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A green future for European electricity?
Energy sources, policies and further determinants of the household price of electricity

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Abstract

There is a controversial debate on how the transition towards electricity generation from renewable energy sources (RES-E) affects European electricity markets in terms of prices and market efficiency. This thesis contributes to this debate by providing the first panel econometric analysis of how both different sources of electricity generation and electricity market policies impact on the household price of electricity. Based on a sample of 29 European countries (EU-27 and two more), it finds that electricity production from combustible sources, natural gas, hydro and wind for the time span of 1991-2007 had a significant price lowering effect (ceteris paribus, on average). In contrast to that, results for the time span of 2004-2007 suggest that RES-E had a price increasing effect which can be related to its rapid growth in the 2000s. Results also suggest that Feed-in-Tariffs, regulatory reforms and the European emission trading scheme play an important role, but their impact depends on country specific characteristics. The latter seem to be an important factor in determining the level of prices.

I) Introduction

Energy policy in Europe and in the European Union (EU) in particular has been dominated in recent years by the transition of the energy economy away from fossil and towards renewable sources of electricity generation. In that regard, the EU aims at the achievement of two major goals: A substantial reduction in greenhouse gas (GHG) emissions, particularly CO_2 and an increase in electricity generation from renewable energy sources (RES-E) that is done in a cost-efficient way (de Miera, et al., 2008). Apart from that, more RES-E promises energy security meaning less exposure to volatile energy imports that are associated with (geo-) political risk. The main instruments to achieve those goals are support policies for RES-E promo-

tion and the EU Emission Trading Scheme (ETS). Whereas the latter was implemented at the EU level in 2005, support policies are applied at the national level.

While in 2010 RES-E contributed for around 20% of electricity consumption, it is expected to be between 33 and 40% for 2020 (EREC, 2011). Critics have highlighted the potentially enormous cost of such a rapid transition leading to inefficiencies and a rise of electricity prices putting a high burden especially on electricity consumers. This relates to the fact that most RES-E, except for hydroelectric energy, are young technologies that may be excessively cost-ly, also due to their stage of development, compared to established sources of energy. How-ever, there are a multitude of other factors that can determine electricity market efficiency to a high degree, potentially far outweighing these impacts of the deployment of RES-E. Whereas policy interventions such as subsidies may lead to market distortions, the ETS may increase efficiency through internalization. Market conditions such as the degree of competition or country specific factors also play a role.

In recent years, major reforms have been made in this area. This raises the question of how these changes impact on market efficiency in Europe as captured by electricity prices and which factors matter most. So far, the literature on these aspects has produced inconclusive results. Country case studies do not allow deducing general patterns that may explain price differences among European countries. Simple cost comparisons between sources fall short of taking into account important macro-economic and country specific factors that also impact on the electricity price.

The purpose of this thesis is to take advantage of the variety of electricity markets in Europe with different characteristics and use them to isolate on average effects of variables that may determine the electricity price. Unlike recent literature on RES-E technologies, the analysis is

extended by including other variables relevant for market efficiency. This allows pinpointing which are the main determinants of the electricity price in addition to technology choice. General patterns across Europe can thus be identified.

This thesis is organized as follows: Section II covers the main insights from the quantitative literature that assesses the impact of RES-E deployment on market efficiency. Section III identifies the main factors of electricity markets and energy policy that impact on the price and covers its implications for market efficiency. Section IV presents the model and the theoretical reasoning for variables used. Section V analyses the data. Section VI provides model estimations and interpretation of the findings. Section VII concludes with an outlook for policy makers and future research.

II) Literature review

The empirical literature on the effects on electricity markets of RES-E is still relatively sparse. These studies also vary a lot in terms of scope, referring to the number of countries and sources examined, and methodology used. Methodologically, country case studies mostly use approaches to measure costs of one or more specific source types (Dale et al. 2004) and sometimes compare these costs with benefits specifically related to that source (de Miera et al. 2008), (Frondel et al. 2010), (Kaldellis et al. 2005), (Stevanovic & Puca 2012). These analyses aim at giving an indication as to which technologies may increase market efficiency. Other papers analyze effects of RES-E support polices by employing a model simulation for one energy market and observing equilibrium effects of those policies (Hindsberger et al., 2003), (Unger & Ahlgren, 2007). Also, the interaction of RES-E support and pollution control policy, especially the ETS-market is discussed (Rathmann 2007). Econometric approaches have been used very scarcely (Moreno et al. 2012), (Groba, et al., 2011).

In terms of country scope, most empirical studies remain at a national level with some exceptions looking at a number of countries (Hindsberger et al., 2003), (Lipp, 2007), (Unger & Ahlgren, 2007), (Ragwitz et al., 2006). Only Moreno et al. (2012) looked at the effects of RES-E generation on electricity prices in the EU-27. Particularly striking is the fact that almost all studies focused entirely on either some particular renewable energy source or overall renewable energy production. Very few studies compared a renewable source with a fossil source and only so at the national level (Dale, et al., 2004). No study was found that compared various sources relevant for a country's energy mix in terms of their different effects on market efficiency. Some recent criticism has been that this research neglects other factors that should be considered when assessing electricity market efficiency, such as level of regulation, competition and market conditions (Traber & Kemfert, 2009) or macroeconomic conditions, country specific effects and international energy prices (Moreno et al., 2012).

Summarizing, most studies that address the effects of a transition towards RES-E either do not take into account all relevant sources of electricity generation or do not consider effects that also determine market efficiency. However, this is important to understand to what degree the energy transition towards RES-E actually matters for prices and in terms of market efficiency. Also, there is a need to extend research to include more countries so that general patterns in Europe can be identified.

III) Brief characterization of electricity markets

Please note that market efficiency in this chapter refers to the absence of market distortions. A certain impact of a variable on prices can indicate increases or decreases in distortions. Also, production can become more efficient by being able to offer the same quantity at a lower price due to cost decreases.

1) Relevant aspects of electricity markets affecting the price

In general, electricity markets can be separated into a wholesale market and a retail market. On the first one, producers sell electricity to distributors while on the second, distributors sell to customers. In many cases, the two markets are not separated. Instead, a few or even one sole company dominates both markets. This is the case if vertical integration exists between supplier and distributor. Both concentration and vertical integration cause market distortions that may result in higher electricity prices. This gives rise to the importance of proper regulation e.g. ensuring grid access for newcomers, proper separation of markets etc. Recent reforms have been undertaken across Europe in the 2000s (Erdogdu, 2011). Research on this issue has concluded that not simply liberalization but the quality of regulatory conditions and other country specific factors matter for reducing market distortions (ibid.). In the RES-E literature, only one study confirmed that reduced market concentration (implying increased competition) can do so (Moreno et al., 2012). However, more complex indicators for electricity market conditions exist that have not been used yet, leaving room for improvement (Conway & Nicoletti, 2006). General economic conditions such as GDP per capita and international resource prices should also be accounted for (Erdogdu, 2011) as they affect strongly the electricity price.

On electricity markets, the supply curve, also known as the merit order, consists of the different electricity sources' marginal costs. Basically, the wholesale electricity price is determined by the marginal technology supplying the marginal demand. Since there are significant differences between marginal costs among technologies, the price may change significantly depending on which technology serves the marginal demand. RES-E deployment may affect the merit order (de Miera et al., 2008). Wind, solar and biomass have comparatively low marginal costs, unlike thermal generation (coal and oil) or hydroelectric energy. If capacity of these

sources expands on a sufficiently large scale, the supply curve moves to the right and thus, ceteris paribus, may replace the marginal technology with a technology with lower marginal cost. This would effectively reduce the wholesale price. In that sense a price decrease would capture an improvement in market efficiency as the same supply can be offered at a lower price. Empirical studies analyzing this effect at a country level come to inconclusive results: Some find that the effect outweighs the cost of RES-E promotion (de Miera et al., 2008) (Sensfuß et al., 2008) (Rathmann, 2007) (Sensfuß, 2007), others find the opposite (Ragwitz et al., 2006), whereas some others cannot find proof of its existence (Sorrel, 2003).

In addition to this, the average costs of production determine if more electricity generated by a certain source decreases or increases the price. Generation investment costs and network costs are particularly high for relatively new technologies. How these costs develop depends on the technology's learning curve ratio, which is the price of electricity reduced e.g. per doubling of capacity. Again, empirical studies come to conflicting results with some finding a price de-creasing effect of new technologies while others find the opposite (Dale et al., 2004), (Frondel et al., 2010), (Kaldellis et al., 2005) ,(de Miera et al., 2008). Another particularity is that the electricity sector receives high subsidies as governments seek to lower the electricity price or increase production by certain sources. This artificial increase of production makes it difficult to distinguish between price decreases related to a subsidization of a certain source and those related to lowering of production costs (efficiency gains). Disentangling these effects empiri-cally is virtually impossible due to the lack of data for many countries (Kitson et al., 2011) (Badcock & Lenzen, 2010).

The existence of an ETS-market and a price for carbon implies that these additional costs for generators and distributors can be passed to electricity prices thus increasing them (Moreno, et al. 2012). However, if RES-E substitutes electricity generation by fossil fuels, emissions will

be reduced, thus lowering the price of carbon and this may lower under certain circumstances the electricity price (Rathmann, 2007).[1]

2) RES-E promotion and Feed-in-Tariffs

Policies aimed at promoting RES-E can range from support in R&D to various forms of subsidies. FIT schemes are by far the most used and considered to be the most important RES-E support policy in Europe (Ragwitz et al., 2006), (Poputoaia & Fripp, 2008). FITs work as follows: "[…] renewable energy installations receive long-term contracts that guarantee access to the electricity grid at an elevated price. These contracts generally differentiate among renewable sources, offering higher incentives for more expensive technologies […]" (Fischer & Preonas, 2010: 5). Empirical literature on the effectiveness of FITs and its implications for market efficiency and the price is still relatively sparse. One stream of studies compares different policy schemes adopted in several countries and their outcome in terms of RES-E capacity expansion (Lipp, 2007). Others compare the costs of the policy related to the subsidies with potential benefits of lowering the electricity price via effective RES-E promotion (de Miera, et al., 2008). While some find a positive effect for single countries (de Miera, et al., 2008) (Traber & Kemfert, 2009), others find the opposite (Frondel et al., 2010).

The essence of these results is that a FIT policy can be considered effective if it promotes strong RES-E growth without leading to too big market distortions. In terms of market efficiency it could lead to inefficiencies if too costly projects are financed leading to higher electricity prices. On the other hand, it could lead to more efficiency if RES-E lower electricity prices by lowering marginal costs of the marginal technology in a given market (merit order

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[1] Given that the reduction in the carbon price does not lead to a rebound in fossil production.

effect). Still, moderate price increases with substantial RES-E growth are often considered as an effective outcome (Mulder, 2008).

When assessing the effectiveness of an FIT scheme, Traber & Kemfert (2009) point out that one should account for electricity market conditions (such as emission related or general regulation or abuse of market power) as these determine the impact of the FIT. For instance, oligopolies may lead to higher profit-cost margins for electricity providers meaning that they may still increase prices substantially referring to the higher costs of RES-E despite the cost coverage via the FIT.

Ragwitz, et al. (2006) stress that administrative and market barriers (e.g. grid access) are crucial in determining the overall effect of an FIT scheme. Also, commitment and proper implementation of the policy scheme is necessary (Lipp, 2007), (Genius & Vergis, 2010), (Río, 2008) Hence, country specific policy design may play an important role for effectiveness.

IV) The model

The following 3 models contribute to the literature by analyzing what are the main determinants of the household electricity price in Europe. With these models it can be addressed if RES-E (e.g. wind, hydro) increases the electricity price and if non-RES-E sources lower the price. This outcome was often expected in the literature reviewed. Also, it can be seen what kind of electricity market policies affect the price and how. A first intuition about possible results will be given in section V. In section VI the findings will be interpreted, also in relation to market efficiency.

1) Model specification

Model 1: Effect of RES-E on household electricity price

$$\ln y_{it} = \propto_i + \beta_1 lnRESE_{it} + \beta_2 Competition_{it} + \beta_3 lnED_{it} + \beta_4 lnGDPpc_{it}$$
$$+ \beta_5 lnGHG_{it}$$

Model 2: Effect of single production sources on household electricity price

$$\ln y_{it} = \propto_i + \beta_1 lnCombustibles_{it} + \beta_2 lnGas_{it} + \beta_3 lnHydro_{it} + \beta_4 lnWind_{it}$$
$$+ \beta_5 Regulation_{it} + \beta_6 lnED_{it} + \beta_7 lnGDPpc_{it} + \beta_8 lnGHG_{it}$$

Model 3: Effect of electricity market policies on household electricity price

$$\ln y_{it} = \propto_i + \beta_1 FIT_{it} + \beta_2 Regulation_{it} + \beta_3 lnED_{it} + \beta_4 lnGDPpc_{it} + \beta_5 lnGHG_{it}$$

where i = 1,…29 (country), t = 1991,…,2007 (model 1 and 2), t = 2004,…,2007 (model 1) and t = 2001,…,2007 (model 3). $\propto_i$ refers to country effects to take into account any possible country specific effects that may determine the price beyond the variables included. Ln indicates the logged form of a variable (applied to variables of quantities to observe the elasticity).

In model 1 and 2, variables for RES-E and single electricity sources are included. The coefficients include the total effect of possible merit-order effects, production costs and the effect of subsidies for each individual source. These factors determine whether an increase in production leads to a decrease or increase in prices.

Model 1 aims to look at the overall effect of RES-E on the electricity price. This is based on the work of Moreno et al. (2012). Different to their work, the analysis will be done for two time periods instead of one: 1991-2007 and a shorter period 2004-2007. The 2000s represent a period with high RES-E growth and policy support, whereas the 1990s do not (see also

section V). The impact of high RES-E growth on the electricity market can be analysed by comparing the two periods. A change from a negative coefficient to a positive coefficient may be due to an increase in production costs caused by the RES-E growth. For instance, construction costs may increase as demand for input factors for plant construction increases. The change of the direction of the coefficient may also indicate less efficiency if even comparatively bad investment projects receive funding due to the subsidies. The variable Competition will be compared with Regulation (Model 2 and 3) which has not been used in such a regression to see which is the best to capture market conditions.

Model 2 will look at which sources of electricity have a price decreasing or increasing effect for the time span of 1991-2007. This allows to compare single RES-E and non RES-E sources separately. The significance and magnitude of the RESE-variable's coefficient in model 1 reflects the effects of each renewable source. This may lead to misinterpretations. Renewable sources contained in RESE may be counteracting and neutralizing themselves. For instance, positive (price-increasing) effects of one variable and negative (price-decreasing) effects of another may lead to a small magnitude for the coefficient of overall RESE, suggesting that renewable sources do barely influence the price. This improves interpretation of model 1.

Model 3 looks exclusively at policy variables. The idea is to take into account that major reforms of the electricity sector such as the improvement of market conditions and the introduction of renewable energy support schemes broadly started across Europe at the beginning of the 2000s. Therefore, restricting the time period to 2001-2007 allows looking at these effects. Model 3 will thus give an indication on if FITs and regulatory reforms are related with higher or lower prices. Production variables were not plugged as this would cause problems observing the full effects of FIT and plugging too many variables would destabilize a model for such

a short time horizon. It will also be checked if country specific effects influence the significance of FIT and Regulation as proposed by Groba et al. (2011). This would imply that country specific policy design, implementation and other conditions matter for policy effectiveness (ibid.).

Certain control variables were plugged for all three models because they may contribute strongly to explaining the electricity price as was suggested by the literature, namely Greenhouse Gases, Energy Dependency, GDP per capita. I will also be examined to what degree country specific conditions explain electricity prices.

2) Theoretical Determinants of Electricity Prices

For the logged production variables, the sign of its coefficients can be interpreted in two ways. 1) A one percentage increase in supply decreases the price by a certain percentage. This implies that the supply expansion all else (market conditions, demand, other supply quantities etc.) constant lowers the price of electricity of the particular source. If the source is used for electricity production on a sufficiently high scale, this influences the overall price, since the overall price of household electricity is a compounded price of the individual prices of electricity produced by source. If the particular source is relatively cheap in production meaning that the individual price is below the total price, the overall household electricity price will be lowered. 2) For a positive relation this works vice versa. Note that the price adaption process depicted here is affected by market distortions typical for electricity markets (market failure, externalities etc.). For instance, prices may not decrease because of a monopoly. Controlling for these special conditions ensures that such an interpretation is possible despite that. A negative coefficient for a RES-E source will mean that the price lowering effects (cost advantages, merit-order effects, cost reductions by subsidies) dominate the potential price increasing ef-

fects (cost disadvantages). In the case of a positive coefficient this is vice versa. For a non-RES-E source a negative coefficient again implies the dominance of price lowering effects over the potentially price increasing effects.

lnED % change in "Energy Dependence" price index. A compounded annual price of international gas and oil price averages was constructed using the most relevant price data for Europe: Dated Brent for oil and the Russian natural gas border price in Germany. Note that this is a time series variable equal for all countries. As Europe is considered to be energy dependent, an increase in ED index is expected to increase the electricity price.

lnGDP: % change of GDP per capita. When the general economic activity expands, demand increases and one can expect a positive effect on prices.

lnGHG: % change of greenhouse gases (GHG) emitted by the electricity industry. This variable should capture the price effect of regulation on all GHG polluting sources (Gas and Combustibles). The sign of the coefficient depends on the strictness of regulation. Consider two scenarios: 1) If a country contaminates relatively more ceteris paribus (production being constant and not increasing) than another country, it is because regulation is relatively less strict. This means less costs are imposed on production and it can be produced cheaper. If this is the case for most countries, one can expect a negative coefficient. The more GHG emitted, the lower additional regulatory costs imposed and the lower the electricity price.[2] 2) Vice versa, if most countries oblige producers to comply with standards such as installing filters or making payments, costs increase, which is captured by a decrease in GHG. In case of strong regulation one can expect a positive coefficient. The more GHG emitted, the higher the electricity price. Data on greenhouse gas pollution is by far the most comprehensive data in terms of

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[2] Under this scenario the price of polluting sources such as coal is not increased due to the absence of internalization, making it more viable to use coal as a potentially cheaper source. Hence, lnGHG also captures part of the effect of production of these sources on the price.

years and countries that can serve as a proxy for regulation of energy industry related pollution. Data on Carbon Market Prices is too recent since the European Emission Trading Scheme (ETS) only started in 2005.

Competition: Measures the market share of the biggest provider of electricity in the given national market and thus gives an indicator of market concentration. Rather concentrated markets can indicate abuse of market power and thus comparatively higher prices. Effects of policies aimed at liberalization of electricity markets can be captured by this variable, as liberalization tends to go along with less market concentration. Data was only available for 1999 on.

Regulation: Indicator of regulatory conditions for the electricity sector. This is a sector specific indicator as proposed by Conway & Nicoletti (2006). It has a range from 0.0 to 6.0 whereas a 6 represents bad regulatory conditions, a 0 represents optimal conditions according to economic theory. Conway & Nicoletti checked for the existence of conditions that aim at tackling the sector specific problems leading to potential welfare loss. It checks for entry possibilities for new comers (grid access, liberalized wholesale market, consumer ability to choose among providers), public ownership and vertical integration between generation and transmission segments. Compared to Competition, this is a far more comprehensive indicator for market conditions and quality of regulation policy. One can expect that the higher the index, the higher the electricity price due to market distortions. This implies that the more regulation and or market conditions resemble an efficient electricity market, the lower the price. Hence a price decrease can be related to higher market efficiency.

FIT: Dummy variable with the existence of a Feed-in-Tariff policy being = 1. Two channels were identified through which a FIT can affect the electricity price a) FITs may increase costs

if the promoted renewable sources are more costly than their counterparts and thus increase the final price. b) A large scale expansion of renewable sources can have a Merit-Order effect, thus decreasing the final price. Note that a) and b) are not captured by FIT if one controls for renewable production. Hence, a strong price increase through the existence of a FIT may indicate a decrease in market efficiency. According to the literature a moderate increase or decrease would indicate a effective policy. Data was constructed by using information provided by REN21. The implementation of a FIT scheme in a certain year was plugged as a 1 for this year and subsequent years unless the scheme was stopped. More detailed data on exact quantities of FIT or on other policies such as Renewable Portfolio Standards was discarded due to the lack of comprehensive data for European countries.

V) Data Analysis

1) Descriptive Analysis of Data

Data on electricity production, prices, emissions and general economic activity were retrieved from Eurostat. International gas and oil prices were obtained from the IMF. Data on Feed-in-Tariffs was obtained from the Renewable Energy Policy Network and on the electricity sector regulation from the OECD. All data is given per year and per country. Overall, the data set comprises 29 countries (see Annex) over the period 1991-2007 or 17 years. Based on bi-annual data, annual average electricity prices (excluding taxes) for households with an average yearly consumption of 3500 kWh was constructed. Of all available bandwidths it is the closest to the EU country average consumption.

A descriptive analysis of price data can give already an understanding of what patterns and factors may influence European price levels and growth rates (see Annex II). Overall, national prices show very similar patterns as most of them decrease slightly until 2000 and then pick

up. In terms of levels, prices vary a lot among European countries. Whereas Italy's electricity price has varied between 0.19 and 0.14 € per kWh with an average of 0.16 €, Greece's has merely fluctuated between 0.06 € and 0.07€ with an average of 0.06€. Most national prices were between the range 0.06€ and 0.014€ per kWh, which emphasizes the quite strong differences regarding levels. This is reflected by the standard deviation of 0.03 with an average and median of 0.09. These findings stress that there may be two types of factors explaining differences in prices. First, most countries have maintained their price levels through most of the period with some growth in the last years. This may indicate that there are factors that impact on countries in a similar way explaining the same growth patterns. Also, with some exceptions, the ranking in price levels between countries has not changed a lot. Hence, there may be factors explaining different price levels that either did not change significantly over time or are constant over time. Second, the strong growth in prices in some countries (compared to the more moderate growth or stable prices in other countries) can be explained by time varying factors.

Regarding production data, the most notable development is the strong growth of new technologies such as wind, solar, biomass and gas that takes place particularly in the beginning of the 2000s. Biomass, solar and nuclear energy are excluded from the analysis due to a lack of observations. International resource prices have been relatively stable throughout the 1990s, but increased significantly in the 2000s. Whereas in the beginning of the 1990s, Feed-in-tariffs were only implemented in 5 countries, this number increased to 21 until 2007. In the 1990s, regulatory conditions of electricity markets in the 1990s were far from optimal, possibly heavily distorting markets, as given by our indicator for regulatory conditions. This situation improved in the 2000s.

2) Tests for Panel Data

As descriptive analysis has shown, country specific effects that are constant over time may influence the electricity price significantly and thus should be controlled for to avoid unobserved heterogeneity and biased estimators. A Hausman test was run for each model to check whether a random or fixed effects model was the best specification. For all models, H0 could be rejected (see Annex) confirming the presence of time fixed country specific effects. Therefore, fixed effects models were chosen. F-Tests for each model confirmed the significance at the 1% level of the fixed effects in ai. Hence, the models were correctly specified. Since panel data always also has a time series dimension, problems related to this type of data may arise. Seasonality will not be an issue as the data is yearly. All variables were checked for following a unit root process. The presence of a unit root in one or more of the variables may cause spurious regression results, so testing and correcting for this is vital to obtain robust results. This is something that has been neglected in previous panel data analyses (Moreno et al., 2012). Augmented Dickey-Fuller tests were computed accounting for a trend where necessary (see Annex). For all three models, non-stationarity is not a problem. All regressions were corrected for heteroskedasticity by using robust standard errors. Testing for time-fixed effects gave that including time dummies is not necessary. Tests for serial correlation and cross sectional dependence were not necessary since the panel features less than 30 years of observations (Baltagi, 2008). Due to a recent change in methodology in 2007, data for electricity prices beyond that year could not be used. However, this restricts the analysis only by 2 years (2008, 2009) that are published with the new methodology.

VI) Results & interpretation

Model 1 - Effect of RES-E on household electricity price

Panel regression results for 1991-2007 gave the overall model a high significance at the 1% level (see output table in annex). However, lnRESE and lnGHG closely failed to be significant at the 10% level. Competition and the Energy Dependency were also not significant. Only lnGDPpc proved to be highly significant at the 1% level. Overall, the model's explanatory power is rather mediocre with an R² of 45%. The model was then adjusted, in order to capture effects from the beginning of the 2000s. Significance levels and overall explanatory power improve. LnRESE becomes significant from 2001 on, Energy Dependency from 2002, Greenhouse Gas Emissions from 2003 and Competition from 2004 on. The final model capturing effects from 2004 to 2007 has a good explanatory power with an R² of around 67% and an overall significance at the 1% level as given by the F-Test results. lnGHG and lnRESE and time-constant fixed effects are very significant at the 1% level whereas lnGDPpc and lnED are so at the 5% and Competition at the 10% level. With respect to partial elasticities, logged GDP per capita has the highest impact on electricity price. A 1% increase in GDP per capita leads to an increase of the household electricity price of 0.26 %, ceteris paribus, and on average. A 1% increase in greenhouse gas emissions emitted by the electricity production sector increases the price by around 0.17% and a 1% increase in the energy dependence price index leads to a price increase of around 0.11% on average and ceteris paribus. Logged RESE and Competition have a lesser magnitude inducing only a price rise of 0.07% and a price decrease of 0.002%, respectively on average ceteris paribus. Fixed country specific effects have a strong impact, although the exact magnitude cannot be interpreted by construction of the model. It can be confirmed that an increase in RESE increases significantly the price. The

same is the case for GDP per capita and Energy Dependency. GHG emissions have a strongly positive impact.

Model 2 - Effect of electricity sources on household electricity price

Panel regression results gave model 2 overall a high significance at the 1% level and a good explanatory power with an R² of 64%. Like in model 1, GDP per capita, Energy Dependency, the variable for market conditions, and the fixed effects are all significant with similar magnitudes. Regarding the different production variables by source, lnHydro and lnGas are significant at the 1% level and lnWind at the 5% level. lnCombustibles is only significant for production capacities above 10.000 GWh and if lnGHG is omitted.[3] All of them show a negative coefficient, thus lowering the price. Again, lnGHG is significant at the 5% level, but unlike in model one, the coefficient is strongly negative. A 1% increase in generation from combustibles decreases the electricity price by 0.16% on average and ceteris paribus. Hydroelectric generation does so by 0.15%, natural gas by 0.05% and electricity generated by wind by 0.03%. Contrary to results from model one, a 1% increase of GHG emissions decreases the price by 0.31%.

Model 3 - Effect of electricity market policies on household electricity price

Model 3 is also overall highly significant at the 1% level and exhibits a good explanatory power with an R² of 67%. Again, logged GDP per capita and the fixed country specific effects are significant at the 1% level. Unlike in model 1 and 2, lnGHG and lnED are not significant. Regarding lnGHG, this can be attributed to the fact that the coefficient of lnGHG changes over time. While it is negative for the whole period, it is positive from 2004 on (see model 1). This change occurs in the years before 2004, which is why the coefficient becomes insignifi-

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[3] lnGHG captures here those effects were pollution (use of polluting sources like coal) is related to a price decrease.

cant. Hence, results for lnGHG in model 1 and 2 are still valid. Regarding lnED, the variable may be affected by the relatively short time period for model 3. Due to the short time horizon, effects of ED may become part of the fixed effects constant $\propto_i$. Since it is just a time series variable that is equal for all countries, observations may be too few to give a stable estimate. FIT and Regulation both have a positive effect on electricity prices that is significant at the 10% level. For the period of 2001-2007, the existence of a FIT scheme does increase the household electricity price by 0.9% as compared to having no FIT in place on average, ceteris paribus. Also, a one point increase in the regulatory index, meaning a worsening of market conditions, leads to a price increase by 2.7%.

Interpretation of results in the context of EU RES-E policy

Please note that when references are made to how a variable influences the prices and may impact on market efficiency, that the effects captured in the model can materialize or not, depending on the final general equilibrium result in a real market.

According to the panel regression results run in model 1, increasing RES-E does seem to increase prices for 2004-2007. The price increases starting in 2000 clearly coincide with that (see descriptive part) and may be to some degree caused by the expansion in renewable generation. This can be attributed to the expansion of RES-E in the 2000s. However, results of model 1 for 1991-2007 indicate no such effect was significant. In fact, results from model 2 show that for 1991-2007 all single electricity sources did not increase but decrease prices.

This underlines that there may have been a shift in the 2000s when RES-E expansion caused price increases to a certain degree. High subsidy levels that fueled an increase in RES-E generation capacity in the 2000s may explain this. The sudden expansion in scale of RES-E may have lead to increases in production input prices (for plant construction), increasing produc-

tion costs. Also, in the short run, average costs tend to be higher for new plant investments (Varian, 2007).[4] This may explain that for the short period of 2004-2007 more costly production made prices increase.

Also, subsidies may have not been efficient in selecting projects or may have been so high that investments with too high costs involved were made. Moreover, electricity companies may have kept the income from subsidies without passing lower costs to consumers. Another aspect may be the type of technology that received more investment. Note that e.g. solar power increased in the 2000s.

Model 3 results show that Feed-in-Tariffs have a price increasing effect so this particular policy seems to be related with the effect of RES-E on the price and the possible inefficiencies associated with that. RES-E funded by FIT seems to exercise a price increasing effect. Costs related with supported RES-E production seem to outweigh a possible merit-order effect. As expected from theory, sound regulation and addressing of market distortions (as captured by Regulation) decrease prices and thus seem to increase market efficiency stressing the importance of electricity market reforms. Despite that, one can see that the magnitude of impact of a FIT scheme only translates into a modest price increase of 0.9%. This highlights the importance for future studies to investigate how the quality of FIT implementation changes this as suggested by Lipp (2007).

Policies aimed at improving the regulatory environment though seem to be more promising to increase market efficiency. Moving from relatively bad market conditions (6 on the index) to very good conditions (0 on the index) would imply a decrease in the household electricity

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[4] According to theory, every amount of electricity output has its ideal number or size of plants (where average costs are lowest). However, if output increases, a company cannot adapt that rapidly by building more plants. Its average costs increases. In the long run, it can adapt its plant portfolio to the optimal size, so that average costs are lower.

price by 16.2%. Some countries have shown that these large scale reforms are possible. Poland for instance brought down its indicator from 6.0 to 2.2 within 10 years. The comparison between model 1 and 3 shows that these factors matter far more than market concentration: Competition has very little impact on the electricity price. Even a decrease of 50% of the biggest provider's market share would decrease price on average and ceteris paribus only by 0.085%.

The high significance and strong impact of GHG emissions in model 1 indicates that in the analyzed period of 2004-2007, internalization of external effects is working in a sense emissions are related to additional expenditures (abatement measures or payment for emission certificates) that lead to a higher price. This can be accounted to the implementation of the ETS in 2005 and a priced in anticipation of this process by producers in 2004. Contrary to results from model 1, GHG emissions have a strong negative effect on the electricity price in model 2. Apparently, for the whole period from 1991-2007, GHG related regulation was relatively weak across Europe. Since little cost were imposed on electricity generation related to GHG pollution, higher GHG emissions imply lower additional costs, leading ceteris paribus to lower prices. This changed with the emergence of stronger regulation, such as the ETS.

Lastly, as suggested already by the descriptive analysis, country fixed effects play a substantial role in determining the electricity price. These structural aspects can explain the consistent difference in price levels among European countries. They may also limit a country's ability to make use of comparatively cheaper electricity sources due to preferences, historical reasons or geography disabling the use or access to certain sources. For all three policy variables (lnGHG, Regulation, FIT), not controlling for fixed effects biased the results making the coefficients insignificant. Thus, all the policy variables depend on country specific effects, so policy design, implementation and commitment seem to play an important role.

VII) Conclusion

The use of a panel data econometric approach for 29 European countries sheds new light on the debate of efficiency of RES-E. The thesis finds that electricity generated from combustible sources, natural gas, hydro and wind for the time span of 1991-2007 had a price lowering effect (for each single source ceteris paribus, on average). In contrast to that, for the time span of 2004-2007, RES-E had a price increasing effect. High subsidies fueled an increase in RES-E capacity in the 2000s may explain this. Higher production costs may be due to higher short term average costs or increase in input prices. Also, subsidies may have not been efficient in funding projects. Moreover, electricity companies may have kept the income from subsidies without passing lower costs to consumers. Future research should thus consider longer time series of data once available to see if price increases are rather a temporary effect caused by high short term costs of new plants or the product of inefficiencies. In order to capture inefficiencies, one could see if higher profit-cost margins of electricity providers are related with higher prices. This would indicate that price increases are related with companies making more profits through higher prices despite lower generation costs.

Further analysis on policy variables shows that Feed-in-Tariffs have a price increasing effect. Sound regulation and addressing of market distortions decrease prices and thus seem to increase market efficiency stressing the importance of electricity market reforms. Also, the ETS seems to contribute to market efficiency through internalization of externalities that increase electricity prices. Policy-makers should take into account that not the mere existence of a policy matters. The policy variables depend on country specific effects, so policy design, implementation and commitment seem to play an important role. Country specific characteristics are an important factor that determines prices. To study the impact of FITs' impact on market efficiency future research should thus develop comprehensive measures of FIT quality.

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VIII) Annex

1) Data

The 29 countries chosen for the analysis were the EU-27 as well as Norway and Croatia. The latter were selected for being strongly integrated in the EU's electricity market. Other countries for which this applies had to be excluded due to a lack of data.

2) Table 1: Output & tests

	Model Specifications: Model 1 – (1), (2); Model 2 – (3); Model 3 – (4) (Robust standard errors of coefficients are in parentheses)				Unit root tests for each variable
	(1)	(2)	(3)	(4)	Augmented Dickey-Fuller Test (H0: all panels contain unit roots)
lnHHPrice (dependent)	1991-2007	>2003	1991-2007	>2000	Reject H0*** for time > 1999
lnRESE	0.038 (0.033)	0.066*** (0.022)	-	-	Reject H0***
Competition	-0.001 (0.003)	-0.002* (0.001)	-	-	Reject H0***
lnCombustibles	-	-	-0.158* (0.087)	-	Reject H0***
lnGas	-	-	-0.045*** (0.009)	-	Reject H0***
lnHydro	-	-	-0.151*** (0.041)	-	Reject H0***
lnWind	-	-	-0.028** (0.012)	-	Reject H0***
Regulation	-	-	0.008 (0.141)	0.027* (0.014)	Reject H0***
FIT (dummy, 1= FIT in place)	-	-	-	0.090* (0.044)	-
lnED	0.004 (0.032)	0.107** (0.042)	0.087*** (0.020)	0.028 (0.022)	Reject H0*** for time >2000
lnGHG	0.091 (0.127)	0.176*** (0.063)	-0.311** (0.143)	-0.017 (0.024)	Reject H0***
lnGDPpc	0.525*** (0.114)	0.265*** (0.117)	0.611*** (0.073)	0.668*** (0.106)	Reject H0***
constant $\propto_i$ (fixed effects)	-8.788*** (1.775)	-7.674*** (1.316)	-3.567** (1.583)	-9.066*** (0.959)	-
Observations	171	88	199	133	
R²	0.56	0.67	0.64	0.68	
F-Test for joint significance	Reject H0***	Reject H0***	Reject H0***	Reject H0***	
Hausman-Test	FE	FE	FE	FE	
Wald Test for heteroskedasticity (use robust SE if H0 rejected)	Reject H0***	Reject H0***	Reject H0***	Reject H0***	
Wald Test for time-fixed effects (H0: no time-fixed effects)	Reject H0* (discarded)	Reject H0* (discarded)	Reject H0***	Accept H0	

Note: *(**,***) = significant at the 10% (5%, 1%) level

Table 1: Stable electricity prices in 9 selected European countries (unit: 1€)
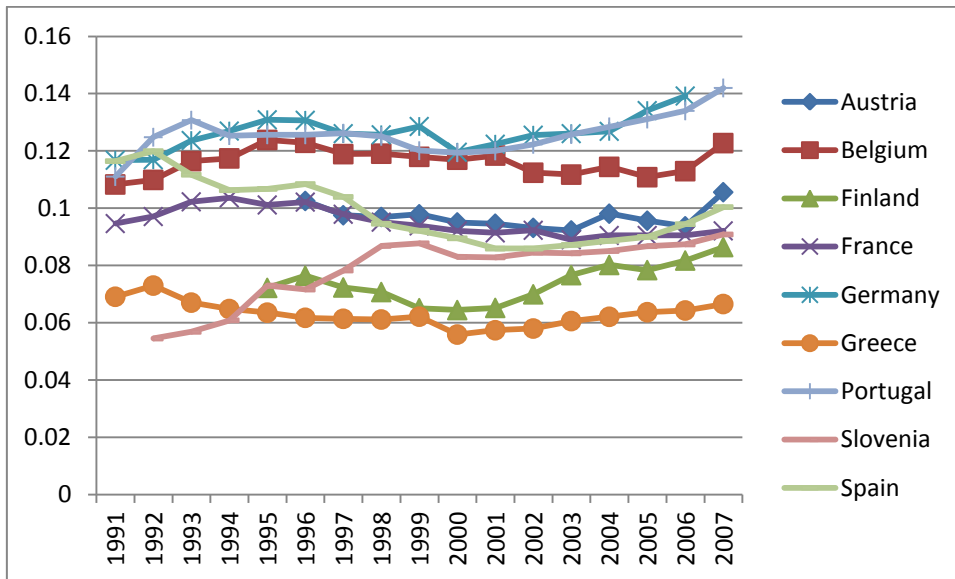

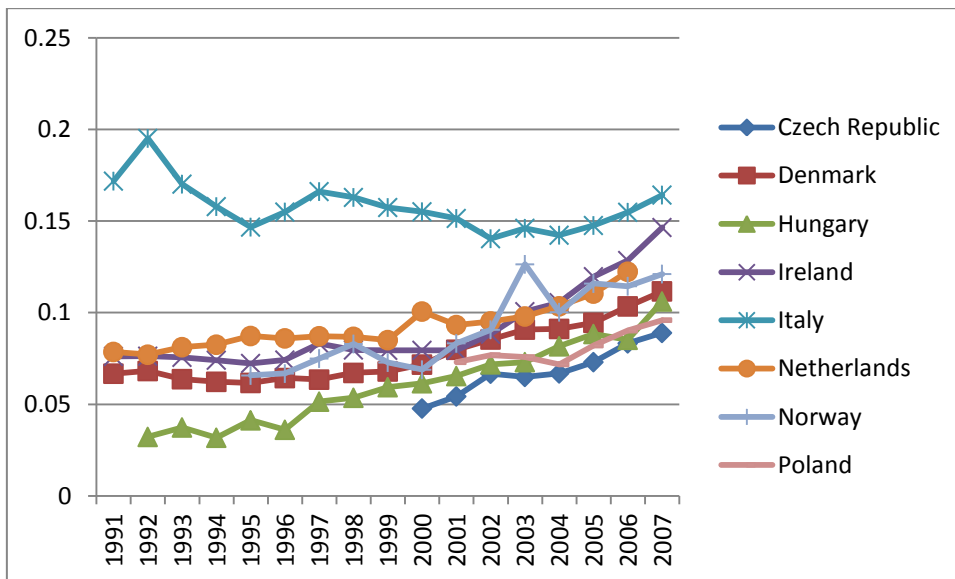Table 2: Volatile or strongly growing electricity prices in 8 selected European countries (unit: 1€)

Table 3: Energy dependency Index for Europe (equal for all countries)
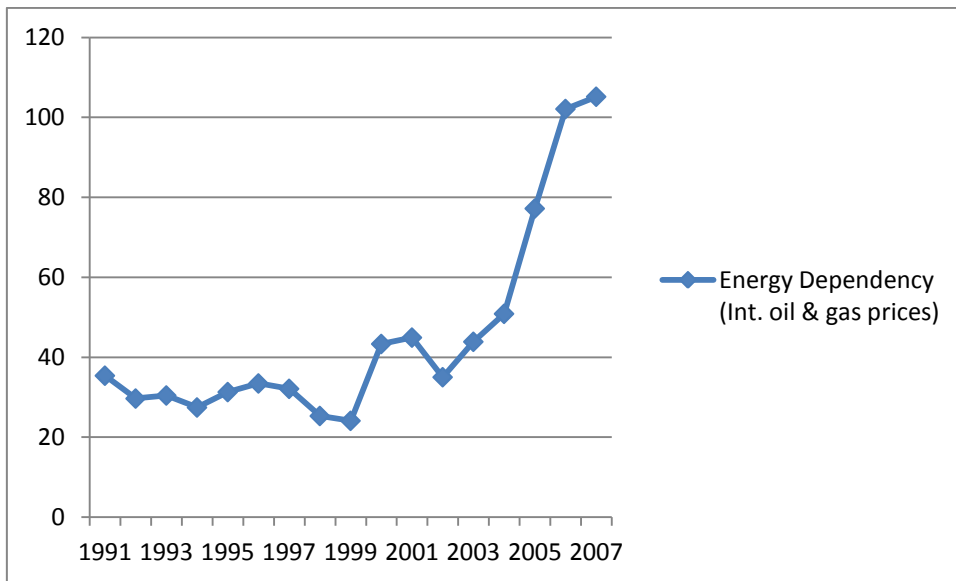

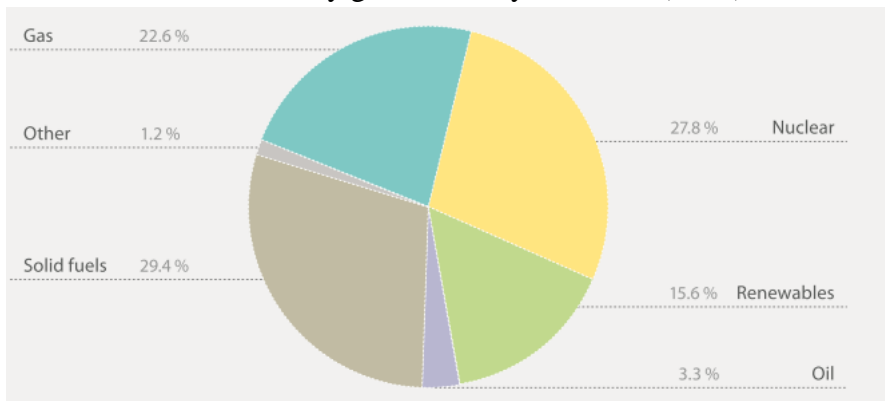Table 4: EU-27 Electricity generation by fuel in % (2007)
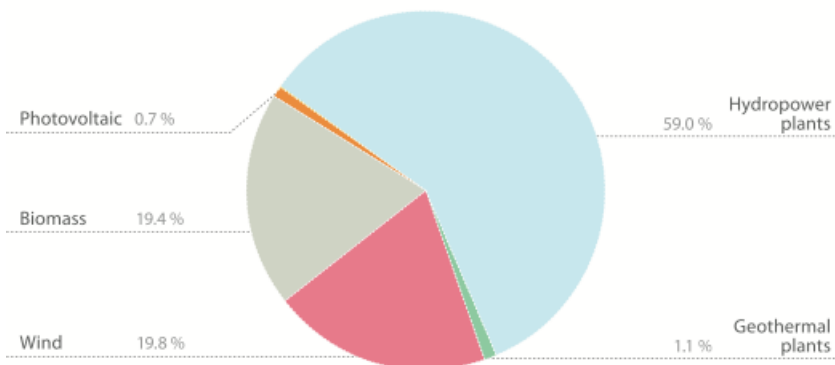

Table 5: EU-27 Electricity from RES-E in gross electricity production in % (2007)

Source: European Commission. Market Observatory for Energy Report 2009