page 83). The Swedish energy efficiency policy is based on the following principles:

- instruments should be general and not bound to specific technologies;
- the prices must give the correct (or desired) information;
- search costs must be reduced by developing and disseminating information; and
- the removal of barriers, e.g. by amending existing legislation.

Government initiatives are targeted at both the use and supply of energy and are aimed at promoting energy efficiency initiatives that take place spontaneously in society and as a consequence of instruments adapted to the mechanisms of the market. Therefore, the role of the government is considered to be to identify and eliminate market failures, particularly external effects and a lack of information.

The current portfolio of energy efficiency instruments is consequently very broad and covers general financial instruments, as well as energy and carbon dioxide taxes and an Emissions Trading Scheme, in addition to more targeted administrative instruments that regulate, for example, requirements for permits to carry out environmentally hazardous activities and requirements for energy performance and energy labelling for energy-related products and buildings. In addition, various supplementary initiatives are used, which serve in different ways to rectify information gaps in the market and increase awareness and knowledge, in addition to the legitimacy of various (technology and/or behavioural) measures for energy efficiency and energy saving. Examples include government support for municipal energy and climate advice, government support for energy audits in small enterprises, regional climate and energy strategies, network activities and technology procurement, in addition to other measures for early market introduction. A combination of financial market-based instruments and supplementary and targeted information initiatives are considered to create good conditions for achieving socio-economically effective energy efficiency measures.

An obligation scheme for energy savings (white certificate) is not considered to deal with market failure that is not already addressed by other instruments, with the result that white certificates would not promote more efficient energy usage in Sweden in a more cost-effective way. Accordingly, **Sweden does not intend to introduce an obligation scheme for energy savings to achieve the cumulative energy saving required pursuant to Article 7 by 31 December 2020. Sweden intends instead to achieve the target through the use of other instruments pursuant to the scope provided for under Article 7(9).** Existing instruments are described in more detail below in the section entitled ‘Description of the instruments’.

Work is also currently under way to formulate both national and regional programmes for energy efficiency with support from the European Regional Development Fund. In addition, work is also being carried out in connection with the development of a national strategy for the energy efficient renovation of buildings in accordance with Article 4 of the Energy Efficiency Directive. These processes could lead to the introduction of further instruments and measures that may help to achieve the cumulative energy saving amount. As the formulation of these programmes has not yet been determined, it would be inappropriate to give an account of the instruments in the plan. The same applies to any instruments that may be proposed by the checkpoint due to take place in 2015 with the aim of following up Sweden’s energy and climate policy goals through until 2020. One of the energy policy targets is the target of a 20 % reduction in energy intensity by 2020, which has previously been reported to the Commission as Sweden’s indicative target pursuant to Article 3 of the Energy Efficiency Directive.

2.2 Description of the instruments

Energy taxes and carbon dioxide taxes

Through the energy and carbon dioxide tax being levied in Sweden pursuant to the Swedish Energy Tax Act[2] (1994:1776), Sweden is fulfilling the minimum tax levels

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[2] A consolidated version of this Act may be viewed using the following link: http://rkrattsbaser.gov.se/cgibin/thw?%24%7BHTML%7D=sfst_lst&%24%7BOOHTML%7D=sfst_dok&%24%7BSNHTML%7D=sfst_err&%24%7BMAXPAGE%7D=26&%24%7BTRIPSHOW%7D=format%3DTHW&%24%7BBASE%7D=SFST&%24%7BFORD%7D=FIND

specified in Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity[3] (the Energy Taxation Directive).

The Swedish authority that administers and follows up the taxation is the Swedish Tax Agency. The energy tax on electricity is primarily levied on those who generate taxable electric power commercially and those who supply electrical power commercially[4]. Those liable to pay energy tax and carbon dioxide tax on fuel are primarily warehouse keepers, consignees and stockholders approved by the Swedish Tax Agency[5]. The tax liability for fuel generally arises when it exits the suspension arrangement[6] and is therefore released for consumption, or in the case of approved stockholders when deliveries are made to a buyer who is not an approved stockholder or alternatively to the stockholder's own sales outlet[7].

Table 2. Energy and carbon dioxide tax levels in Sweden in 2014

	Unit for tax rate	Tax rate	Tax rate (öre per kWh)
Energy tax			
Petrol	SEK/litre		
Environmental class 1		3.13	34.3
Alkylate petrol[1)]		1.40	15.4
Environmental class 2		3.16	34.7
Other		3.90	42.9
Diesel fuel	SEK/m^3		
Environmental class 1		1 759	18.0
Environmental class 2		2 028	20.7
Environmental class 3		2 169	22.1
Fuel oil	SEK/m^3	816	8.2
Natural gas, fuel	SEK/1 000 m^3	0	0
Natural gas, heating	SEK/1 000 m^3	902	8.2
LPG, fuel	SEK/tonne	0	0
LPG, heating	SEK/tonne	1 048	8.2
Coal and coke	SEK/tonne	620	8.2
CTO	SEK/m^3	3 904	39.8
Carbon dioxide tax			
Petrol	SEK/litre	2.50	27.5
Diesel and fuel oil	SEK/m^3	3 088	31.5
Natural gas, fuel	SEK/1 000 m^3	1 850	16.8
Natural gas, heating	SEK/1 000 m^3	2 313	21.0
LPG, fuel	SEK/tonne	2 599	20.3

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[3] Official Journal of the European Union, L 283, 31 October 2003, page 51.

[4] Chapter 11, Article 5 of the Swedish Energy Tax Act (1994:1776).

[5] Chapter 4, Articles 1 and 12 of the Swedish Energy Tax Act (1994:1776).

[6] Suspension arrangements are as referred to in Directive 2008/118/EC regarding designated suspensive procedures.

[7] The entry into force of the tax liability is regulated in Chapter 5 of the Swedish Energy Tax Act (1994:1776).

LPG, heating	SEK/tonne	3 249	25.4
Coal and coke	SEK/tonne	2 687	35.5
Energy tax on electricity	öre/kWh		
Manufacturing industry, agriculture, forestry and aquaculture		0.5	0.5
Certain municipalities in northern Sweden[2)]		19.4	19.4
Municipalities elsewhere in Sweden		29.3	29.3

1) Alkylate petrol is intended for two-stroke engines, primarily for boats.
2) All municipalities in the counties of Västerbotten, Norbotten and Jämtland, and Sollefteå, Ånge and Örnsköldsvik in the county of Västernorrland, Ljusdal in Gävleborg, Torsby in Värmland and Malung-Sälen, Mora, Orsa and Älvdalen in Dalarna.

The applicable tax rates are specified in Chapter 2, Articles 1, 3 and 4 of the aforementioned Act. The tax rates are not fixed over time but are reviewed and amended annually through an index-linked scheme which takes into consideration any changes in the consumer price index. This maintains the control signal given by the taxes over time. The applicable tax rates for 2014 are specified in Ordinance (2013:859) on the determination of converted amounts for energy tax and carbon dioxide tax for 2014, and are shown in Table 2. The tax rates for fuel in 2015[8] have previously been determined on the basis of forecasted changes in the consumer price index.

For heating fuel outside the EU emissions trading scheme (EU ETS), the industrial, combined heat and power, agriculture, forestry and aquaculture sectors pay 30 % of the general energy tax level and 30 % of the general carbon dioxide tax level. From 2015 onwards, these sectors will pay 60 % of the general carbon dioxide tax level. For heating fuel within the EU ETS, the industrial and combined heat and power sectors pay 30 % of the energy tax level, but no carbon dioxide tax. For diesel, the industrial sector pays the full energy and carbon dioxide tax, while the agriculture, forestry and aquaculture sectors pay the full energy tax, but pay a lower level of carbon dioxide tax at SEK 1.70/litre. The Swedish parliament has decided that this level will be reduced to SEK 0.90/litre in 2015.

The EU’s minimum tax levels for motor fuel are given in Table A in Annex I to Directive 2003/96/EC. Table B specifies the minimum tax levels for motor fuel used for the purposes stated in Article 8(2) of Directive 2003/96/EC. Table C specifies the minimum tax levels for fuel for heating and electricity. Article 15(3) of the abovementioned Directive states that Member States may apply a level of taxation of down to zero to energy products and electricity used within the agriculture, horticulture, pisciculture and forestry sectors.
The minimum tax rates are specified in Table 3.

[8] Act (2012:681) amending Act (2010:1823) amending Act (2009:1497) amending Act (1994:1776) on energy taxes.

Table 3. The EU's minimum tax rates for fuel and electricity

	Unit for tax rate	Tax rate	Tax rate (öre/kWh [1])
Motor fuel			
Leaded petrol	EUR/1 000 litres	421	39.94
Unleaded petrol[)]	EUR/1 000 litres	359	34.06
Diesel	EUR/1 000 litres	330	29.07
Kerosene	EUR/1 000 litres	330	
LPG	EUR/1 000 kg	125	8.44
Natural gas	EUR/GJ gross heating value	2.6	8.12
Motor fuel for purposes specified in Article 8(2)			
Diesel	EUR/1 000 litres	21	1.85
Kerosene	EUR/1 000 litres	15	
LPG	EUR/1 000 kg	41	2.77
Natural gas	EUR/GJ gross heating value	0.3	0.94
Fuel for heating and electricity			
Diesel	EUR/1 000 litres	21	1.85
Heavy fuel oil, heating	EUR/1 000 kg	15	1.15
Kerosene	EUR/1 000 litres	0	0
LPG	EUR/1 000 kg	0	0
Natural gas	€/GJ gross heating value	0.15	0.47
Coal and coke	EUR/GJ	0.15	0.47
Electricity, commercial use	EUR/MWh	0.5	0.43
Electricity, non-commercial use	EUR/MWh	1.0	0.86

1 The conversion was performed using the heating value for the various fuels in accordance with the report 'Energy in Sweden, facts and figures 2012' and the official exchange rate on 1 October 2013: 8.6329 SEK/EUR.

Municipal energy and climate advice

The Swedish Energy Agency pays out state support to the country's municipalities to enable them to obtain energy and climate advice. Energy and climate advice is provided in all of Sweden's 290 municipalities. The support is regulated through Ordinance (1997:1322) on support for municipal energy and climate advice and the Swedish Energy Agency's Regulations (STEMFS 2008:2, STEMFS 2008:6). The purpose of the advice is to mediate impartial, free and technology-neutral information and advice concerning energy efficiency options. The Swedish Energy Agency supports the municipal energy and climate advice both financially and through the provision of training and information. There are a total of 14 energy agencies distributed across the country.

The energy and climate advice is targeted at a number of target groups and areas:

- Industry: The advice is aimed at small and medium-sized enterprises and organisations). For example, advisors may support the introduction of systematic energy work through their company advice (energy management) or make the company aware of the need for energy audits and the availability of government support for energy audits.
- The public: Advisors may for example provide homeowners with information regarding investments in heating systems.
- Transport advice aimed at companies and the public.

Each month, the municipal energy and climate advisors report to the Swedish Energy Agency on the nature and number of advice initiatives during the past month, and the measures that will be adopted as a result of the advice given.

Support for energy efficiency in municipalities and county councils

Since 2010, the Swedish Energy Agency has provided state support to municipalities and county councils for strategic work in connection with energy efficiency from a system perspective within individual organisations. Energy efficiency support has been granted to approximately 96 % of the country's municipalities and county councils. This work is regulated through Ordinance (2009:1533) on state support for energy efficiency in municipalities and county councils and the Swedish Energy Agency's regulations and general recommendations (STEMFS 2010:5) concerning state support for energy efficiency in municipalities and county councils. The municipalities and county councils that have applied for and been granted support have undertaken to establish a strategy for energy efficiency containing energy efficiency targets through to 2014 and 2020 respectively, in addition to an action plan describing how the targets will be achieved. Municipalities and county councils receiving support are obliged to report the results to the Swedish Energy Agency annually, which facilitates national follow-up.

Sustainable Municipalities (Uthållig kommun)

'Sustainable Municipalities' is a cooperation programme administered by the Swedish Energy Agency which is intended to strengthen the institutional capacity of participating municipalities to implement local energy and climate strategies. Work in connection with Sustainable Municipalities has been taking place since 2003, firstly through a five-year pilot phase (2003-2007) involving five municipalities, and then through a three-year phase (2008-2010) involving 66 municipalities. Since 2011, a third programme period has been implemented, with a focus on the development, application and dissemination of cutting-edge examples of methods for municipal work aimed at creating the right preconditions for the sustainable use of energy both locally and regionally. The work has been carried out in nine project areas, divided into two thematic areas (industry policy and energy-smart planning). A total of 37 municipalities participated in the programme. The thematic area of *industry policy* encompasses the project areas of energy management systems for local development and energy-driven business development. The thematic area of *energy-smart planning* encompasses the project areas of energy-efficient planning in small and medium-sized municipalities and the energy-efficient reconstruction of the 'Million Programme'.

Regional climate and energy strategies
Since 2008, all county administrative boards have been given the task of managing and coordinating work in connection with the development and implementation of regional energy and climate strategies. Since 2010, the county administrative boards have received financial reimbursement from the government for their work, paid by the Swedish Energy Agency. The Swedish Energy Agency wants to support the work of the county administrative boards. The purpose of the initiative is to strengthen the conditions for the development and implementation of regional energy and climate strategies. The work is carried out in cooperation with the Sustainable Municipalities programme in relation to regional energy issues, training for the county administrative boards and other regional bodies such as the Energy Agencies and Regions/Regional Associations, in addition to process management training for the county administrative boards. The county administrative boards must also provide regional support for municipalities and county councils in their work relating to energy efficiency within the framework of the energy efficiency support. The county administrative boards report their results annually to the Swedish Energy Agency.

Energy audit checks
Companies with an energy consumption in excess of 500 MWh per year have been able to apply for financial support to carry out an energy audit since 2010. Additionally, enterprises involved in the primary production of agricultural products may apply for support if their activity involves at least 100 livestock units. The support aims to eliminate any lack of awareness by conducting an audit of the organisation’s energy consumption, and thereby promote the implementation of potentially profitable energy efficiency measures. The support covers up to 50 % of the cost of an energy audit, subject to a maximum of SEK 30 000. The Swedish Energy Agency is responsible for administration of the energy audit support. The support is regulated through Ordinance (2009:1577) on state support for energy audits and the Swedish Energy Agency’s regulations and general recommendations (STEMFS 2010:2) on state support for energy audits. Companies receiving support undertake to report on the energy efficiency measures they have implemented and the effects thereof.

Programme for energy efficiency in electricity-intensive industries
The programme for energy efficiency in energy-intensive industries (PFE) aims to promote energy efficiency among Swedish energy-intensive industrial companies. Participation is voluntary and participating companies receive an exemption from energy tax on electricity (0.5 öre/kWh) used in the manufacturing process. The programme is regulated through the Swedish Programme for Improving Energy Efficiency Act (2004:1196). The Swedish Energy Agency is the competent authority for the programme and the Swedish Tax Agency handles any tax reductions. In order to join the programme, the participating company must meet any criteria that are set regarding energy intensity, use electricity in the manufacturing process and be assessed as able to implement any measures arising as a result of participation in the programme. Through its participation, the company undertakes to perform an energy audit, introduce a certified energy management system, introduce special routines and implement electricity efficiency improvement measures. The company must report to the Swedish Energy Agency on three occasions during the period.

The guidelines for government support for environmental protection announced in 2008 have restricted the scope to grant tax exemptions to companies. As a result of this, the Programme for Improving Energy Efficiency Act (2004:1196) was repealed in 2012. This means that companies can no longer join the programme. However, the provisions of the repealed Act still apply to companies that joined up until 2012. This means that the majority of programme participants will leave the PFE programme on 30 June 2014, and the companies that joined last will leave in 2017. The second programme period is currently underway with around 90 participating companies, and will continue to generate effects over the coming years.

Network management in industry
The Swedish Energy Agency is working to promote the formation of operator networks in industry. The purpose of these networks is to raise awareness of how to make energy consumption more efficient at all levels in industrial companies through the provision of information and the exchange of knowledge. Networks have for example been formed in the mining and steel industries, material processing industries and the sawmill industry.

The network for energy efficiency (ENIG) was started in 2009 and is a network for energy efficiency with the aim of creating, collating and disseminating information concerning energy efficiency within the Swedish manufacturing industry. The focus is placed on casting, surface treatment, heat treatment, sheet metal forming and plastic processing. The purpose of the project is to reduce the company's energy consumption by 5 % per year, or by a total of 30 % by 2015, and to promote the implementation and commercialisation of at least ten new energy-efficient processes or products.

The Energy Efficiency in the Sawmill Industry network (EESI) started in 2010 and has the purpose of helping to reduce the specific energy consumption in the sawmill industry by at least 20 % by 2020. The project is now in its second phase. The target will be achieved through a programme for energy efficiency involving measures ranging from energy consumption audits to the modelling of efficiency options and a plan for demonstrations at selected sawmills. The project is part-financed by the Swedish Energy Agency, but the majority of the financing comes from the industry.

The Swedish Energy Agency also runs a network within the construction and property sectors, which includes bodies from the public sector, industry and property and tenancy owners. The network is divided into a number of client groups:

- The client group for premises (BELOK) and the client group for housing (BEBO) are the client groups for owners and managers of commercial and residential properties respectively. The client group (BeLivs) is aimed at food premises. The purpose of the network is to establish and follow up demonstration projects for energy efficiency relating to existing apartment buildings and premises and to drive the development of technology and system solutions for energy efficiency.
- The client group for commercial tenants (HyLok) aims to ensure that government authorities set an example through the energy efficiency of their own activities, and by reducing the overall energy consumption of the premises that they use. The activities of HyLok include benchmarking, 'green IT' and

energy-efficient server rooms, acquisition strategies for energy statistics, 'green offices', 'green tenancies' and public procurement.
- The client group for residential tenants (HyBo) works to develop the potential of tenants to actively contribute to energy efficiency in apartment blocks, partly in cooperation with property owners.

Technology procurement
Technology procurement is an instrument that aims to promote the development of new technology and the use of more energy-efficient products and systems. The Swedish Energy Agency administers project support pursuant to Ordinance (2003:564) on grants for measures promoting effective and environmentally sustainable energy supply. The Swedish Energy Agency carries out technology procurement projects and demonstration/market introduction projects in the building sector, industry and transport sectors.

Technology procurements are primarily carried out within the areas of heating and control systems, hot water and sanitation, ventilation, white goods, lighting and industry. Technology procurement is aimed at a number of target groups: manufacturing companies, the public sector and industry. The use of technical procurement in the BELOK and BeLivs networks for example is a proven method promoting energy efficiency in residential buildings and commercial premises. See the Agency's website for a list of all the technical procurements that the Swedish Energy Agency has carried out[9].

Information initiatives
A number of Swedish authorities have developed information-based tools with the aim of disseminating knowledge concerning energy consumption. Such information initiatives are aimed at households, companies and authorities.

The energy calculation[10] is administered by the Swedish Energy Agency and is a web-based calculation program that aims to provide households with information on how they can make their energy consumption more efficient.

Energiaktiv[11] *(Energy active)* is a web-based information and advice portal. The website is a collaboration between the Swedish National Board of Housing, Building and Planning, the Swedish Board of Agriculture and the Swedish Energy Agency, which is primarily aimed at home and property owners, but also companies in the manufacturing industry, transport and agriculture. The purpose of the portal is to mediate information and support the implementation of energy efficiency measures in homes and commercial premises. The structure is process-supporting and guides users step-by-step from assessment to the follow-up of measures.

Environmental inspections and inspection guidance
The Swedish Environmental Code (1998:808) entered into force in 1998. At the time, the requirement for energy conservation and the use of renewable energy became of greater importance when it was highlighted in a rule of consideration, which is the mainstay of the Environmental Code. According to the Environmental code, all

[9] http://www.energimyndigheten.se/sv/Teknikupphandlingar/.
[10] http://energikalkylen.energimyndigheten.se/.
[11] http://www.energiaktiv.se/.

enterprise operators must be more economical with energy and use renewable energy sources in the first instance. This means that operators must:

- acquire knowledge regarding energy consumption;
- identify possible measures; and
- implement reasonable measures on an ongoing basis.

The inspection authorities are responsible for ensuring that the principle of conservation is being followed, and additionally also have the task of providing advice. They are entitled to request any information required for the inspection, such as audits, analyses and measures. It is therefore particularly important that the work relating to energy conservation is documented.

Pursuant to the Environmental Inspection Regulation (SFS 2011:13), the Swedish Energy Agency has had inspection responsibility for matters concerning self-regulation by operators since 2011 with regard to energy conservation and the use of renewable energy sources. This work involves the provision of support and advice to the operative inspection authorities, municipalities and county administrative boards and following up and evaluating the operative inspections.

3. Estimated effect of the instruments for energy efficiency

3.1 General considerations regarding energy-saving calculations

Pursuant to Article 7(12), Member States must ensure that when the impact of instruments (policy measures) or individual measures overlaps, there is no duplicated counting of energy savings. As described in Section 2, Sweden intends to apply a broad range of instruments that complement each other. The actual measures adopted for energy efficiency arise as a result of the interaction between these instruments.

The energy and carbon dioxide taxes make energy more expensive. The taxes provide an incentive through their control signal to the energy user to adopt energy-saving measures in order to reduce/make their energy consumption more efficient. In some cases, the measures may be simple to introduce and adopt. However, a more detailed knowledge of the measures that can be adopted and the measures that are appropriate in individual cases is often lacking. The information regarding potential and appropriate measures is often asymmetrical, which means that the final energy user, and therefore the person who is to implement (purchase) the measures, is often at a disadvantage in terms of information with respect to the seller of energy-efficient techniques or other solutions for energy efficiency. Therefore, the control signal provided by the energy price often fails to reach its target. Energy users who react to price signals are often also affected by other instruments. End users may obtain a better knowledge of the measures that should be adopted through the provision of support for the energy audit. Impartial advice regarding appropriate measures may be obtained from a municipal energy and climate advisor.

Both the energy audit support and the municipal energy and climate advice are followed up on an ongoing basis through feedback requirements and surveys. Thus, it is possible to gain a good overview of the measures and energy-saving effects resulting from these initiatives. For example, the Swedish Energy Agency has estimated that the support for energy efficiency in municipalities and county councils could lead to a cumulative energy saving of 10 TWh during the period 2014-2020.[12] The Swedish Energy Agency furthermore estimates that the contribution to the cumulative energy-saving during the period 2014-2020 will amount to 0.5 TWh from the support for energy audits and almost 14 TWh from the municipal energy and climate advice. However, this does not exclude the duplicated counting of the effects if the effects reported from the various instruments are added together. The risk of duplicated counting will be greater if the effects of taxes, which are calculated top-down, are added to the effects of other instruments, which are calculated bottom-up.

In order to avoid completely the risk of the duplicated counting of the energy savings from various complementary instruments, Sweden intends to investigate and calculate the effects of the various instruments as a single package. As the starting point for the Swedish energy efficiency policy has been to influence price signals through the application of general financial instruments, the basic instrument will be the **combined effect of the instruments applied in Sweden calculated in accordance with the method specified by the Directive for the calculation of the effects of energy and carbon dioxide taxes.** Therefore, the effects of the other complementary instruments reported in Section 3 will not be followed up and will be calculated separately.

3.2 Method for calculating energy savings from taxes

In accordance with Article 7(10)(f), energy savings are calculated using the methods and principles specified in point 3 of Annex V of the Directive. A detailed calculation method is not specified in the Directive. However, the provisions state that consideration should only be given to energy savings resulting from taxation measures that exceed the minimum tax levels that apply to fuel in accordance with the Energy Taxation Directive (2003/96/EC) or Council Directive 2006/112/EC of 28 November 2006 on the common system of value added tax. In addition, it is stated that actual and representative official information concerning price elasticity must be used to calculate the effects of the taxes.

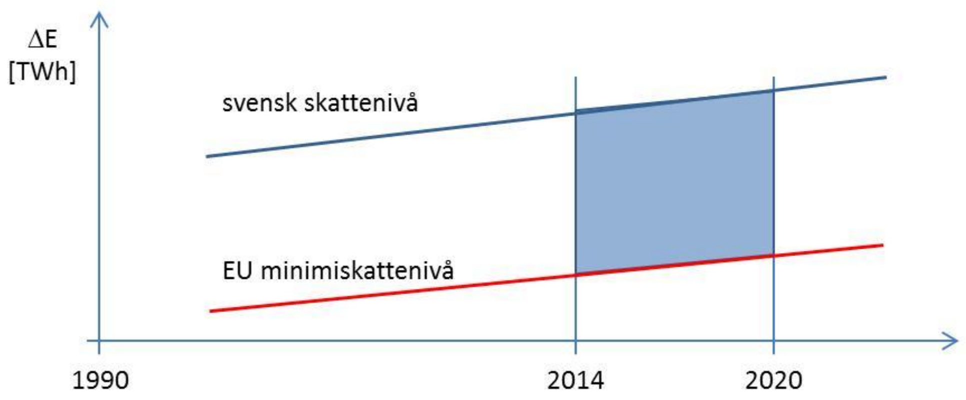
Therefore, the energy savings that can be credited are the savings that are made as a result of the price difference arising in cases where Swedish tax levels are higher than the EU's minimum tax levels for both energy tax and value added tax. A somewhat simplified calculation of the energy saving can be performed by multiplying the price difference in connection with price elasticity and energy consumption.

No requirement is imposed in Article 7 which requires the cumulative energy saving to be achieved through the use of new instruments. However, such a saving must be achieved by new measures. These could follow from new and/or existing instruments. The levels of the Swedish energy and carbon dioxide taxes and value added tax have been higher than the EU's minimum taxation levels for a long time. The taxes have promoted, and will continue to promote, energy savings both by stimulating changes in behaviour (e.g. through reduced vehicle use) and investments in energy-efficient technology (e.g. by purchasing more energy-efficient vehicles). A critical question in the calculation of the effects of the instruments is the starting date that is to be used. The energy efficiency measures that will be adopted during 2014 are the result of the

[12] Swedish Energy Agency (2013), *Implementering av artikel 7 i energieffektiviseringsdirektivet – Energimyndighetens beräkningar och förslag,* ER 2013:04.

tax levels (and other instruments) in existence in 2014, but will also be affected by the tax levels and instruments available both in 2013 and previously.

In order to calculate the effect of the taxes, the energy savings made during the period 2014-2020 must be evaluated contrafactually, i.e. compared on the basis of the alternative scenario that as of 1 January 2014, the tax levels were lowered to those of the EU's minimum tax levels (e.g. in order to introduce an alternative instruments in the form of white certificates instead). The steering effect of the higher tax levels then helps to keep energy consumption down compared with the alternative scenario in which the taxes are lowered. The cumulative energy saving then becomes *the difference between the scenarios*, which consists of the increased use of energy that results from the lowered taxes (see Figure 1). If instead we were to calculate the effect of the taxes during the period 2014-2020 using a starting point as of the date on which they were introduced, the energy saving would be much higher. This is because the full effect of the price difference would have already been achieved before 2014 and would then remain. In this context, it is worth emphasising that the Swedish energy and carbon dioxide levels are recurrently indexed, which means that they retain their steering effect, even in cases where the CPI increases. As a result, the control signal of the taxes is not eroded in real terms. The taxes have also been adjusted on various occasions. For example, the Swedish Parliament has already reached a decision concerning lower reductions in the carbon dioxide tax in certain sectors from 1 January 2015.



Key:
Svensk skattenivå = Swedish tax level
EU minimiskattenivå = EU minimum tax level

Figure 1. Energy saving as a result of differences between the Swedish tax level and the minimum tax level

As mentioned previously, the price-raising effect of the taxes has had an effect in both the short and the long term. In order to capture this effect, the energy saving should wherever possible be calculated dynamically and cumulatively, giving consideration to both short- and long-term price elasticity. It is also key that the effect of the energy consumption is delimited so that the effect on energy efficiency is measured insofar as is possible, rather than the effect of a switch between different types of fuel, e.g. from petrol to diesel.

With regard to the use of long-term price elasticity, the calculations do not assume that the full effect will be achieved during the first year. This poses no risk in a dynamic model, but in cases where a dynamic model does not exist, assumptions need to be made regarding how long it will take before the full effect is achieved and how the effect will develop over time. This may be done in various ways. A linear increase in the annual saving should be assumed if the connection between long- and short-term elasticity is not known. In some cases, the full effect of the price increase that arises as a result of differences in tax levels may not be achieved until after 10-12 years, which would be a number of years after 2020. More detailed information regarding the calculation models and price elasticity, etc. that have been used to calculate energy savings for the Swedish instruments is given in the following section. Calculations have been performed for various fuels/energy carriers in the sectors for housing and services (excluding land-based industries), land-based industries, transport and industry.

New econometric estimates of price elasticity have been made for electricity consumption in housing and services[13] and for the use of petrol and diesel in the transport sector[14]. It is notable that these new estimates result in an elasticity that is lower than that of previous estimates (see *Ett energieffektivare Sverige* ('A more energy-efficient Sweden'), SOU 2008:25, Annex 5).

With regard to the data for the calculation and future follow-up of the effects on energy saving of the taxes and other instruments, the energy consumption in the respective sectors for 2013 should be used as a starting point throughout. This is the level that is applicable at the start of the period 2014-2020. Energy prices and tax levels for 2014 should be used in connection with the follow-up of the effects during 2014. The average energy prices and tax levels for 2014 and 2015 should be used for the forthcoming follow-up of effects during 2015, and 2014 and 2015 combined. The average energy prices and tax levels for 2014, 2015 and 2016 should be used in connection with the follow-up of energy savings for 2016, and so on until 2020. Data for other years have been used in the following calculations because these data are not yet available, which means that the estimated energy savings are provisional.

3.3 Energy savings for housing and services (buildings)

Only savings for electricity have been reported for the housing and services sector. The reason for this is that the calculations for the direct use of oil for heating in this sector result in negative consumption, i.e. the energy saving as a result of the tax differences is greater than the actual amount of oil consumed. This may be explained by the fact that the current levels for direct oil consumption for heating purposes for housing and services are very low and the information available concerning price elasticity is based on circumstances when oil consumption was significantly higher.

[13] Brännlund (2013) *Bostadssektorns elefterfrågan i Sverige*, Report to the Swedish Ministry of Finance.

[14] Brännlund (2013) *The effects on energy saving from taxes on motor fuels: The Swedish case*, CERE Working Paper 2013:6.

For the calculation of electricity savings in the housing and services sector (buildings) during the period 2014-2020, a dynamic model is used[15], which consists of a long-term linear relationship between electricity consumption and the independent variables of price, income and heating requirements, and a dynamic, more short-term relationship dependent on both deviations in electricity consumption from the long-term relationship and/or the fact that the underlying variables (prices or income) change between the previous and current time periods (short-term dynamic). A description of the model used to estimate both long-term and short-term price elasticity and to simulate the electricity saving resulting from higher tax levels in Sweden compared with the EU's minimum tax levels is given in Annex 1. The Annex also shows the data and results concerning the estimation of elasticities.

The estimates of price elasticity show that a higher electricity price reduces electricity consumption in the housing and services sector. A price increase of 10 % indicates a reduction in electricity consumption of around 5 % in the long term. Electricity consumption is only reduced by 0.7 % in the short term following a price increase of 10 %. The descriptive analysis shows that it takes a long time for the household and services sector to adapt fully to changes in prices and incomes. People keep the same buildings, heating systems and other installations from one year to the next, which means that they can only make minor changes in electricity consumption from one year to the next as a result of electricity price changes, for example. However, this does not mean that this consideration cannot be included in long-term changes in connection with the calculation of the cumulative energy saving. Some households and companies will adapt quicker than others.

The abovementioned elasticities have been used to calculate the electricity saving as a result of the Swedish electricity tax in the household and services sector being higher than the EU's minimum tax rates, and the fact that this in combination with other complementary instruments stimulates a reduction in energy consumption compared with a situation where such instruments did not exist. The calculations also take account of the fact that Sweden's value added tax rate is higher than the EU's minimum tax rate (25 % compared with 15 %).

The principle for the simulations is as follows. The parameters to be estimated are entered in the following equation (see Annex 1 for a more detailed explanation):

$$q_t^b = \gamma_0 + b_1 p_t + \gamma_1 p_{t-1} + b_2 y_t + \gamma_2 y_{t-1} + b_3 Temp_t + \gamma_3 Temp_{t-1} + \gamma_4 t + \gamma_5 q_{t-1} + u_t$$

This assumes that the year prior to the first year (2013) was in a long-term equilibrium corresponding to the observed use of electricity. Following the calibration for 2013, assumptions are made regarding the development of prices and GDP from 2014 up to and including 2020 in a *reference scenario* and an *alternative scenario*. The only difference between the reference scenario and the alternative scenario in this case is the final consumer electricity price (including excise duties and value added tax). The calculations are based on price differences of 33 and 38 % respectively, based on 2009 prices. The latter corresponds to the price difference inclusive of value

[15] This model was developed by Prof. Runar Brännlund at the Centre for Environmental and Resource Economics (CERE), Umeå University (www.cere.se). It is described in more detail in the report entitled *Bostadssektorns elefterfrågan i Sverige.*

added tax (however, this must only be paid by households and companies without a deduction entitlement), while the former corresponds to the price difference exclusive of value added tax. There is a weighted price difference between these two levels. The trend in GDP is the same for both scenarios. The difference in electricity consumption between the alternative and reference scenarios is then calculated.

Table 4 shows estimates of the annual and cumulative electricity savings within the household and services sector during the period 2014-2020.

Table 4. Annual and cumulative electricity savings in the household and services sector

	ΔP= 33%			ΔP= 38%		
Year	ΔElectricity TWh/year	ΔElectricity %	ΔElectricity TWh Cumulative	ΔElectricity TWh/year	ΔElectricity %	ΔElectricity TWh Cumulative
2014	2.2	2.9	2.2	2.6	3.4	2.6
2015	3.4	4.5	5.6	4.1	5.4	6.7
2016	4.5	6.0	10.1	5.4	7.1	12.0
2017	5.5	7.3	15.6	6.6	8.8	18.7
2018	6.5	8.6	22.1	7.8	10.3	26.4
2019	7.3	9.7	29.4	8.8	11.6	35.2
2020	8.1	10.7	37.5	9.8	12.9	45.0

Based on the presentation of the elasticity estimates in Annex 1, we know that the long-term effect on electricity consumption is a reduction in demand of 5 % with an increase in the electricity price of 10 %. In this case, this means that the long-term reductions in demand amount to 3.3 and 3.8 times 5 %, i.e. 16.5 and 19 % respectively. However, from the estimate of elasticity (Annex 1, Table B1:2), we can see that the rate of adjustment to the new equilibrium is slow (0.09), which means that it takes a significant number of years until the adaptation is fully complete.

As can be seen from Table 4 above, the immediate short-term effects of the price change are around 2 and 3 % respectively, while the effects in the final year of 2020 are around 11 and 13 % respectively. In other words, around two thirds of the long-term energy saving effect in the household and services sector is achieved during the period up until 2020.

Overall, this shows that the Swedish instruments contribute a cumulative electricity saving in the household and services sector of around 38-45 TWh during the period 2014-2020, depending on whether or not differences in value added tax are included in the calculations. The lower level has been specified in compiling the cumulative energy saving from all instruments (Table 11, Section 3.7), as not all final customers in the sector pay value added tax.

3.4 Energy savings in the transport sector

An overall reduction in the use of petrol and diesel has been reported in the transport sector. Savings for pure biofuels and electricity are not reported.

A dynamic model[16] has been used to calculate energy in the transport sector during the period 2014-2020, in the same way as for electricity savings in buildings. This model consists of a long-term relationship between total fuel consumption and the independent variables of price and income, and a dynamic, more short-term relationship dependent on both deviations in fuel consumption from the long-term relationship and/or the fact that some of the underlying variables change between the previous and current time periods (short-term dynamic). A detailed description of the model used for estimating the both long- and short-term price elasticities and for simulating the energy saving as a result of higher tax levels in Sweden compared with the EU's minimum tax levels is shown in Annex 2. The Annex also describes the results concerning the estimation of elasticities.

The estimates of price elasticity indicate that a higher petrol price reduces petrol consumption, and that a higher diesel price reduces diesel consumption. Furthermore, the results show (as expected) that petrol and diesel are substitutes. This means that, if all other circumstances remain unchanged, a higher petrol price will lead to an increase in diesel consumption. The interpretation of this is of course that some substitution is taking place from petrol-engined vehicles to diesel-engined vehicles. The opposite applies in the case of high diesel prices. In connection with this, it is particularly relevant to consider the cross-price elasticity for petrol and diesel in order to calculate the total energy saving for high petrol and diesel prices. The result from the econometric estimate of price elasticity thus indicates that a price increase of 10 % for both petrol and diesel will lead to:

- A 4.0 % reduction in petrol consumption in the short term;
- A 6.4 % reduction in petrol consumption in the long term;
- A 0.5 % reduction in diesel consumption in the short term;
- A 0.0 % reduction in diesel consumption in the long term;
- A 1.9 % reduction in total fuel consumption in energy units in the short term;
- A 2.6 % reduction in total fuel consumption in energy units in the long term.

The results also indicate that higher incomes or increased financial activity will lead to an increase in fuel consumption. It can also be noted that the income elasticity is less than 1 and that it is not statistically significant for diesel. This can partially be explained by the fact that a positive trend in diesel consumption has been identified, which was detected by the parameter for the deterministic trend *(t)*, which is relatively strongly correlated with GDP. The parameter for the deterministic trend *(t)* is negative for petrol consumption, which may be interpreted as indicating a downward trend in petrol consumption as a result of a combination of technical development and changes in consumer preferences. The fact that this is negative for petrol consumption can reasonably be explained by the fact that there have been rapid technical advances in the sense that both petrol- and diesel-engined vehicles have become much more energy-efficient. The fact that we can identify a positive trend for diesel vehicles does not mean that diesel vehicles have become less energy-efficient, quite the opposite in fact. Increasingly 'consumer-friendly' and energy-efficient diesel vehicles have led to a trend of substitution with respect to diesel-engined vehicles. This is also apparent in

[16] This model was developed by Prof. Runar Brännlund at the Centre for Environmental and Resource Economics (CERE), Umeå University (www.cere.se) and is described in more detail in the report *The effects on energy saving from taxes on motor fuels: The Swedish case*, CERE, Working Paper 2013:6.

the sharp rise in the proportion of diesel-engined vehicles in the statistics for new vehicle sales.

The estimated elasticities have been used to calculate the energy saving as a result of the fact that the Swedish energy and carbon dioxide tax levels and the level of value added tax are higher than the EU's minimum tax levels, and the fact that this, combined with other complementary instruments, is stimulating the reduction in energy consumption compared with a situation where these instruments did not exist. The calculations also take account of the fact that Sweden's value added tax rate is higher than the EU's minimum tax rate (25 % compared with 15 %).

The principle for the simulations is as follows. The parameters to be estimated are entered in the following equation for petrol, and correspondingly for diesel (see Annex 2 for a more detailed explanation):

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

This assumes that the year prior to the first year (2013) was in a long-term equilibrium corresponding to the observed fuel consumption. Following the calibration for 2013, assumptions are made regarding the development of prices and GDP from 2014 up to and including 2020 in a reference scenario and an alternative scenario. The only difference between the reference scenario and the alternative scenario in this case is the final consumer price for petrol and diesel (including excise duties and value added tax). The calculations are based on a price difference of 42 % for petrol and 36 % for diesel, based on 2009 prices. The trend in GDP is the same for both scenarios. The difference in fuel and energy consumption between the alternative and reference scenarios is then calculated.

Table 5 shows estimates of annual and total cumulative fuel and energy savings within the transport sector during the period 2014-2020.

Table 5. Annual and cumulative energy savings for the transport sector, assuming no economic growth

Year	Δpetrol %	Δdiesel %	Δpetrol TWh/year	Δdiesel TWh/year	Δenergy TWh/year	Δenergy %	Δenergy TWh Cumulative
2014	21.5	2.5	7.5	1.31	8.8	10.1	8.8
2015	28.2	0.6	9.9	0.31	10.2	11.6	19.0
2016	32.1	0.2	11.3	0.09	11.4	12.9	30.4
2017	34.4	0.1	12.1	0.04	12.1	13.8	42.5
2018	35.7	0.1	12.5	0.03	12.5	14.3	55.1
2019	36.4	0.1	12.8	0.03	12.8	14.6	67.8
2020	36.8	0.1	12.9	0.03	12.9	14.8	80.8

At first glance, our assumptions regarding economic growth may appear unimportant (i.e. the change in GDP), as we are calculating the difference between two scenarios with the same rate of economic growth. This is also true, provided we are only interested in the percentage changes in volumes (litres of fuel). If, however, we are interested in *fuel savings in energy terms (TWh)* (as in this case), then this no longer applies. In simple terms: fuel consumption will be greater in a situation with positive economic growth. This implies that a given percentage change will result in a greater change and, as the fuels have different energy contents, this change will not be the same.

In Table 5, we can see that the accumulated energy saving amounts to around 80 TWh during the entire period. We can also see that the energy saving almost entirely comes from a reduction in petrol consumption. In 2014, the petrol saving is 7.5 TWh, while the diesel saving is 1.3 TWh, owing to the Swedish tax levels. The petrol saving increases in subsequent years, such that in the year 2020 it amounts to almost 13 TWh. The opposite is true of diesel, and the saving is reduced year-by-year, such that in the year 2020 it amounts to just 0.03 TWh.

3.5 Energy savings within the industrial sector

In contrast to the energy saving calculations for both the housing and services and transport sectors, there is currently no econometric model to dynamically calculate the cumulative energy savings in the industrial sector. A simpler linear model has been used here instead, with the price difference that follows from the higher Swedish tax levels being multiplied by the long-term individual price elasticity for different fuels in order to determine the long-term reduction in demand. The annual and total cumulative energy saving during the period 2014-2020 can be determined assuming a linear increase in the effect.

The industrial sector is not homogenous, but consists of a number of differentiated sectors using electricity and fuel to varying extents. Energy savings as a result of energy and carbon dioxide taxes and complementary instruments may be calculated for the electricity-intensive sectors: mining, timber, pulp and paper, chemicals, rubber and plastic, earth and rock and iron and steel. Enterprises under the emissions trading scheme differ from enterprises outside this scheme, as different tax rates apply to these enterprises.[17]

The price elasticities for electricity and fuel consumption in the abovementioned sectors have been estimated on the basis of data for the years 1990-2004 (see Table 6).[18] The price elasticities calculated are estimates and represent an average value for the sectors. This means that a given company in a sector may be either more or less affected than the average values. Statistically insignificant price elasticities have been set to zero.

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[17] This division has been made using FRIDA, which is a micro-level database with registers for different types of company.

[18] Brännlund & Lundgren (2011) *Beräkningar av effekter för den elintensiva industrin av att dessa branscher i olika grad omfattas av kvotplikt inom elcertifikatsystemet*, CERE Working Paper, 2011:7 (http://www.cere.se/documents/wp/CERE_WP2011-7.pdf).

Table 6. Price elasticities in the industrial sector

	p^{el}	p^{b}
Mining	0	-0.79
Timber products	-0.39	-0.21
Pulp and paper	-0.41	-0.16
Chemicals	-1.03	-0.68
Rubber and plastic	-0.41	-1.43
Mineral and stone	0	-0.87
Iron and steel	-1.24	-0.97

The long-term reduction in demand and energy savings can be calculated using the above, in addition to information on the price difference arising as a result of the higher Swedish tax levels. The energy consumptions of various sectors in 2011 and the 2011 real energy prices were used for the calculations. The latter are presented in Table 7.

Table 7. Energy prices

Fuel	**Price** [öre/kWh]
Fuel oil 1	65.6
Fuel oil 5	45.0
Coal	12.8
Coke	39.8
Natural gas, city gas	33.7
CTO	
Peat 45 % moisture content (0.3 % sulphur)	15.8
Electricity	80.1
Diesel	68.7

Overall, the long-term saving within the part of the industrial sector included in EU ETS amount to approximately 3 TWh, equivalent to a saving of around 4.5 %. For the part of the industrial sector not included in EU ETS, the long-term saving amounts to 0.34 TWh, equivalent to a saving of around 1.5 %. Assuming that the full effect will be achieved after seven years and that the increase is linear, the total annual and cumulative energy savings can be calculated (see Table 8).

Table 8. Annual and cumulative energy savings in the industrial sector

Year	EU ETS Δenergy TWh/year	EU ETS Δenergy %	EU ETS Δenergy TWh Cumulative	Non-EU ETS Δenergy TWh/year	Non-EU ETS Δenergy %	Non-EU ETS Δenergy TWh Cumulative
2014	0.43	0.6	0.43	0.049	0.2	0.049
2015	0.86	1.3	1.29	0.098	0.4	0.15
2016	1.28	1.9	2.57	0.15	0.6	0.29
2017	1.71	2.5	4.28	0.20	0.8	0.49
2018	2.14	3.2	6.42	0.24	1.1	0.73
2019	2.57	3.8	8.99	0.29	1.3	1.03
2020	**3.00**	**4.5**	**11.99**	**0.34**	**1.5**	**1.37**

3.6 Energy savings in land-based industries

In contrast to the energy saving calculations for both the housing and services and transport sectors, there is currently no econometric model to dynamically calculate the cumulative energy savings for land-based industries. A simpler linear model has been used here instead, with the price difference that follows from the higher Swedish tax levels being multiplied by the long-term individual price elasticity for different fuels in order to determine the long-term reduction in demand. The annual and total cumulative energy savings during the period 2014-2020 can be determined assuming a linear increase in the effect.

Diesel, fuel oil, LPG, natural gas and electricity are all used in relatively small quantities in land-based industries. For the fuels for which the tax levels differ, Table 9 shows the average energy consumption for 2010-2011, average nominal energy prices (excluding tax) for 2010-2012, current (2014) tax levels, price differences as a result of the higher Swedish tax levels and price elasticity.

No price elasticities have been specifically produced for fuel consumption within land-based industries. The elasticities applicable to the timber products industry have been used instead. As the total energy consumption for the sector is so low, this will have little effect on the total result, even though it would appear that the elasticity used is too high.

Table 9. Energy consumption and energy prices within the land-based industries

	Energy consumption [TWh]	Price (excl. tax) [öre/kWh]	Swedish tax [öre/kWh]	Price difference [%]	Price elasticity
Fuel oil 1	1.03	52.87	11.80	18	-0.21
Fuel oil 5	0.12	44.73	11.10	22	-0.21
Natural gas	0.11	35.17	8.70	23	-0.21
Diesel	5.24	66.30	32.20	45	-0.21

The long-term reduction in demand and saving can be calculated using the data above. For light fuel oil, the saving amounts to 3.78 % or 0.039 TWh, while for heavy fuel oil the corresponding figure is 4.62 % (0.006 TWh), for natural gas 4.85 % (0.005 TWh), and for diesel 9.45 % (0.49 TWh). Overall, the long-term saving amounts to 0.54 TWh, corresponding to a saving of 8.3 %. The total annual and cumulative energy saving can be calculated assuming that the full effect will be achieved after seven years and that the increase is linear (see Table 10).

Table 10. Annual and cumulative energy savings within the land-based industries

Year	Δenergy TWh/year	Δenergy %	Δenergy TWh Cumulative
2014	0.077	1.2	0.077
2015	0.15	2.3	0.23
2016	0.23	3.5	0.46
2017	0.31	4.8	0.77
2018	0.38	5.8	1.15
2019	0.46	7.1	1.61
2020	**0.54**	**8.3**	**2.15**

3.7 Overall assessment of energy savings from instruments

The total annual and cumulative energy savings from Swedish instruments, calculated as an effect of higher tax levels for energy and carbon dioxide taxes and value added tax respectively in Sweden compared with the EU's minimum tax levels, are shown in Table 11. The table shows that **the total cumulative energy saving resulting from the Swedish instruments during the entire period 2014-2020 amounts to 134 TWh. This exceeds the cumulative energy saving that must be achieved in Sweden (see Section 1).**

Table 11. Annual and cumulative energy savings resulting from Swedish instruments

		2014	2015	2016	2017	2018	2019	2020
Housing and services[1]	*TWh/year*	*2.2*	*3.4*	*4.5*	*5.5*	*6.5*	*7.3*	*8.1*
	TWH cum.	2.2	5.6	10.1	15.6	22.1	29.4	37.5
Land-based industries	*TWh/year*	*0.08*	*0.15*	*0.23*	*0.31*	*0.38*	*0.46*	*0.54*
	TWH cum.	0.08	0.23	0.46	0.77	1.2	1.6	2.2
Transport	*TWh/year*	*8.8*	*10.2*	*11.4*	*12.1*	*12.5*	*12.8*	*12.9*
	TWH cum.	8.8	19.0	30.4	42.5	55.1	67.8	80.8
Industry	*TWh/year*	*0.48*	*0.95*	*1.43*	*1.91*	*2.39*	*2.86*	*3.34*
	TWH cum.	0.48	1.4	2.9	4.8	7.2	10.0	13.4
Total	***TWh/year***	***11.6***	***14.7***	***17.6***	***19.8***	***21.8***	***23.4***	***24.9***
	TWH cum.	**11.6**	**26.2**	**43.9**	**63.67**	**85.6**	**108.8**	**133.9**

[1] For the *Housing and services* sector, the energy savings are reported without consideration for differences in value added tax. If these differences are included and it is assumed that all final customers in the sector pay value added tax, the total energy saving for the sector amounts to 45 TWh, with the total for Sweden amounting to 141 TWh during the period 2014-2020.

Annex 1. Estimation of price elasticity for electricity consumption in the housing and services sector

This annex reproduces selected parts of the report entitled *Bostadssektorns elefterfrågan i Sverige*, written in 2013 by Professor Runar Brännlund of CERE, Umeå University on behalf of the Swedish Ministry of Finance with the specific aim of providing a basis for Sweden's implementation of Article 7 of the Energy Efficiency Directive.

The model

The model framework that has been used follows from basic economic theory, and corresponds to and is comparable with other studies within the area. Based on standard consumption theory, electricity consumption is assumed to depend on electricity price *(P)*, income *(Y)* and heating requirements, which in turn depend on the temperature *(T)*. The latter means that colder years (colder winters in reality) lead to the consumption of more electricity than warmer years (winters), assuming that other factors remain unchanged. In addition, electricity consumption is particularly dependent on heating, changes in efficiency, changes in areas being heated and changes to appliances in the home and other buildings. However, no data is available for these factors. As an approximation, we have assumed that the type of changes that take place can be identified using a time trend (t). In general, we can express the demand function (per capita) as follows:[19]

$$Q_t = f(P_t, Y_t, T_t, t) \qquad (1)$$

The demand function in (1) can (in the best case) be interpreted as a long-term relationship. In the short and medium terms, it is reasonable to believe that people will not adjust fully to changes in prices and incomes. People keep the same house and heating systems from one year to the next, which means that they can only make small adjustments to their electricity consumption from one year to the next as a result of electricity price changes, for example.

The latter point that people do not adjust fully in the short term as a result of price changes is also reinforced by a descriptive analysis of electricity consumption. A formal descriptive analysis of electricity consumption, electricity price, income (GDP) and temperature indicates that none of the variables are thought to be stationary. The stationarity test that was performed (Dickey-Fuller test) indicated that we cannot reject the possibility that the variables are integrated by the first order. This means in practice that the first differences are stationary and that a linear combination of the variables may be stationary. In terms of the model, this means in principle that we can specify a so-called 'error correction model', which consists of a long-term linear relationship between electricity consumption and the independent variables, and

[19] The model presents a very simplified overview of the factors governing electricity consumption in the housing and services sector. It could be said that equation (1), in the best case, is a 'reduced form' of electricity demand. An alternative would be to state that electricity consumption consists of the product of the electricity consumption per volume of room heated and the volume heated. If it is assumed that the electricity consumption per unit volume depends on the electricity price, external temperature and income, and that the total volume (or surface) may depend on electricity price and income, then the reduced form may be written as in (1).

a dynamic, more short-term relationship that results from deviations in electricity consumption from the long-term relationship and/or the fact that some of the underlying variables (prices or incomes) have changed between the previous and current time periods (short-term dynamic).[20]

In other words, the error correction model consists of two equations for each fuel type which encompass both the long-term relationship and the short-term relationship. If we assume that the demand functions (1a) and (1b) are multiplicative, then the long-term relationship between consumption, prices and income can be expressed in logarithmic form as follows:[21]

$$q_t = a_0 + a_1 p_t + a_2 y_t + a_3 Temp_t + a_4 t + \varepsilon_t \qquad (2)$$

It can therefore be stated that equation (2) represents the long-term or static relationship between fuel consumption, prices and income. This can also be expressed as follows:

$$q_t - (a_0 + a_1 p_t + a_2 y_t + a_3 Temp_t + a_4 t) = \varepsilon_t \qquad (3)$$

A condition for the existence of a long-term relationship is that the deviation, or error term in equation (2) or (3), is stationary, i.e. that it has a constant tendency over time to return to the same value (zero). In other words, even if each of the variables in the model is non-stationary individually, a combination of these variables could be stationary. A classic example would be income and consumption, which are both non-stationary time series, yet a linear combination of the two is stationary (in the long term, the entire income will be consumed; thus the difference between the two will become zero).

Given the long-term relationship in the equations (3), the 'error correction equations' (the dynamic equations) can be written as follows:

$$\Delta q_t = b_0 + b_1 \Delta p_t + b_2 \Delta y_t + b_3 \Delta T_t + b_4 \varepsilon_{t-1} + u_t \qquad (4)$$

Parameter b_4 identifies and 'corrects' for deviations from the long-term relationship. Assume, for example, that $\varepsilon_{t-1}>0$, which means (from equation 2) that q_{t-1} is higher than the long-term consumption. This means that we should expect the consumption to decrease towards, or approach, the long-term consumption for the next period, i.e. $\Delta q_t <0$, which in turn means that we should expect a negative sign for b_4 and d_4 in the error correction equation in equation (4).

[20] Non-stationary data series that are co-integrated can be represented in error correction form (Engle and Granger, 1987), which means that an error correction model is suitable here because the times series that we are using are non-stationary.

[21] In multiplicative form, the equation is in principle written as $Q_t = a_0 \cdot P_t^{a_1} \cdot Y_t^{a_2} \cdot e^{a_4 t}$. By putting the right and left-hand parts into logarithmic form, we obtain the 'log-linear' form of the equation (2), in which the small letters (except 't') indicate that they have been put into logarithmic form. This means that the 'parameters' can be interpreted as elasticities, i.e. by what percentage electricity consumption will fall/rise as a result of a percentage change in price or income. The parameter a4 indicates the percentage change between two periods, assuming that all other factors remain unchanged.

By substituting (3) in (4), we obtain an explicit dynamic expression for how the consumption of electricity will develop over time:

$$q_t = b_0 + b_4 a_4 - a_0 b_4 + b_1 p_t + (b_1 + b_4 a_1) p_{t-1} + b_2 y_t - (b_2 + b_4 a_2) y_{t-1} + b_3 Temp_t \\ -(b_3 + b_4 a_3) Temp_{t-1} - b_4 a_4 t + (b_4 + 1) q_{t-1} + u_t \tag{5}$$

which when simplified can be written as:

$$q_t^b = \gamma_0 + b_1 p_t + \gamma_1 p_{t-1} + b_2 y_t + \gamma_2 y_{t-1} + b_3 Temp_t + \gamma_3 Temp_{t-1} + \gamma_4 t + \gamma_5 q_{t-1} + u_t \tag{6}$$

If we are in a ‘steady state’, (3) tells us that:

$$q = \frac{\gamma_0}{1-\gamma_5} + \frac{b_1 + \gamma_1}{1-\gamma_5} p + \frac{b_2 + \gamma_2}{1-\gamma_5} y + \frac{b_3 + \gamma_3}{1-\gamma_5} Temp + \frac{\gamma_4}{1-\gamma_5} t \tag{7}$$

Equation (7) is quite simply another way of writing equation (1), or the long-term relationship. If we now estimate the parameters in equations (2) and (4) and calculate the composite parameters in equation (6), we simply return to the long-term parameters in equation (1).

The advantages of the above model are that it corresponds to the fundamental properties of the time series, and that it gives us both the short- and long-term elasticities and the dynamic from the short to the long term.

Data

The data that have been used to estimate the parameters in the model consist of time series data for the period 1970-2010 (see Figure B1:1-4). The electricity consumption within the housing and services sector (*Q*) is measured as KWh per capita, and the price of electricity is given in öre per KWh for a customer living in an ordinary house. Taxes and network charges are included in the price. Prices are expressed as fixed prices (2009 prices). GDP expressed in fixed prices has been used as a measure of income (*Y*) (2009 prices). A separately constructed (data from SMHI) annual average for Sweden has been used as a measure of temperature (Temp).

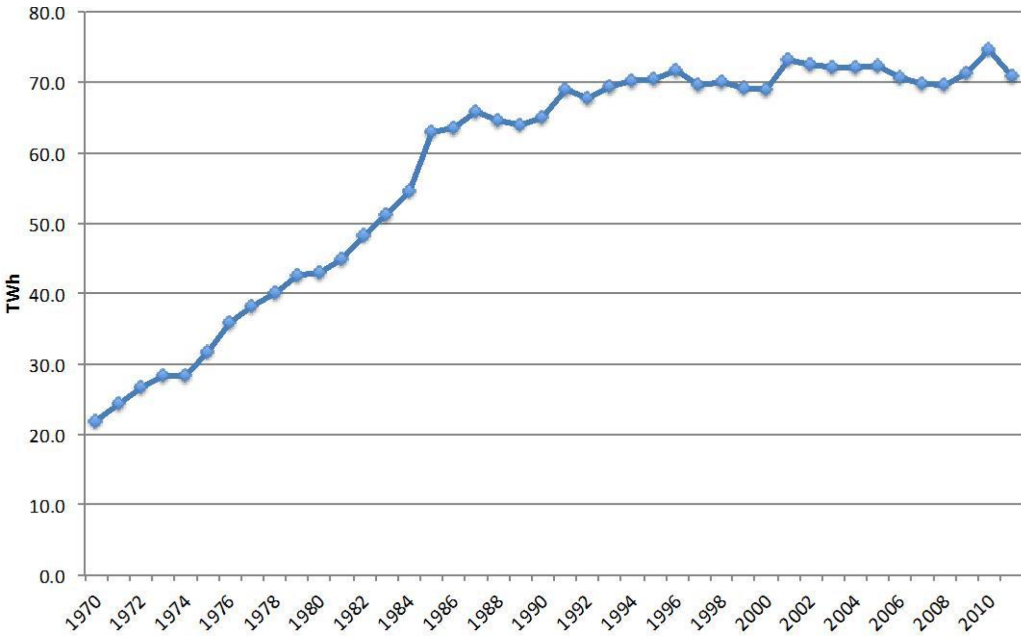
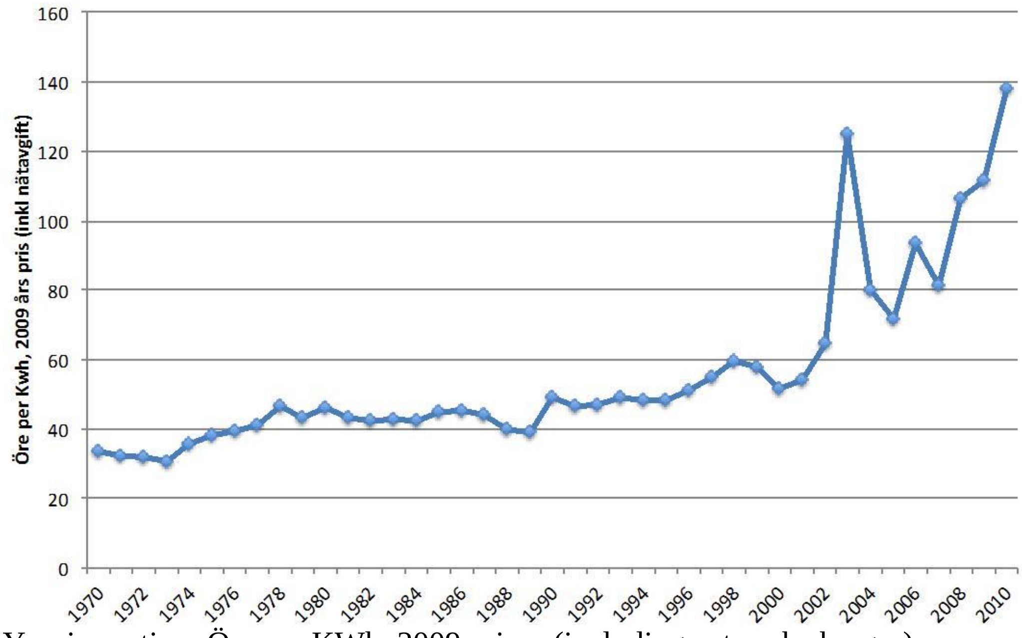
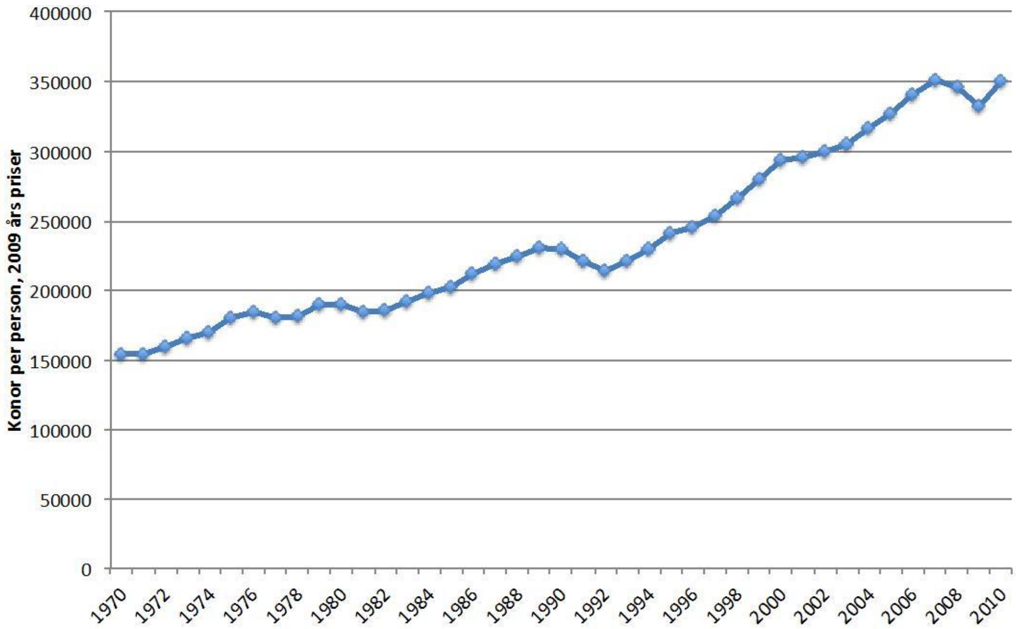


Figure B1:1. Electricity consumption within the housing and service sectors, 1970-2010



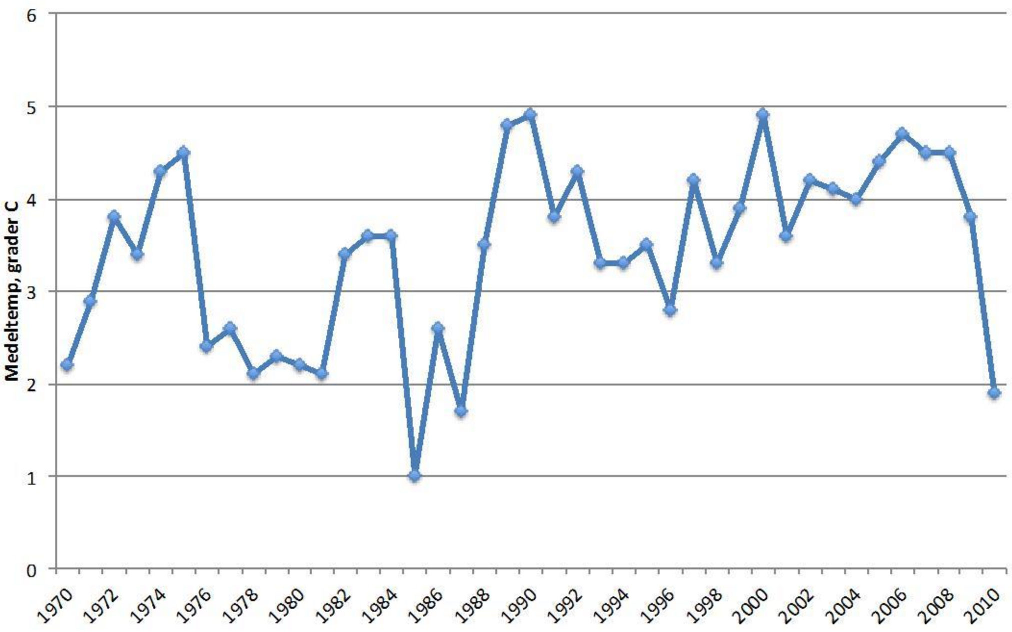
Y-axis caption: Öre per KWh, 2009 prices (including network charges)

Figure B1:2. Electricity price including network charges and taxes for ordinary customers, 1970-2010 (2009 prices)



Y-axis caption: SEK per person, 2009 prices

Figure B1:3. GDP per capita, 1970-2010



Y-axis caption: Average temperature, degrees Celsius

Figure B1:4. Annual average temperatures in Sweden, 1970-2010

Result

Table B1:1 shows the estimate of the long-term relationship (equation 2), while Table B1:2 shows the short-term relationship (equation 4). All variables in the model are in logarithmic form, which among other things means that we can interpret all parameters as elasticities.

Table B1:1. Estimate of the long-term relationship

	Coef.	t-value
Constant	29.1	3.39
p	-0.50	-3.65
y	-1.14	-2.17
Temp	-0.18	-2.46
t	0.060	6.07
R2	0.82	
DW	0.49	
NOBS	41	
DF test[1]	-0.32*	-3.23

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

Table B1:2. Estimate of the dynamic relationship (short-term)

	Coef.	t-value
Constant	0.03	4.02
Δp	-0.07	-1.65
Δy	-0.08	-0.34
$\Delta Temp$	-0.07	-3.68
$EC_{(t-1)}$	-0.09	-1.70
R2	0.22	
DW	0.69	
NOBS	40	

The result in Table B1:1 shows that a higher electricity price will result in a reduction in electricity consumption within the housing and services sector. A price increase of 10 % indicates a reduction in electricity consumption of around 5 % in the long term. Furthermore, the results shown in Table B1:1 indicate that higher incomes appear to have a negative effect on electricity consumption. One possible explanation for this somewhat surprising result is that the income variable is both covariant with other variables and captures differences in efficiency and preferences that are not included in the model. On the other hand, it is clear that temperature has a significant effect on electricity consumption in both the long and the short term. A temperature rise of 10 % would result in a reduction in electricity consumption of approximately 2 % in the long term, while the effect in the short term is a reduction by 0.7 %. The parameter for the deterministic trend (*t*) is positive, which may be interpreted as indicating an upward trend in electricity consumption per capita. A likely explanation for this is that the heated surface per capita has increased over time.

Overall, it is possible to say that the results indicate a need for a more in-depth analysis of electricity consumption within the housing and services sector. For example, higher incomes will probably mean that the volume to be heated will increase as people build larger houses. However, at the same time it is possible that higher incomes will also lead to people modernising their heating systems, replacing windows and becoming more energy efficient in other ways, which would reduce the energy requirements per unit volume. In other words, this means that an increase in income would have two opposing effects, and the possibility that the efficiency effect would dominate the volume effect cannot be excluded, which would then lead to a reduction in energy consumption in the event of higher incomes.

References

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Annex 2. Estimation of price elasticity for petrol and diesel consumption in the transport sector

This annex reproduces the report *'The effects on energy saving from taxes on motor fuels: The Swedish case'*, CERE Working Paper 2013:6, written by Professor Runar Brännlund of CERE, Umeå University on behalf of the Swedish Ministry of Finance with the specific aim of providing a basis for Sweden's implementation of Article 7 of the Energy Efficiency Directive.

CERE

CERE Working Paper, 2013:6

The effects on energy saving from taxes on motor fuels: The Swedish case

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

The rest of the paper is structured as follows. In the next section, section 2, the modelling framework is outlined. The econometric model and the data that are 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. Modelling framework

The modelling 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 kilometre (*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 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 ${\varepsilon_Y}^q$ 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 modelling 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:

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

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.

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

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

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:

$$Q^{E} = \theta_{g} \cdot q^{g} + \theta_{d} \cdot q^{d} \quad (10)$$

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 are 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 are 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 are 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:

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

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

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: $\varepsilon = (\rho\text{-}1)\varepsilon_{t-1}$

* 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 modelling 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]

$$\varepsilon^{i}_{t-1} = \ln q^{i}_{t-1} - (\alpha_{i0} + \sum_{g,d} \alpha_{ij} \ln P^{j}_{t-1} + \alpha_{iY} \ln Y_{t-1} + \alpha_{iT}(t-1)), \qquad (13)$$

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

$$\ln q^{i}_{t} = \alpha_{i0} + \sum_{g,d}\left(\beta_{ij} \ln P^{j}_{t} - (\beta_{ij} + \theta_i \alpha_{ij}) \ln P^{j}_{t-1}\right) + \beta_{iY} Y_t + (\beta_{ij} + \theta_i \alpha_{iY}) \ln Y_{t-1} + (\theta + 1) \ln q^{i}_{t-1} \qquad (14)$$

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/litre		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 fulfil 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 fulfil 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 signalling 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 signalling effect, and it is therefore an interesting subject for further empirical research.

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Appendix A

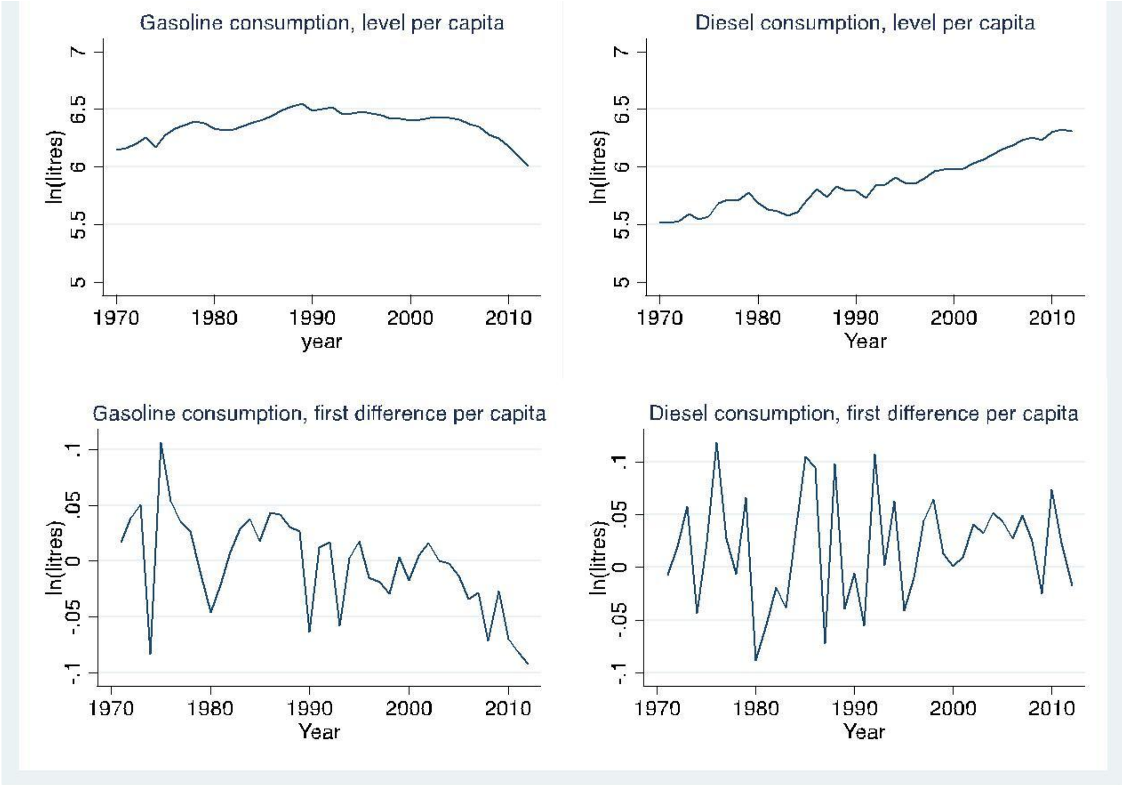

Figure A1. Gasoline consumption (logarithm of litres per capita).

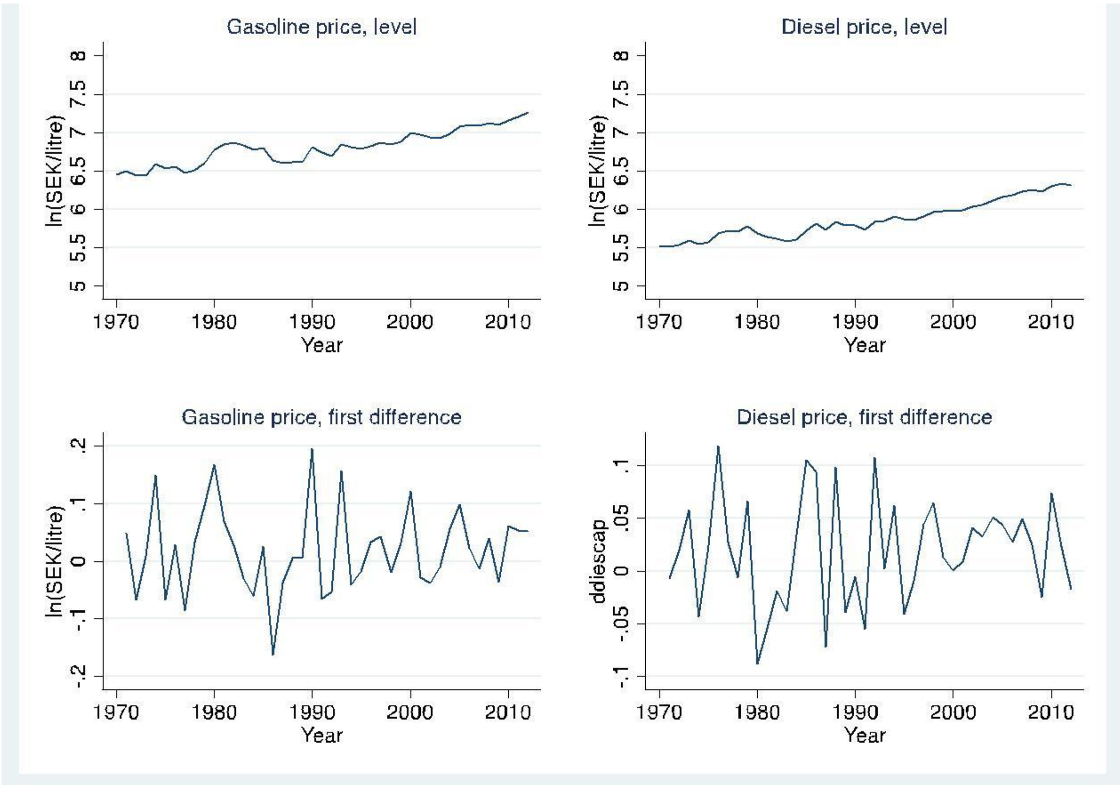

Figure A2. Gasoline and diesel price (logarithm of SEK per litre).

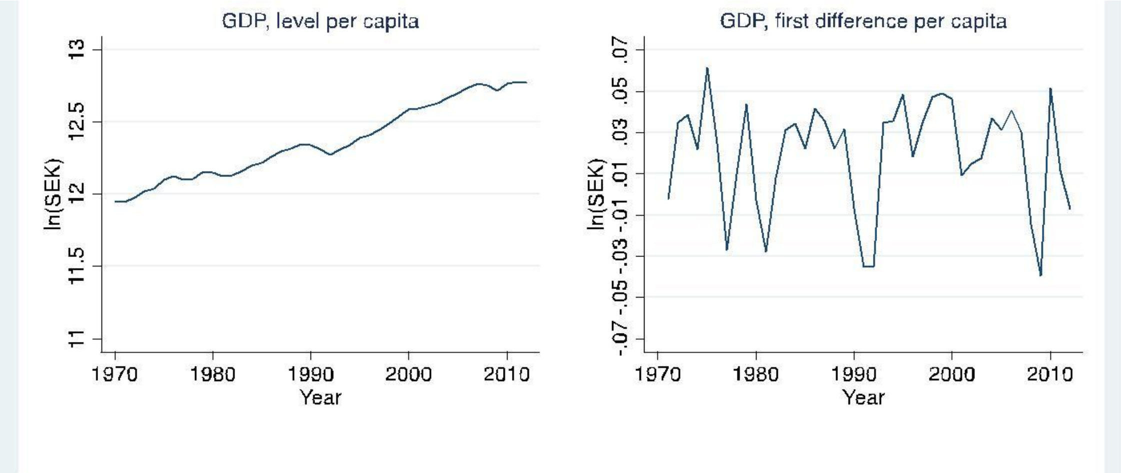

Figure A3. GDP (logarithm of SEK per capita).

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.