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Energy Conservation of Residential Buildings in the European Union – An Exploratory Analysis of Cross-Country Consumption Patterns

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Appendix: Basic Outline for Designing a CO2-Taxation Policy

(in German)

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Energy Conservation of Residential Buildings in the European Union

– An Exploratory Analysis of Cross-Country Consumption Patterns

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Abstract

We use quantitative data on observable characteristics such as energy prices, climatic conditions, income, and living space in order to explain country differences in building energy use in Europe. We then examine the unexplained variation by sorting between-country-differences as well as plotting within-country changes over time. In a second step, we use qualitative methods in order to analyze the policy environment of certain countries. We conduct interviews and examine the legal rules regarding building energy efficiency. It can be shown that regulatory standards can effectively lower energy consumption, thereby confirming the previous studies. However, as countries with similar levels of regulatory standards display different levels of energy consumption other explanatory factors are required. We present evidence on the effectiveness of CO2-taxation.

Keywords: CO2 taxation, energy efficiency, energy conservation, climate policy

JEL Classification: H23, K32, P18, Q58

1. Introduction

The energy efficiency of residential buildings is becoming increasingly singled out by EU environmental policy1 as a means of addressing climate change. Consequently, researchers have followed suit and have started to address the topic more frequently (Ryghaug and Sorensen, 2009; Noailly, 2010; Feser und Runst, 2016; Runst, 2016; Eskeland and Mideska, 2009; Ranson et al., 2014; Manur et al., 2008; Geller et al., 2006; O'Broin et al., 2015; Andor et al., forthcoming; Filippini et al., 2014; Bertoldi und Mosconi, 2015; Filippini und Hunt; 2010; Sunnikka-Blank und Galvin, 2013; Sunnikka-Blank und Galvin, 2012; Lin and Li, 2011).

In this paper, we analyse differences in energy efficiency across European countries and investigate factors of economic / environmental policies which can explain these differences.

In a first step, we use panel data techniques (LSDV) in order to explain building energy consumption (from 2000 till 2015) of European countries by a number of observable characteristics such as energy prices, climate, income, and living area. Country dummy coefficients can be regarded as unexplained between-country-deviations from expected consumption levels (where the expectation is contingent on observable characteristics). Regression residuals can also be plotted and represent a measure of changing conservation levels within countries over time.

In a subsequent qualitative analysis, we investigate the energy efficiency policies (with respect to buildings) in selected countries by sifting through official policy documents and by conducting interviews with experts in these countries.

In line with previous findings by O'Broin et al. (2015) and Filippini et al. (2014), we present evidence on the effectiveness of regulatory (building efficiency) standards. The evidence also suggests additional factors to be at work. In particular, we conclude that energy taxes and CO2 taxation represent effective means of energy conservation. We also show that the level of CO2-taxation plays a critical role for its effectiveness.

[1] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings. 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 Text with EEA relevance.

2. Antecedents in the Literature

Differences in climatic conditions, levels of income and living area, etc. preclude any simple cross country comparison of energy consumption in the building sector. Some studies circumvent this problem by comparing regulatory standards of new buildings (Schild et. al, 2010) although this also greatly reduces the scope by excluding the bulk of existing buildings which make up most of the overall energy demand. Alternatively one may control for observable characteristics that are known to influence consumption levels.

The empirical analysis by Filipini et al. (2014) combines an energy demand model which includes climate conditions, income levels and living area, with a so called frontier analysis.The authors generate six policy indicators within three main categories. There are (i) regulatory standards (e.g. U-values), (ii) financial/ fiscal incentives, and (iii) informative measures based on the cross country database on energy policies (MURE). It is striking that subsidies for specific types of technologies and broader incentives such as energy taxation are lumped together in category (ii). i.e. quite distinct policy measures are treated as if they are identical. In addition, by simply counting the number of policies there are no weights which signify the relative impact of these measures.

One of these policy indicators may serve as another example of the general tendency of blurring meaningful differences. The indicator is equal to 1 if there are two or more regulatory standard in place that prescribe rules for buildings or heating within a country, and 0 otherwise. Many different kinds of standards fall within the precinct of this category. The authors recognize this problem when they state „This is arguably a relatively simplistic approach because [..] the measures are heterogeneous; hence, counting the number of measures introduced in each group could be imprecise" (Filippini, 2014, 78).

The inherent uncertainty of such a quantitative measure of public policy can be illustrated with the example of Sweden. Table 1 (Filippini, 2014, 76) lists Sweden as one of the countries with relatively few regulatory standards. This representation does not correspond well to reality. As we will show below, the regulatory standards in Sweden must be seen as the strictest across Europe.

In summary, the results suggest that regulatory standards and financial/ fiscal incentives affect energy consumption, whereas informative measures do not. These findings are in accordance with Feser & Runst (2016) who investigate why subsidized information campaigns for home owners do not seem to be effective in increasing the rate of energetic retrofits (and point toward lacking profitability and asymmetric information as reasons).

O'Broin et al. (2015) pursue a similar strategy as Filipini et al. (2014) but introduce a stronger quantitative element in generating the policy-indicators. The authors use a panel data set of 15 European countries for the time period if 1990 till 2010. They estimate the determinants of heating energy consumption. Instead of simply counting the number of different types of policies (Filipini, 2014; also Bertoldi and Mosconi, forthcoming), O'Broin et al. (2015) generate what they call a semi-quantitative index, whereby they apply different impact-weights to different policies in order to include a measure of effectiveness (and the effect size) for different policies. The policies recorded in the MURE-database are therefore divided into low, medium and high impact, which correspond to an energy savings of 0.1%, 0.1-0.5%, and more than 0.5%. Accordingly, each policy is coded as 1, 10 or 20. The semi-quantitative approach thereby transforms a more or less informal expert consensus on the effectiveness of a policy by mapping tem onto the numbers 1, 10, or 20. The resulting semi-quantitative policy indicators also enter the empirical specification as lags (t-1 until t-7) in order to capture medium run effects. There are three policy categories – financial, informative and regulatory.

The authors show that regulatory policies impart the greatest effect on energy consumption. In contrast to Filipini et al. (2014), the results indicate a seven year delay in the effectiveness of informative measures. Information effect sizes are also relatively small. The authors suggest the increased implementation of regulatory measures.

A semi-quantitative approach necessarily emphasizes similarities between heterogeneous policies in order to create a feasible number of categories, which are therefore somewhat coarse. To be sure, any process of quantification faces this challenge as the counting of entities (variable values) within constructed categories (variables) always entails some degree of artificially introduced homogenization. However, if researchers do not carefully weigh the advantages and disadvantages, apples and oranges may well end up within a fruit category in which subtle differences of flavors are entirely lost.

In addition, O'Broin et al. (2015) state that certain policies (such as CO2 taxation) can be safely excluded from the index as they "would already be represented in the energy price time series" (O'Broin et al., 2015, 220). This is arguably not correct. The amount of collected energy and CO2 taxes does not necessarily correlate with the size of the tax rate. Individuals will adjust their behavior in the medium and long run and substitute taxed sources (e.g. coal and oil) in favor of non-taxed or lightly taxed sources (heat-pumps) of energy. Thus, for countries in which energy and CO2 taxes have been in effect for many years (e.g. Sweden), the CO2 tax revenue underestimates the full impact of tax based energy policies as oil and coal are no longer in use. In other words, if people have already switched to renewable energy sources a high CO2 tax rate is not necessarily mirrored in a high energy price index.

Our critique of the policy-quantification approach must not be construed as an outright dismissal, however. The studies discussed above (Filipini et al., 2014; O'Broin et al., 2015) have made valuable contributions to the literature and it is noteworthy that regulatory measures impart effects on building energy consumption in both of these papers. Instead, our concerns impel us to scrutinize and cross-validate their results by applying different methods. Our findings confirm their conclusion about the effectiveness of regulatory building standards. In addition our analysis suggests that the effectiveness of CO2-taxation has been previously underestimated (see Lin and Li, 2011).

3. Quantitative Analysis

We employ a mixed-methods approach. Our quantitative analysis serves the purpose of explaining energy consumption by country and year by observable characteristics. We pay close attention to individual country fixed effects as they can indicate a higher (or lower) level of energy consumption than what we would expect from the vector of observable characteristics. We also plot the country specific residuals over time. Systematic changes over time indicate improvements or decline in energy conservation. We then build upon these quantitative insights by qualitatively investigating certain countries, which stand out due to their better-than-expected energy conservation, in detail. These case studies identify likely (policy) causes for their high levels of energy conservation.

Having data of the 28 countries of the European Union and Norway for the years from 2000 – 2015, we use panel data methods. The mean energy use per dwelling by country i and year t (as tons of oil equivalent) represents the dependent variable in our empirical model which takes the following form:

$$Energy_{it} = \beta_0 + \beta_1 \bar{X}_{it} + \beta_2 WAPItax_{it} + \beta_3 longitude_i + \beta_4 latitude_i + \beta_5 country_i + \beta_6 year_t + \varepsilon_{it}$$

In order to capture the country-specific effects a Least Squares (Country) Dummy Model will be run. Therefore, a country dummy variable $country_i$ is included in the model controlling for time-invariant country-fixed effects. These country dummies show whether a country consumed more or less energy than others after having controlled for country-specific conditions. Using a Least Square Dummy Variable Model can also prevent from endogeneity caused by omitted variables since it captures all country specific effects. However, in this case we expect that the country fixed effects mainly capture public policy differences across countries. It has been shown that cross country analyses often suffer from omitted variable bias (Ranson et al., 2014). Both Filipini et al. (2014) and O'Broin et al. (2015) include only a small set of controls. Besides the LSDV approach, we consequently add a number of additional variables which plausibly affect energy consumption captured by $\bar{X}$.

The vector $\bar{X}$ is composed of the following time-variant explanatory variables: $WAPItax_{it}$ is the weighted average price index which calculates the energy price according to the country's specific energy mix and prices (including taxes and levies). Alternatively, we also used a net weighted average price index (excluding taxes and levies). However, due to a large number of missing values in the time-line and across countries, we did not include WAPInet in the model specifications. In any way, the results were almost identical. Furthermore, the mean floor area and GDP per capita are included. Both are expected to have a positive impact on energy use. Their squared terms are included as well since we do not expect further positive impact on energy use from a certain floor area or GDP per capita onwards. Share of homes that are owned (as opposed to being rented) is included in the model in order to test for the existence of the owner-tenant dilemma. Moreover, the share of apartments (as opposed to free standing houses) is an important explanatory variable as apartments are more energy efficient due to the lower number of outer walls. In order to control for climatic differences we use HDD_{it}, $longitude_i$ and $latitude_i$ as additional variables. HDD_{it} are heating degree days which is a proxy variable for the country's specific climate, whereas $longitude$ captures possible effects related to continental climates in eastern European countries. The thermal properties of the building stock depend on its age. Therefore, we use the share of newly constructed residential buildings each year in conjunction with the share of buildings after 1980 in order to construct the variable $post1980$ for all years and all countries. We also included the country's average household size as an explanatory variable since we expect higher energy consumption with increasing household size. However, the household size does not vary substantially across countries and neither within countries over time. Besides, the variable household size was not significant and the regression output did not change substantially after the inclusion of the variable. Only the variable floor area lost some significance which could mean that the variable floor area partially captures household size. Therefore, the variable household size was dropped from the model. Finally, ε_{it} is the error term in this model.

The results of a Breusch-Pagan Test showed that the model contains heteroscedastic residuals. As often observed in panel data, we also detect autocorrelation. This is due to the country specific effects which are not constant over time. Therefore, heteroscedasticity and autocorrelation robust standard errors are specified in both model specifications.

Furthermore, Energy prices are most likely affected by energy demand. In order to address this endogeneity problem Bigano et al. 2006 rely on lagged energy demand and Arellano-Bond dynamic panel-data estimations. Although a robustified Durbin-Wu-Hausman test on endogeneity led us to accept the null hypothesis of exogenous prices (WAPI tax), we nevertheless use an instrumental variable approach in order to safely rule out potential endogeneity. To that end, the first year lag of the energy prices is used as an instrument for the energy prices. Energy prices were highly correlated with their lags and the lagged energy prices are not endogenous to the demand of energy. We use a two-stage least-squares (2SLS) estimator since it is more efficient than ordinary instrumental variable estimators Cameron and Trivedi (2010). In the first stage regression we regress the potentially endogenous variable WAPItax on the instrument and all exogenous variables. The first stage regression output shows that the instrument (L1.WAPItax) is statistically highly significant and its t statistic is relatively high. This confirms the use of our instrument. The second stage replaces WAPItax in the structural regression by the predicted values from the first stage regression. The results of the second stage regression show that the negative coefficient is larger. This suggests that the negative effect of prices on energy consumption was underestimated by 6 percent in the original regression. As the standard errors are not substantially larger and the t statistics did not become smaller compared to the original model we can conclude that L1.wapitax is a strong instrument. The strong association between WAPItax and its first year lag emphasizes this. Furthermore, a Stock-Yogo weak ID F test defines the critical value to be 16.38 at a 10% maximal relative bias toleration. Since we have a minimum eigenvalue statistic of 90.86 and an F statistic of 25.77 (due to robust standard errors) we exceed the critical value of 16.38 and therefore, can reject the null hypothesis of weak instruments. By including exactly one instrument for one potentially endogenous regressor our model is just-identified. This is also proved by the Kleibergen-Paap rk LM statistic which shows that our model is identified. Although WAPItax was not found to be endogenous, the estimates are still consistent. Consequently, by conducting a Two-Stage Least Squares (2SLS) Regression in the second model specification, reverse causality can be circumvented. With the inclusion of the instrumental variables the model takes the following form:

$$Energy_{it} = \beta_0 + \beta_1 \bar{X}_{it} + \beta_2 \widehat{Wapitax}_{it} + \beta_3 longitude_i + \beta_4 latitude_i + \beta_5 country_i + \beta_6 year_t + \varepsilon_{it}$$

Where:

$$\widehat{Wapitax}_{it} = \gamma_0 + \gamma_1 Wapitax_{it-1} + \gamma_2 exogenous\ regressors_{i(t)} + \varepsilon_{it}$$

Where:

$$\gamma_2 = 0$$

3.1. Data Sources

All variables, their sources, and basic descriptive statistics are displayed in table 1.The data for energy consumption per dwelling in tons of oil equivalent was obtained by the ODYSEE-MURE website, which represents a collaborative effort by several European national energy agencies. The data is normalized to account for varying severity of winter weather conditions from year to year. ODYSEE-MURE further provided the data on home floor space and heating degree days (HDD). The latter variable is defined as the distance between Temperature Tm and 18 degrees Celsius (weighted by the number of days), if outdoor temperature is 15 degrees or less and zero otherwise:

$$HDD = \begin{cases} (18\,°C - Tm)\ x\ days, & Tm \leq 15° \\ 0, & Tm > 15° \end{cases}$$

where: $Tm = \frac{\sum(Tmin\ + Tmax\ /\ 2)}{\#days}$

We use both latitude and longitude as additional climate controls, whereby longitude controls for continental climates of eastern European countries. These variables were taken from the CIA fact book and verified with additional online sources. The median age is available at Eurostat. Home ownership and the fraction of the population living in apartments (for each country and year) are also available at Eurostat. However, these two variables do not contain values for each year, especially between 2000 and 2006. We graphically inspected the existence of a time trend in each country. If the slope is close to zero, it can be assumed that no systematic trend exists and the last available value was used for imputation. No more than three years of missing data was filled in in this manner.

The weighted average price index represents energy prices according to the country specific energy mix as well as country specific prices and taxes on each energy carrier. Therefore, the share of the main energy carriers (oil, coal, gas and electricity)[2] of the country's energy mix was calculated. Thereafter, prices of each energy carrier for each year were deflated to the prices of the year 2010 and denoted in USD. If the prices were only available in other currencies, the prices were converted into USD using the exchange rate of the respective year. To have a common base of measurement consumption of oil, coal, gas and electricity was converted into the unit tons of oil-equivalents using the IEA unit converter. In addition to this, different conversion efficiencies of the energy sources were considered, too. Therefore, the prices were multiplied by the energy carrier's conversion efficiency factor (NCV). Finally, the prices per ton of oil equivalent in USD and in NCV of one energy carrier (in one year) were multiplied by the carrier's share of the energy mix. Adding up these prices of each energy carrier yields the country and year specific weighted average price index. The data to construct this weighted average price index was drawn from Odysee-Mure, Eurostat, IEA, OECD and Statista.[3]

Data for GDP per capita and floor area were both drawn from Eurostat. In order to construct the variable $share\_post80$ we use data on newly constructed residential buildings in each year and those constructed after 1980 drawn from the European Commission, Odysee and Norway Statistical Offices. Table 1 presents the descriptive statistics and data sources.

[2] Some country's energy mix includes biomass, wood as well as district heating as energy carriers. Due to a lack of data on prices of these energy carriers in most of the respective countries, we did not include these energy carriers in the WAPItax calculation. Instead, we subdivided the cumulated share of these three energy carries onto the other main energy carriers according to their share.

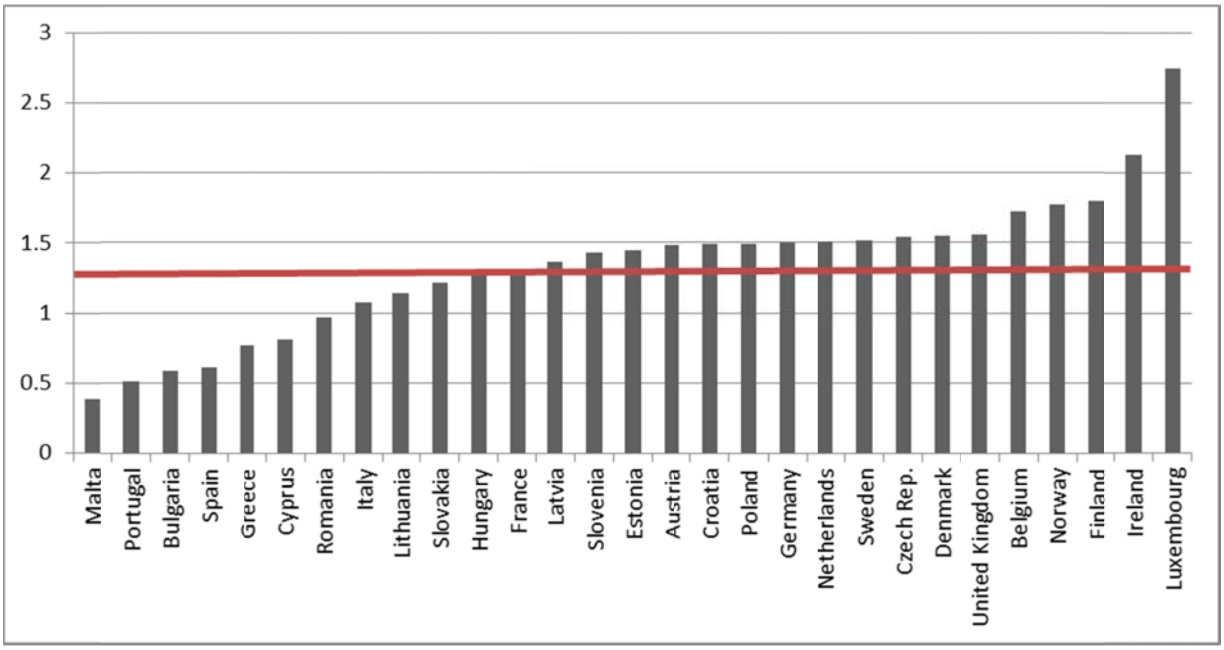
[3] Missing values were carefully imputed up to three years. If a systematic trend was observable, the value was adapted to the trend otherwise the value of the last year available was adopted or the mean between two years' value was chosen.

Table 1: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max	Data Source
consumption (in toe_dw)	406	1.336	0.516	0.300	3.277	Odysee
wapitax	444	1368.910	606.238	229.616	3334.713	based on: Odysee, IEA, OECD, Eurostat, Statista
age	434	39.280	2.344	32.400	45.600	Eurostat
hdd	435	2942.892	1221.309	306.604	6058.319	Odysee
latitude	464	49.136	7.239	35.126	61.924	CIA Fact Book
longitude	464	14.947	13.657	-8.244	60.128	CIA Fact Book
floor_area	417	90.415	22.081	34.360	145.771	Eurostat
gdp_capita	435	29430.310	21918.140	1609.281	116612.900	Eurostat
home-ownership	358	75.861	10.545	51.600	97.600	Eurostat
aprtmt_share	365	38.009	16.860	2.500	69.700	Odysee
share_post80	464	31.749	10.808	2.030	74.230	based on: European Commission, Odysee, Norway Statistical Offices

Figure 1 depicts the average annual energy consumption per dwelling and country sorted from least consuming to most consuming. One can see that southern countries consume, on average, less energy than central or northern European countries. The countries with the highest average consumption per dwelling are Luxembourg, Ireland, Finland and Norway.

Figure 1: Average annual energy consumption per dwelling and country



3.2. Quantitative Results

Regression results are presented in Table 2. Model specification 1 are the results of an LSDV estimation including the heteroscedasticity- and autocorrelation robust standard errors, whereas model specification 2 shows the results of the 2SLS regression using an instrumental variable (IV) for the energy prices. As expected the weighted average price index has a negative impact on energy use in both specifications. The 2SLS regression shows that the original model underestimated the negative effect of prices on consumption by almost 6%. The climate control variables HDD, longitude and latitude are jointly significant in both model specifications. As expected, energy consumption increases with more heating degree day and with increasing latitude. Longitude has a positive impact on energy consumption as well which suggests that continental climate has a positive impact on energy consumption.

Age is only significant in model 2 and has, unexpectedly, a negative impact; it's squared terms are not significant in either model. Floor area and GDP per capita and their squared terms are significant in both models. As expected, GDP per capita has a positive impact on energy consumption. However, a reverse trend is observable once a certain income is reached and less energy is consumed. Equally, increasing floor area leads to higher energy consumption up to the point at which floor area exceeds about 100 square meters after which consumption is decreasing again. This is most probably due to selective heating of rooms within a large dwelling. The share of owned homes does not affect the dependent variable. The tenant-owner-dilemma does not seem to be a major hurdle for the implementation of energy efficiency measures. The share of apartments affects energy demand negatively in both models. Similarly, the share of dwellings built after 1980 has a negative impact on energy use, albeit only in model 2.

Overall, our model's explanatory power is very high with an R^2 of around 0.983. This is due to the fact that the Least Squares Dummy Variable Models capture the effects of otherwise omitted variables.

Coefficients of year and country dummies are not listed in Table 2. A negative time trend is observable, which can be explained by technological progress as well as increasingly stringent European energy efficiency policies. Figure 2 depicts the country fixed effects sorted from least consuming to most consuming country. Country effects which were not significant have a coefficient of 0. Germany and France left out as a control group and therefore have a coefficient of 0 as well. The ten countries which display the lowest energy demand and were jointly significant in all specifications are Sweden, Bulgaria, Malta, Finland, Slovakia, Lithuania, Cyprus, Hungary, Greece and Romania. The two countries which display the highest energy requirements are Ireland and Luxembourg.

Our model results coincide with additional evidence. According to data by the International Energy Agency[4], Bulgaria's residential energy consumption per capita is only about one third of Germany's, whereas Luxembourg requires 35% more energy than Germany. A study by the University of Luxembourg (Maas et. al., 2007) also concludes that residential energy requirements are 30% to 40% above German and Swiss ones.

Sweden, Finland will be analyzed in more detail below. They are interesting cases since they display low energy requirements (contingent on observable characteristics). Being geographic neighbors, they are also situated in a similar climatic and cultural zone and are thus, ideally suited for a direct policy comparison. In addition we will analyze Ireland because of its relatively high energy demand.

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[4] https://www.iea.org/statistics/

Table 2: Results after Panel Regression

	Model 1 LSDV	Model 2 IV
log_wapitax	-0.109**	-0.163*
	(0.043)	(0.052)
log_hdd	0.162*	0.160*
	(0.086)	(0.06)
longitude	0.0102***	0.0297***
	(0.003)	(0)
latitude	0.0378**	0.00846*
	(0.018)	(-0.076)
age	-0.133	-0.145*
	(0.149)	(0.08)
age2	0.00146	0.00161
	(0.206)	(0.119)
floor_area	0.0230***	0.0235***
	(0.008)	(0.002)
$floor\_area^2$	-0.000115***	-0.000119***
	(0.007	(0.002)
gdp_capita (x1,000)	0.00676*	0.00613*
	(0.082	(0.083)
gdp_capita^2	-4.86e-11**	-4.72e-11**
	(3.00E-02)	(1.90E-02)
home_ownership	0.00114	0.00139
	(0.424)	(0.291)
apartment_share	-0.00751***	-0.00751***
	(0.002)	(0.001)
share_post80_	-0.00348*	-0.00299*
	(0.059)	(0.083)
N	276	275
R2	0.983	0.983

Note: Country and time fixed effects are included in both models. P-values are displayed in parentheses.

Figure 2: Country fixed effects after Panel Regression

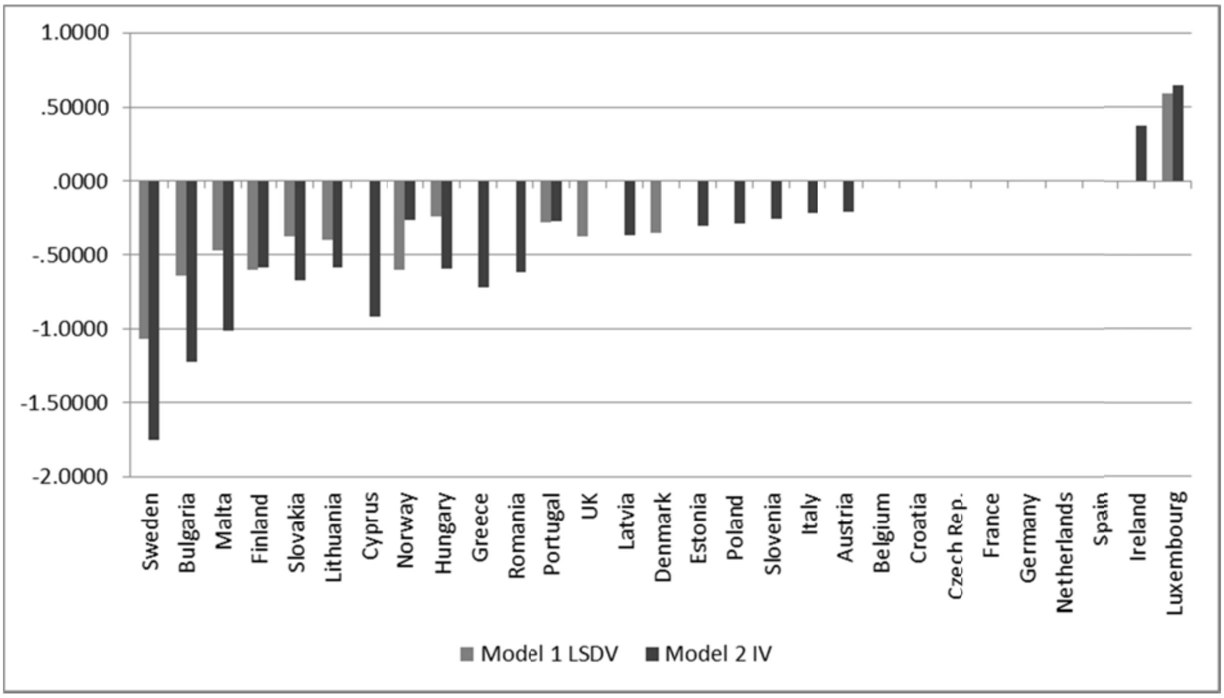


Figure 3: Residuals after Panel regression by country over time

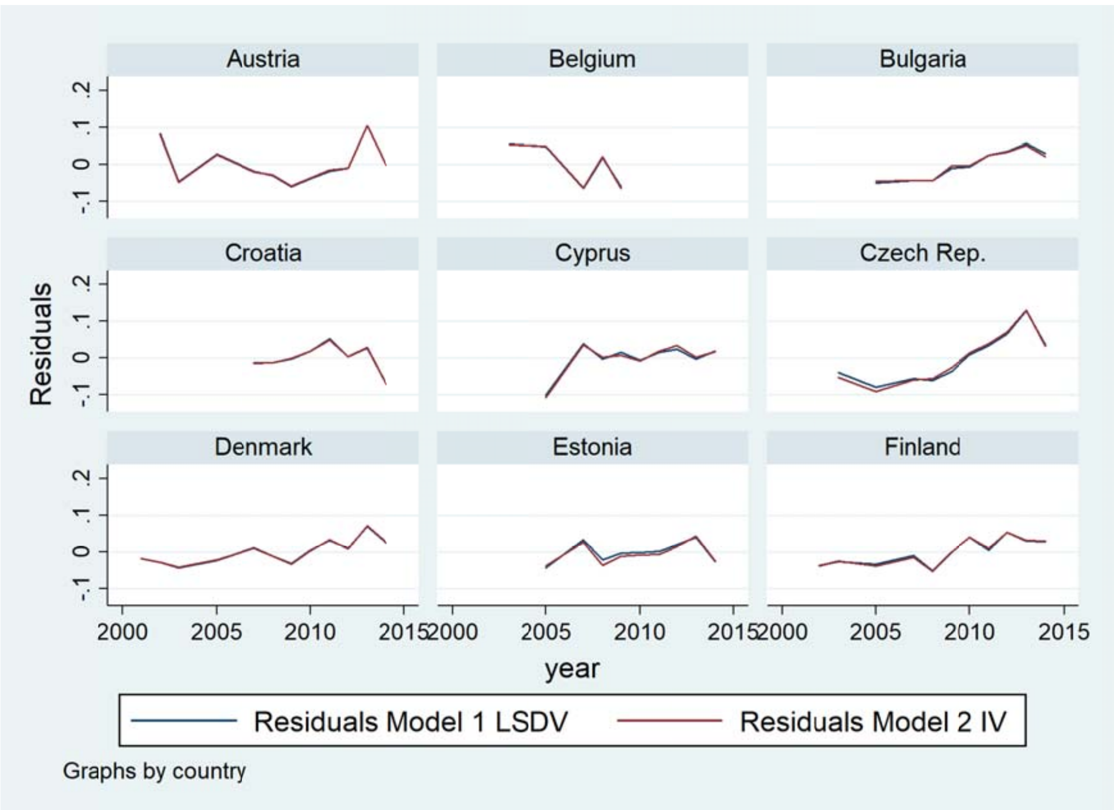


Figure 3 (continued): Residuals after Panel regression by country over time

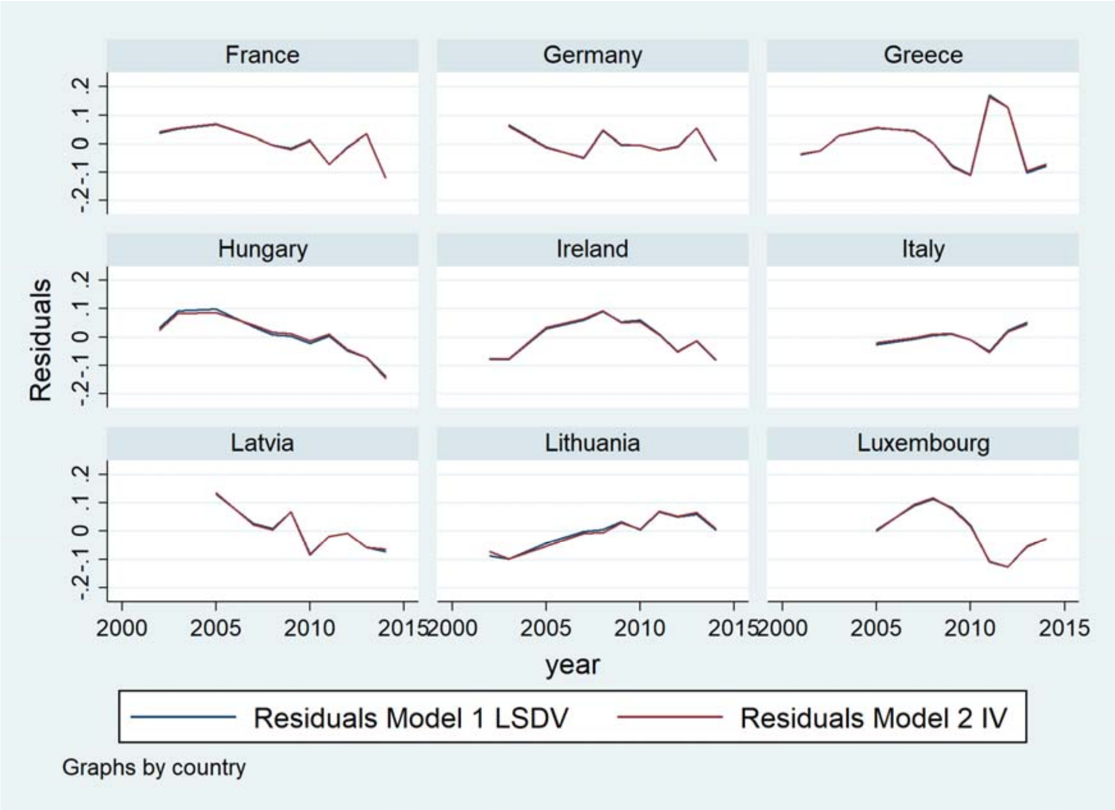
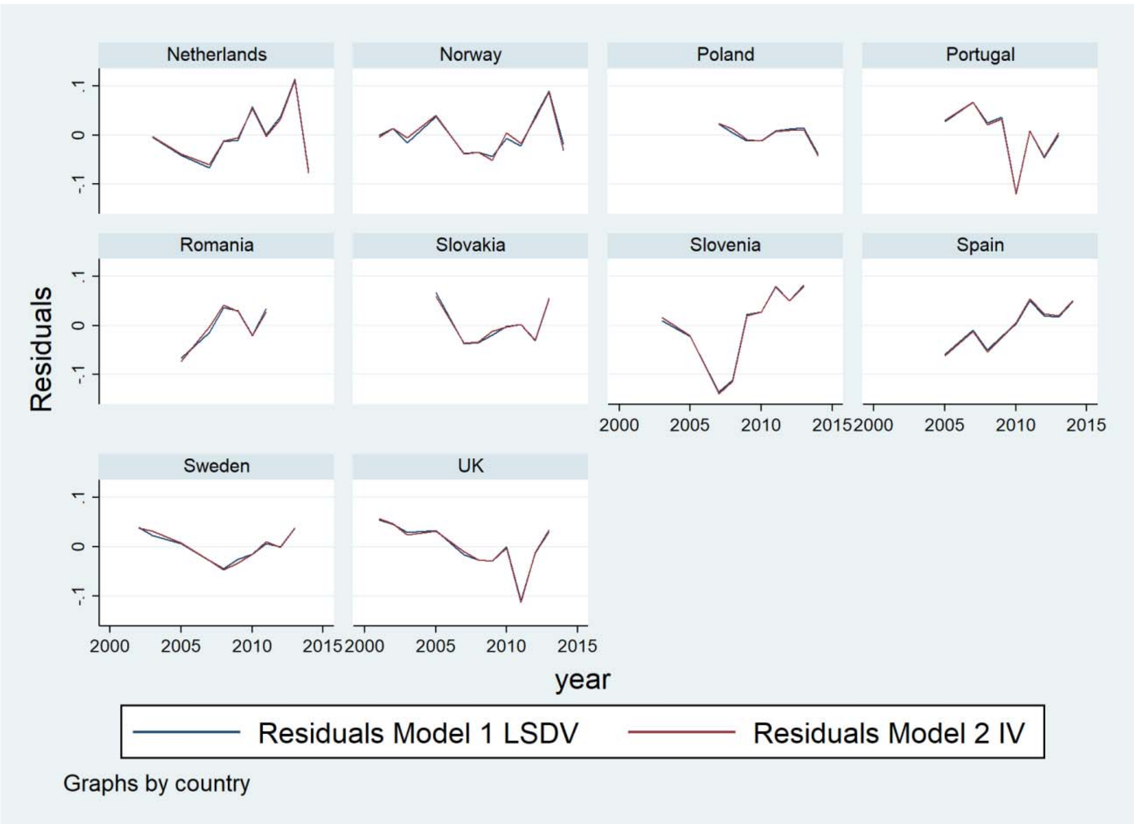


Figure 3 (continued): Residuals after Panel regression by country over time



Finally figure 3 depicts the residuals of the model by country over time. While the country dummies have removed mean deviations from the overall energy demands, these graphs can be interpreted as within-country changes over time that are not explained by observable characteristics. The countries which clearly display a negative trend over time are Belgium, France, Germany, Hungary, Latvia and Luxembourg.

4. Qualitative Policy Analysis

As a result of our quantitative analysis, we obtain information about a country's average energy consumption and its consumption changes over time (see figure 2 and 3). It has to be stressed that "low energy consumption" refers to cases in which the actual energy consumption is lower than predicted by the observable characteristics (income, dwelling size, climate, etc.). Sweden performs exceptionally well, which is why we will put special emphasis on this case in our qualitative analysis. Other Scandinavian countries also appear to perform better than predicted, as for example Finland. As we will see below, a comparison of the two countries will be particularly instructive. On the other end of the spectrum, Ireland performs less well than predicted, hence, we also analyze this case in more detail.

4.1. On Method

For the purposes of our qualitative policy analysis of the respective countries, original policy documents were examined, research articles were consulted, and experts were interviewed, as table 3 summarizes. All the material was evaluated with regard to the research question whether there are any distinct policies that may explain the country's relative energy consumption position. This analysis is meant to be explorative. Our aim is to formulate hypotheses, not to test them. Nevertheless, we try to validate them to a certain degree, in order to yield theses that have already been subject to a decent amount of plausibility testing.

Table 3: Overview on documents and interviewees

Country	Policy documents	Interviewees
Sweden	Boverket (National Housing Board) building part regulation: www.boverket.de SBN 1975 Supplement 1, BFS 1993; BFS 2002:6; BFS 2008:20; BBR 16;	Economic Science: 1 Swedish Energy Agency: 2 Boverket: 1 Swedish Green Building Council: 1
Ireland	Building Regulations Technical Guidance Document L 1991, 1997, 2002 (Reprint 2005), 2007 (Reprint 2008), 2011	Economic Science: 1
Finland	Odysee-Mure Policy Database	Ministry of the Environment: 1 Energy Authority: 1
Other	*Germany* – Wärmeschutzverordnung 1977; Energieeinsparverordnung 2014 UK – National Audit Office, 2016.	None None

4.2. Sweden

Sweden is an interesting case for our policy analysis because of its exceptionally low average energy consumption. Descriptively, Swedish residential energy consumption is on par with Germany's even though climatic conditions are less favorable. Once we take all observable characteristics into account, the Swedish residential sector uses the least amount of energy per dwelling. Descriptive data by the Swedish Energy Agency display a falling total consumption between 1995 and 2008 (see figure 4). The residuals of our quantitative analysis above display a similar trend, even though we only have data starting in 2003 (figure 3). Three characteristics of Swedish energy policy turn out to be noteworthy: regulatory energy standards for new buildings, the energy and CO2 taxation systems as well as district heating.

Energy regulation standards for new buildings

Swedish energy regulation is quite rigorous, compared with other European countries (see table 3). This is not only the case for the timespan of our quantitative analysis (2000-2015). The regulation from 1978 (SBN 75, Supplement 1) comprises energy requirements that are equal to, or even stricter than those from Germany in 2014 (ENEV 2014). In the meantime, the computational basis for U-values has Sweden changed (BFS 1993; BFS 2002:6) and standards were tightened in 2007 (compare BFS 2006:12 of 2007 as well as BFS 2008:20

BBR 16). 2007's tightening of building part regulation was accompanied by the introduction of a preliminary 2-year license and periodical consumption metering. In the case of non-compliance, buildings have to be subsequently modified.

Figure 3 depicts Swedish total residential energy consumption over time. As the regulations have been strict since the 1970s and as they have been tightened further in 2007, they cannot be regarded as the main explanatory factor for the decline of Swedish energy consumption without further qualification. If we put aside the oil price shocks of the 1970s, we can observe that energy demand is on decline since 1995, or, perhaps 1990, whereas it showed no further reaction to the tightening regulation in 2007.

Furthermore, it is not necessary that tighter building part regulations were introduced for environmental purposes. They could, perhaps, simply be explained by utility maximizing decisions in colder climate zones. If house owners invest without being forced by regulation, in order to gain more energy efficiency, a law that codifies this practice will not encounter much opposition. Legal codification, in this case, would only translate a common practice into formal law. Thus, the causal relationship is not necessarily running from law to energy consumption.

The comparison to Finland supports such a view. Finland's U-values are similarly strict (see table 4). Nevertheless, its residential building sector has only a higher middle rank position within our panel data analysis. It seems likely that the reference to tight regulation cannot be the only explanatory factor for Sweden's energy efficiency status.

Table 4: Building part regulation across chosen countries (U-values)

	Finland			Germany		Sweden	
Year	*1978*	*1985*	*2010*	*1977*	*2014*	*1978*	*2008*
Wall	0,29 - 0,35	0,28	0,17	1,45 - 1,75	0,28	0,25 - 0,30	0,18
Roof	0,23 / 0,29	0,22	0,09	0,45	0,2	0,17 - 0,20	0,13
Windows	2,1 / 3,1	2,1 / 3,1	1,00	1,6 - 3,5	1,3	1,0 - 2,0	1,3
Ground Floor	0,23 / 0,4	0,22 / 0,36	0,16	0,9	0,35	0,17 - 0,30	0,15

Remark: All values are U-values. The unit is $\frac{W}{m^2K}$

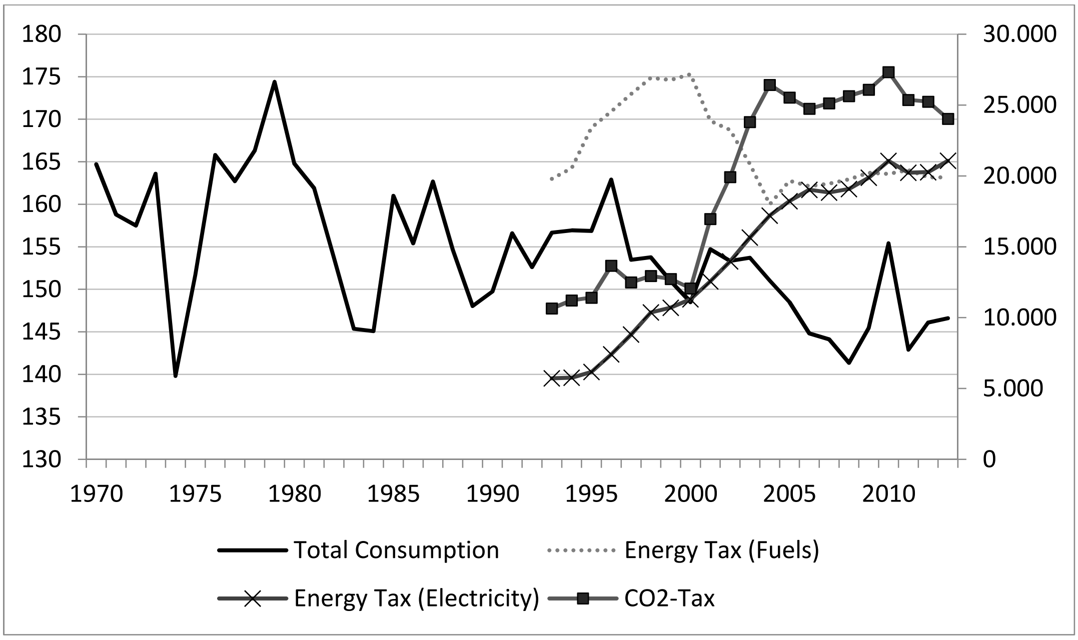
Sources: *Finland* – Odysee-Mure Policy Data Base
Germany - Wärmeschutzverordnung 1977, nichtamtliche Fassung S. 9-12; Energieeinsparverordnung 2014 nichtamtliche Fassung S. 41f.
Sweden - SBN 1975 Supplement 1 S. 17, BFS 2008:20 BBR 16 S. 10.

Energy and Carbon Taxation

Figure 1 shows that a major proportion of energy conservation was achieved from 1995 on and this decline cannot be explained by regulatory reforms. In addition, the tightening of building part regulation in 2007 is not a plausible explanatory factor either because it was introduced after the bulk of conservation had already been achieved. Instead, it seems reasonable to assume that the introduction, and more importantly, the upward adjustment of the CO2 tax play a significant role. In 1991, Sweden was on of the first countries to introduce a CO2 tax, right after Finland and Poland did so in 1990. In current prices the tax rate was at 20 €/ton of C02, but in subsequent years it was subject to continuous increases. The highest raise occurred in between 2000 and 2004: the price per ton grew up to 100€. At the moment, the price is at around 140€.

The energy- and electricity as well as the CO2 tax revenues are also shown in figure 4. The continuous increase of the electricity tax revenue after 1993 and the increase of the carbon tax rate after 2000 mirror the declining energy consumption trend. The reduction of fuel energy taxation is strongly overcompensated by the increase of electricity and carbon taxation.

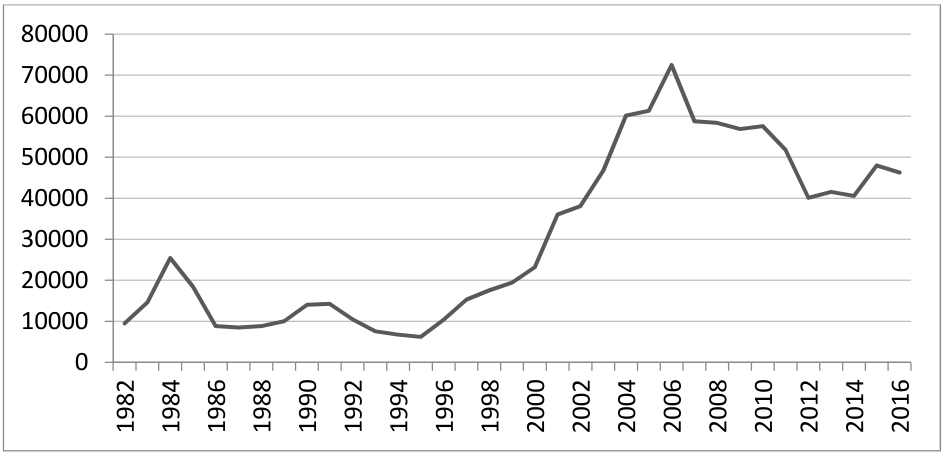
Figure 4: Total residential energy consumption (1970-2013, in TWh) and environmental tax revenues in Sweden (1993-2013, in Mio. SEK).



Source: Swedish Energy Agency, Statistics Sweden

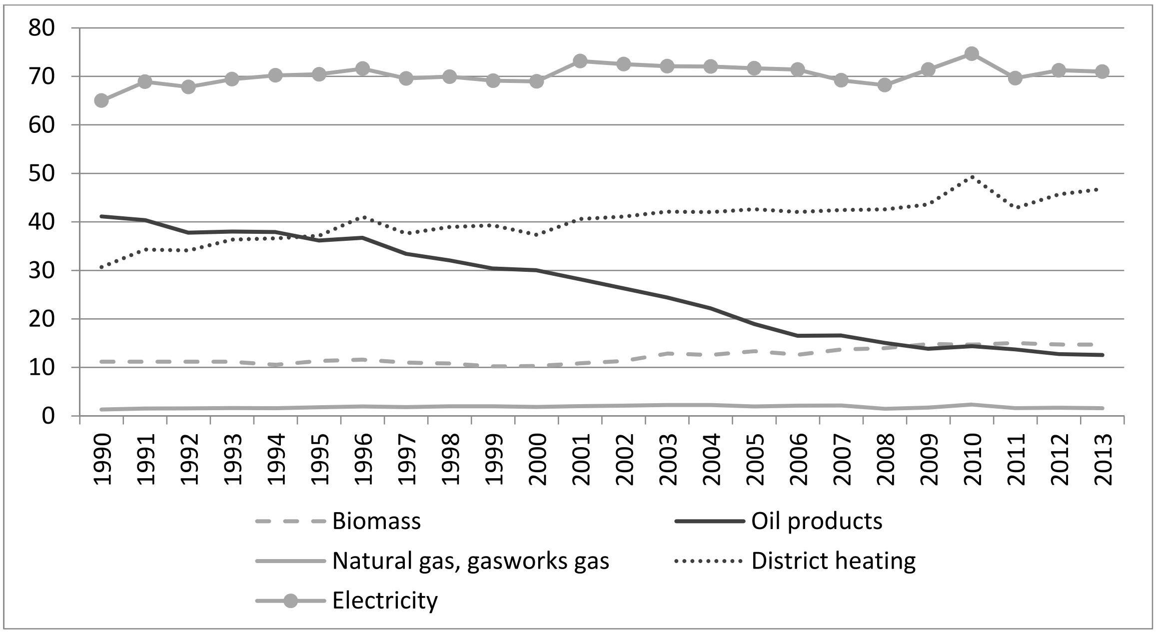
There are two presumed effects of the CO2-tax: (1) a general reduction in energy consumption and (2) changes of the energy-mix. Especially the reduction of oil consumption (figure 6) and the intensified use of heat pumps (figure 5) are most likely caused by the tax increase, which is supported by their covarying time trends. Interestingly, the spread of heat pumps did not cause an increase in electricity consumption after the year 2000. Furthermore, the oil consumption reduction is partly compensated by an increase in biomass consumption. The actual increase in biomass consumption is underestimated in figure 3, as a large portion of district heat (which is listed separately) is fueled by biomass as well.

Figure 5: Number of heat pumps sold per year in Sweden



Source: *Svenska Kyl&Värmepump Föreningen* [Swedish association for heat pumps]

Figure 6: Energy consumption (households) by energy carrier (Sweden, in TWh)



Source: Swedish Energy Agency

District Heating

Before we conclude, it is necessary to shed some light on another Swedish peculiarity. As a reaction to the oil price shocks in the 1970s, a political promotion of municipal district heating occurred. District heating is per se relatively energy efficient (Joelsson and Gustavsson, 2009). Due to high energy taxation, the district heat production was incrementally adjusted to include a greater share of renewable energies instead of fossil fuels since the 1990s. District heating had a market share of around 55% in 2014 (Werner, 2017).

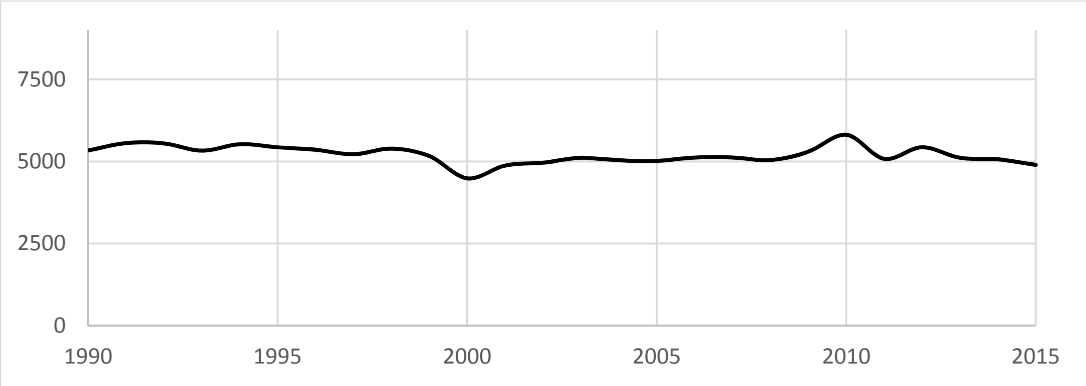
Summary

Three elements should be regarded as most probable causal factors for the excellent Swedish energy performance in the residential sector: (1) the building part regulations for new buildings are very strict since the 1970s, compared to other European countries. They became even tighter since the turn of the millennium and were supplemented by mechanisms of control and sanction. Our findings, thus, coincide with O'Broin et. al. (2015) and Filipini (2014) who investigate the effectiveness of European regulatory schemes, and other similar research contributions (Jacobsen and Knotchen, 2013; Regulatory standards do not suffice to explain the Swedish energy efficiency level, however. Comparatively high carbon dioxide and energy taxes (2) were also identified as an explanatory factor. The massive increase of tax rates co-occurred with a declining energy consumption and increasing use and spread of heat pumps. (3) A high share of district heating exists, which has been found to positively affect energy conservation (Joelsson and Gustavsson, 2009).

4.3. Finland

Finland makes use of a policy mix that displays remarkable similarities to Sweden's. Therefore, it seems appropriate to expect Finland's residential energy conservation level to be roughly similar to the one in Sweden. Surprisingly, this is not the case. Finish residential energy consumption is higher than the one in Sweden in both descriptive statistics, as well as in our regression analysis (see figure 2). Descriptive statistics by the IEA (figure 7) as well as the residuals in our quantitative analysis above (figure 3) show hardly any change in total residential energy consumption over time. In the following paragraph we will outline the reasons for Finland's lower, yet, by European comparison still quite satisfactory, energy performance.

Figure 7: Total Residential Consumption Finland 1990-2015 (ktoe)



Source: International Energy Agency (IEA)

As we have already stressed in the section on Sweden, Finland employs one of the hardest building part energy efficiency regulations in Europe (see table 4). Furthermore, Finnish energy efficiency policy incorporates a range of economic incentives such as energy audits for households or industrial production as well as energy grants for households in order to promote energy efficiency in the old building stock.

Like Sweden, Finland also makes extensive use of district heating which has a market share of about 45% (Sweden: 55%, see above; Vainio et. al. 2015). Alternatively, country statistics provided by Euroheat & Power (2013) estimate that about 50% and 52% of all customers are served by district heat in Finland and Sweden respectively. The fossil fuel intensity within the district heating energy mix and the overall residential energy mix has been declining over the last decade. It is being mostly substituted by renewable and carbon neutral energy sources. District heating may again be one of the main causes for a high energy efficiency level but it cannot explain the gap between Sweden and Finland.

We conclude, Finland displays a high degree of similarity to Sweden in energy policy regarding regulations, use of subsidies, and the prevalence of district heating. Therefore, the discrepancy in energy efficiency performance calls for another explanation.

Carbon dioxide tax

Being the first country to do so, Finland enacted a carbon tax in 1990. This tax has been subject to major reforms (e.g. in 1997, 2007, 2011) of which the merging with the energy tax is of particular importance. Since 1997 the carbon tax also applies to traffic and heating fuels. In Finland, different energy carriers are subject to different CO_2 tax rates, either expressed in c/l (light/heavy heating fuels) or c/kg (coal). Heavy fuel oil and coal make up only an insignificantly small share of the heating energy mix, whereas light fuel oil is the most important fossil energy carrier after wood. If we project the 2015 tax rate for light fuel oil (9,94c/l) to tons of CO2 (Statistics Finland, 2017), it can be concluded that the current carbon tax rate in Finland is set at around €30 per ton of CO2 for light fuel oil. This is, as a World Bank study shows, rather high in international comparison, although the Swedish carbon tax rate is much higher (World Bank, 2015: 15). Lower tax rates are imposed on natural gas, certain biofuels, and peat. The relatively lower tax rate, can be regarded as the main factor that distinguishes Finland from Sweden.

In summary, both Finland and Sweden display energy performance levels above what we would predict based on observable characteristics. Their relative position can be explained by tight regulatory standards. Finally, more stringent CO2 taxation seems to explain Sweden's more advanced position when we compare the two. Therefore, we conclude that the carbon tax cannot be argued to having made a decisive impact on energy consumption in Finland and Finland's lower position compared to Sweden mainly due to its lower rate of CO2 taxation.

4.4. Ireland

In comparison to Sweden and Finland, Ireland is underperforming when it comes to energy conservation in the residential sector. However, the descriptive data shows a 25% decline in residential energy use between 2000 and 2015. Our residual analysis in figure 3 does not mirror this decline because it is already captured in the variable 'post_80', which records the share of buildings constructed after 1980. Thus, while Ireland displays poor energy performance on average, there have been considerable improvements during the last two decades. A rough back-of-the envelope calculation based on our regression coefficients suggests that at least one quarter of the overall decline in energy use between 2000 and 2015 can be traced back the construction of new buildings.[5] The single most important policy measure seems to be the building part regulation in Ireland, which is currently comparatively strict.

[5] We assume the share of new buildings to be 33%, whereas the coefficient for the variable 'post_80' is 0.0035. The latter number signifies the reduction in energy consumption (measured in toe) caused by a 1 percent increase of new buildings. Multiplying 0.0035% with 33 yields 0.12, which represents about a quarter of the total reduction of the Irish energy consumption.

The building part regulation was drastically tightened between 2000 and 2014. Table 5 shows its development over time. It applies to new buildings as well as to renovation for existent buildings, although in the former case, it is more demanding. Between 2000 and 2015, the building stock grew from 1,2 Mio. to 1,7 Mio. permanently occupied buildings. Therefore, a large portion of buildings is subject to the tightened regulations of 2002 and 2007. The average area per building grew during that period, but energy demand per dwelling declined (Irish Energy agency, 2016). The Irish Energy Agency explains this improvement by the increasing spread of central heating which is more energy efficient than space heating systems.

CO2-taxation has been introduced for heating and motor fuels in 2010. Its original rate was set at 15€ per ton of CO2, which was raised to 20€ per ton in 2012. The residuals from our quantitative analysis above, as well as descriptive statistics show a marked decline in total energy use after 2010 despite the general increase in living space (Irish Energy Authority, 2016, 65-66). While this may indicate an impact of CO2-taxation, the intervention is too recent for drawing more definite conclusions.

The case of Ireland illustrates that hard building regulations take time to become effective. Because of the building boom, about a third of the Irish building stock was built after the year 2000, thereby being subject to current standards, the average Irish energy consumption level is still higher than in most European countries.

Table 5: Building part regulations (U-values) for existent and new buildings in Ireland

		New Buildings				
Year	1991	1997	2002	2007	2011	2017
Wall	0,45 - 0,6	0,45 - 0,6	0,27	0,27	0,21	0,21
Roof	0,25 - 0,35	0,25 - 0,35	0,16 - 0,22	0,16 - 0,22	0,16 - 0,2	0,16 - 0,2
Windows	--	3,30	2,2	2	1,60	1,60
Ground Floor	0,45 - 0,6	0,45	0,25	0,25	0,21	0,21
Source:	BRTGDL, 1991, S. 8	BRTGDL, 1997, S. 8	BRTGDL, 2002 (Reprint 2005), S. 9	BRTGDL, 2007 (Reprint 2008), S. 17	BRTGDL, 2011, S.17	BRTGDL, 2017, S.18
		Existent Buildings / Renovation				
Year	1991	1997	2002	2007	2011	2017
Wall	0,60	0,45 - 0,6	0,6	0,27	0,35 - 0,55	0,35 - 0,55
Roof	0,35 - 0,6	0,35 - 0,6	0,35	0,16 - 0,22	0,16 - 0,25	0,16 - 0,25
Windows	--	3,30	2,2	2	1,6	1,6
Ground Floor	--	--	--	0,25	0,45	0,45
Source:	BRTGDL, 1991, S. 8	BRTGDL, 1997, S. 8	BRTGDL, 2002 (Reprint 2005), S. 9	BRTGDL, 2007 (Reprint 2008), S. 28	BRTGDL, 2011, S. 26	BRTGDL, 2017, S. 27

Remarks: All values are U-values. The unit is $\frac{W}{m^2K}$
BRTGDL = Building Regulations Technical Guidance Document L

4.5. United Kingdom

The United Kingdom displays mean residential energy consumption slightly above the one of Germany, thereby falling squarely in the middle of our country ranking. This fact is confirmed by descriptive statics by the IEA, which shows a per capita consumption slightly lower than that of Germany. A national audit has stated that the UK exhibits low energetic standards in regard to building components (National Audit Office, 2016). There are no subsidies for residential energetic improvements, nor is there CO2-taxation scheme in place, except a very moderate climate change levy. The Green Deal, which uses information based measures, has so far not reached its goals.

5. Conclusion

In this paper, we examine the effectiveness of environmental policies in reducing residential energy consumption. In our quantitative analysis we regress the mean annual energy use per dwelling in 29 European countries on a number of observable characteristics. We then plot country dummy coefficients in order to identify countries that exhibit unexplained low or high energy consumption. We also plot residuals by country over time in order to spot improvements in energy conservation. Sweden, Bulgaria, and Finland stand out because of their low energy requirements, whereas, Ireland and Luxembourg can be found on the other end of the spectrum.

In the second part of the paper we analyze the policy environment of certain countries qualitatively. We find that building regulations are an effective policy instrument for reducing the consumption of energy in residential buildings. However, the impact of regulatory standards becomes only visible over time. Sweden and Finland exhibit stringent regulatory demands that have existed for more than 40 years and have been further adjusted over time. In the case of Ireland, where a third of the buildings have been constructed during the last 15 years, regulation has also markedly contributed to the reduction of overall energy consumption in a comparatively short amount of time.

However, as regulatory standards as well as other factors (such as shares of district heating) are almost identical in the case of Sweden and Finland, another explanation is required in order to understand the advantage of Sweden relative to Finland when it comes to energy consumption. We assert that this crucial difference can be found in the high CO2-taxation rates that have existed in Sweden since the year 1990. The decline in the energy consumption pattern over time is consistent with such an explanation as the increases in taxation coincide with the decline.

There are certain limitations our approach. Most importantly, we have focused on generating hypotheses, not hypothesis testing. While our qualitative analysis leads us to belief that CO2-taxation can be an effective policy instrument for reducing energy consumption, quantitative efforts should test this assertion. As more and more countries introduce CO2-taxes, the data for such an endeavor will be available in the near future. In this regard, Lin and Li (2011) have already provided a valuable first contribution by running difference-in-differences regressions in order to examine the impact of CO2-taxation on CO2-emissions. Future studies should be careful to include the varying tax rates as our results indicate that the difference between a 30€ and 140€ Euro tax per ton of CO2 will cause markedly different outcomes.

Finally, while we conclude that both regulatory building standards as well as CO2-taxation are effective policy approaches for reducing energy consumption, we have not addressed the cost-benefit aspects of these policies. There are strong theoretic reasons to believe that a taxation scheme will cause market actors to discover the most cost-efficient means of lowering CO2-emissions. If the costs of CO2-reduction should exceed a certain level, the likelihood of losing public support for further climate policies will increase, thereby jeopardizing global efforts to mitigating climate risks.

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Appendix: Eckpunkte für die Ausgestaltung einer CO2-Steuer

(1) Die Bemessungsgrundlage einer CO2-Steuer sollte so breit wie möglich ausfallen.

Die Bemessungsgrundlage sollte im Rahmen praktischer Restriktionen möglichst breit ausfallen. Regenerative Brennstoffe sollten nicht besteuert werden. Der Effizienz-Vorteil einer CO2-Steuer kann nur dann voll zum Tragen kommen, wenn ein großer Anteil der CO2-Quellen einbezogen wird. Der Effizienzvorteil ergibt sich dadurch, dass Konsumenten und Produzenten durch höhere Preise veranlasst werden, CO2 einzusparen. Wenn CO2 über alle Quellen hinweg gleich besteuert wird, wird der Suchprozess nach Alternativen nicht auf bestimmte Bereiche reduziert und dadurch nicht verzerrt. Mit anderen Worten, eine breite Bemessungsgrundlage garantiert Sektoren- und Technologie-offenheit.

Diese Analyse beschreibt zunächst ein Steuermodell, welches alle fossilen Energieträger einbezieht (Basismodell). Regenerative Brennstoffe werden, auch wenn durch die Verbrennung selbst CO2-freigesetzt wird, nicht besteuert. Ergänzend wird die Erweiterung auf landwirtschaftliche Produkte (vorrangig Fleisch und Milchprodukte) diskutiert. Eine Erweiterung ist generell wünschenswert, denn ob eine Tonne CO2 durch Nichtverzehr von Fleisch oder durch Wärmedämmung ausgelöst wird, ist aus klimapolitischer Sicht irrelevant und sollte den Wirtschaftssubjekten selbst überlassen bleiben, damit dort CO2 eingespart wird, wo es am kostengünstigsten ist.

Die CO2-Emissionen, welche durch die Verbrennung der jeweiligen Energieträger bzw. der Herstellung landwirtschaftlicher Produkte entstehen, sind vor der Einführung einer Steuer noch einmal wissenschaftlich zu prüfen und zu fixieren. Eine solche Prüfung muss in regelmäßigen Abständen wiederholt werden. Die bei der Szenario-Berechnung verwendeten Annahmen und ihre Quellen können in Tabelle 1,2 und 4 eingesehen werden.

(2) Eine effektive Steuer sollte mindestens 70 Euro pro Tonne CO2 betragen.

Eine Reihe von Ländern in Europa hat CO2-Steuern bereits politisch umgesetzt, insbesondere Schweden (ca. 140 Euro pro Tonne), Schweiz (ca. 88 Euro pro Tonne), Finnland (ca. 30 Euro pro Tonne), Dänemark, Norwegen Frankreich, Slowenien und Irland. Mit Ausnahme von Schweden, der Schweiz und Finnland, liegt die Steuer pro Tonne CO2 in diesen Ländern jedoch meist deutlich unter 30 Euro.

Unsere quantitative Studie ergab, dass Schweden und Finnland die einzigen Europäischen Länder[6] sind, welche sehr niedrige Energieverbrauchswerte im Gebäudesektor aufweisen, obwohl ihr durchschnittlicher Lebensstandard dem deutschen gleicht und ihr Klima vergleichsweise unvorteilhaft auf den Verbrauch einwirkt.

[6] Die Schweiz wurde auf Grund von mangelnder Datenverfügbarkeit nicht untersucht.

Schweden und Finnland weisen sehr ähnliche politische Strategien auf (hohe regulatorische Anforderungen seit 1970, hoher Anteil von Wärmenetzen, ein Mindestmaß an informatorischen Ansätzen). Unsere Studie deutet darauf hin, dass nur durch die unterschiedliche Höhe der CO2-Steuer der starke relative Erfolg Schwedens bei der Energieeffizienz im Gebäudesektor erklärt werden kann.

(3) Die Höhe der Steuer muss von Anfang an langfristig festgelegt sein: Der Abgabesatz sollte nach 5 Jahren auf 100 Euro/t CO2 und nach 10 Jahren auf 140 Euro/t CO2 steigen.

Im Gegensatz zu Frankreich, wo die Höhe der ökologischen Besteuerung oft volatil ist, weil kein breiter politischer Konsens besteht, ergeben sich Vorteile nur dann, wenn die Steuer langfristig und glaubwürdig angelegt ist. Ohne eine verlässliche Grundlage werden Konsumenten und Produzenten nicht nach CO2-Vermeidungsstrategien suchen, denn viele dieser Maßnahmen erfordern einen zumindest mittelfristigen Planungshorizont (Bsp. Investitionen in Gebäude). Die Umstellung auf CO2-ärmere Methoden wird Zeit in Anspruch nehmen. Eine schrittweise Erhöhung ist deswegen wünschenswert. Diese sollte von Anfang an festgelegt sein, so dass sich die Akteure auf einen Preispfad einstellen können.

(4) In der Übergangsphase zu einer globalen CO2-Besteuerung, können Steuerminderungen für die gewerbliche Wirtschaft helfen, die deutsche Wettbewerbsfähigkeit zu erhalten und die geografische Verlagerung von CO2-intensiven Unternehmungen zu verhindern.

Um einen breiten Konsens innerhalb der Bevölkerung zu garantieren, ist es in der Übergangsphase zu einer globalen CO2-Besteuerung notwendig, Ausnahmen für die gewerbliche Wirtschaft einzuführen. Diese Ausnahmen und Steuerminderungen sind in fast allen bisherigen europäischen Gesetzen implementiert. Ohne diese Vorkehrungen kann die Gefahr von Wettbewerbsnachteilen und des carbon-leakage, also der geografischen Verlagerung von Industrien, gegeben sein.

Wir schlagen einen Besteuerungsfaktor von 50% auf die gewerbliche Nutzung von fossilen Energieträgern vor. Außerdem regen wir an, die bisherige Energiebesteuerung (EnergieStG) durch CO2-basierte Steuern zu ersetzen, so dass sich weitere Kompensationen für den Wirtschaftssektor ergeben. Selbst bei einer unveränderten Gesamtsteuerbelastung sind positive mittelfristige CO2-Einspareffekte durch das Ersetzen von Energiesteuern mit CO2-Steuern zu erwarten. Außerdem führt diese Ersetzung nicht zu einem Anstieg der Komplexität des Steuersystems. Nach einer schrittweisen Erhöhung des CO2-Preises auf 140 Euro pro Tonne CO2 kann der Besteuerungsfaktor, welcher zu Beginn 50% beträgt, auf 40% abgesenkt werden.

Damit sich die maximale Effizienz einer CO2-Besteuerung entfalten kann, sollten mittelfristig auch landwirtschaftliche Produkte inkludiert werden.

(5) Eine CO2-Steuer von 70 Euro pro Tonne CO2 führt zunächst zu einem Steueraufkommen von ca. 38.7 Mrd. Euro

Die Berechnung zieht die fossilen Hauptemittenten Kohle, Mineralöl, Gase, Stromerzeugung und Fernwärme ein. Die gewerblichen Emissionen von CO2 werden mit einem Faktor von 50% des regulären Satzes besteuert. Unter Anwendung dieser Parameter wird das jährliche Steueraufkommen auf ca. 38.7. Mrd. Euro geschätzt. Eine Erhöhung auf 100 Euro pro Tonne CO2 (140 Euro) führt zu einem geschätzten Steueraufkommen von 55.3 Mrd. Euro (77 Mrd.).

Wir gehen in der Berechnung davon aus, dass es keine nennenswerten kurzfristigen (2 Jahresfrist) Substitutions- und Einspareffekte geben wird, da die gegenwärtige Energiebesteuerung durch CO2-Besteuerung ersetzt wird und es zunächst nicht zu einer Erhöhung der Gesamtbesteuerung kommt (siehe Tabelle 1). Mittelfristig (5-7-Jahresfrist) wird der Verbrauch an fossilen Energiequellen sinken, da Privatpersonen und Unternehmer nach Energieeinsparpotentialen und erneuerbaren Energieträgern suchen werden. Längerfristig (nach 10-13 Jahren) sollte die Steuerlast auf mindestens 140 Euro pro Tonne CO2 ansteigen und es werden eindeutige Verminderungen in der Nutzung von fossilen Energieträgern erwartet (siehe Tabelle 2).

Tabelle 1: Energienutzung nach Energieträgern und die daraus resultierende CO2-Emission

	Gesamt	**Haushalte (2015)**	**GHW (2015)**	**Verkehr**	**Industrie**	**CO2 Gehalt**	
	TWh	*TWh*	*TWh*	*TWh*	*TWh*	*Kg/KWh*	*t/TWh*
Stein- und Braunkohle	**126**	7	0	0	119	0.37	370,000
Mineralölprodukte*	**921**	135	84	683	19	0.26	260,000
Gase	**593**	235	110	2	247	0.24	240,000
Strom**	**520**	132	149	12	228	0.58	580,000
Fernwärme	**114**	47	18	0	50	0.12	120,000
Erneuerbare Wärme	**169**	81	27	30	32	0	0
Sonstige	**21**	0	0	0	21	0	0
Summe	**2464**	637	388	727	716		

* Diese Kategorie enthält Benzin, Diesel und Heizöl
** Der CO2-Gehalt der Stromerzeugung wird sich in Zukunft verändern.

Quelle: Umweltbundesamt (Verbrauch), verschiedene (CO2-Gehalt)

Damit sich die maximale Effizienz einer CO2-Besteuerung entfalten kann, sollten mittelfristig auch landwirtschaftliche Produkte inkludiert werden. Wird das Steuermodell auf die landwirtschaftlichen Produkte mit der höchsten CO2-Emission ausgeweitet (Rind-, Schweinefleisch, Geflügel, Milch, Joghurt und Käse), erhöht sich das geschätzte Steueraufkommen von 38,7 auf 43 Mrd. Euro (bei einem CO2-Preis von 70 Euro pro Tonne) bzw. auf 61,4 oder 86 Mrd. Euro (bei einem Preis von 100 oder 140 Euro pro Tonne).

(6) Die Erhebung einer CO2-Steuer sollte zunächst abgabenneutral und fiskalisch neutral erfolgen

Um den Rückhalt der deutschen Bevölkerung für weitere umweltpolitische Maßnahmen nicht zu gefährden, sollte eine CO2-Steuer über noch zu bestimmende Methoden an alle Individuen zu möglichst gleichen Teilen zurückgeführt werden. Der Anreiz, CO2 zu sparen, bleibt hierdurch erhalten, weil der Empfang eines Teils des Steueraufkommens unabhängig vom Verbrauch ausfällt.

Bei den oben angenommenen Parametern (Besteuerung fossiler Energieträger, 70 Euro pro Tonne CO2, Minderbelastung für Unternehmen) wird ein Steueraufkommen von ca. 38,7 Mrd. Euro erreicht.

Möglichkeit I: Die Streichung der EEG-Umlage und vollständige Finanzierung durch CO2-Steuern: Die geschätzten Gesamtkosten der EEG-Umlage für das Jahr 2017 belaufen sich auf ca. 30 Mrd. Euro.

Möglichkeit II: Die Ersetzung der Energiebesteuerung durch eine CO2-Besteuerung. Das jährliche Steueraufkommen durch Energiesteuern beträgt ca. 42 Mrd. Euro. Diese Summe ließe sich durch eine Besteuerung von 70 Euro pro Tonne CO2 kompensieren, wenn landwirtschaftliche Emittenten ebenfalls in das Steuersystem aufgenommen werden, wie weiter unten gezeigt wird.

Möglichkeit III: Die bisherige Energiebesteuerung wird zunächst durch CO2-Besteuerung ersetzt. Nach einer mittelfristigen Anhebung des CO2-Preises auf 100 bzw. 140 Euro wird die EEG-Umlage gestrichen und die bisher eingegangen Verpflichtungen zu garantierten Stromeinspeisevergütungen werden durch das CO2-Steueraufkommen gedeckt. In Übereinstimmung mit dem Sachverständigenrat der Bundesregierung sollten mittelfristig keine weiteren Verpflichtungen über die Zahlung von Stromeinspeisevergütung eingegangen werden. Nach dem Auslaufen der Verpflichtungen würde die CO2-Besteuerung die zentrale klimapolitische Maßnahme darstellen und könnte die Vielzahl an gegenwärtigen Interventionen (EEG-Umlage, Sanierungssubventionierung, etc.) ablösen. Ein solches Arrangement würde klimapolitische Ausrichtung der Bundesregierung nicht nur effizient gestalten, sondern auch die Komplexität der Maßnahmen und den bürokratischen Aufwand verringern.

Die Autoren dieser Studie plädieren für Möglichkeit III.

(7) Die langfristige Entwicklung des CO2-Steueraufkommens genügt, um die Streichung der Energiesteuer zu kompensieren.

Die erste langfristige Szenario-Schätzung des Steueraufkommens basiert zunächst auf der sehr optimistischen Annahme, dass der deutsche Energiemix des Jahres 2030 dem schwedischen Energiemix von 2015 ähnelt, wenn der heutige schwedische CO2-Preis erreicht wird. Diese Annahme ist höchstwahrscheinlich zu optimistisch, da Schweden von kostengünstiger Wasserkraft profitiert und einen hohen Anteil an Kernenergie aufweist. Beide Energieträger müssten in Deutschland anderweitig kompensiert werden. Aufgrund dieser optimistischen Annahme wird das Steueraufkommen des Jahres 2030 im Szenario I sehr wahrscheinlich unterschätzt.

Die optimistische Schätzung geht insgesamt von einer CO2-Reduktion von 50% im Energiesektor aus, die ebenfalls zu ambitioniert sein dürfte. Die CO2-Reduktion in der Landwirtschaft lässt sich kaum vorhersagen, da es keine bisherigen Beispiele gibt. Wir gehen von einer Reduktion von 25% aus. Bei einem CO2-Preis wurde der Faktor für die gewerbliche Wirtschaft, wie weiter oben beschrieben, von 0.5 auf 0.4 abgesenkt.

Des Weiteren wird angenommen, dass die CO2-Steuer im Jahre 2030 140 Euro pro Tonne CO2 beträgt (der heutige Wert in Schweden). Dadurch ergibt sich ein geschätztes Steueraufkommen von 40.3 Mrd. Euro. Da die angenommene CO2-Reduktion größer sein dürfte als die tatsächliche Reduktion, kann davon ausgegangen werden, dass 40,3 Mrd. Euro ein Mindestwert darstellt. Ein weniger optimistisches Szenario II, in dem die CO2-Reduktion nur 25% beträgt, führt zu einem Steueraufkommen von 58 Mrd. Euro (siehe auch Tabelle 3).

Die vorgeschlagene Streichung der Energiesteuer kann laut den hier angestellten Szenario-Berechnungen langfristig durch eine CO2-Steuer kompensiert werden. Zusätzlich ist es wahrscheinlich, dass ein progressiver Anstieg auf 140 Euro pro Tonne CO2 dazu führt, dass die Streichung der EEG-Umlage, zumindest in Teilen, ebenfalls kompensiert werden könnte.

Tabelle 2: Die geschätzte langfristige Entwicklung der Energiezusammensetzung

	(2015)				Schätzung (2030)			
	Nutzung		*CO2-Gehalt*	*CO2-Emission*	*Nutzung*		*CO2-Gehalt*	*CO2-Emission*
	TWh	**Anteilig**	**t/TWh**	**Tonnen**	**Anteilig**	**TWh**	**t/TWh**	**Tonnen**
Stein- und Braunkohle	**126**	5.1%	370,000	46,620,000	3.8%	94	370,000	34,643,840
Mineralölprodukte	**921**	37.4%	260,000	239,460,000	25.6%	631	260,000	164,003,840
Gase	**593**	24.1%	240,000	142,320,000	1.5%	37	240,000	8,870,400
Strom	**520**	21.1%	580,000	301,600,000	25.2%	621	203,840	126,584,640
Fernwärme	**114**	4.6%	120,000	13,680,000	13.6%	335	120,000	40,212,480
Erneuerbare Energien	**169**	6.9%	0	0	29.4%	724	0	0
Sonstige	**21**	0.9%	0	0	0.9%	22	0	0
Landwirtschaft*				61,052,280				45,789,210
SUMME	**2,464**	**100.0%**		**743,680,000**	**100.0%**	**2,464**		**420,104,410**

Anmerkungen: In den Bereichen Kohlen, Mineralölprodukte, Gase, Fernwärme und Sonstige wurde im Szenario I angenommen, dass sich die Anteile wie heute bereits in Schweden verhalten. Im Strombereich wurden auf Schätzungen von RWI und Prognos zurückgegriffen.

Im Szenario II wurde eine allgemeine 25% Reduktion der Gesamtemissionen angenommen.

* Im Bereich Landwirtschaft wurden nur die Hauptemittenten aufgenommen (siehe Tabelle 4).

Tabelle 3: Das geschätzte CO2-Steueraufkommen (in Mrd. Euro)

	2018		2030
CO2-Preis pro Tonne			
70 €	38.7	43	-
100 €	55.3 *	61.4 *	-
140 €	77 *	86 *	40.3 bis 58
Landwirtschaft eingeschlossen	*nein*	*ja*	*ja*

Anmerkungen: * Ein CO2-Preis von mehr als 70 Euro pro Tonne ist bei Einführung nicht zu empfehlen. Da die Nutzer Zeit benötigen, um sich auf die neue Preisumgebung einzustellen, wird ein Preis von 70 Euro pro Tonne mit schrittweisem Anstieg auf 140 Euro pro Tonne bis 2030 vorgeschlagen. Gleichzeitig ersetzen die CO2-Steuereinnahmen das Steueraufkommen durch alle bisherigen Energiesteuern (ca. 42 Mrd. Euro, EnergieStG).

Tabelle 4: CO2-Emission durch landwirtschaftliche Hauptemittenten

	Kg CO2 / Kg Produkt
Rindfleisch	12.3
Geflügel	3.7
Schweinefleisch	4.2
Fisch	5
Milch	1.38
Käse	5.82
Joghurt	2.37

Anmerkungen: Die Daten wurden dem „Klimarechner“ des IFEU Instituts entnommen, sowie den Publikationen des Bundesverbands der deutschen Fleischwirtschaft (BDVF).