PRICES AND COSTS OF EU ENERGY

Annex 2 Econometrics

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ANNEX 2 - Econometrics

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Glossary

Definitions

Price of energy: The amount of money for which an amount of energy is sold at the wholesale or retail market

Price components: Retail prices for energy consist of three components: energy, network and taxes/levies.

Cost of energy: Energy price multiplied by energy consumption.

Direct impact: This refers to those taxes and levies as well as policies requiring the delivery of certificates, which change the retail prices for energy directly.

Indirect impact: Several policies affect the generation mix, supply routes and energy market systems. These will also ultimately affect the retail price but in a more indirect way, for example by changing the wholesale price.

Abbreviations

AGEB	Arbeitsgemeinschaft Energiebilanzen
CAISO	California Independent System Operator
CAPEX	Capital expenditures
CO_2	Carbon dioxide
DE	Germany
DSO	Distribution system operator
EC	European Commission
ECB	European Central Bank
ENTSO-E	European Network of Transmission System Operators for Electricity
EPEX	European Power Exchange
ERCOT	Electric Reliability Council of Texas
ETS	Emission Trading Scheme
EU	European Union
FE	Fixed effects estimator
FR	France
GDP	Gross domestic product
GOG	Gas-on-Gas Competition
GRP	Government regulated prices
IEA	International Energy Agency
JRC	Joint Research Centre

LME	London Metal Exchange
LNG	Liquid natural gas
MS	Member State
MURE	Energy efficiency policies and measures - From the Frech, Mesures d'Utilisation Rationnelle de l'Energie
NACE	Statistical Classification of Economic Activities in the European Community – From the French, Nomenclature Statistique des activités économiques dans la Communauté européenne
NL	Netherlands
O&M	Operation & maintenance
OECD	Organisation for Economic Co-operation and Development
OPE	Oil-price escalation
OPEX	Operational expenditure
OTC	Over the counter
PJM	Pennsylvania-New Jersey-Maryland Interconnection
PPP	Purchasing power parity
RCE	Random Correlated Effects
RCA	Revealed comparative advantage
RE	Random effects estimator
RES	Renewable energy sources
SILC	Statistics on Income and Living Conditions
SME	Small and medium-sized enterprises
TSO	Transmission system operator
UEC	Unit Energy Costs
UK	United Kingdom
UN	United Nations
US	United States of America
USGS	United States Geological Survey
VAR	Vector autoregression
ECM	Error Correction Model
VECM	Vector Error Correction Model
WB	World Bank

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1 Introduction

1.1 Aim of the econometric analysis

The econometric analyses aim to identify the drivers of the electricity and natural gas product wholesale and retail prices in the Member States of the European Union and in its major trading partners. Further, the study assesses the contribution of the main identified drivers to energy prices and shows how prices have converged between selected member states over time The analysis builds on existing statistical information, includes some newly collected data by DG Energy, and is supplemented with detailed information about regulatory impacts of single policies on prices at national level.

This Annex provides detailed information on data and models applied for the econometric analyses as well as detailed results.

1.2 Structure of the econometric analysis

Different econometric analyses will be conducted, each addressing different research questions, data and approaches:

1. Drivers of wholesale electricity prices (monthly): fixed effect regression (FE) and random effect regression
2. Evolution of wholesale electricity prices (daily/monthly) between selected countries: ECM/ to show price convergence between EU member states and plotting of price evolution over time
3. Drivers of retail electricity price component energy: fixed/random effect regression
4. Drivers of wholesale natural gas prices (monthly): time-series analyses via linear regression of first differences as well as panel analyses via fixed- and random-effect regressions including group means (RE Mundlak)
5. Evolution of wholesale gas prices (monthly): plotting of price evolution over time
6. Drivers of retail gas price component energy: fixed/random effect regression (RE/FE)

1.3 Sources and data

The data applied in this analysis are based on the following sources:

Table 1: Overview on data and their sources

Variables	Unit	Sources
Wholesale electricity prices	EUR/MWh	APX, BPX, ELEXON, EPEX, EXAA, NordPool OTE, PolPX, OMEL, GME, OTE, HUPX, BSP, OPCOM, DESMIE, SEMO, Platts, daily prices
Wholesale gas prices	EUR/MWh	CEGH, TTF, GASPOOL, NBP, NetConnect, Zeebrugge, ThomsonReuters, Waterborne
Retail prices and price components (electricity and gas)	EUR/kWh	Eurostat: http://ec.europa.eu/eurostat/data/database VaasaETT: http://www.vaasaett.com/projects-2/#dg-ener Ad-hoc-data collection (by DG ENER and national offices/agencies and complemented by Ecofys, Fh-ISI and CASE) Ad-hoc data collection: covering household and industrial consumer bands for electricity and natural gas in 2008 2010, 2012, 2014, 2015. Eurostat data: monthly data derived from biannual price data and monthly electricity (gas) consumer price indices (compiled by DG ENER) VaasaETT: monthly data on prices only of households
Crude oil prices	EUR/bbl	Platts, EIA, Eurostat; IEA
Coal prices	EUR/t	Platts, EIA
Market shares (competition) and market opening (liberalization) and de/regulation; market and price coupling		EC DG ENER; ACER report 2015, 2014, 2013; CEER; NordPool, EPEX
Total generation and per technology, consumption, border flows	GWh	ENTSO-E; Enerdata
Heating and cooling days		EC JRC, MARS; KAPSARC
Growth rate, exchange rates, price indices		Eurostat

2 Energy wholesale and supply prices –global developments

Historically, there have always been differences in prices of electricity and natural gas across regions worldwide. In the 1990s, there was a only slowly varying spread between the wholesale prices of natural gas in North America, Europe and Asia of roughly 1 – 2 USD/MBtu (BP 2015). In the first decade of the new millennium, the regional differences slowly disappeared and the price volatility became even larger than the regional spread. In 2009/2010, however, the price gaps reoccurred and started to widen significantly, in particular for natural gas in the US, Europe and Asia. Major drivers for this development have been the shale gas boom in the US, resulting in oversupply of markets, a strong increase of gas demand in Japan in the aftermath of Fukushima, as well as the changing importance of oil-indexation on gas price and the dynamics in the EU and Asia. In the context of falling oil prices in recent years, the gaps have become smaller again though. The situation for wholesale prices of electricity prices is much more intricate, as these are also strongly influenced by different mixes of generation technologies and the impacts of climate policies. The objective of this section is to describe co-movements, correlations and convergence of prices across different markets.

Before we look at the global developments of wholesale prices of electricity and natural gas more in detail, we shortly focus on the recent development of the global benchmarks for crude oil and coal, as these have been major drivers for all energy markets in the past:

- The crude oil benchmarks have continuously shown high volatility since the year 2000. Crude oil prices started to drop significantly only in the middle of 2014 again due to higher extraction rates, in particular by the OPEC countries. Due to the importance of crude oil for the functioning of economies in the 20th century and the relatively low transport costs, the international markets became highly liquid quite early when compared to other commodities. Until the beginning of 2011, the price spreads between the international crude oil benchmarks, in particular the West Texas Intermediate (WTI) and North Sea Brent crude oil benchmarks, had been marginal. The high level of crude oil prices allowed the US to produce an increasing share of crude oil domestically at internationally competitive prices. Most likely due to the international export ban for crude oil in the US, the WTI stagnated at a significantly lower price level than the North Sea Brent in the following years (spread up to 28 $ per Barrel). In the mid of 2013 the spread started to shrink and completely disappeared, when the crude oil prices severely dropped in the mid of 2014 (see Figure 1).
- In contrast to crude oil, the international trade of coal accounts only for around 20 % of the regional coal markets. The main international coal benchmarks (Amsterdam-Rotterdam-Antwerp hub, Newcastle hub, Richards Bay Port) have been continuing to show very little spreads since the year 2000. They had also been strongly correlated with the global crude oil prices until the mid of 2011. While the crude oil price stagnated at a high level for the following three years, the coal benchmarks started to relax slowly but steadily. This trend has

not been broken in 2013 – 2015. However, the significant drop of the oil price since the mid of 2014, has reestablished the former price relation between crude oil and coal, though the price developments may still be decoupled (see Figure 1).

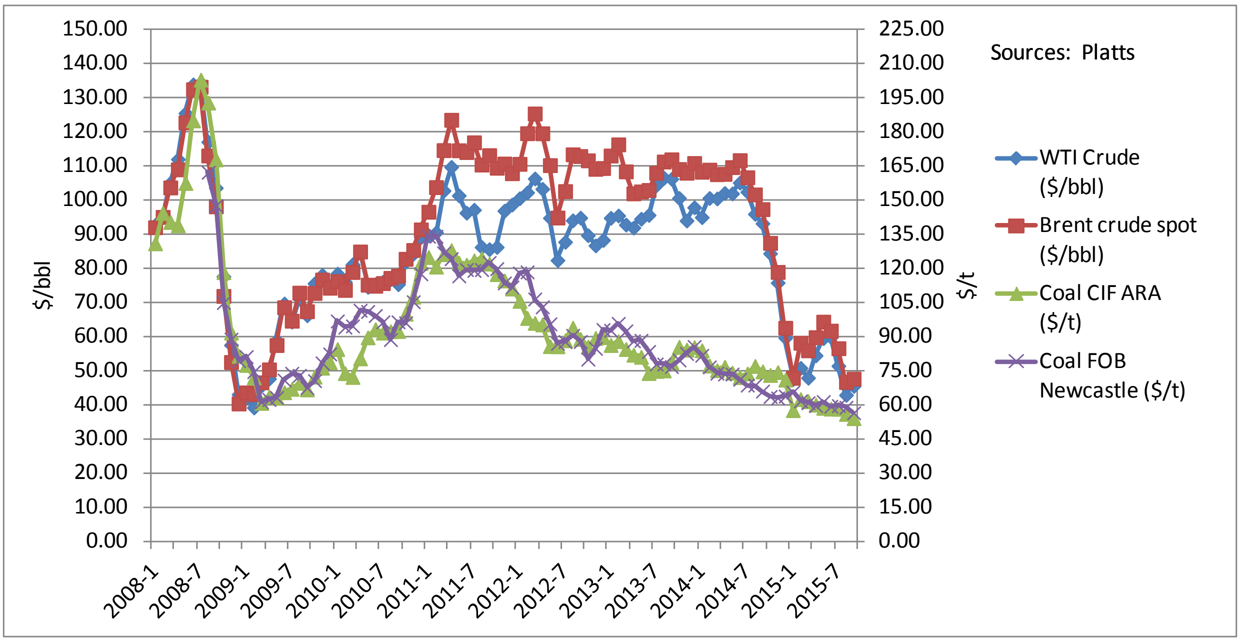


Figure 1: The monthly averages of crude oil and steam coal prices at the markets in the US and the EU.

Until 2009, the global development of **wholesale prices for natural gas and LNG** was strongly coupled to the crude oil price mainly due to oil-indexed long-term contracts. At the beginning of 2010, natural gas prices at spot markets in the EU and the US as well as LNG import prices in the EU were all in the range of 5 – 6 US-$/MMBtu showing only a marginal gap. The import prices of LNG in Asia Pacific (in particular, Japan, South Korea and China) were approx. 40 % higher. Since 2010, the prices across the major wholesale markets have developed quite differently (see Figure 2, also compare for ACER 2015 and EC 2014):

- The wholesale prices for natural gas in the US have completely decoupled from the oil price development due to the significant increase of domestic gas production through shale gas. The prices more than halved until the beginning of 2012, which reflects the lack of opportunity to export LNG. After recovering in 2012 and 2013, the prices peaked during a cold spell at the beginning of 2014 and have halved again afterwards.
- Reflecting the high share of oil-indexed contracts in Asia Pacific, the LNG import prices in Japan, China and South Korea have stayed strongly correlated to the oil price (0.85 for the monthly averages in 2010 – 2015). Gas demand has also risen in the region due to economic growth in China and South Korea, and the switch from nuclear to gas plants after the Fukushima incident in Japan. Hence, the LNG prices increased by more than 150 % until the beginning of 2014 while undergoing high fluctuations in between, which were partly related to

the seasonal changes of demand levels. Afterwards the prices fell again to the level of 2010 within one year, following the global crude oil price.

- The prices at spot markets in the EU temporarily decoupled from the development of the crude oil price in 2011, as the shale gas boom in the US resulted in an oversupply of the LNG markets in the EU. In the following, the prices were affected by the oil price again, to a lesser extent though. As a consequence, significant spreads with respect to the lower prices in the US and the higher prices in Asia Pacific have developed.
- While the LNG prices in Spain correlate with those in France and LNG prices in Belgium correlate with those in the UK (0.99 for the monthly averages in 2010-2015 in both cases), the correlation between the two markets is somewhat lower (0.76 – 0.85). This is because, the prices in Spain and France still reacted quite sensitively to fluctuations of the crude oil price (in 2011 – 2014), whereas the prices in Belgium and the UK mainly correlate to the spot market prices in the EU.

In 2014 and 2015, the wholesale prices of natural gas and LNG in the EU and Asia Pacific have converged in parallel with the decline of the crude oil price. The prices are still a bit higher in Asia Pacific, but the price gap between the EU and Asia Pacific is now smaller than before the beginning of the spreading in 2011. The prices at the European spot markets stay somewhat below the LNG import prices suggesting there is some liquidity in the markets. In contrast, the wholesale prices at the spot markets in the US have been staying at levels more than 50 % below those in the EU indicating that the boom of shale gas production in the US is ongoing.

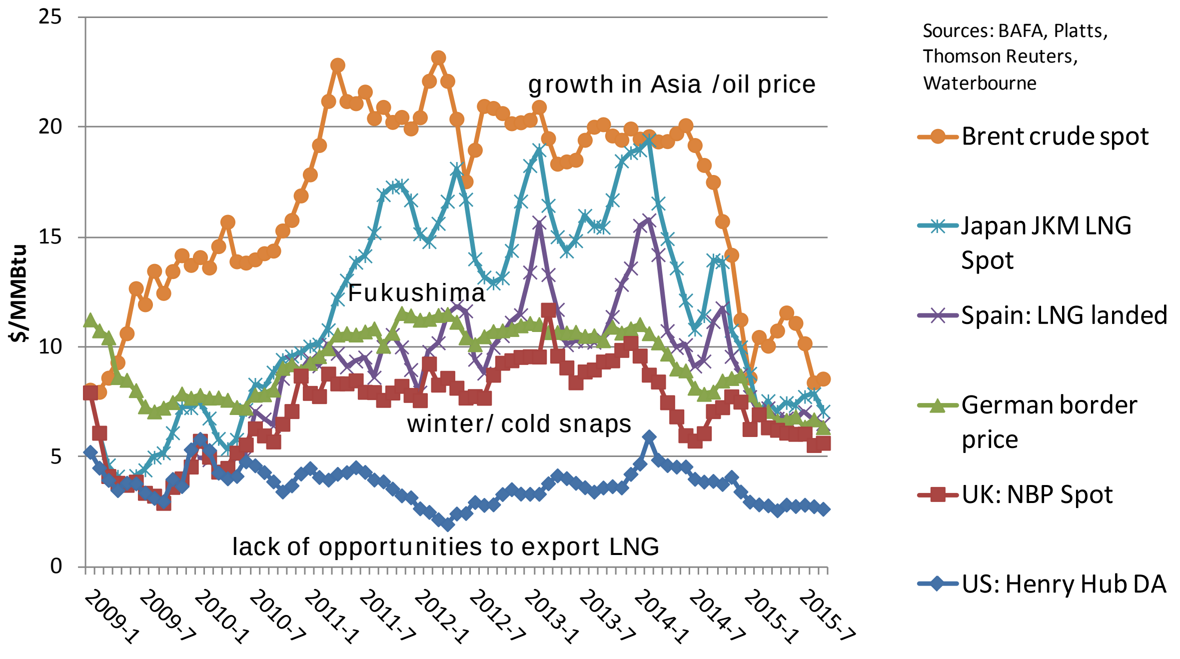


Figure 2: The monthly averages of natural gas prices at the markets in Japan, Spain, Germany, the UK and the US.
Note: Henry Hub is the most important gas hub in the US. The crude oil price of Brent is provided for orientation.

It is important to note that a relevant part of the changing price spreads is induced by fluctuations of the currency exchange rates. For Australia and Japan, the exchange rates with respect to the Euro have reduced by upto 30 % from 2008 to 2012, but relaxed to a level of 80 – 90 % in 2015. For the US, the fluctuations were below 15 % from 2008 to 2014.In 2015, however, the average annual exchange rate dropped by about 25 % when compared to 2008 (see Figure 3). The role of exchange rates will also be addressed in the following sections, which looks at the drivers of wholesale prices more closely.

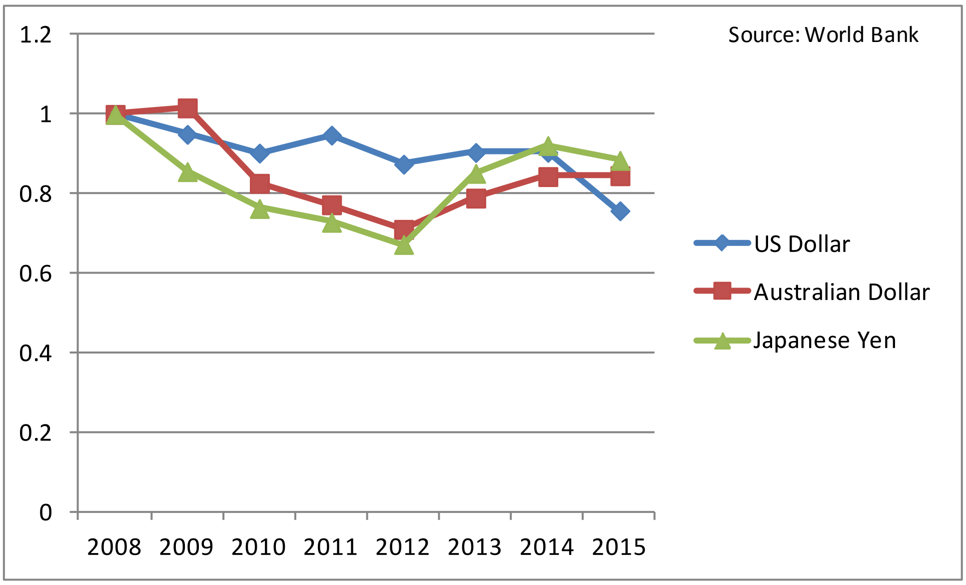


Figure 3: Indices of the currency exchange rates of Australia, Japan and the US (local currency/EUR; base year 2008)

At the beginning of 2008, there was a significant spread (up to approx. 70 EUR/MWh) between average **electricity prices in the wholesale markets** in Japan, the EU, the US and Australia. While the prices decreased throughout during the economic crisis in 2009 and the gap narrowed down to less than 25 EUR/MWh, the prices across the major wholesale markets developed rather differently in the years following 2009 (see Figure 4, also compare for ACER 2015 and EC 2014):

- The wholesale prices in Australia showed short-time peaks in the first quarters of 2010 and 2011 in coincidence with two heat waves. After the introduction of a carbon pricing mechanism by the Australian government in July 2012 the average wholesale prices more than doubled and fell only slowly afterwards. When the mechanism was abandoned in the mid of 2014, the prices returned to the level they had been before the introduction.
- In the US, the prices began to increase when the electricity demand recovered in 2010. However, the prices fell again in 2011 as the domestic shale gas boom resulted in low generation costs for gas plants. In the following period, the average wholesale prices have shown an approx. constant trend except for strong peaks during extreme cold spells, e.g. in the first quarters of 2014 and 2015 at the East Coast.

- In the EU, the prices also slowly increased when the electricity demand recovered in 2010 and 2011. Afterwards, however, prices began to decrease again partly in correlation with the declining prices at coal markets and with the carbon price in the EU ETS. In addition, the rising shares of renewable energies have given rise to the so-called merit-order effect, which reduced wholesale prices thanks to the vanishing marginal costs of renewable energies.
- In Japan, wholesale prices have reached an all-time high after the Fukushima incident, as the nuclear power plants have been temporarily shut down throughout the country. Since they have been replaced mainly by gas- and oil-fired plants, the price shows a strong correlation to the global crude oil price and the oil-indexed LNG import price (0.88 for the monthly averages in 2013-2015). The recent decline of oil prices has in turn led to a significant decrease of electricity prices.

In 2014 and 2015, the wholesale prices in Japan have stayed at significantly higher levels than in the EU in spite of the relaxation, though the price spread has strongly reduced after the end of the complete nuclear shutdown in Japan. The average prices in EU of approx. 40 EUR/MWh are still 30 – 40 % higher than those in the US and Australia reflecting among others the higher coal and gas prices in Europe. Moreover, there is a significant regional variation in wholesale prices in Australia and the US. In the low-price regions, the average prices are only half as high as in the EU.

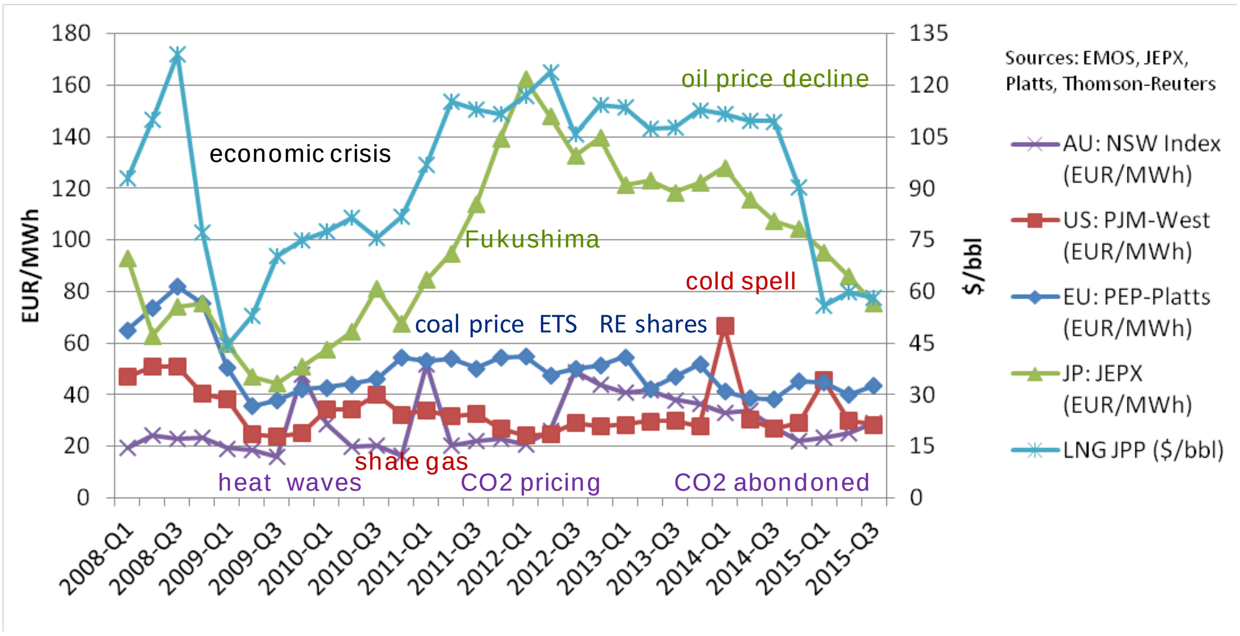


Figure 4: The quarterly averages of base load-type prices at the electricity markets in Japan, EU (Platts Pan-European wholesale electricity price index (PEP)), the US and Australia.

Note: The New South Wales (NSW) index covers the largest pricing zone in Australia. PJM-West is a large pricing zone in the US stretching out from Pennsylvania to the East Coast. The Japanese LNG import price is provided as a reference.

For gas, there are three main different pricing mechanisms that coexist on the global scale, sometimes even within the same region, namely government regulated prices (GRP), oil-price escalation (OPE) and spot market pricing in competitive gas markets (GOG). While the EU is slowly but steadily shifting from a dominance of OPE to more GOG, the latter clearly dominates the North American market with fully liquid trading markets in the USA and Canada and the wholesale price in Mexico being referenced to prices in the USA. The markets in Asia Pacific have a dominant share of OPE, but also some GOG. Russia and Central Asia have a diverse mixture of markets with highest share of GRP.

For electricity, many non-EU countries are also on their way to fully install liberalised markets. However, some still have partly regulated prices (Canada, Turkey, US) and/or are dominated by very few actors, part of which are even government-owned (Japan, South Korea, China). In India, wholesale electricity trading is based mainly on bilateral contracts. Moreover, there are several coexisting markets in some countries, for instance in Australia and the US.

The status of liberalisation of electricity and gas markets in the EU's major trading partners and the EU itself is quite diverse. Detailed information can be found in ACER 2015. The following table provides an overview for the remaining G20 countries.

Table 2: Overview of wholesale market structures for gas and electricity in the G20 countries (without EU)

Country	Structure of wholesale electricity markets	Structure of wholesale gas markets
Canada	Alberta is the only province to have established a fully competitive electricity wholesale market. Ontario retains a hybrid model with a regulated and partially open wholesale market structure. Wholesale electricity prices are regulated in all other provinces and territories by a quasi-judicial board or commission. Most provinces have established open access to their wholesale electricity markets. (Source: IEA 2015a)	Canada's natural gas markets are heavily integrated with those of the United States. Natural gas is generally purchased on a short-term basis (GOG). The most important hub is the Alberta hub, which is reflected in the fact that the intra-Alberta natural gas spot price is one of North America's leading natural gas price-setting benchmarks. (IGU 2015)
United States	Both regulated and competitive markets coexist across different states. In regulated states, supply and distribution rates are set through economic regulation. In restructured states, generation is deregulated and supply rates are set by markets. (Source: Nazarian 2012)	US gas markets are competitive markets built on physical hubs (GOG only). The Henry Hub, located in Louisiana, is the intersection of more than a dozen interstate pipelines and it is the most liquid trading hub in North America. (IGU 2015)
Mexico	Price of electricity is regulated, but recently markets are undergoing reforms to open up wholesale markets for private companies. (Source: Thomsen Reuters 2014)	The wholesale price for gas is referenced to the spot prices in the US up to a small share used in refinery processes and enhanced oil recovery. (IGU 2015)
Brazil	Electricity is traded in two separate environments In the regulated market energy is procured at auctions designed to contract all the electricity required to meet estimated demand for the next five years. The resulting costs are passed through to consumers. In the modified single buyer model, long term contracting through a series of auctions held every year. Roughly 30% of the electricity is traded in the free market (Haraiva 2012).	Brazil has a hybrid gas-pricing regime: imported gas prices are determined by the price formulae of the various energy supply agreements, while domestic producers can freely negotiate the price of domestic gas. (Source: Gomes 2014)

Argentina	Private and state-owned companies carry out generation in a competitive, mostly liberalized electricity market, with 75% of total installed capacity in private hands.	The wholesale gas market operates with multiple buyers and sellers entering into bilateral agreements. (Source: IGU 2015)
Australia	Since 2005 there are few barriers to interstate trade and there is a nation-wide market for wholesale trade, originally based on five interconnected regions and meanwhile extended into South Australia and Tasmania. (IEA 2012a)	There is no national wholesale market for gas. Most gas production is contracted on a long-term basis, traditionally of up to 20 years. Recently, the duration of these contracts tends to be five years or less due to price uncertainties. (IEA 2012a)
Indonesia	Independent power producers must sell electricity directly to the vertically integrated state-owned utility in its concession area, but can also sell electricity directly to the public within certain other concession areas. All such agreements are based on power purchasing agreements for fixed terms of approx. 30 years or longer. Cross-border power purchases may take place only if local electricity needs cannot be reliably met and national interests of sovereignty and security are not adversely affected. (IEA 2015)	Natural gas prices are low compared to international prices and largely determined by government policy decisions rather than the market. Indonesia, however, intends to establish a domestic gas market in the near future. (IEA 2015)
Japan	Currently, the market is partially liberalized but competition is still very low. Recent market reforms should result in full competition by 2016. (Yamazaki 2015)	Prices are based on long term contracts and the fuel cost adjustment mechanism by reflecting the external factors of foreign exchange rate and crude oil prices. There is currently no trading hub on which natural gas companies can buy and sell natural gas. IEA 2013)
Republic of Korea	Korea's wholesale market is based on pseudo-competition of a few state-owned actors and operates on a cost-based pool, in which the price of electricity has two components: a marginal price, representing the variable cost of generating electricity, and a capacity price, representing the fixed cost of generating electricity. (IEA 2012c)	Prices are regulated based on the cost of service for the internal market. LNG import prices are based on OPE for long term contracts and GOG for short term contracts. South Korea has no trading hub where companies can buy or sell wholesale natural gas. (IEA 2013)
China	Fully regulated in the past, China is trying to move to market based pricing mechanisms. There is competition on the generation side, but all prices are still being strictly regulated. (Shi, Y. 2012)	Domestic gas prices in China have traditionally been regulated by the central government. A pricing reform with a netback approach based on oil price indexation is already being piloted in two provinces and extension of trials to other provinces has been proposed. (Chen 2014)
India	Wholesale trading is based on bilateral contracts, mainly long-term contracts but also a relevant share of short-term contracts. Prices are regulated based on a cost plus principle. (IEA 2012b)	India's natural gas prices are regulated and set at different levels for gas originating from different producers. Joint venture gas producers are paid based on formula pegged loosely to international prices but the government maintains close oversight of price adjustments. (IEA 2012b)
Russia	On Russian wholesale markets, electricity is traded at regulated and free prices. The territory of the country is split into areas, where due to lack of competition electricity is traded at regulated prices, and price zones where trading at free prices is possible. Russia has yet to determine a roadmap for the completion of the electricity wholesale market reforms, which remains a major challenge (IEA 2014b)	From having domestic production completely in the GRP category in 2005, there was partly a switch to GOG as the independent producers began to compete with each other. Moreover, pricing switched from BIM to OPE in intra-FSU trade, in particular with the Ukraine. (IGU 2015)

Turkey	Market is competitive since 2006, but wholesale prices are regulated. Wholesale trade is dominated by bilateral contracts. (EPDK 2012)	Market is open to competition since 2001, but still dominated by a state-owned actor. (PwC 2014)
Saudi Arabia	Most of the generation controlled by a state-owned company. Restructuring in progress, which permits large consumers to obtain their requirements of electricity services directly from the suppliers of their choice on the basis of mutually agreed prices and other commercial terms. (ERRA 2015)	Regulated market - regulation social and political (RSP) where the price is set, on an irregular basis, either to cover increasing costs or as a revenue raising exercise. (IGU 2015)
Republic of South Africa	Regulated market with electricity generation dominated by a state-owned power company, which currently produces over 95 % of the power used in the country. (RSA 2010)	Regulated market – regulation based on cost of service along with some bilateral contracts with a monopolist. (IGU 2015)

3 Drivers of wholesale and retail electricity prices

The objective of this section is to analyse the drivers of the wholesale prices. Given complete competition and market transparency, prices equal marginal costs (variable part of cost) in theory. As energy wholesale markets are not always fully liberalized and transparent, other factors besides variable costs (i.e. fuel costs) determine prices, for example, monopolistic structures, bottlenecks in infrastructure and market organisation, both restricting free trade. To capture all these aspects, commodity or fuel prices, generation shares and demand accounting for the market mechanism as well as market features such as concentration, regulation, and cross border trade reflecting internal market/trade are included in this analysis. Fuel and CO_2 prices affect the shares of different fuels used to generate electricity, and hence affect the merit order. However, this applies only for the marginal power generators, i.e. between very efficient gas and low efficient coal based generators. Therefore both, prices and shares will be included as potential drivers. Two models have been developed for wholesale electricity markets, the Fixed and Random Effects models (FE/RE) and the Error Correction models (ECM). The FE/RE model builds on panel data. Panel data allow investigating drivers that are different between countries and across time. The ECM analyses how prices between countries are converging.

3.1 Main drivers of wholesale electricity prices

Affordability of energy for households and competitiveness of industries is affected by retail prices. Three components make up the retail electricity price: taxes and levies, network fees and the energy component. Energy components are driven by wholesale prices but also by market conditions such as the degree of competition, market liberalisation and deregulation. Furthermore, market power of consumers, i.e. demand side aspects also impact prices. At the wholesale level, the generation mix, fuel and CO_2 prices, or international commodity prices as well as trade features (historic contracts, organisational, infrastructure), the degree of competition and demand determine wholesale prices. This complex interdependency is depicted in Figure 5.

To analyse drivers, data of about 28 countries over a time period of up to 8 years are available. To capture the main drivers, an FE/RE analysis is chosen that takes into account the changes of factors within a country (over time) but also between countries. This is especially interesting when comparing different markets (structures and designs) that display sometimes less (fast) changes a prices do. The use of fixed and random effect estimator for the analysis of panel data is standard in the literature (see e.g. [ECFIN 2014; Chouinard and Perloff 2007]). The analysis relies on monthly data. To capture the influence of regulation, competition or market coupling and to gain better insight into the relationship of prices and some selected drivers, the analysis splits the EU member states into subsets, respectively.

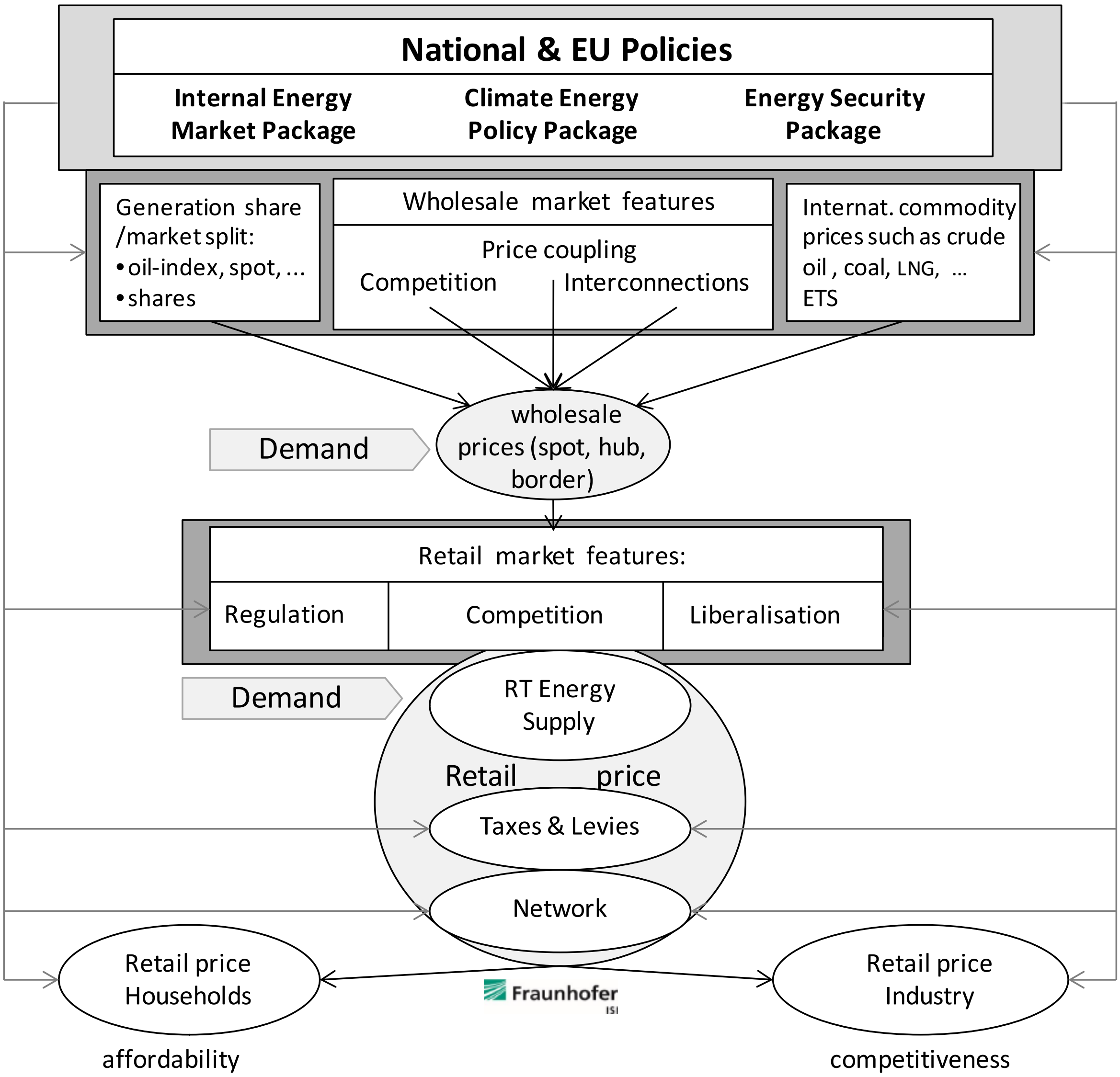


Figure 5: Drives of electricity and gas wholesale and retail market prices

3.1.1 Fixed effect / random effect estimator

3.1.1.1 Model

To estimate the influence of certain drivers of wholesale prices in light of significant unobserved heterogeneity, we use a fixed/random effect panel data model (linear specification, selection of random vs fixed effects model via a standard Hausman test) covering monthly data between from 01/2008/ to 12/2015 – given data availability – and all EU 28 Member States (no data for BG, CY, HR, MT) and trading partners of EU member states. The model is based on monthly data, even though only annual data on market features are available. If some variables are approximately constant over time (e.g. variable reflecting market framework or degree of regulation), they are only poorly identified within fixed effects estimator. Therefore a random effect estimator is also applied to account for these specific variables. The Hausman test of the random vs. fixed-effects mode shows whether the fixed or random effect provides more consistent estimations. In case the fixed effects estimation is consistent, it has the drawback that it does not allow modelling the unobserved heterogeneity explicitly, especially between countries, if for example generation shares show time invariant values. Part of the total variance seems to be driven by the difference between groups. Thus, the fixed effects approach may be undesirable because a major part of the potentially interesting variance is dropped if time invariant. One way to be more explicit about the unobserved heterogeneity is to model it parametrically in so-called Random Correlated Effects (RCE). These types of models – sometimes also referred to as Mundlak Model (Mundlak 1978) - incorporate the by-group means of some or all of the exogenous variables as additional variables to explain the heterogeneity. We make selective use of this approach, in particular in the case of variables that are approximately constant over time but are expected to vary between groups (countries). The analysis with a detailed set of drivers is conducted for all EU countries for which data were available (EU model). Depending on the degree of data availability, reduced analyses are conducted for Switzerland, Norway and for major trading partners of EU countries (global model) including US, Australia, Japan and Russia.

3.1.1.2 Data at wholesale level

In the case of electricity markets, the endogenous variable to be explained by the model is the wholesale price at the spot markets (peak load). In general, wholesale prices should be determined by the marginal generation technology at the stock exchange, i.e. the marginal costs of generation, which are mainly fuel costs. Therefore the generation mix and commodity prices determine which and how often a technology becomes the price setting technology. Furthermore, the degree of competition often measured by the number of market participants, market entries or exits and market shares of the largest players and the development of the internal EU market might also affect the price. The data are available for most of the EU countries (except for BG, CY, HR MT) and some major trading partners of EU member states (mainly NO, CH, US, AU, JP, RU) and cover a time range varying between 2008 and 2015. The global model includes selected EU countries and trading partners, the EU model includes all EU countries of which data are available.

Regarding the drivers, i.e. exogenous variables, we focus on the following groups of drivers: generation shares (not adding up to 100% as lignite and hydro is excluded), fuel and CO_2 prices, market features such as competition and EU internal market, and control variables such as consumption, heating day, growth (GDP), exchange rate index. Commodity prices of coal, natural gas and to a lesser extent crude oil and LNG as well as CO_2 prices have a positive correlation with the wholesale price. The impact of generation shares of the main energy carriers (coal, gas, nuclear, RES) is more subtle, as it is linked to merit order effects and the carbon price at the EU ETS. The latter, hence, is itself also a driver for electricity prices. Finally, there are drivers linked to the market structure such as the number and shares of market participants, the cross-border flow between member states. These variables are considered as proxies for market competition and integration and the hypothesis is that monopolistic market features result in higher prices and an improving internal

EU market in lower ones. Liberalisation is assumed to have an impact as well. As dummies will be dropped in FE models if they are time invariant, liberalisation is captured as the logarithmic value of the time periods (year) since market opening. The reason for a log-value is to account for the decreasing impact of liberalisation when time is passing. At the beginning the impact of market opening on prices is expected to be strong, but after 10 years the impact of the eleventh year since market opening on prices is expected to be low. To account for demand, inflation and growth, control variables such as heating and cooling degree days as well as exchange rates, GDP deflator/index or inflation rates are included. Prices, shares and some control variables are available on a monthly basis, while some market features are annual. Table 3 provides an overview of the included variables, their use in the model as well as remarks about their availability or use.

Table 3: Drivers of wholesale electricity prices – fixed / random effect estimator for the EU and major trading partners

Variables applied and units	Unit	Global, EU	Notes
Endogenous: monthly Wholesale prices electricity price (day-ahead): Base load annual	ws_base (wsprice_el) [Euro/MWh]	EU and global	Varying observations over time, e.g. for some countries only 1-2 years
Exogenous: monthly Generation share of: • Gas , coal, oil • nuclear • RES • Hydro	Shares [%]	EU, US	Focus is on shares of nuclear and RES (PV and wind) Gas, coal and crude oil share is included, lignite and hydro shares are excluded
Exogenous: monthly Fuel, CO2 prices • Coal • Brent crude oil • ETS CO_2	Coal [Euro/t] Crude brent [Euro/bbl] ets [Euro/t]	Coal, oil: EU and global ETS: EU	For Non-EU countries commodity prices of the closest spot market are chosen
Exogenous: monthly Gas prices • Gas combined	Gas spot Gas border Gas lng Gas combined [Euro/MWh]	EU and US, JP	spot market prices are hub prices for EU countries. Border price is calculated as the average import price of piped gas, lng is based on import prices. Gas combined shows the lowest price if a country has more types of gas prices
Exogenous: annual Market feature • CR1 –CR3 share, annual • De/Regulation, annual • Liberalisation, annual	CR3-share [%] Dummy CR3 share (><80% of CR3) Dummy regulation (>< 50% of regulated prices) Dummy liberalization and number of periods in ln since liberalisation	EU	CR3-share: ACER MMR 2015 and before, CEER; annual data Regulation: DG ENER, ACER, CEER; Liberalisation: ACER MMR 2015
Exogenous: monthly/annual Internal EU market/market opening • Border flows per consumption • Interconnection [annual]	Gross border flows [% to final consumption] Interconnection capacity [% to production capacity], annual; dummy interconnection (><	EU	Gross cross border flows: standardized by final consumption (monthly) reflecting internal market power exchange

• Price/market coupling [annual]	10%) Coupling: dummy		
Further exogenous var: Control variables, annual & monthly: • Heating /cooling degree days • Deflator (GDP) • Inflation rate • Exchange rate	Hhd, ccd Deflator [Index] Exchange rate index, base year 2008 [foreign.curr/Euro] Infl_rate [%]	EU EU Global global EU, global	control variables to capture economic and demand aspects

Sources: see Table 1

3.1.1.3 Results of the EU model

The evolution of wholesale electricity prices of base and peak load for EU countries is depicted in Figure 6. The boxes show prices of the second and third quartiles (above 25% lowest and below 75% highest prices), the white bars in the boxes presents the median and the lower and upper lines 25% of lowest and highest values (first and fourth quartiles). The spread of wholesale prices has been large in 2008, and small in 2009 and 2011 then slightly increasing but at a low level. The convergence of prices in 2009 is due to the oversupply of electricity caused by the economic crisis. The prices have been low in 2009 but recovered in 2010/11 and have been decreasing since then. The decline in prices is parallel to decreasing coal, gas and CO_2 prices, increasing RES shares. Further factors such as market integration, competition and market opening are assumed to have an impact on prices as well. Nevertheless, the spreads in Figure 6 also reflect heterogeneity in prices between countries, as there are differences in fuel shares, resources, market features, growth and demand.

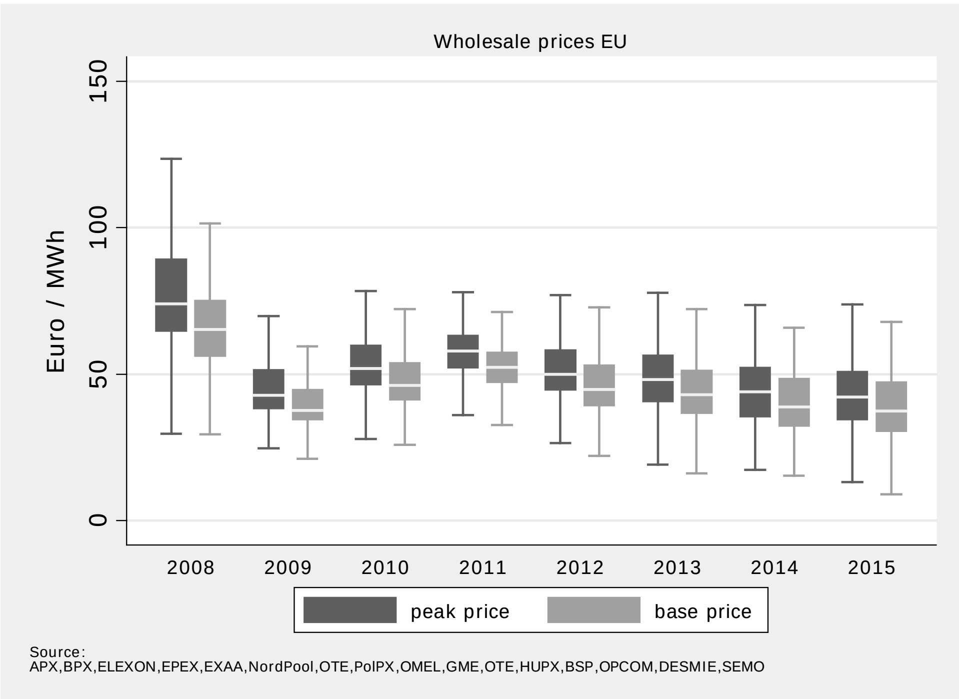


Figure 6: Annual electricity wholesale prices between 2008 and 2015 of EU member states (n = 8-24), (Euro/MWh)

To explain changes in wholesale prices, the fixed/random effects estimator is applied for the EU countries. The explaining variables are generation shares of selected fuels/technologies (nuclear, RES shares based on PV and wind power, gas, oil, coal). They are supposed to affect the marginal price the larger their share is; further explaining variables are prices of gas, coal and CO_2, while crude oil prices are omitted as they are reflected in oil indexed gas prices (see factor analysis below). Fuel prices might influence the generation shares by changing the merit order of supply. This applies especially at the edge of each technology supply. For example inefficient coal plants and highly efficient gas power plants could shift order under increasing prices. On the other hand, generation structures (capacities) do adjust slowly over time and monthly prices might level out some of these effects. Therefore, it is expected that there is no significant impact of prices on generation shares of gas and coal. To have a measure for market competition, the market share of the top three generators is included on an annual basis, while cross border flows per consumption are assumed to reflect trade, i.e. a growing internal market leading to reduced price differences. Finally demand aspects are addressed by heating and cooling degree days as well as by growth rate and exchange rate indices.

To see how strongly the selected variables correlate with each others, correlation coefficients are estimated (Table 4). Apart from oil and gas shares the correlation is very low between the variables. Thus there is only an inter-linkage between crude oil prices with gas and ETS prices (0.5) as well as between gas and coal prices (0.6). In addition, a factor analysis is conducted to show whether some variables load on same factors and, hence, the number of variables could be reduced. The factor analysis shows that the generation shares mainly load on one factor and prices on two others (Table 5). But as the uniqueness or unexplained variation of many variables is still high, i.e. the variance of these variables cannot be explained by the common factors, and since variables such as ETS or coal price are considered as crucial and distinct drivers of wholesale prices, only crude oil price are skipped. In case of multicollinearity problems, the variables will be dropped by the statistical program (Stata). Finally, correlations with lagged variables are conducted to see whether there is a time lag between wholesale prices and commodity prices. The results differ per country. Overall, the correlation is low, but a lag of about 3 time periods (months) for crude oil, no lag for gas prices seems appropriate, while for coal the lag could comprise 0 to 2 periods. When applying different lag structures in the model, zero lags for gas and coal give reasonable results. The selected variables, i.e. prices and shares are included as they are determined by different factors. For example, shares depend on infrastructure and resources, while prices react quickly to policies and economic effects. To test whether there are differences in econometric results when omitting shares in the model, an analysis is conducted without shares. Significance and coefficients show small changes, apart from the ETS coefficient, which displays a significant increase.

Table 4: Correlation matrix

	price	nuc_s	re_s	oil_s	gas_s	coal_s	crude_~e	coal_p~e	gas_pr~e	ets	cr3_sh~e	border~s
price	1.0000											
nuc_s	-0.2152	1.0000										
re_s	-0.0774	-0.2274	1.0000									
oil_s	0.5121	-0.3336	0.2736	1.0000								
gas_s	0.5293	-0.1633	0.1262	0.5424	1.0000							
coal_s	0.1751	-0.1761	0.0378	0.1595	0.2921	1.0000						
crude_price	-0.0300	0.1155	0.1215	-0.1060	-0.1866	0.0923	1.0000					
coal_price	0.5428	0.0231	-0.1630	0.0969	0.1350	0.0225	0.2373	1.0000				
gas_price	0.0974	0.0807	-0.0180	-0.0174	-0.2073	-0.0854	0.4994	0.1510	1.0000			
ets	0.4767	-0.0766	-0.2308	0.1519	0.2737	-0.0559	-0.4618	0.6489	-0.3347	1.0000		
cr3_share	-0.0962	0.3228	-0.3821	-0.2291	-0.2225	-0.4190	0.0040	0.0247	0.3782	0.0162	1.0000	
borderflows	-0.2391	0.1335	-0.3470	-0.3248	-0.4115	-0.2852	0.2005	-0.0250	0.3484	-0.1780	0.5869	1.0000
cdd	0.1928	-0.1081	0.1177	0.2611	0.1709	-0.0105	-0.0112	0.0697	-0.0307	0.0854	-0.0087	-0.1299
hdd	-0.0397	0.0067	-0.1213	-0.1187	-0.1039	0.0180	0.0108	0.0077	0.1249	-0.1101	0.0395	0.0696
ex_rate	-0.0753	-0.0042	-0.1224	-0.1727	0.0217	0.3835	0.0311	-0.0945	-0.0486	-0.1162	-0.1594	-0.2216
growth_ind	-0.2712	-0.0301	-0.1140	-0.2170	-0.3481	-0.3096	0.1857	-0.1038	0.4274	-0.2285	0.5655	0.4784

	cdd	hdd	ex_rate	growth~d
cdd	1.0000			
hdd	-0.3741	1.0000		
ex_rate	0.0112	-0.0277	1.0000	
growth_ind	-0.0646	0.0998	0.0362	1.0000

Table 5: Factor analysis

Factor loadings (pattern matrix) and unique variances

Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7	Factor8	Factor9
nuc_s									
re_s	-0.4217								
oil_s	-0.4998			-0.4087					
gas_s	-0.5081								
coal_s	-0.4831								
crude_price		-0.4871	0.6656						
coal_price		0.5524	0.7115						
gas_price	0.4252		0.4244						
ets		0.9419							
cr3_share	0.7790								
borderflows	0.7189								
cdd									
hdd					0.4735				
ex_rate									
growth_ind	0.6483								

Variable	Uniqueness
nuc_s	0.6789
re_s	0.5159
oil_s	0.4698
gas_s	0.5543
coal_s	0.5376
crude_price	0.2257
coal_price	0.1181
gas_price	0.4749
ets	0.0845
cr3_share	0.2536
borderflows	0.3981
cdd	0.7067
hdd	0.6742
ex_rate	0.6071
growth_ind	0.3972

(blanks represent abs(loading)<.4)

Results of the panel data regressing peak load prices on the selected variables (FE/RE analysis) are depicted in the first column of Table 6. The FE/RE approach in the statistic program STATA controls for multicollinearity. Peak load prices, which are determined by the highest marginal technology cost (price setting), are assumed to reflect the different commodity prices and shares better than base load prices. As the correlation coefficient between peak and base load prices is 0.98, the differences are small. The econometric results show highly significant values for all shares except for nuclear power, significant coefficients for prices, market competition and integration as well as for demand factors. An increase of the RES share by one percentage point compared to the benchmark technologies lignite and hydropower reduces in the short-run prices by about 0.4 Euro/MWh at the EU level. As this result is based on monthly prices and not on hourly, this is effect might be more pronounced when hourly prices are applied. An increase in gas, oil or coal generation shares (by one percentage point) could in average across all countries increase wholesale prices by 0.2 to 1.3 Euro/MWh. However, given that countries differ by their generation shares or pricing mechanisms the country specific effects might divert from these averages. Thus, to the extent that the marginal producer, i.e. the one setting the price in the whole sale market differs, changes in fuel shares will lead to differential effects across the hours of the day. Similarly, increases in gas, coal or ETS prices (by one Euro per unit) lead under the given model specification to an increase of average wholesale prices by 0.2 to 0.8 Euro/MWh. As some fuel prices, e.g. for natural gas, differ between countries, the country specific effect might deviate from these results. Regarding the market share, an increase of the market shares of the top 3 players by one percentage point increases prices in average by 0.5 Euro/MWh while increasing internal market (by one percentage point) reduces prices by about 0.1 Euro/MWh. Overall, increasing demand and growth leads to increasing prices. As at the EU level the exchange rate index is only different for non-Euro countries, the impact is expected to be low (a weakening of the local currency is supposed to result in lower prices in Euro). Applying the “robust” option in STAT reports heteroskedasicity robust standard errors. Then the coefficients of coal share, border flows and growth become insignificant. Omitting the variable “coal share” changes neither significances nor signs nor impacts of all the other variables including the constant. Similarly, reducing the shares to renewable and nuclear shares, the signs and significances remain almost unchanged while ETS seems to capture the impact of the omitted shares (ETS coefficient increases from about 0. 5 o 0.8). To account for a potential multiplicative relation between the variables, the logarithms of the variables is taken (coal, gas and oil shares are not included). Again, the results show the same signs and significances for all variables, while the coefficient value differs due to the logarithmic values and the within R square decreases from 0.55 to 0.51. Overall, the results are rather robust for the EU analysis, even though the wholesale electricity markets differ between the member states as they are heterogeneous in available or accessible resources (fuels), commodity prices, infrastructure and market conditions such as degree of market competition.

3.1.1.3.1 Regions

To see whether major differences between price coupling of regions have influenced wholesales prices, subsets of countries are formed. Market coupling optimises the allocation process of cross-border capacities. It is based on a coordinated calculation mechanism of prices and flows between countries. The auction is implicit, i.e. players do not actually receive allocations of cross-border capacities but bit for their exchange, which is then used to minimise price differences. In February 2014 price coupling between the North Western European markets took place, as a pan European solution for the calculation of prices and flows were used. While the NordPool formed a common market before 2000 with NO, SE and FI and gradually including DK, LT, LV and EE, other regions were slower. Because the Baltic States form a very close market, they are depicted separately as entity in the analysis. The Northwest regions (FR, NL, BE, DE, AT, DK, NO, SE, FI, UK, LT, LV, EE, PL) applied the common price coupling of region mechanism in 2/2014, Spain and Portugal joining in 5/2014, Italy and Slovenia followed via France and Austria in 2/2015. In contrast, CZ, SK, HU and RO formed a distinct market with price coupling in 11/2014. In the following the wholesale prices of different regions and market are depicted and a fixed effect estimator is applied for these regions, to see whether price coupling had any effect on wholesale prices within this region and whether there are differences in drivers.

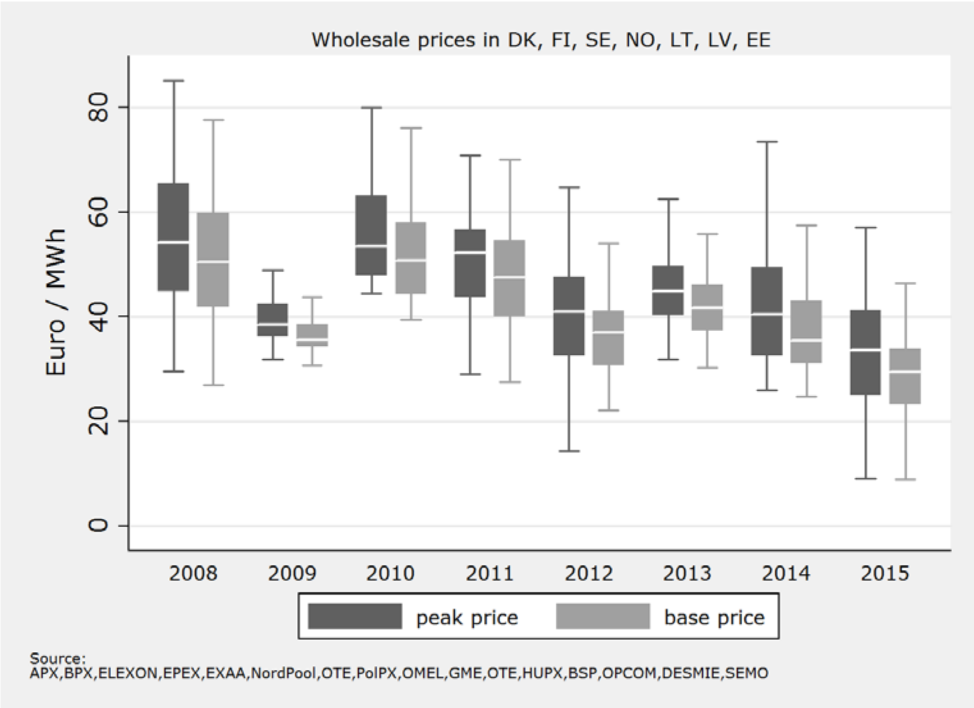


Figure 7: Annual electricity wholesale prices between 2008 and 2015 of NordPool area, (Euro/MWh)

Prices in the NordPool market (Figure 7) are lower than at the EU level and in the East EU countries. The development of prices displays a similar pattern with a more pronounced decrease and increase of prices in 2012 and 2013, respectively. The spread of the price between these selected countries is as large as for the EU in total except for 2009.

In the Eastern countries (Figure 8) the prices are lower than at the EU average, while their spread seems to be similarly large. The development of prices follows the EU pattern, but with more distinct peaks and lows.

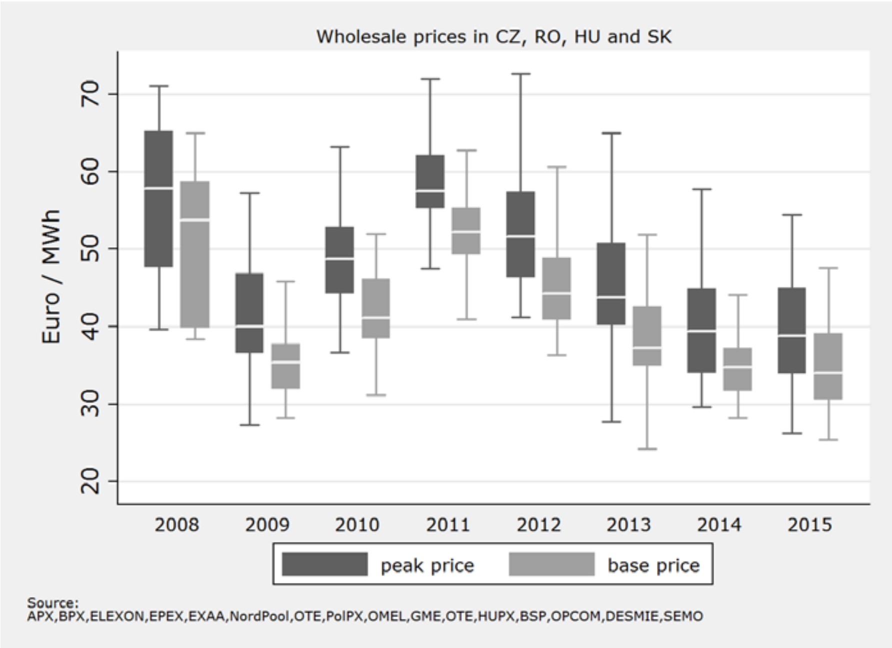


Figure 8: Annual electricity wholesale prices between 2008 and 2015 of CZ, RO, HU, SK, (Euro / MWh)

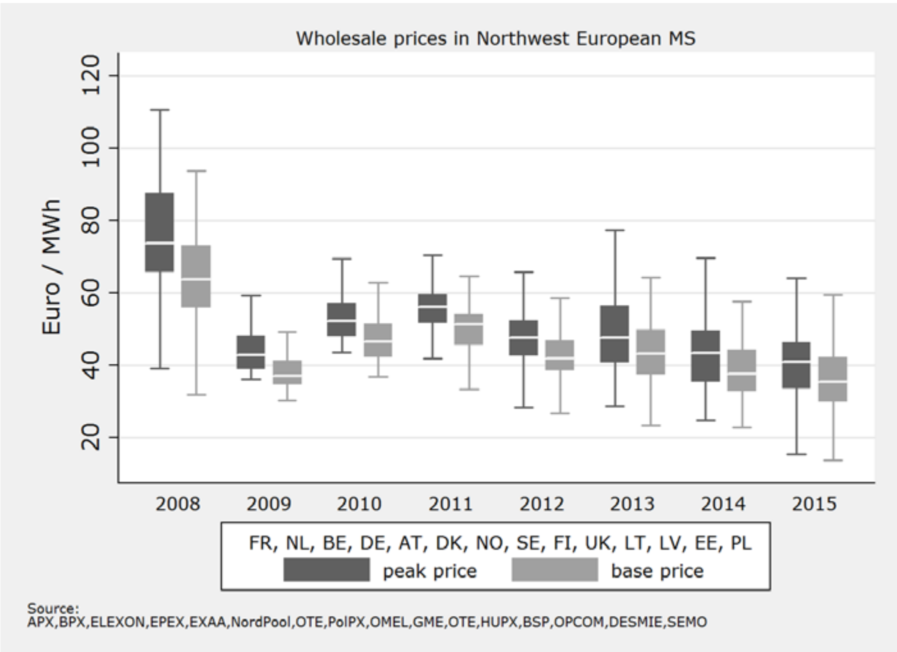


Figure 9: Annual electricity wholesale prices between 2008 and 2015 of Northwest EU countries, (Euro / MWh)

Figure 9 depicts the wholesale prices of the Northwest EU countries which comprise besides the NordPool market area also Poland, France, Netherlands, Belgium, Austria and Germany. Again the drop in prices is significant till 2009, while an increase follows till 2011. The spreads increase slightly as well. Overall, prices display a decreasing trend, but move at a slightly higher level than all EU prices.

Figure 10 shows the wholesale prices of France, Spain and Portugal. The pattern is quite similar to that of the Northwest EU countries, but the level is higher and the spreads have significantly increased in 2013/14 compared to 2009.

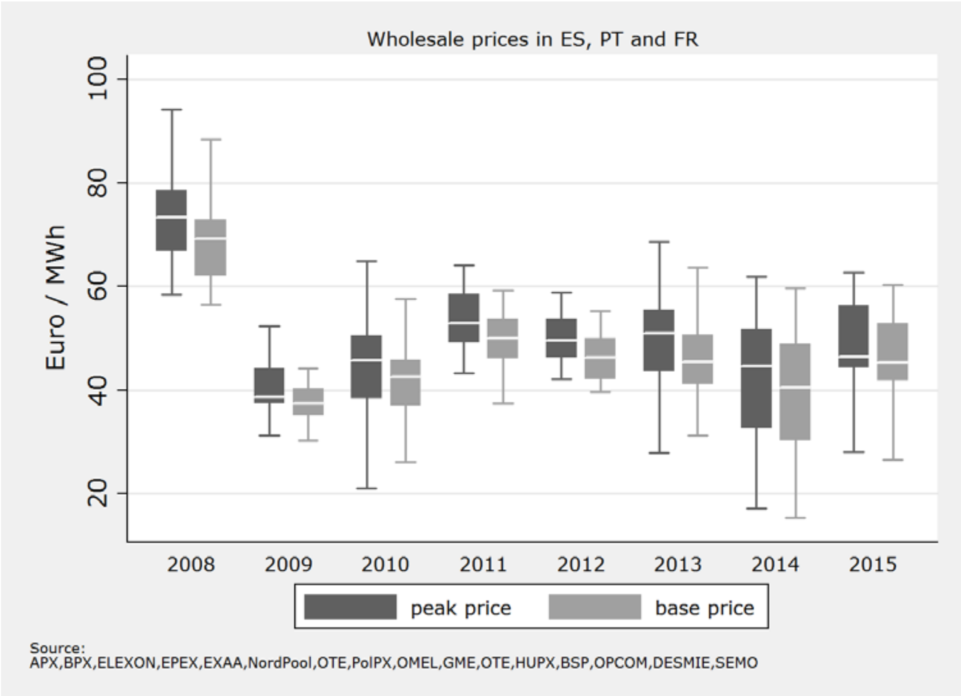


Figure 10: Annual electricity wholesale prices between 2008 and 2015 of ES, PT, FR, (Euro/MWh)

Very late in the period Italy and Slovenia joined the price coupling regions via France and Austria. Figure 11 illustrates the evolution and spread of their prices, which are mainly driven by high prices in Italy and low prices in Austria.

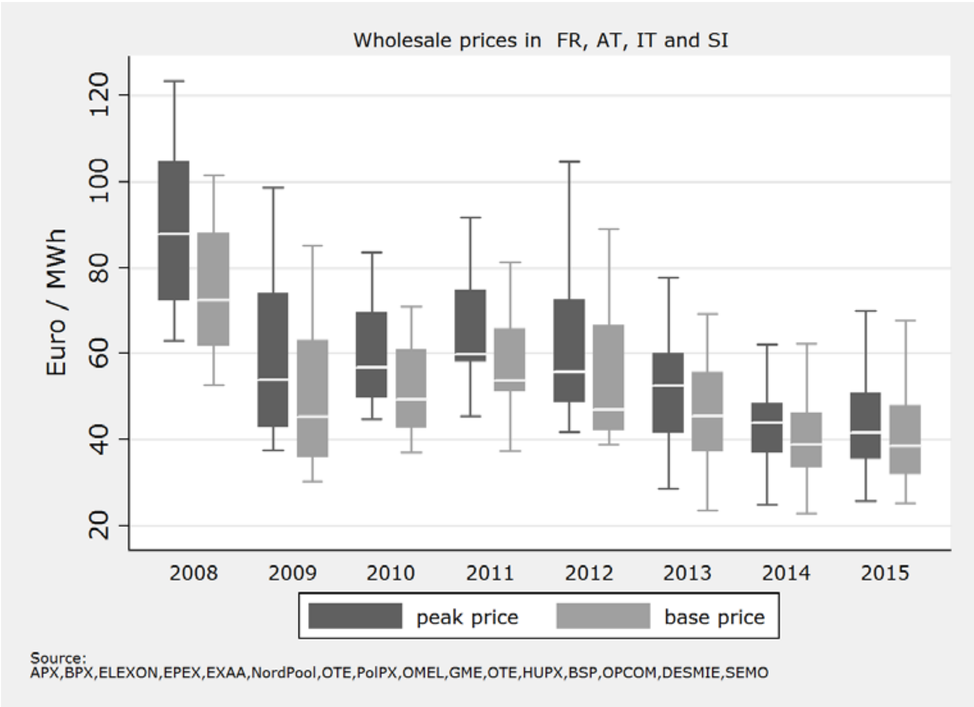


Figure 11: Annual electricity wholesale prices between 2008 and 2015 of Fr, AT, IT SI, (Euro/MWh)

Overall, the evolution of the price level and spread across countries can be explained by several factors. To capture their significance an econometric analysis is performed.

The econometric analysis is applied for the subset of countries as depicted above. A dummy depicting the price coupling of regions is included, but is dropped due to multicollinearity. Major difference to the analysis with all EU countries can be observed by Northwest EU countries. The oil share, cooling days and exchange rate are not significant and ETS and gas prices and growth display a slightly stronger impact. The dummy reflecting price coupling is insignificant. The NordPool countries show a stronger impact of coal share (high share in DK, FI and EE) and a negative impact of heating degree days, although the causal relationship is unclear as heating is not based on electricity. In the Baltic States RES and gas shares are significant as well as border flows are. Similarly to the Scandinavian market, the sign of heating degree days is not plausible. Gas has a high share in LV and LT, but its price is not significant). In the analysed East EU countries the coal share (especially high in CZ) has a large impact as well as the nuclear power (high in HU and SK) and gas share (high in HU). For Spain and France the cross border flows is significant and large as the capacity is limited and any increase in border flows might have a large negative marginal impact. Oil and gas (decreasing in ES) share and ETS are also significant. When looking at the countries AT, IT, SI and FR, the coal and oil share is significant with a large impact as well as the market share.

Table 6: Fixed and random effect estimators for EU countries

Dependent variable: wholesale prices	FE estimator EU	FE estimator NordPool + UK, DE, NL, BE, FR, AT, PL	FE estimator NordPool (NO, DK), FI, SE	FE estimator EE, LV, LT	RE estimator CZ, HU, RO, SK	RE estimator ES, FR (PT)	FE estimator FR, AT, IT, SI
Number of countries	20	12	2, NO, DK dropped	3	4	2, PT dropped	4
Nuclear share	0.068	-0.002	0.412***	0.000	0.211***	0.204	0.139
	(0.99)	(-0.02)	(2.96)	(.)	(2.94)	(0.92)	(1.43)
RES share (wind, PV)	-0.433***	-0.589***	-0.743	-0.767**	-0.728*	0.157	-0.221
	(-3.44)	(-3.16)	(-1.39)	(-2.51)	(-1.94)	(0.55)	(-0.67)
Gas share	0.233***	0.220***	1.768***	0.305***	0.616***	0.278	0.296**
	(6.36)	(5.76)	(3.33)	(4.85)	(5.74)	(1.33)	(2.36)
Oil share	1.296***	0.833	0.547	0.685	3.010	2.794***	1.703***
	(4.87)	(1.13)	(0.19)	(0.51)	(1.55)	(2.75)	(3.32)
Coal share	0.194***	0.026	0.767**	0.000	2.597***	1.814***	1.175***
	(3.25)	(0.39)	(2.52)	(.)	(5.85)	(9.90)	(4.70)
Gas price	0.799***	0.975***	0.003	-0.881	0.434***	0.173	0.784***
	(11.77)	(9.66)	(0.01)	(-1.65)	(3.44)	(1.02)	(6.79)
Coal price	0.233***	0.133***	-0.174	0.030	0.267***	0.219***	0.190***
	(7.89)	(3.24)	(-1.14)	(0.13)	(4.44)	(3.62)	(3.10)
ETS price	0.491***	0.771***	1.182***	-0.406	0.509**	1.085***	0.287
	(4.11)	(4.84)	(2.91)	(-0.60)	(2.16)	(3.39)	(1.08)
Market share top 3	0.465***	0.784***	0.096	-1.835	-0.219	0.993***	1.423***
	(4.11)	(5.47)	(0.13)	(-0.66)	(-1.21)	(3.13)	(4.17)
Share of cross border flows	-0.115***	-0.204***	-1.084***	-0.239***	0.103*	-1.334***	-0.221***
	(-2.89)	(-3.52)	(-7.22)	(-3.14)	(1.65)	(-4.86)	(-2.99)
Cooling degree days	1.656***	0.177***	-0.375***	-0.543***	2.242*	0.970	2.175**
	(3.50)	(3.13)	(-2.74)	(-4.22)	(1.86)	(1.08)	(2.50)
Heating degree days	0.220***	1.210	-33.672	-5.844	0.090	0.304*	0.111
	(4.95)	(0.42)	(-0.41)	(-0.82)	(0.93)	(1.72)	(0.84)
Exchange rate index	0.411***	0.207	0.345	0.000	0.516***	0.000	0.000
	(3.78)	(0.70)	(0.57)	(.)	(4.27)	(.)	(.)
Growth index	0.208**	0.755***	0.196	-0.110	0.132	2.534**	0.233
	(2.40)	(3.56)	(0.52)	(-0.27)	(1.38)	(2.52)	(0.73)
Dummy price coupling		0.330				2.993	
		(0.28)				(1.25)	
Observations	1078	562	54	89	249	119	232
Within R2	0.59	0.628	0.818	0.537	0.548	0.828	0.740
Between R2	0.02	0.003	1	0.513	0.991	1	0.0032
Overall R2	0.20	0.027	0.435	0.509	0.588	0.828	0.079

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: To understand the potential impact of endogeneity between fuel prices and generation shares, the model is estimated without generation shares. The FE estimates show no major changes in significance and coefficient values, except for ETS which increased from about 0.5 to 0.8. Significance levels remain essentially unchanged.

To account for the impact of competition, interconnections and price coupling, these features are included in the fixed effect models. High competition is assumed if the market share of the top three generators is equal to or less than 80%; and high interconnection if the interconnection capacity exceeds 10% of installed generation capacity. Coupling depends on the time of market or price coupling between countries.

3.1.1.3.2 Competition, interconnections and market coupling

Market liberalisation in the European Energy market has been pushed by three packages aiming at increasing competition in the market. Liberalisation included the freeing up of the supply side, i.e. opening the market for new generators and suppliers and increasing competition. However, sufficient interconnection capacities and a common calculation scheme for calculating market prices are preconditions for internal market.

Competition

In economic theory prices are equal to marginal costs under an highly competitive environment. Thus increasing competition is assumed to result in low prices. Subsequently, the degree of competition is related to wholesale market price. The more competition, the lower the market prices are. As measure for competition, the market share of the three largest generators is applied. The different wholesale market prices are depicted by market shares above and below 80% (Figure 12). Figure 12 reveals that market prices in markets with a higher market concentration (market share of top 3 generators above 80%) are not significantly higher and do not display a larger spread. This observation can be explained by the fact, that highly concentrated markets might still be price regulated by authorities and, given different initial points and a slow pace of structural changes, between country effects cannot be captured. The econometric results, however, show a significant coefficient at least for the country mean of the competition variable (Table 7).

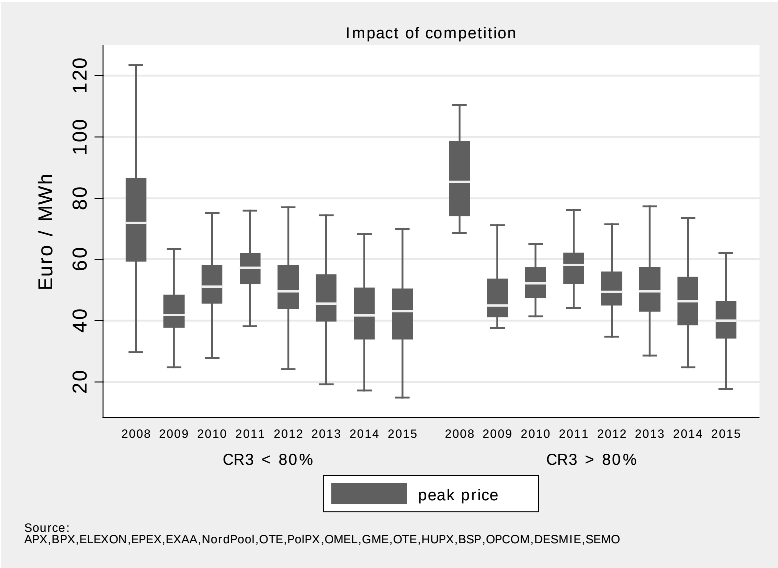


Figure 12: Annual electricity wholesale prices between 2008 and 2015 by degree of competition, (Euro/MWh)

Interconnections

The larger the capacity of interconnectors the less constraints and bottlenecks in transnational border flows. To account for the impact of this trade facility, data on interconnectors' capacities relative to production are used for 2014, and assumed to be about the same in 2015 and 2013. In addition to a dummy signalling the interconnection level (<>10% of production) the mean of interconnection level is applied in the econometric analysis as well. The econometric results in Table 7 report decreasing prices if interconnection capacities are high. This is confirmed by Figure 13, which shows some differences in the level of wholesale prices as well.

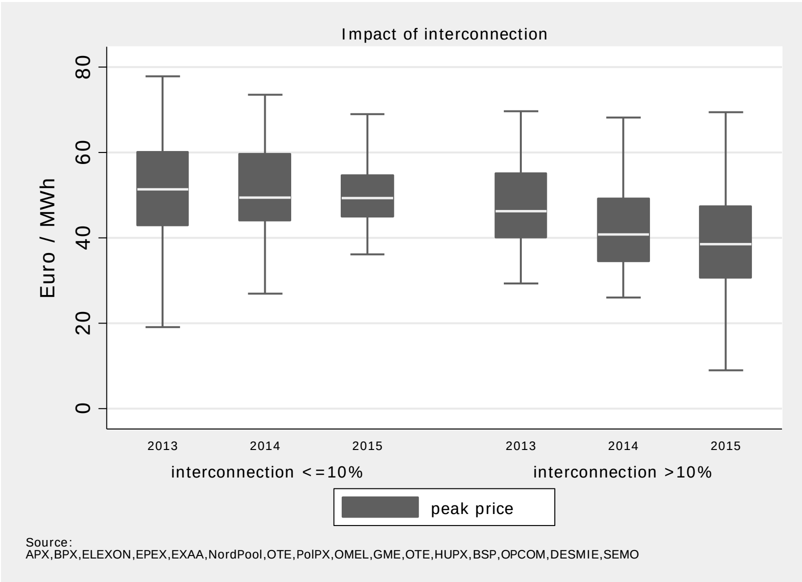


Figure 13: Annual electricity wholesale prices between 2013 and 2015 by interconnections (Euro/MWh)

Market or price coupling

Observations are grouped into those that belong to coupled markets and those that do not. It is assumed that under price coupling overall wholesale prices might be lower. However, Figure 14 shows no clear differences between these two groups: neither prices are consistently higher nor spreads are consistently larger. The econometric results however report decreasing prices under market coupling (Table 7).

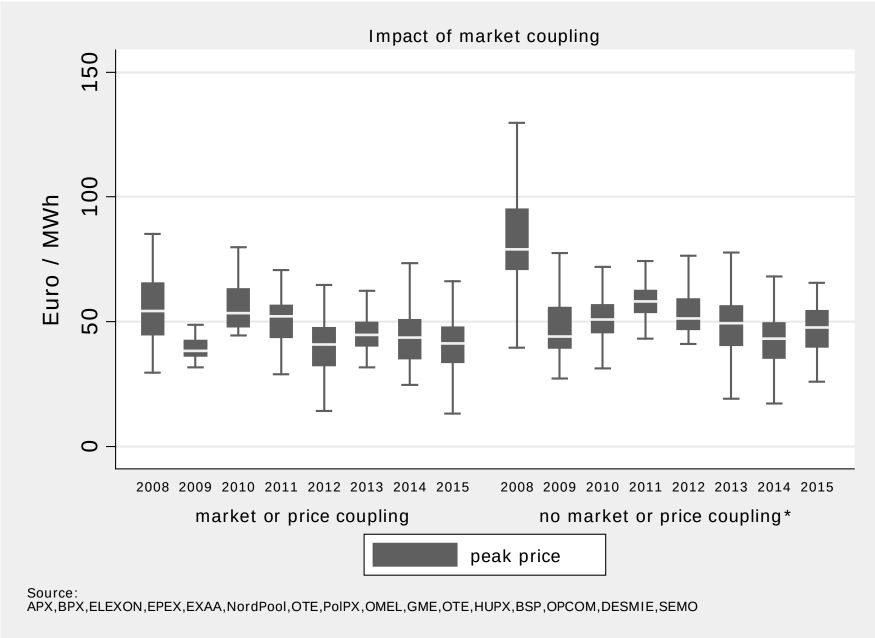


Figure 14: Annual electricity wholesale prices between 2008 and 2015 by market coupling, (Euro/MWh)

Accounting for differences between countries (heterogeneity), dummies for competition, interconnection and price coupling are included as dummy and as country averages in an RCE Model (random effects with Mundlak). To keep the model simple and the number of observations high (e.g. interconnection only for 2013-2015, growth index up to2014), the explaining variables are reduced to the minimum required: nuclear and RES (PV and wind) shares, gas, oil and ETS prices, market share, cross border flows and demand (hdd, cdd). The variable country mean of competition, coupling and interconnection reflect a parameter for the country fixed effects, while the variable competition shows the impact of this dummy over time. Significant values of the country means point to unobserved heterogeneity which could explain wholesale price differences. The dummies and mean dummies are scaled between zero and one, while the other variables range mainly between one and one hundred. Overall the results show:

- Increasing impacts of RES and nuclear shares and ETS.
- Market shares become insignificant.
- Market coupling (country fixed effect) is significant pointing to country differences, which could explain differences in wholesale prices.
- Competition (country fixed effects) is significant suggesting heterogeneity between countries, which might have an impact on prices (lower prices).
- Interconnections (effect over time) lead to lower prices.

Table 7: Random effect results (Mundlak) for EU countries including dummies for interconnection, competition, price coupling

Dependent variable: wholesale prices	RE Mundl.	RE Mundl.	RE Mundl.
Number of countries	20	20	18
Nuclear share	-0.214***	-0.207***	-0.149***
	(-4.44)	(-4.11)	(-2.73)
RES share (wind, PV)	-1.012***	-1.064***	-0.897***
	(-8.77)	(-9.00)	(-7.25)
Gas price	0.555***	0.553***	0.482***
	(4.92)	(4.94)	(3.74)
Coal price	0.539***	0.565***	0.581***
	(4.57)	(4.82)	(4.44)
ETS price	2.382***	2.171***	2.373***
	(5.53)	(5.44)	(5.33)
Market share top 3	0.067	-0.141	0.075
	(0.83)	(-0.95)	(0.91)
Share of cross border flows	-0.146***	-0.130***	-0.145***
	(-3.43)	(-2.96)	(-3.08)
Heating degree days	-0.063	-0.064	-0.075
	(-1.02)	(-1.05)	(-1.11)
Cooling degree days	1.535***	1.532***	1.549***
	(2.89)	(2.88)	(2.81)
Coupling	-1.054		
	(-1.06)		
Mean Coupling	-11.755**		
	(-2.26)		
Competition		18.408	
		(1.61)	
Mean competition		-26.661**	
		(-2.08)	
Connection			-7.116**
			(-2.51)
Mean connection			(.)
			(.)
Constant	2.647	16.344	-0.631
	(0.26)	(1.04)	(-0.06)
Observations	641	641	546
Within R^2	0.268	0.264	0.225
Between R^2	0.160	0.166	0.186
Overall R^2	0.168	0.179	0.150

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$;

3.1.1.4 Global model

Including the wholesale prices of EU trading partners in Figure 15 displays a similar evolution and pattern as for the EU only. The model structure for analysing the major drivers of wholesale prices of major trading partners of EU countries (Non-EU countries) follows the EU model structure. In particular, the endogenous variable are the monthly day-ahead prices and the period covered will be 2008 - 2015. However, the diverse, non-coupled markets in the EU's major trading partners do not allow for integrating impacts of market integration. Moreover, cross-border flows are not meaningful for electricity on the global level and thus discarded. Data on wholesale market structure such as the concentration measure are not available. To account for different foreign currency impacts, exchange rates are included as explaining variable. Wholesale markets with a sufficient time series exist only for Australia, Japan, Norway and the US and Russia (purchasing prices are available). The resulting panel dataset of monthly data from the most important trading partners of the EU is too small to reach a robust level of statistical significance though. As a remedy, we make use of the similar model structures of EU countries and enlarge the dataset by adding selected EU country (DE, IT, FR, GR, IT, NL, PL, SK, RO, SE, UK) data (selected to avoid an EU bias).

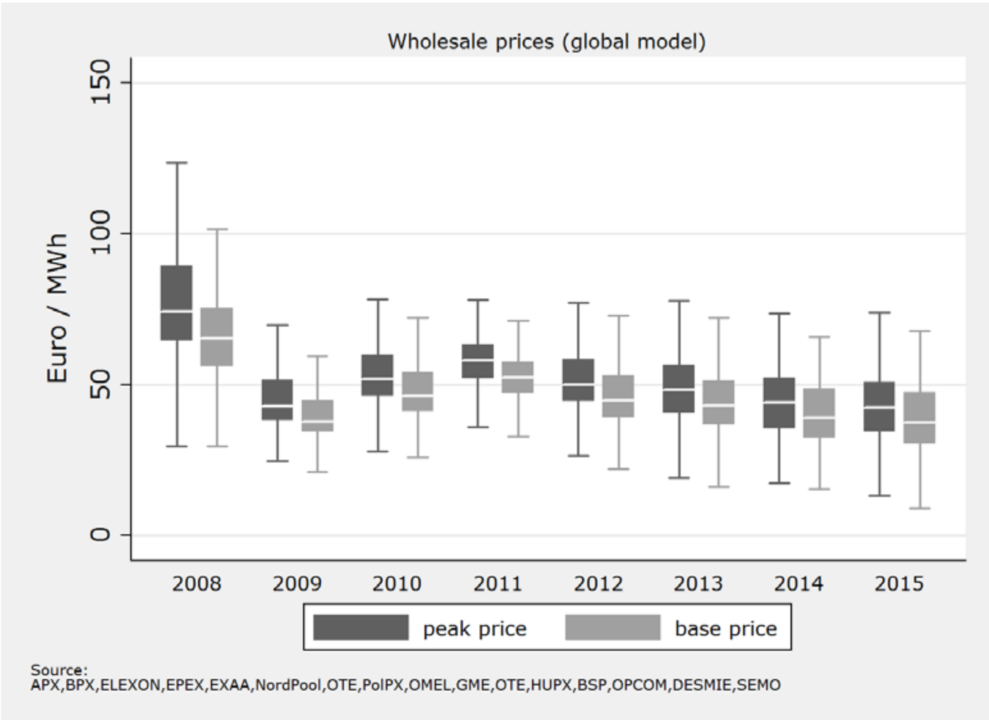


Figure 15: Annual electricity wholesale prices between 2008 and 2015 of EU countries + NO, CH, RU, JP, AU, US (Euro / MWh)

Two models are specified, one with FE estimators relying on generation shares, coal and crude oil prices and exchange rate as explaining variables. In this model only three non-EU countries are included: US, NO, CH, and in addition 11 EU countries summing up to 14 countries (Table 8). This set of countries is also analysed with a RCE model (RE estimator based on the Mundlak approach). In a reduced form, the coal price, crude oil price lagged by 3 periods and exchange rate are included. This enlarges the model by RU, AU and JP to 17 countries (see Table 1 and Table 8). The set of variables applied in the analysis are described in Table 3. However to account for the multiplicative effect of exchange rates, the model could be specified in natural logarithms, as no shares or market shares are included (as different scales of variables within one model should be avoided).

Table 8: Selected countries for the global analysis

country	Freq.	Percent	Cum.
AU	86	5.61	5.61
CH	93	6.07	11.68
DE	95	6.20	17.87
ES	93	6.07	23.94
FI	95	6.20	30.14
FR	94	6.13	36.27
GR	93	6.07	42.34
IT	93	6.07	48.40
JP	85	5.54	53.95
NL	95	6.20	60.14
NO	95	6.20	66.34
PL	89	5.81	72.15
RO	93	6.07	78.21
RU	81	5.28	83.50
SK	69	4.50	88.00
UK	95	6.20	94.19
US	89	5.81	100.00
Total	1,533	100.00	

The results are all depicted in Table 9. Including non-EU countries reports significant coefficients for RES, nuclear and goals shares and coal prices. While RES shares seems to have a reducing effect, all other factors increase prices.

The second model, which is reduced to prices only and could therefore assessed based on a multiplicative relation reports significant results for coal and oil prices as well as for exchange rate. A one% change of prices (coal, crude oil) would increase wholesale electricity prices by about 0.6% and 0.08% respectively, while a one percent decrease in the exchange rate index (decreasing values of the EURO) leads to a 0.18%-increase in wholesale electricity prices. Thus the impacts are moderate or small.

The analysis of the US markets is limited by the data applied: less than 90 observations on monthly average US power and commodity prices and generation shares. The electricity markets in the US differ by their resources, demand and market features and, thus, a panel analysis of the US market might provide better insights than the time series analysis. A linear regression of first differences is conducted due to the long-term trends, i.e. non-stationarity (Box and Jenkins 1970). The applied regression approach reports significant results only for heating degree days, with wholesale prices increasing with the number of heating degree days, all other variables such as shares or prices are insignificant.

Table 9: Fixed/random effects and arima wholesale electricity prices of EU countries, major EU trading partners and US, 2008-2015

	FE Selected EU countries + US, NO, CH	RE (ln values) selected EU countries + US, NO, CH, AU, JP, RU
Nuclear share	0.239***	
	(3.04)	
RES share (wind, PV)	-0.399***	
	(-4.28)	
coal share	0.318***	
	(6.14)	
gas share	0.063	
	(1.40)	
Coal price	0.386***	0.553***
	(19.29)	(18.72)
Crude oil price lag 3	0.004	0.082***
	(0.20)	(5.25)
Exchange rate index	0.087	-0.182**
	(1.49)	(-2.18)
RES share (mean)		
Constant	4.014	1. 985***
	(0.65)	(4.56)
Observations	1183	1500
Within R^2	0.404	0.270
Between R^2	0.013	0.169
Overall R^2	0.115	0.211

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Both analyses, the EU countries' and EU trading partners' analyses suggest that higher renewable shares, gross border flows and surplus as well as decreasing fuel and CO_2 prices lead to falling electricity prices. At the global level the impact of coal prices is significantly stronger than crude oil prices. A price increase by one per cent would increase electricity prices by about 0.6 % (Table 9). However, the countries differ in their electricity market – size, structure, generation and regulations. To capture these differences an increased number of observations could improve the estimation results.

3.1.2 Testing for market integration

In this analysis, we will analyze the degree of integration in the European electricity market. Market integration should lead to price equalization across different national electricity markets, because price differentials should only be temporary due to arbitrage processes. However, infrastructure bottleneck could still lead to significant windows of arbitrage. Based on the assumption of unconstraint cross border flows the central question of our analysis is whether prices converge due to possible cross border flows (competition) and how quickly prices converge across markets. We further investigate whether the degree of market integration measured by the speed of price equalization has increased during the last years. Such an increase may be the result of policies (organisation of markets, application of market pricing mechanism, infrastructure) both at the European and the national levels aiming at increasing the degree of market integration.

3.1.2.1 Methodological approach – overview

In order to obtain statistically reliable estimates of the market integration hypothesis, we will first have to determine the main properties of time series of the electricity prices under consideration. This requires us to test for:

- Stationarity
- Seasonal trends
- Autoregressive order (and potentially MA-order)
- Conditional heteroscedasticity

These tests will be implemented within the Box Jenkins framework, which distinguishes between model selection, parameter estimation, and model checking. We will do that based on the Error Correction Model (ECM), because data is stationary and we can derive it from the stationary ADL model.

3.1.2.2 Price convergence between member states: Error Correction Models

Vector error correction models provide a useful framework for testing for the degree of market integration and answering the question set out above. In particular, we will focus on how electricity prices in any specific country are influenced by the prices in the neighbouring countries. For this we construct an average power price based on the power prices of the neighbouring countries weighted by their imports, i.e. the share of imports from them. Our focus is not the relationship between two selected countries but the impact of market integration i.e. the impact of countries' j prices on the power price of country i. Therefore we explain power price changes of country i by the power prices of country i in t-n and by the weighted average of the power prices of countries j. Other factors, e.g. commodity prices affecting wholesale prices will be analysed on a monthly basis. Assuming we have a time series of electricity prices in country i denoted by $\{y_{it}\}_{t=1}^{T}$ and time series of average prices in the neighbouring countries $\{y_{Nt}\}_{t=1}^{T}$.. We start by defining a Vector Autoregressive (VAR) Model in the following way:

$$y_t = v + A_1 y_{i,t-1} + \ldots + A_p y_{i,t-p} + u_t \quad (1)$$

Where y_t is 2x1 vector containing the time series for country i and the neighbouring countries, $A_1 - A_p$ are 2x2 coefficient vectors and u_t is a 2x2 idiosyncratic error term. u_t has expectation zero, but whether it is independently and identically distributed will be dependent on the assumptions made about it. While it is potentially useful to investigate the cross-coefficients in $A_1 - A_p$ to see how past prices in the neighbouring countries affect prices in country i, this specification often runs into estimation problems, if not all elements of y_t are integrated of order 1, i.e. if $y_t \neq I(0)$. To see this note that (1) can be always be rewritten as in the following way:

$$\Delta y_t = v + \Gamma y_{t-1} + \ldots + \sum_{i=1}^{p-1} \Psi_i \Delta y_{i,t-i} + u_t \quad (2)$$

With $\Gamma \equiv \sum_{j=1}^{j=p} A_j - I_2$. This representation is also known as a Vector Error Correction (VEC) model. y_t is usually assumed to be I(1). Then we can see that Δy_t is by definition I(0). The same holds for $\Delta y_{i,t-i}$. Obviously, if the y_t is I(1) so is y_{t-1}. So, this specification does not prevent by default from estimation problems. However, if $\{y_{it}\}_{t=1}^{T}$ and $\{y_{Nt}\}_{t=1}^{T}$ are co-integrated, i.e. there exists a vector (η_0, η_1) such that $y_{i,t-1} - \eta_0 + \eta_1 y_{N,t-1} = I(0)$, then the term Γy_{t-1} is also I(0) for the co-integrating vector (η_0, η_1). Such a relationship would usually result from the arbitrage occurring whenever the price differentials in country i and the neighbouring countries become too large. In practice (η_0, η_1) is not known, but it can be generally estimated from the data by maximum likelihood..

One issue with using VECMs is the reliance on non-stationary cointegrated data. Thus requirement is however not strict. In particular, Davidson and McKinnon (1993), Bannerjee et al. (1993), Keele and De Boef (2005) derive the Error Correction (ECM) Model from the Autoregressive Distributed Lags (ADL) Model. Since ADL models are stationary, the so has the EC model a many. In fact, Phillips (1957) introduced EC long before concepts of non-stationarity and cointegration were formally developed.

3.1.2.3 Data

The data used for this ECM is briefly described in Table 10.

Table 10: Exogenous variables for wholesale price natural gas and electricity – ECM model

Variables	Data source / file
Endogenous: Spot market prices electricity in t of country i	Source: stock exchanges, see Table 1 Data: daily Country: selected member states and their neighbouring countries Time period: 2009- 2015

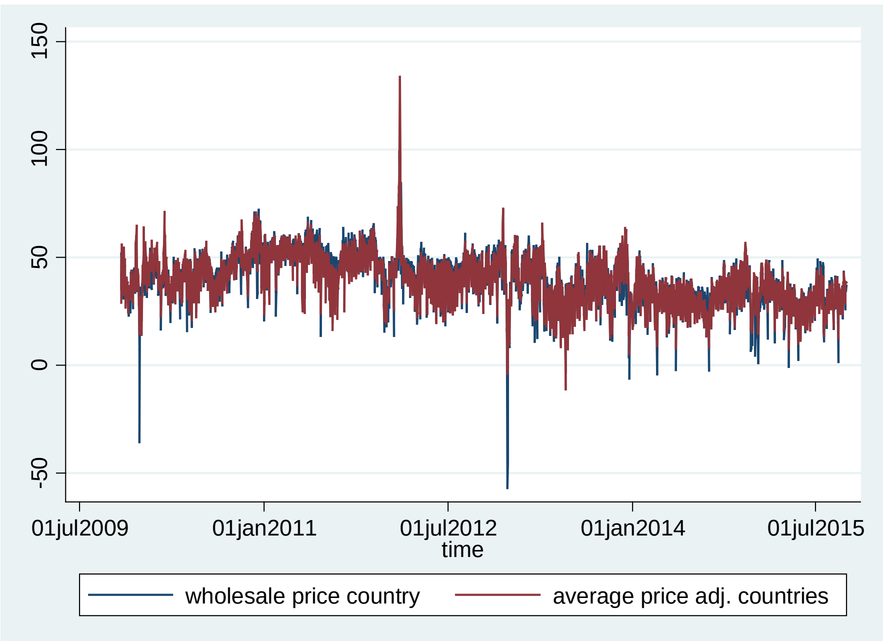
Exogenous: Spot market prices electricity in t-1 and t-2 of country i	Source see Table 1 Data: daily Country: selected member states Time period: 2009- 2015
Spot market prices electricity in years t-1 and t-2 of countries j	Source: see Table 1 Creation: daily weighted averages, per country and cross-country averages Country: neighbouring countries of selected member states Time period: 2009- 2015

3.1.2.4 General properties of the German and average price time series

3.1.2.4.1 The original time series

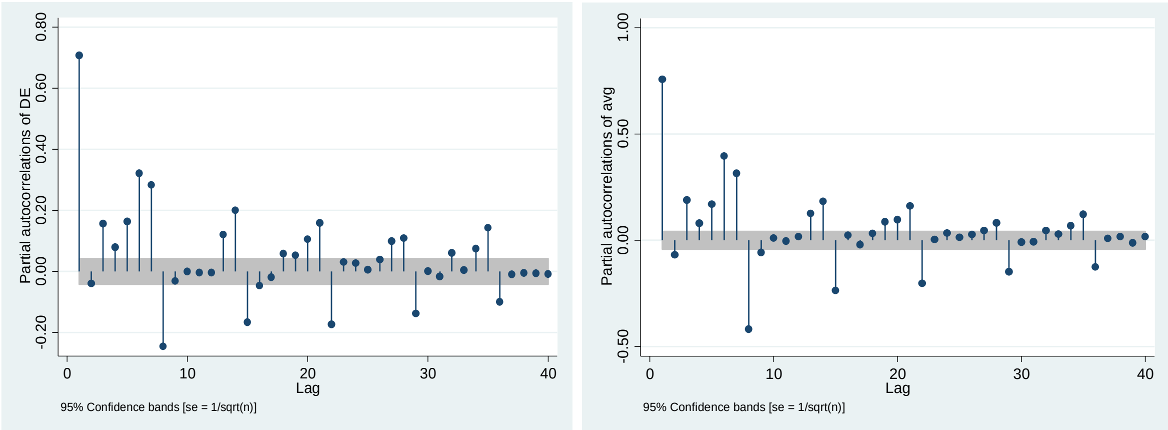
By plotting the two time series, we receive a first impression in particular as concerns stationarity. In fact, Figure 16 seems to show time series, which may over time follow slight trends but generally hover around an average value without systematically departing from it. Thus, the time series both for Germany and the average prices probably close to stationary. In fact, the Dickey-Fuller statistics confirm this result.

Figure 16: Daily wholesale prices (black) of Germany and the weighted average of wholesale prices of neigbouring countries (red)



To obtain an impression of the autoregressive order, we plot the partial autocorrelation function of the time series below.

Figure 17: PACFs for German prices (left) and average prices (right) of adjacent countries



From Figure 17 we can draw two conclusions. First, there is a strong weekly recurrent pattern in the partial autocorrelation function, which suggests that a considerable dependence of prices on the week days. Second, both time series display autoregressive terms that die out only very slowly. In fact, even after 40 periods there are still significant autoregressive terms. Formal tests (Table 11, Table 12) of the autoregressive order confirm that, where the tests suggest the inclusion of at least 35 lags for both the German and the average electricity prices.

Table 11: Autoregressive order Germany

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-8455.37				147.245	7.82998	7.83094	7.8326
1	-7702.56	1505.6	1	0.000	73.4036	7.13385	7.13577	7.13911
2	-7700.91	3.3059	1	0.069	73.3593	7.13325	7.13613	7.14113
3	-7674.07	53.663	1	0.000	71.6255	7.10933	7.11317	7.11984
4	-7667.04	14.065	1	0.000	71.2265	7.10374	7.10855	7.11689
5	-7637.53	59.016	1	0.000	69.371	7.07735	7.08311	7.09312
6	-7519.08	236.91	1	0.000	62.2223	6.96859	6.97532	6.98699
7	-7430.01	178.14	1	0.000	57.3498	6.88705	6.89474	6.90807
8	-7362.55	134.92	1	0.000	53.9269	6.82551	6.83416	6.84916
9	-7361.54	2.0159	1	0.156	53.9265	6.8255	6.83511	6.85179
10	-7361.53	.01195	1	0.913	53.9762	6.82642	6.837	6.85534
11	-7361.48	.10148	1	0.750	54.0237	6.8273	6.83884	6.85884
12	-7361.48	.0035	1	0.953	54.0736	6.82822	6.84072	6.8624
13	-7345.62	31.726	1	0.000	53.3346	6.81446	6.82792	6.85126
14	-7300.17	90.889	1	0.000	51.1843	6.77331	6.78773	6.81274
15	-7268.56	63.228	1	0.000	49.7538	6.74496	6.76035	6.78702
16	-7266.17	4.7727	1	0.029	49.69	6.74368	6.76002	6.78837
17	-7265.74	.87292	1	0.350	49.7159	6.7442	6.76151	6.79152
18	-7261.81	7.8588	1	0.005	49.5812	6.74149	6.75976	6.79143
19	-7259.02	5.5684	1	0.018	49.4994	6.73984	6.75907	6.79241
20	-7246.75	24.556	1	0.000	48.9852	6.72939	6.74958	6.7846
21	-7219.34	54.82	1	0.000	47.8019	6.70494	6.72609	6.76277
22	-7187.55	63.572	1	0.000	46.4585	6.67644	6.69855	6.73689
23	-7186.6	1.9044	1	0.168	46.4605	6.67648	6.69955	6.73957
24	-7185.76	1.674	1	0.196	46.4676	6.67663	6.70067	6.74235
25	-7185.76	.00856	1	0.926	46.5104	6.67755	6.70255	6.7459
26	-7184.26	2.9881	1	0.084	46.4892	6.67709	6.70305	6.74807
27	-7173.88	20.765	1	0.000	46.087	6.66841	6.69533	6.74201
28	-7161.46	24.842	1	0.000	45.6022	6.65783	6.68571	6.73406
29	-7140.82	41.269	1	0.000	44.7807	6.63965	6.66849	6.71851
30	-7140.81	.02694	1	0.870	44.8216	6.64057	6.67037	6.72205
31	-7140.62	.38174	1	0.537	44.8552	6.64131	6.67208	6.72543
32	-7136.77	7.6901	1	0.006	44.7372	6.63868	6.67041	6.72543
33	-7136.75	.05106	1	0.821	44.7776	6.63958	6.67227	6.72896
34	-7130.55	12.394	1	0.000	44.5627	6.63477	6.66842	6.72677
35	-7110.56	39.981	1	0.000	43.7859	6.61719	6.6518	6.71182
36	-7101.02	19.085*	1	0.000	43.441*	6.60928*	6.64485*	6.70654*
37	-7100.82	.40292	1	0.526	43.4731	6.61002	6.64655	6.7099
38	-7100.82	.00488	1	0.944	43.5133	6.61094	6.64844	6.71346
39	-7100.75	.12408	1	0.725	43.5511	6.61181	6.65027	6.71695
40	-7100.67	.16612	1	0.684	43.5881	6.61266	6.65208	6.72043

Table 12: Autoregressive order average prices

Sample: 01nov2009 - 30sep2015 Number of obs = 2160

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-8356.42				134.354	7.73836	7.73932	7.74098
1	-7439.88	1833.1	1	0.000	57.5555	6.89063	6.89255	6.89588
2	-7433.79	12.182	1	0.000	57.2849	6.88591	6.8888	6.8938
3	-7395.35	76.864	1	0.000	55.3334	6.85125	6.8551	6.86177
4	-7388.75	13.214	1	0.000	55.0469	6.84606	6.85087	6.85921
5	-7352.21	73.071	1	0.000	53.2652	6.81316	6.81893	6.82893
6	-7179.58	345.27	1	0.000	45.4386	6.65424	6.66097	6.67264
7	-7066.27	226.62	1	0.000	40.9509	6.55025	6.55794	6.57128
8	-6844.04	444.47	1	0.000	33.3656	6.3454	6.35406	6.36906
9	-6842.74	2.5869	1	0.108	33.3566	6.34513	6.35475	6.37142
10	-6842.53	.42726	1	0.513	33.3808	6.34586	6.35643	6.37477
11	-6842.44	.17965	1	0.672	33.409	6.3467	6.35824	6.37825
12	-6842.34	.20287	1	0.652	33.4368	6.34753	6.36003	6.38171
13	-6822.37	39.934	1	0.000	32.8547	6.32997	6.34343	6.36677
14	-6783.78	77.172	1	0.000	31.731	6.29517	6.30959	6.3346
15	-6730.95	105.67	1	0.000	30.244	6.24717	6.26256	6.28923
16	-6730.48	.93529	1	0.333	30.2589	6.24767	6.26401	6.29235
17	-6730.33	.30491	1	0.581	30.2826	6.24845	6.26576	6.29577
18	-6728.06	4.5427	1	0.033	30.247	6.24727	6.26554	6.29722
19	-6720.32	15.468	1	0.000	30.059	6.24104	6.26027	6.29361
20	-6707.3	26.044	1	0.000	29.7263	6.22991	6.2501	6.28511
21	-6680.3	53.999	1	0.000	29.0192	6.20583	6.22699	6.26366
22	-6637.34	85.914	1	0.000	27.9135	6.16698	6.1891	6.22744
23	-6637.14	.41658	1	0.519	27.9339	6.16772	6.19079	6.23081
24	-6636.22	1.8332	1	0.176	27.9361	6.1678	6.19183	6.23351
25	-6636.15	.1377	1	0.711	27.9602	6.16866	6.19365	6.237
26	-6635.79	.72818	1	0.393	27.9767	6.16925	6.1952	6.24022
27	-6629.89	11.798	1	0.001	27.85	6.16471	6.19163	6.23831
28	-6621.5	16.769	1	0.000	27.6603	6.15787	6.18575	6.2341
29	-6597.77	47.461	1	0.000	27.0842	6.13683	6.16567	6.21568
30	-6597.76	.03065	1	0.861	27.1089	6.13774	6.16754	6.21923
31	-6597.69	.13458	1	0.714	27.1323	6.1386	6.16937	6.22272
32	-6593.3	8.7767	1	0.003	27.0473	6.13546	6.16719	6.22221
33	-6592.59	1.4147	1	0.234	27.0547	6.13573	6.16842	6.22511
34	-6586.56	12.066	1	0.001	26.9289	6.13107	6.16472	6.22308
35	-6575.09	22.945	1	0.000	26.669	6.12138	6.15599	6.21601
36	-6561.4	27.376*	1	0.000	26.3576*	6.10963*	6.1452*	6.20689*
37	-6561.31	.17665	1	0.674	26.3798	6.11047	6.14701	6.21036
38	-6561.31	.00873	1	0.926	26.4042	6.1114	6.14889	6.21391
39	-6561.27	.08365	1	0.772	26.4276	6.11228	6.15074	6.21743
40	-6560.95	.64016	1	0.424	26.4443	6.11291	6.15233	6.22069

While it is technically possible to estimate models with 35 lags, this usually makes models highly instable and often numerically intractable. Indeed, the attempt to estimate an AR(35) model did not lead to convergence. Since, we are not genuinely interested in the recurrent patterns observable on different time scales, it seems natural to purge the original time series from such patterns, thereby removing the sources of the significant long-term partial autocorrelations. In the following we experiment both monthly patterns as a generalized measure of seasonal differences and with effects based on the day of the week.

3.1.2.4.2 The purged time series

Purging the time series either for month or week-day effects is performed by running a first step regression of the original time series either on month or week-day dummies and extracting the residuals. These residuals can be interpreted as time series which do no longer include such time recurrent patterns. The partial autocorrelation functions for each time series are plotted in Figure 18.

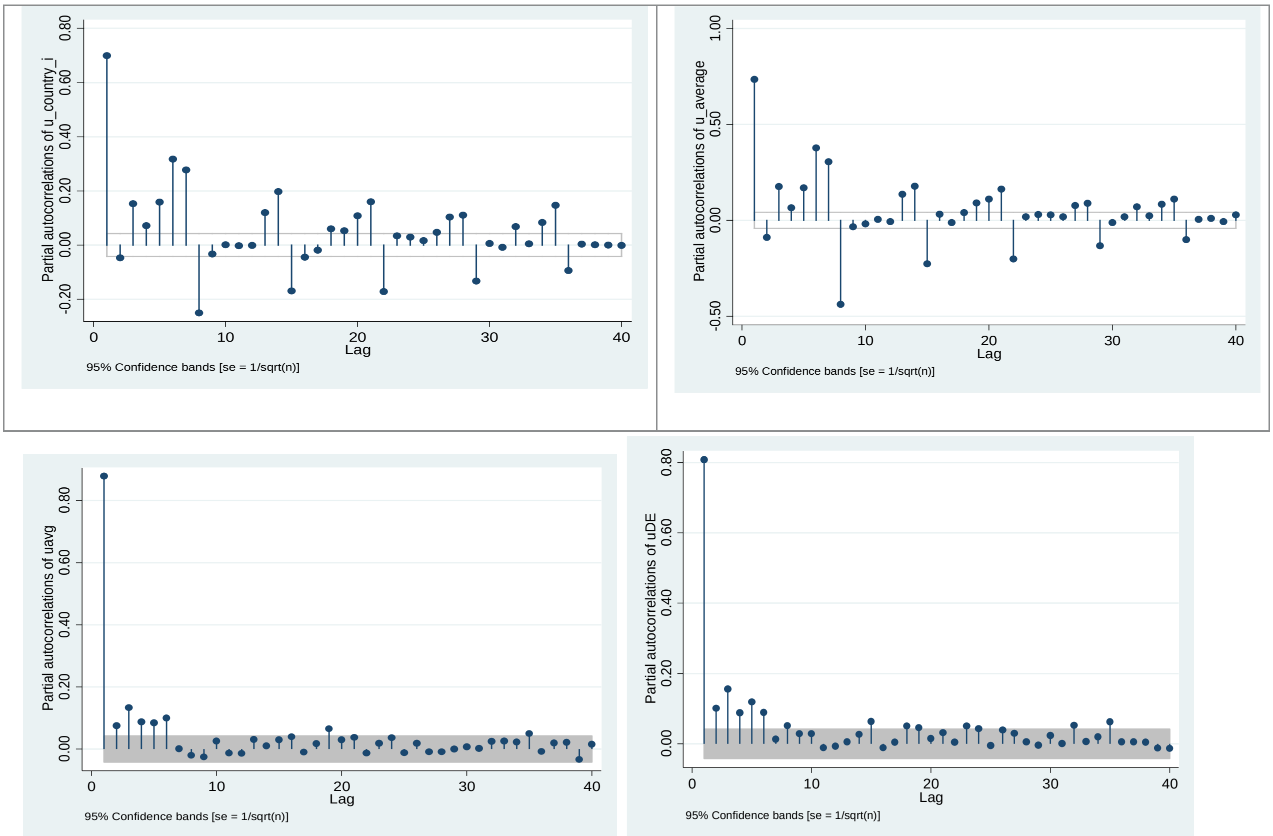


Figure 18: PACFs for German prices with removed month effects (top-left) removed week-day effects (bottom-left) and average prices with removed month-effects (top-right) and removed week-day effects (bottom-right)

The main conclusion is that removing month-effects does not lead to a time series with much lower autoregressive order. However, the purging of week-day effects largely removes partial autocorrelations of order higher than 6. This implies that week-day effects are almost completely responsible for the high number of significant autoregressive lags. Furthermore, the correlation between the original time series and the one rid of week-day effects is still 0.9. Thus, the largest part of the time variance is still incorporated in the weak-day controlled time series. This renders this time series the prime candidate for the further analyses on market integration, because on the one hand we are able to include the necessary number of autoregressive terms, while we still retain 90% of the variance of the original time series.

In order to test the hypothesis that six autoregressive lags are sufficient to describe the week-day purged time series, we perform formal tests of the significance of the autoregressive order (Table 13 and Table 14):

Table 13: Autoregressive order Germany

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-8186.8				117.692	7.60594	7.60691	7.60858
1	-7047.9	2277.8	1	0.000	40.896	6.54891	6.55084	6.55418
2	-7036.71	22.376	1	0.000	40.5107	6.53944	6.54234	6.54735
3	-7010.38	52.657	1	0.000	39.5687	6.51592	6.51977	6.52646
4	-7001.95	16.858	1	0.000	39.2966	6.50901	6.51384	6.52219
5	-6986.54	30.824	1	0.000	38.774	6.49563	6.50141	6.51144
6	-6977.83	17.415*	1	0.000	38.4974*	6.48847*	6.49522*	6.50692*
7	-6977.65	.36347	1	0.547	38.5266	6.48923	6.49694	6.51031

Table 14: Autoregressive order average prices

Sample: 08nov2009 - 30sep2015 Number of obs = 2153

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-8067.94				105.389	7.49553	7.4965	7.49817
1	-6496.83	3142.2	1	0.000	24.5111	6.037	6.03893	6.04228
2	-6492.54	8.5898	1	0.003	24.4362	6.03394	6.03684	6.04185
3	-6470.76	43.557	1	0.000	23.9691	6.01464	6.0185	6.02518
4	-6464.42	12.678	1	0.000	23.8505	6.00968	6.0145	6.02286
5	-6452.33	24.178	1	0.000	23.606	5.99938	6.00516	6.01519
6	-6443.93	16.809*	1	0.000	23.4442*	5.9925*	5.99925*	6.01095*
7	-6443.83	.20019	1	0.655	23.4638	5.99334	6.00105	6.01442

Indeed, Table 13 and Table 14 strongly confirm the results from the visual inspection that 6 autoregressive lags are sufficient.

In summary, the result so far suggest that the price time series are

- stationary
- have a high autoregressive order which
    - cannot be removed by cancelling out month effects,
    - but can be removed by cancelling out week-day effects

This suggests that the week-day purged time series can be adequately described by an AR(6) model. The original time series and the one with removed month-effects would require the inclusion of a much higher number of autoregressive terms, which is usually infeasible due to problems in numerical optimization.

In order to test the adequacy of the AR(6) model we estimate this model by maximum likelihood and test the assumption that the resulting model errors are white noise. Remaining autocorrelation in the errors would hint at some type of model misspecification (Table 15).

Table 15: AR(6) models for original time series (1,2), with removed month-effects (3,4), and removed week-day effects (5,6)

	(1)	(2)	(3)	(4)	(5)	(6)
	wholesale price country	average price adj. countries	wholesale price country; week day effects corrected	average price adj. countries; week effects corrected	wholesale price country; week day effects corrected	average price adj. countries; week day effects corrected
Constant	40.1919***	40.4550***	-0.0736	-0.0894	-0.0212	-0.0396
	(26.91)	(24.91)	(-0.05)	(-0.06)	(-0.01)	(-0.03)
ARMA						
L.ar	0.6638***	0.7281***	0.6662***	0.7292***	0.6755***	0.7799***
	(45.01)	(42.34)	(45.07)	(41.96)	(59.37)	(63.46)
L2.ar	-0.1461***	-0.2046***	-0.1492***	-0.2084***	-0.0226	-0.0539***
	(-7.28)	(-8.01)	(-7.41)	(-8.11)	(-1.46)	(-2.95)
L3.ar	0.0827***	0.0997***	0.0837***	0.0992***	0.0856***	0.0774***
	(3.27)	(4.01)	(3.32)	(3.97)	(3.61)	(3.09)
L4.ar	0.0103	0.0179	0.0078	0.0174	0.0073	-0.0034
	(0.38)	(0.66)	(0.29)	(0.64)	(0.28)	(-0.13)
L5.ar	-0.0664**	-0.1263***	-0.0680***	-0.1308***	0.0575**	0.0359
	(-2.56)	(-4.37)	(-2.62)	(-4.54)	(2.41)	(1.57)
L6.ar	0.3218***	0.3854***	0.3167***	0.3790***	0.0896***	0.0882***
	(17.61)	(20.93)	(17.13)	(20.65)	(4.44)	(5.87)
sigma						
Constant	7.8610***	6.7166***	7.8617***	6.7192***	6.1801***	4.8331***
	(139.50)	(90.22)	(139.36)	(89.87)	(193.72)	(122.69)
Observations	2160	2160	2160	2160	2160	2160
Portmanteau test	1548.85***	2780.94***	1568.31***	3718.57***	51.45	55.90**
D-Fuller	-19.188***	-17.306***	-19.547***	-18.125***	-15.142***	-11.965

t statistics in parentheses   * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

All time series are stationary as indicated by the strongly significant DF-statistics. Furthermore, for all models based either on the original time series or the time series with removed month effects, there remains considerable autocorrelation in the residuals as indicated by the extremely significant Portmanteau tests. This implies that the AR(6) model is misspecified for these time series. If however, week-effects are removed, the AR(6) model leads to residuals that appear to be approximately white noise. In fact, there is no evidence of non-white noise behaviour for the German time series at the 10%, while there may be some indication of non-white noise behaviour of the average price time series at the at most 5%-level. This residual autocorrelation could be removed via the inclusion of MA-terms. However, the subsequent ECM analysis does not easily lend itself to the inclusion of such moving average terms. We therefore do not explore this possibility further and rather consider the AR(6) specification as good enough. This decision is backed by the large drop of the Portmanteau statistic implied by models (5) and (6) as compared to (1)-(4).

3.1.2.5 Results of the ECM

3.1.2.6 Summary of correlation and descriptive analysis

The approach is tested for the case of Germany and its surrounding neighbours. The results for the ECM model are shown in Table 16 and Table 17. In the first of the two tables we do not include the any further lags for the time series of German prices. As already argued that model is equivalent to the ADL(1,1) model, which operates on stationary data. In the second set of model we include the also longer lags, which our previous analysis suggests is necessary. In all models we that there is a relatively high degree of price convergence, where price divergence of one unit as compared to the equilibrium relationship leads to price reduction of above 0.60 unit is Germany's prices in the next period.

By splitting the total sample (left column) into an early period until end of 2011 (middle column) and late period thereafter, we obtain reasonable comparable coefficients in Table 16., implying that the rate of price convergence did not change. However, if we include lags the coefficient drops from -0.6295 in the first period to -0.7904 in the second. This suggests that market integration measured by price convergence was stronger in later periods.[1] Although not formally tested, this may be one reason for the overall declining trend in prices since 2011.

Table 16: ECM for Germany (only German equation)

	Total period _i	2009-2011	2012-2015
L.u (error correction term)	-0.6325***	-0.6177***	-0.6362***
	(-31.56)	(-18.74)	(-25.33)
D.u_average	0.9533***	0.7346***	1.0356***
	(34.87)	(15.35)	(31.31)
Constant	25.4513***	24.9542***	25.5534***
	(31.10)	(18.48)	(24.97)
Long-term coefficients			
L.Price Germany	1	1	1
	--	--	--
L.Price EU average	-0.9089***	-0.8431***	-0.8879
	(57.98)	(25.61)	(42.34)

[1] The intuition for this interpretation is as follows: the error correction term measures by how much prices in Germany are above the prices in the neighbouring states. Thus a positive error-correction term implies excess prices in Germany. Price convergence in the next period therefore occurs if the coefficient on the error-correction term is negative (which is the case in our results). Furthermore, a full one-period price convergence is achieved if the coefficient is exactly -1, because then a positive price differential is completely eliminated. In this respect, the closer the coefficient on the error-correction term is to -1, the faster is the price convergence.

Constant	-0.0000	-1.1622***	-0.5075**
	(0.00)	(3.44)	(-2.37)
Observations	2159	790	1368

Table 17: ECM for Germany (only German equation) with Lags[2]

	Total period _i	2009-2011	2012-2015
L.u (error correction term)	-0.7170***	-0.6295***	-0.7904***
	(-24.02)	(-12.63)	(-20.45)
D.u_average	0.9363***	0.7312***	1.0167***
	(35.35)	(15.64)	(31.93)
LD.u_country_i	0.1341***	0.0886**	0.1770***
	(6.01)	(2.15)	(6.49)
L2D.u_country_i	-0.0293	-0.0980**	0.0215
	(-1.43)	(-2.56)	(0.87)
L3D.u_country_i	-0.0393**	-0.0777**	-0.0096
	(-2.09)	(-2.21)	(-0.43)
L4D.u_country_i	-0.0788***	-0.1156***	-0.0489**
	(-4.67)	(-3.70)	(-2.43)
L5D.u_country_i	-0.2066***	-0.2543***	-0.1750***
	(-12.92)	(-8.74)	(-9.17)
Constant	28.8482***	25.4190***	31.7423***
	(23.88)	(12.56)	(20.34)
Long-term coefficients			
L.Price Germany	1	1	1
	--	--	--
L.Price EU average	-0.9089***	-0.8431***	-0.8879
	(57.98)	(25.61)	(42.34)
Constant	-0.0000	-1.1622***	-0.5075**
	(0.00)	(3.44)	(-2.37)
Observations	2154	785	1368

*t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$*

Sigma convergence

So far we have tested whether price differentials between a country and its neighbours are quickly reduced by arbitrage. We have found evidence in most of the cases. Another perspective on convergence is whether the standard deviations between the prices are reduced, implying that they converge to common level. To test this, for each country we calculate the time series of the standard deviations of price for each observation time between the focal country and its neighbours and

[2] Note that the long-term coefficients in Table 16 and 17 are identical because they result from the same first-stage OLS regression.

analyse how it has developed over time. To get a first impression, we plot the level of the monthly averaged prices of Germany and its neighbours (Figure 19).

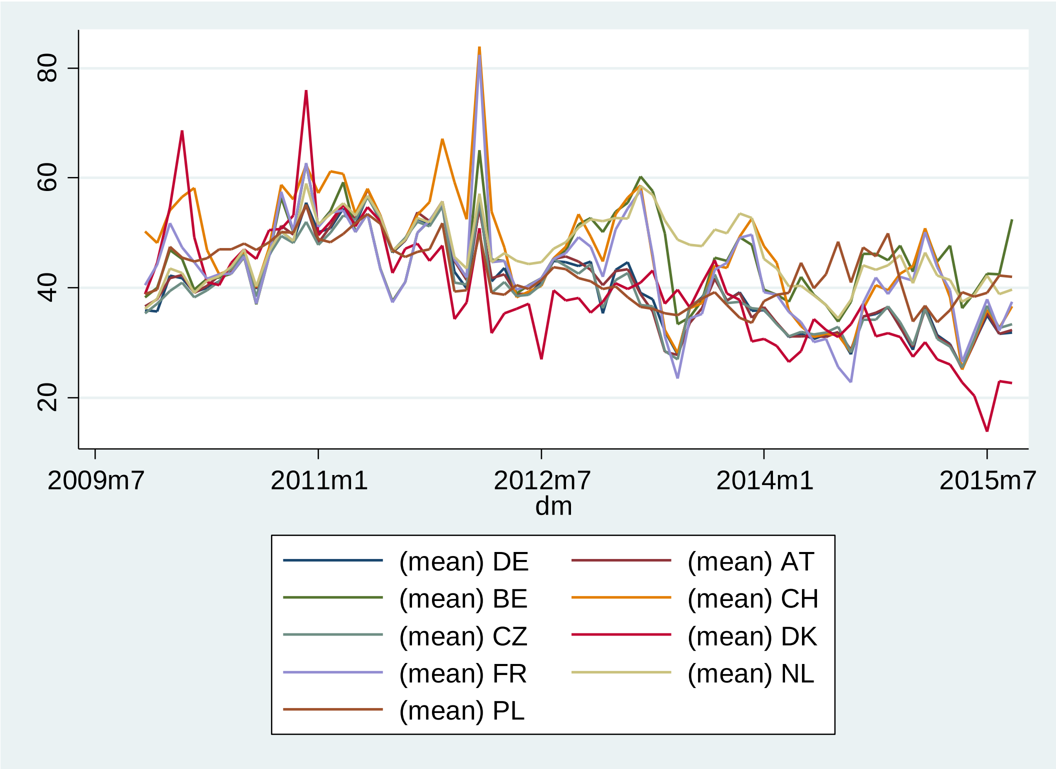


Figure 19: Monthly averaged prices of Germany and its neighbours

Indeed, there appears to be a trend towards a common price level at the beginning of 2010, which lasted, with some periodical interruptions until the beginning of 2012. However, in particular since mid of 2012 we observe a process of divergence. Thus, although the price levels have generally declined, most strongly in Denmark, there is little sign of convergence towards a uniform price.

A formal test of these impressions can be based on a regression approach taking the daily electricity price standard deviation as the dependent variable, the year dummies as key explanatory variables (Table 18). If convergence occurs, later year dummies would have a statistically significant coefficient. Analysis of the time series of the electricity price standard deviation suggests that it is stationary (Dickey-Fuller test: -29.32; critical value at p=0.01: -3.43). Plots of the ACF and PACF as well as formal tests suggest that the time series can be appropriately described by an AR(7) process, which is corroborated by the Portmanteau statistic not being significant.

Table 18: AR(7) with daily electricity price standard deviations, Germany

	(2)
	std_price
main	

jahr== 2009	-2.3911
	(-1.44)
jahr== 2010	-2.9947***
	(-3.08)
jahr== 2011	-3.0715***
	(-3.00)
jahr== 2012	-1.8703*
	(-1.69)
jahr== 2013	-0.1944
	(-0.19)
jahr== 2014	-1.9104
	(-1.38)
Constant	8.1098***
	(10.33)
ARMA	
L.ar	0.2849***
	(27.56)
L2.ar	0.1022***
	(6.31)
L3.ar	0.0592**
	(2.11)
L4.ar	0.0440
	(1.32)
L5.ar	0.0181
	(0.64)
L6.ar	0.0683**
	(2.57)
L7.ar	0.0876***
	(5.80)
sigma	
Constant	4.1343***
	(286.26)
Observations	2160
Portmanteau test	29.94
D-Fuller	-29.326***

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In general, the results strongly corroborate the findings from the plot of monthly average prices. The standard deviations between the daily prices where lowest in 2010 and 2011 (and marginally lower in 2012). After that period the prices diverged again.

Overall, price differences of day ahead prices (windows of arbitrage) between countries e.g. Germany and its neighbour countries disappeared faster in recent years (2012-2015) than earlier (before 2012), but the analysis of the variance of prices shows a different picture. After a convergence around 2011, they show an increasing spread afterwards. This indicates that the development of the internal market has had an effect of equalising prices while at the same time more extreme prices occurred within countries, which increased the spread, for example negative prices due to increasing renewable shares together with different regulations regarding negative prices, increasing the spread. Even so the results show at least a beta convergence, it fails to explain the reasons for this convergence and whether there is a convergence of prices at the retail level, i.e. changes in wholesale prices are passed through. A central question remains- how are retail prices evolving and why are they evolving the way they do. Therefore, the development of wholesale prices over time is depicted in the following for several regions, but no detailed econometric analysis on price convergence will be conducted. Instead the focus of the analysis is on retail prices.

3.1.3 Movement of monthly averaged prices of selected regions

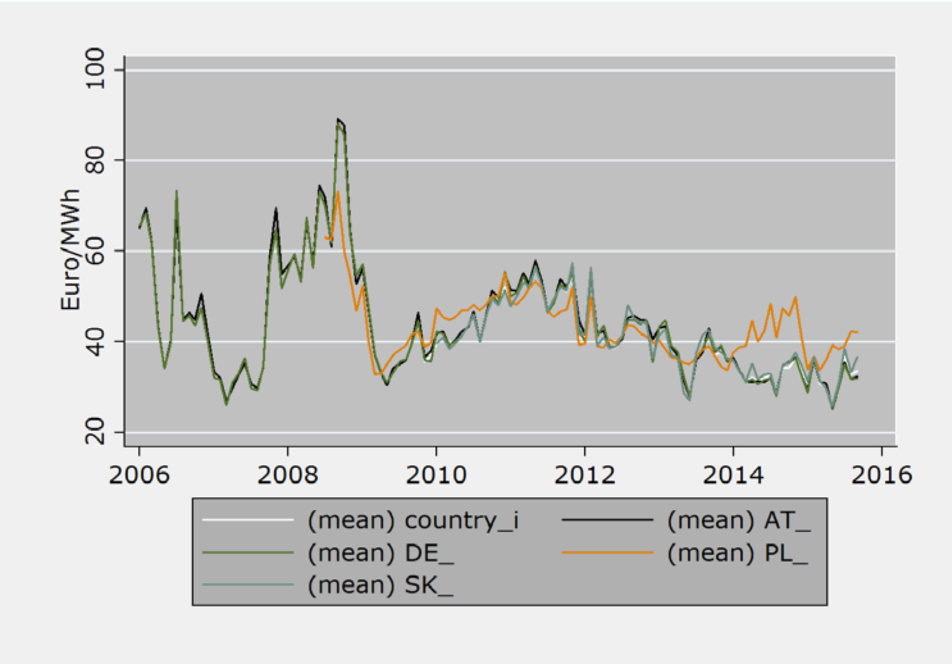


Figure 20: Monthly averaged prices of CZ and its neighhours

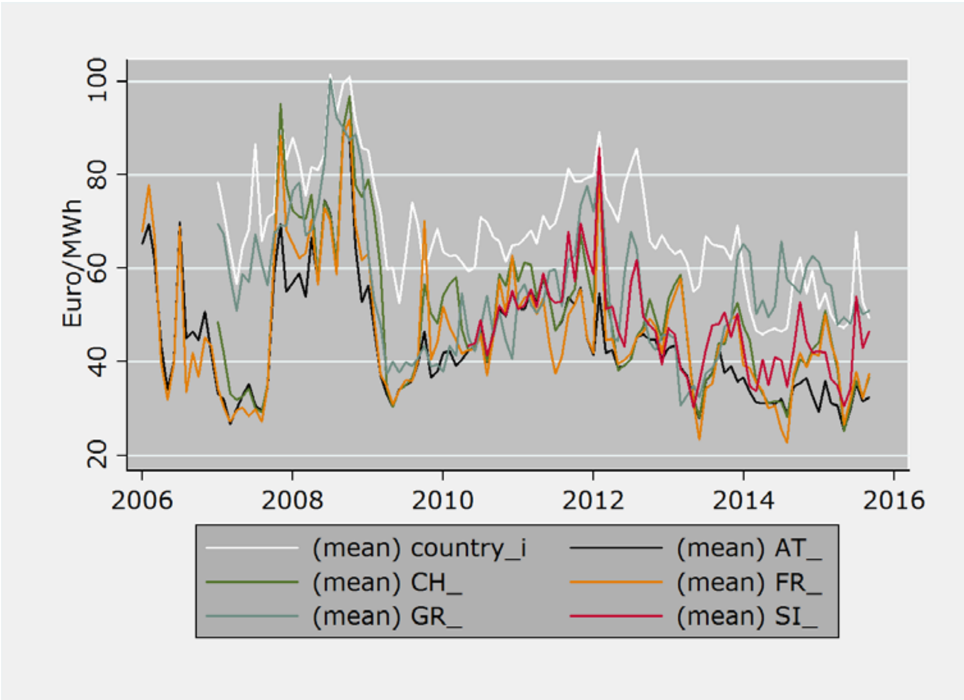


Figure 21: Monthly averaged prices of IT and its neighhours

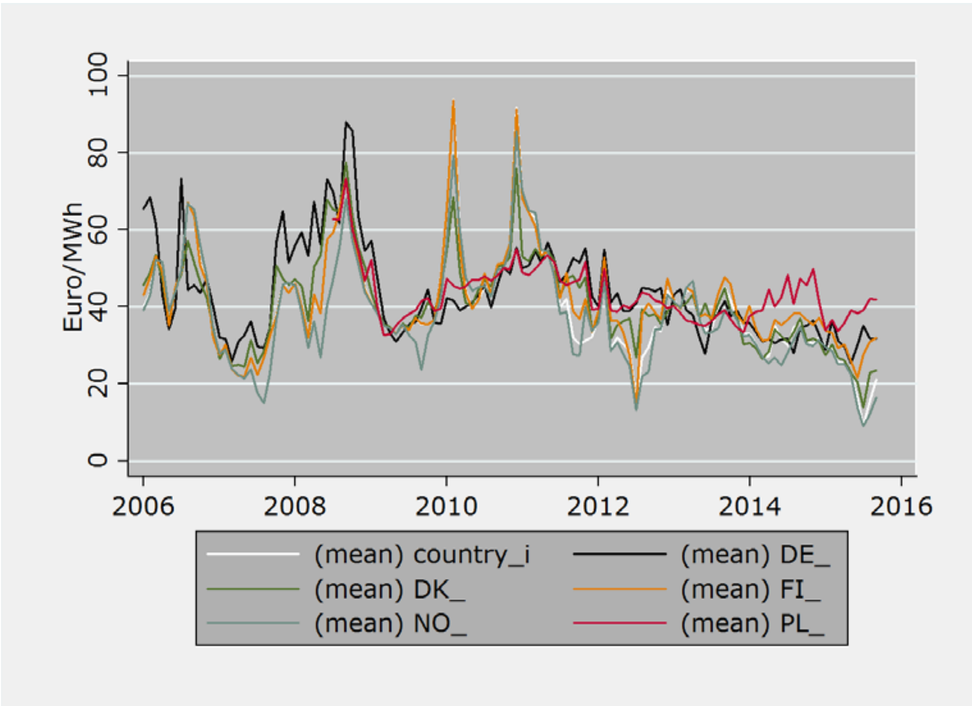


Figure 22: Monthly averaged prices of SE and its neighhours

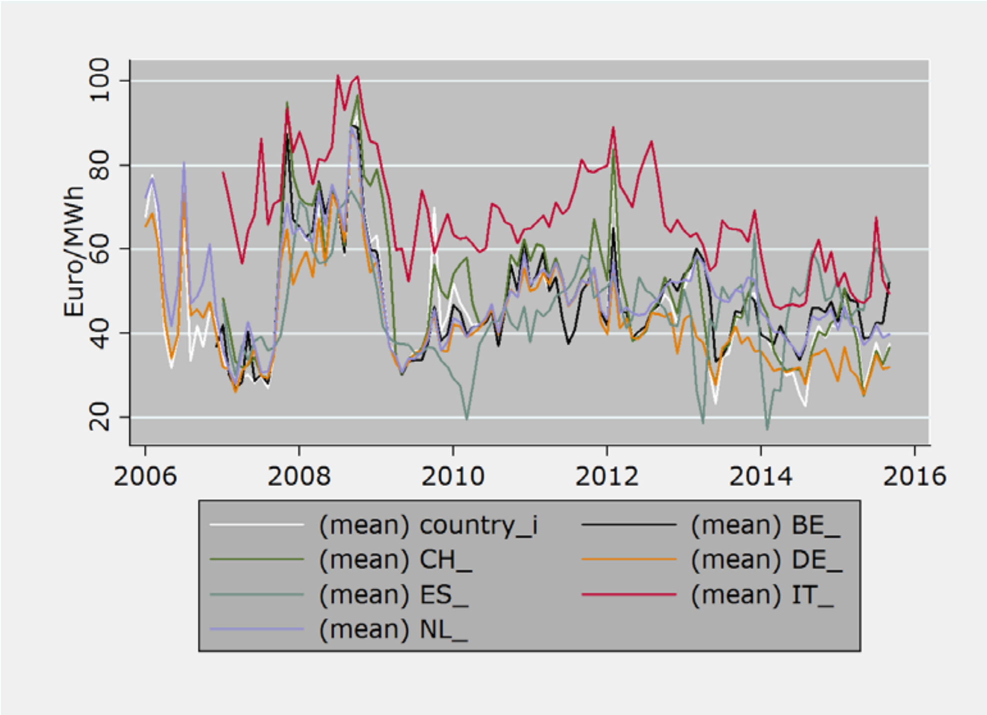


Figure 23: Monthly averaged prices of FR and its neighhours

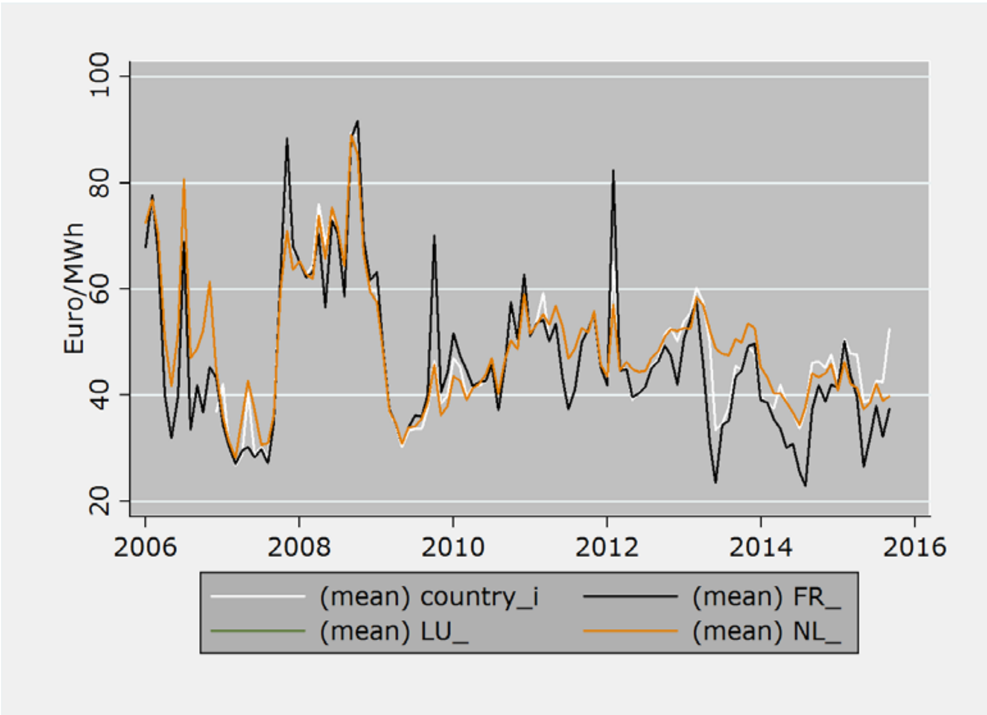


Figure 24: Monthly averaged prices of BE and its neighhours

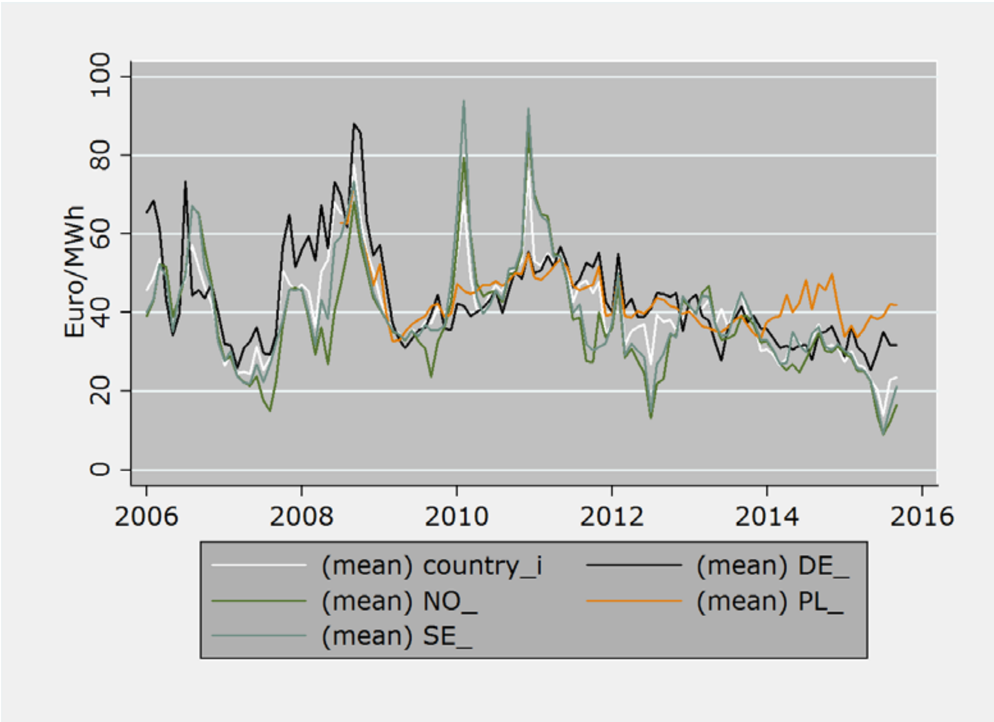


Figure 25: Monthly averaged prices of DK and its neighhours

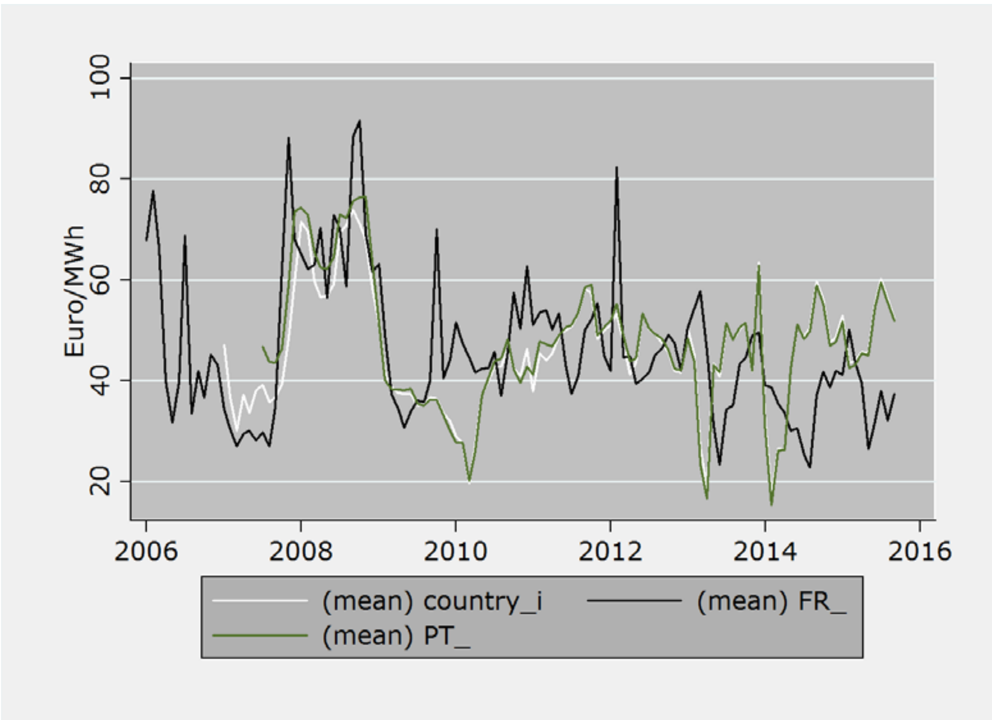


Figure 26: Monthly averaged prices of ES and its neighhours

3.2 Drivers of the energy component - Econometric analysis of composition and drivers of energy retail prices

3.2.1 Introduction

In this section, we look at the factors affecting retail prices and the energy retail price component. What ultimately matters for consumers is what they are spending on energy. Thus the retail price of energy is key when looking at impacts on welfare of households and competitiveness of industries. Therefore it is of great interest in this part of the analysis to understand which impacts have market liberalisation and energy policies on the retail price. As the energy retail price, here electricity retail price consists of three main components, the energy, network fees, taxes and levies. While taxes and levies are price components directly set by regulation and governments, and network fees mainly by infrastructure costs, the price of the energy component is driven by wholesale prices in combination with the degree of market liberalisation.

The objective of this section is to show how the retail price components have evolved over time, and analyse which factors drive the energy component. This includes to analyse how strongly wholesale prices affect energy and what the role is of market liberalisation or competition.

The monthly data on retail prices for the econometric analysis are from VaasaETT and DG ENER (Eurostat based data). The latter database is compiled by DG ENER, which used biannual data and monthly electricity price indices to derive monthly data. The data, which the descriptive part of the analysis partly relies on, are derived from an ad-hoc statistical data collection organised by DG Energy with the help of ESTAT and national statistical institutes. Data from Eurostat and the adhoc data collection are differentiated into electricity consumption bands DC (electricity household annual consumption between 2 500 and 5 000 kW) and IB and ID (electricity industrial annual consumption between 20-70 GWh), while data from VaasaETT only include household prices from capital cities.

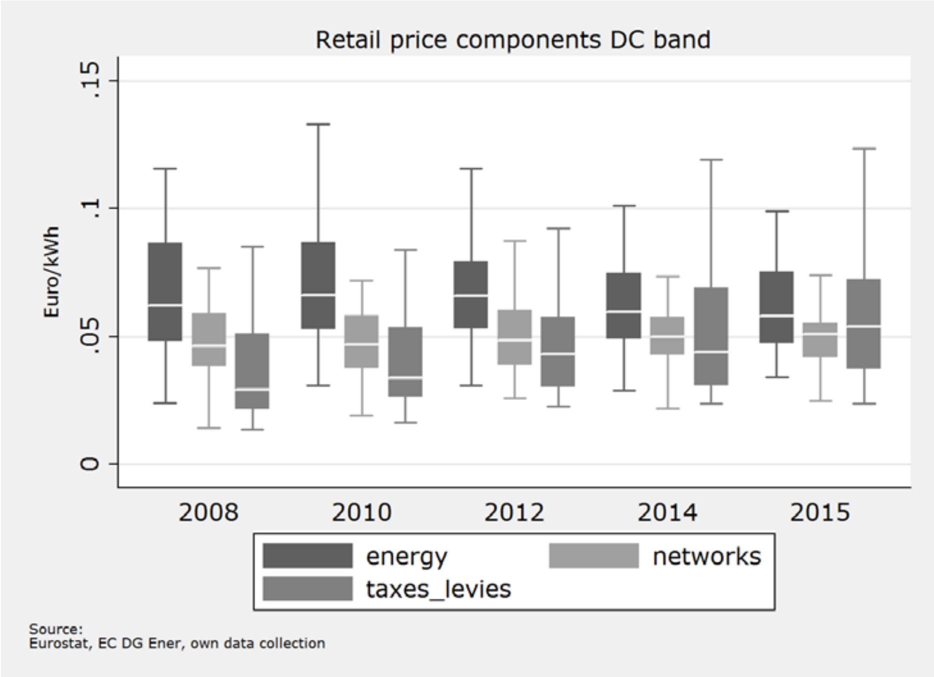


Figure 27, Figure 28 and Figure 29 depict the evolution of the retail price components of the adhoc data base by selected years and consumption bands DC (households), IB and ID (industry). The vertical lines below and above the boxes show the minimum and maximum values of the components, the boxes the range between the 25^{th} - 75^{th} percentiles (second and third quartiles), the line in the boxes shows the median. It becomes obvious that

- Energy component is the lowest for the ID band, while Households pay little more than the industry of consumption band IB. Compared to households (peak load), industries often display a very different consumption pattern (base load) and have special procurement contracts with lower prices than households.
- The spread of the energy component is lowest in the ID band, underpinning the assumption that large consumers can exert market power.
- Network fees are lowest in the ID band and highest for households (DC) because industry has access to higher voltage and require higher capacity levels than households.
- Network fees remain at a relatively low level compared to the other two components.
- The spread of network fees is small for all consumption levels suggesting that infrastructure costs are more homogenous than the other two components.
- Taxes and levies increase over time and become the largest component for households and industries at the consumption band IB.
- The spread in taxes and levies is also increasing indicating that the member states apply a bundle of different charges or schemes.

Overall, the main drivers of the retail electricity price are taxes and levies. They have replaced the energy component as main driver of the retail price. Given that both network fees and taxes and levies, as it is described above, depend on conditions which lie beyond energy market developments, the analysis focuses on the energy component, i.e. the wholesale prices as main factors driving this component as well as the market liberalisaiton which allows to which degree wholesale prices are passed through to the retail prices.

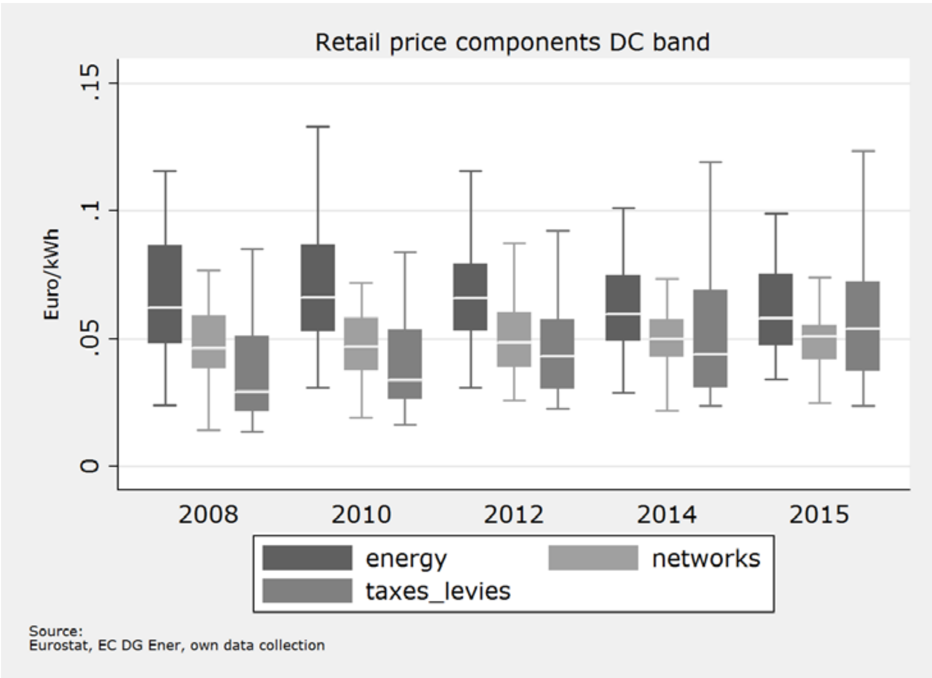


Figure 27: EU distribution and evolution of retail price components energy, network, taxes and levies between 2008 and 2015 (EU (28) plus NO, electricity CD band Euro/kWh

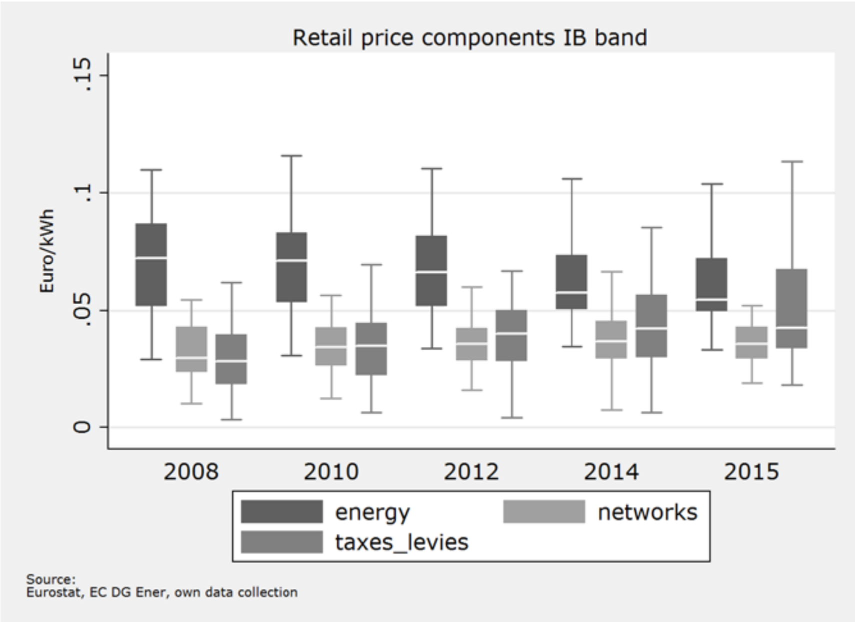


Figure 28: EU distribution and evolution of retail price components energy, network, taxes and levies between 2008 and 2015 (EU (28) plus NO, electricity IB band Euro/kWh

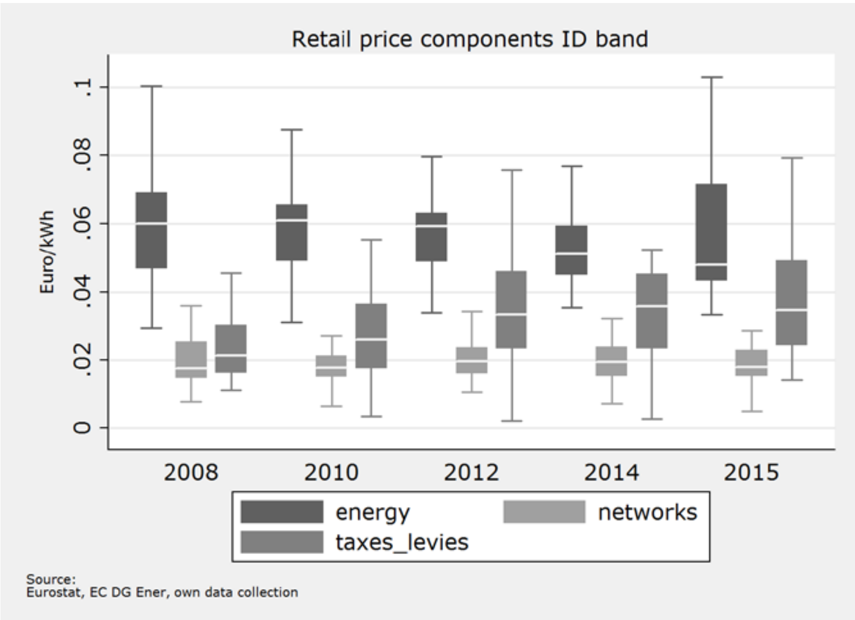


Figure 29: EU distribution and evolution of retail price components energy, network, taxes and levies between 2008 and 2015 (EU (28) plus NO, electricity ID band Euro/kWh

3.2.2 Methodology

The main objective of this section of the study is the estimation of the size and speed of the pass-through effect between the wholesale and retail markets for electricity in the EU. To assess this, a panel analysis based on fixed and random effects is conducted (linear specification, selection of random vs fixed effects estimator via a standard Hausman test). This analysis allows incorporating time variant variables and country specific characteristics. In addition a correlation with lagged wholesale prices is conducted and the evolution of wholesale price and energy price component is depicted.

Even the taxes and levies affect retail prices through demand elasticities (Chouinard and Perloff 2007), they are not included here. Similarly, the grid fee is not included. To capture the potential effects of market liberalisation (e.g. Swadley and Yücel 2011), the years in logarithmic form since market opening, the market shares of the largest suppliers and market regulation are included, but data on these are available on an annual basis only.

3.2.3 Data

The focus of the analysis is on the energy component. We analyse the drivers in different energy bands, electricity consumption band CD, IB and ID of Eurostat data. Data from Eurostat are available on a biannual basis but were adjusted with monthly electricity price indices by DG ENER to monthly prices. In addition prices paid by households in capital cities are available from VaasaETT. The correlation of the energy price component between these two data sets is 0.9. Finally, the adhoc data collection of the price components provides detailed data on diverse components but only every two years.

The analysis is conducted on monthly prices. The exogenous variables are listed in Table 19. In principle, a panel of 30 countries and eight years (2008- 2015) would allow for a sufficiently large sample but limitations of data on market characteristics or the fact that some countries introduced wholesale markets later than 2008 or retail price are not available, etc. reduces the number of observations in the analysis.

To account for the heterogeneity of the member states' retail market groups of MS are formed based on the year of market liberalisation and on market price coupling. To see how long it takes until price changes at the wholesale market are passed through to the energy component, correlations between the energy component and different lagged wholesale prices are calculated

The variables are depicted in Table 19, the sources are depicted in Table 1.

Table 19: Variables used to analyse drivers in the retail electricity market

Variables	Description	Available Data
Retail price component energy and supply	Endogenous energy supply, monthly data	Ad-hoc data collection, covering household and industrial consumer bands for electricity and natural gas; 2008 2010, 2012, 2014, 2015, Eurostat data monthly data derived from biannual data VaasaETT data, monthly, only for households
Wholesale price	Exogenous base load prices, monthly	See Task 1.1
Liberalisation	Years since free choices for consumers, annual, included as dummy f	ACER MMR 2015
Regulation	Years since free price setting (deregulation) for suppliers, annual, included as dummy	ACER MMR 2015, CEER
Competition	Share of top 3 suppliers, annual; included as dummy (share ><80%)	ACER MMR 2015, CEER
Heating and cooling degree days	To account for demand	See task 1.1
Exchange rate index	To account for changes in domestic currency to euro	See task 1.1
Growth rate index	To account for changes due to growth	See task 1.1

3.2.4 Results households

In economic theory a measure for competition is the closeness of realised prices to marginal costs. If we assume the wholesale prices to reflect the marginal costs and the energy component as the realised price, we can see how competition has evolved over time. The difference between the energy component and the wholesale prices is depicted in Figure 30. However, this difference includes besides the profit margin further cost such as marketing expenditures. The difference is called magin. Margin 1 depicts the differences between the energy component derived from Eurostat data and wholesale prices, margin 2 from VaasaETT and wholesale prices. Both margins show a slight decreases and increases over time and a rather constant spread across countries. In contrast to the adhod database which has detailed data on all energy price components, the database of Eurostat and VaasaETT isn't that distinct and hence might mix up components. Based on this development, competition in the retail market has not changed much over time. Given this uncertainty on price components, no econometric analysis of the margin is conducted. However, the development of wholesale price and energy price components is depicted per country in chapter 3.2.4.2.

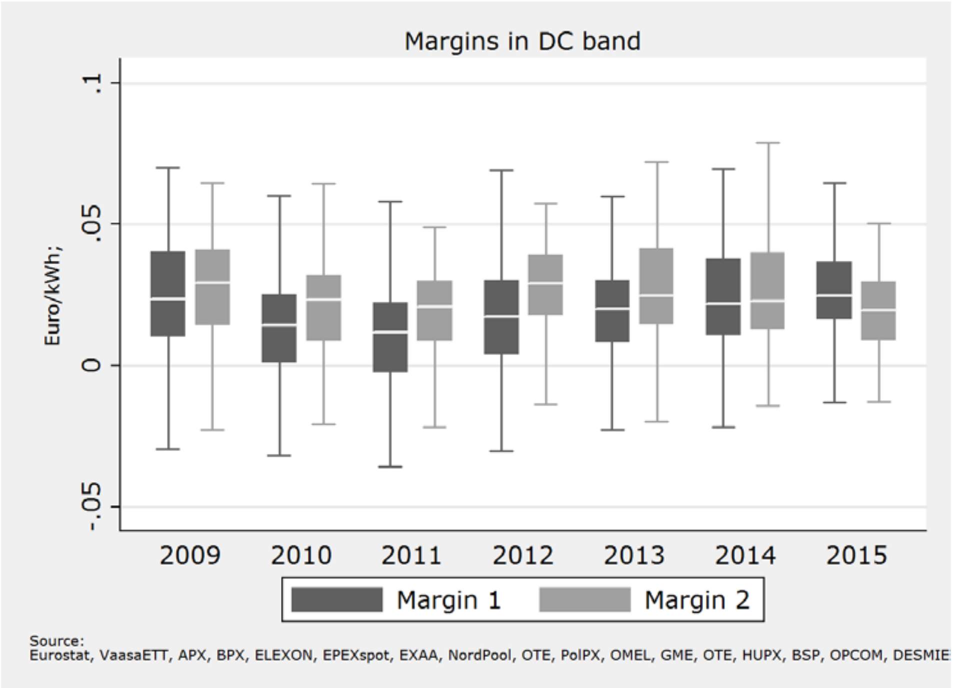


Figure 30: Margins between 2008 and 2015 (EU (28) plus NO, electricity ID band Euro/kWh

To address the question how quickly energy price components adjust to changes in wholesale prices, correlations between the retail price component and the wholesale price with different lags is conducted (see Chapter 3.2.6.2). The time lag between the energy component (Eurostat and VaasaETT) and wholesale price is at the EU level zero to two time periods (months) and the correlation is in general rather low (0.3). However, at country level this differs: High correlations with zero to one lag display Norway and Slovenia (correlation between 0.7 and 0.8), and Sweden (0.6 and 0.7), while Italy and Netherlands (0.6-0.7) have up to eight lags. Estonia displays a high correlation (0.7-0.8) with one/three lags. Between 0.5 and 0.6 is Hungary with four lags and Austria with zero lag, Czech Republic with one/eight lags and Denmark with one/four lag. Negative correlations are displayed by Germany with two/eight lags and France with eight lags. All others show rather low correlation values. This heterogeneous picture can be explained by the fact, that in some countries, prices are still regulated, in others not; in some countries prices are fixed for a given time period, in others they are indexed to the wholesale market. In case of fixed prices, the average monthly prices rely on old and new contracts, the latter reflecting current changes at the wholesale market. Therefore, the speed of passing-through depends on very specific market and tariff designs of the retail markets for which no comprehensive data are available. For example in some countries the prices are regulated for all or a certain share of customers, in other countries the market is open, and fixed or flexible tariffs are offered. Especially the latter allow a quick adjustment to the wholesale price development. Therefore regulation and its effect is difficult to capture.

The results of econometric analysis at EU level shows some drivers: wholesale prices lagged by one month are significant and an increase in one Eurocent (per kWh) pushes in the short run the energy price component up by 0.05 Eurocents per kWh (Eurostat) or 0.09 Eurocents per kWh (VaasaETT) in average (see Table 20). The coefficient is relatively small, as wholesale costs account for a large share of the energy price component. This result points to one major challenge of the overall analysis: the diversity in pricing mechanism, competition and regulation. First, some prices are for all or certain customer still regulated in some countries, such that wholesale prices are not passed-on through the market. Second, is some countries the degree of concentration is still very high, which could entail either a slow pass-through of price drops or larger margins than in more competitive markets or both. Third, in some cases - within the same country - retail prices could be fixed for one or two years, in others they are indexed to wholesale prices, or a combined mechanism is applied. Therefore, in the short-run changes in the wholesale price cannot be fully passed on to end user prices. This effect is enforced by the data on retail electricity prices (Eurostat), as they are averages. Heating and cooling degree days as well as the growth index (demand) display very small values signalling no impact on the energy component. Certainly other factors such as capacity markets, ancillary services and regulatory measures are potential cost drivers, but monthly and country specific data on these factors have not been compiled in the framework of this study.

When including a dummy for market liberalisation, the dummy is ignored since it is rather time invariant within the observed time period, while market opening as logarithmic value (number of years since market opening) is only significant with VaasaETT prices, but the coefficient is very small. Differentiating between regions leads to similar results apart from the wholesale price, whose coefficient slightly changes. All other coefficients are very small, and hence, have no impact even if they are significant. Moreover, the R square is small for most of the regional analyses as well.

Table 20: Regression results FE estimators for retail prices, Eurostat and VaasaETT data

	FE Eurostat energy component	FE Eurostat energy component	FE VaasaETT energy component	RE VaasaETT energy component
Wholesale price lagged 1 month	0.053^{***}	0.052^{***}	0.091^{***}	0.091^{***}
	(2.78)	(2.75)	(3.80)	(3.80)
Cooling degree days	0.001^{*}	0.001^{**}	0.000	0.000
	(1.94)	(2.00)	(0.44)	(0.65)
Heating degree days	0.000	0.000^{*}	0.000	0.000
	(1.63)	(1.67)	(0.15)	(0.23)
Exchange rate index	-0.000	-0.000	-0.001^{***}	-0.001^{***}
	(-1.50)	(-1.43)	(-6.68)	(-6.30)
Growth index	0.001^{***}	0.001^{***}	-0.001^{***}	-0.000^{***}
	(7.59)	(11.25)	(-6.04)	(-5.54)
Years since market liberalization (ln)	0.001		0.005^{***}	
	(0.51)		(3.29)	
Market liberalisation (dummy)		(.)		(.)
		(.)		(.)
Constant	0.014	0.010	0.241^{***}	0.213^{***}
	(0.90)	(0.75)	(9.50)	(9.37)
Observations	1268	1268	950	950
Within R^2	0.141	0.141	0.078	0.067

between R^2	0.351	0.362	0.345	0.314
overall R^2	0.249	0.264	0.159	0.142

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ Note: logarithm of years is based on positive values beginning with 1., all other variables are not in logarithm.

3.2.4.1 Market conditions

To address the question whether retail energy prices differ by market regulation, liberalisation and the degree of competition, prices under liberalized and non-liberalized, regulated and deregulated, competitive and concentrated markets are compared.

Market liberalisation offered the opportunity for new players to enter markets through acquisition of existing companies or through establishing own new companies/subsidiaries. More actors and different actors compete for customers such that prices are set under a competitive environment, margins are reduced and the number of products and product differentiations increase. However, a first step is the opening of market for new market players, here called market liberalisation. How prices are set is captured by the feature “regulation”. Data on market opening are derived from the ACER MMR 2015 report.

In case of a price **regulation**, prices offered to customers are subject to regulation or control by a public authority, e.g. government or national regulation authorities and are not determined by demand and supply. In most of the countries, either, price cap, revenue cap or rate of return is applied as regulation mechanism. Given the variety in mechanisms and concerned customers, regulation is not a uniquely defined criteria. But nevertheless it is assumed that regulation might limit competition by inhibiting market entry when prices are set below a certain threshold and hence hinder competing markets and prices in the long run. Challenging is the fact that the share of customer, the type of regulated customer and the type of regulation differ substantially across the member states. Data are based on the ACER MMR 2015 and previous reports as well as on data of CEER and DG ENER. If more than 50% of customers are supplied under regulated prices, then the country is said to be regulated. For 2015 regulation is assumed to similar to 2014 if no further information were available. The frequency of the analysis is monthly, while regulation data are available on an annual basis only. Therefore the estimates might be biased. As information is missing to which extend regulation is still applied for industrial customers, the analysis refers to households only.

Finally, according to economic theory the **degree of competition** is strongly related to pricing. Under polypolistic competition, profits or margins are assumed to be zero and prices are low. Similarly, competitive duopolistic markets are highly competitive, while rather monopolistic structures benefit from monopoly rents. To capture competition it is assumed that the market share of the three largest market suppliers above 80% reflects a rather concentrated market with reduced competition, while shares equal or below 80% are assumed to be competitive markets. Data and additional information are derived from CEER and ACER MMR 2015 and previous reports. For missing data in 2015 it is assumed that shares are quite similar to 2014.

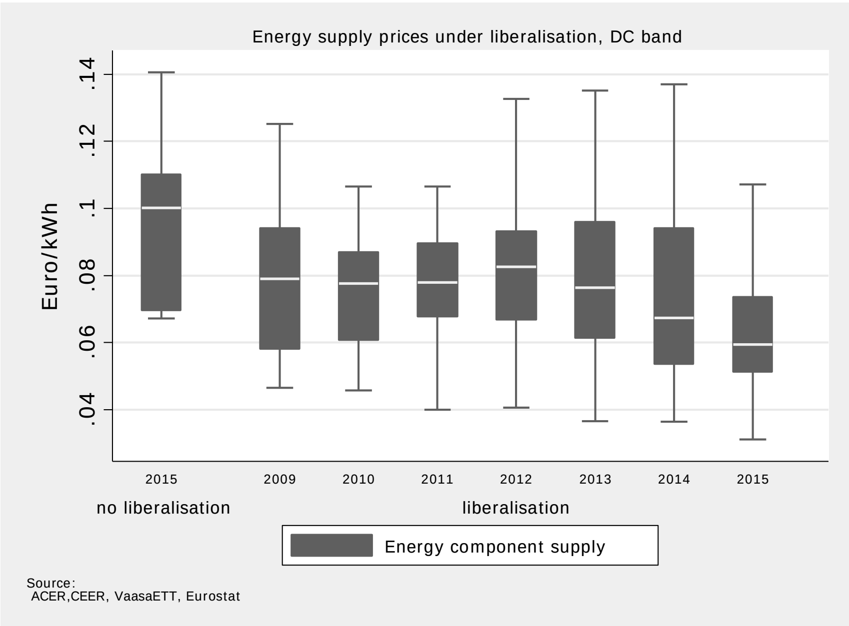


Figure 31: Energy component by status of market liberalisation, 2008 - 2015 (EU (28) plus NO, electricity DC band Euro/kWh

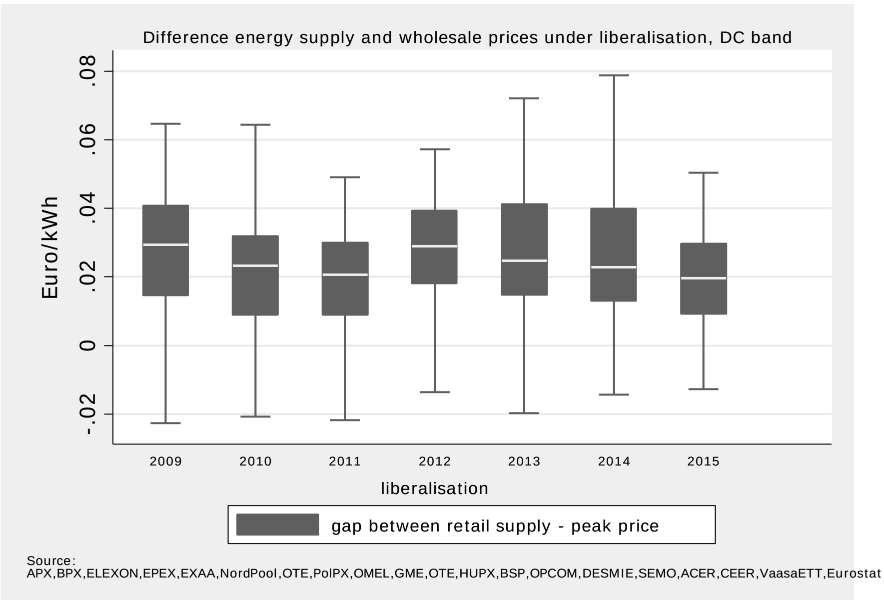


Figure 32: Difference between energy and wholesale prices by status of market liberalisation, 2008 - 2015 (EU (28) plus NO, electricity DC band Euro/kWh

In many countries market has been opened before the time period under investigation. In addition availability of market price data coincidences with market opening, therefore for many countries data on prices before market opening (liberalisation) are only available for 2015. Subsequently, energy price components and differences between retail energy component and wholesale prices could differ before and after market liberalisation, but cannot be captured (see Figure 31 for prices and Figure 32 for margins).

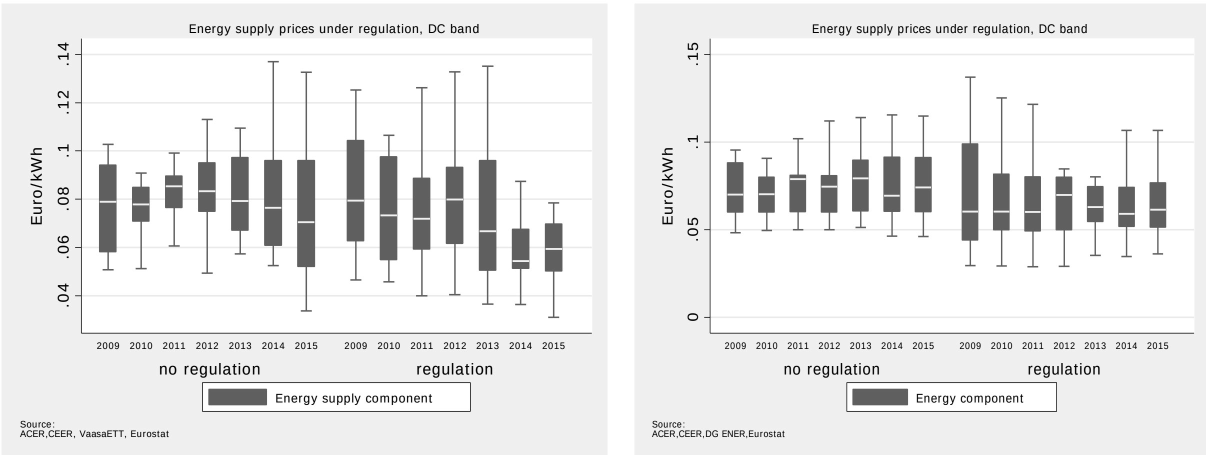


Figure 33: Energy component by status of market regulation; with VaasaETT data (left) and Eurostat data (right), 2008 - 2015 (EU (28) plus NO, electricity DC band Euro/kWh

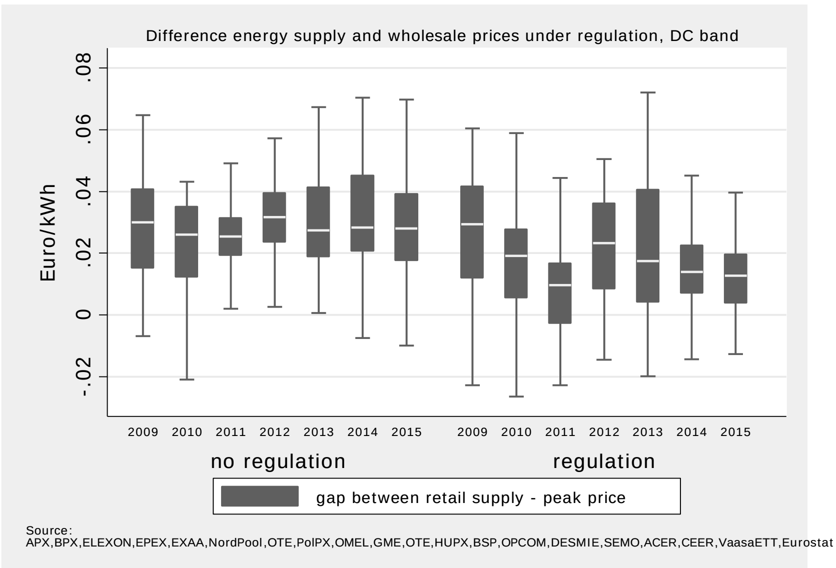
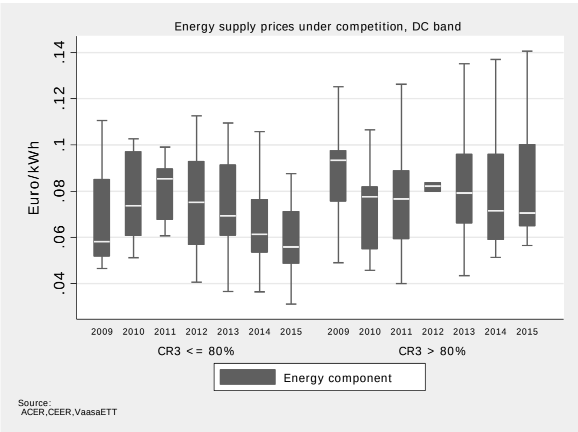


Figure 34: Difference between energy component and wholesale prices by status of market regulation, 2008 - 2015 (EU (28) plus NO, electricity DC band Euro/kWh

In regulated markets a public authority determines or influences retail market prices. Therefore, regulation or deregulation could have different impacts on retail prices. As Figure 33 shows, prices in a regulated market seem to be lower, while they were higher in 2009 and some other years with the VaasaETT database. Regarding the differences between energy component and wholesale prices, they seem to be larger under deregulation (Figure 34). This could be explained by the fact, that there is no regulator in deregulated markets, who would compensate losses caused by setting retail prices too low. Overall the average price across countries and years in regulated markets is about 0.8 Eurocents lower than in deregulated markets. The econometric analysis reports that the impact of wholesale prices in deregulated markets is significant while the dummy for regulation is not (Table 21). It is important to note here that the reported R-squared is rather low for all of the models, which suggests that the parameters covered by the available data do not include all major factors.

Regarding competition, both databases (VaasaETT and Eurostat/DG ENER) show in recent years lower prices under competition while in 2010 and 2011 the relation is reversed. The differences between retail energy and wholesale prices depict a similar picture. The average price between these two groups is about one Eurocents lower under competition than in highly concentrated markets. Econometric results show that wholesale prices have a more significant and stronger impact on prices under competition than under concentrated markets while the dummy is insignificant (Table 22). Again, the reported R-squared is rather low indicating that some important factors cannot be covered within the model.



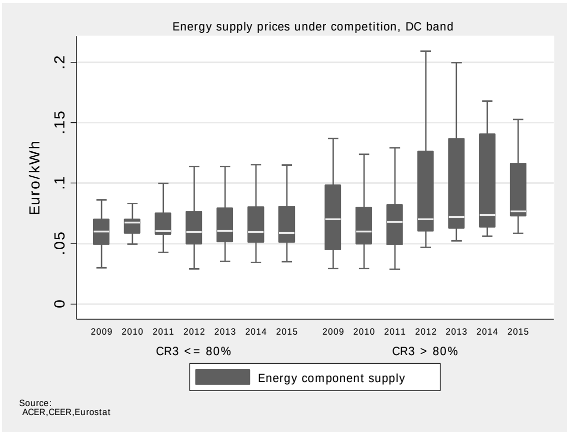
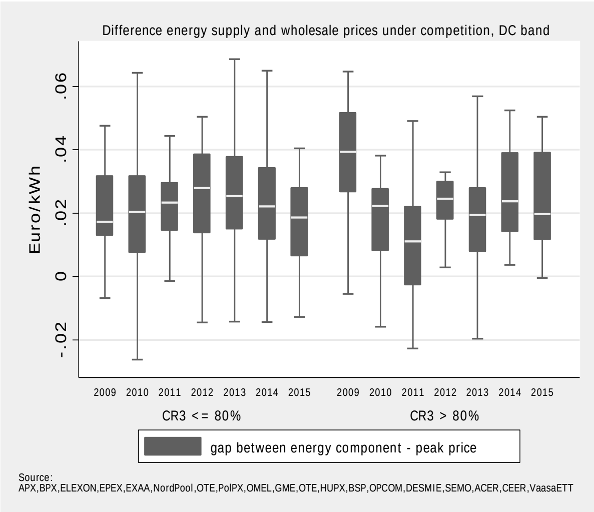


Figure 35: Energy component by degree of competition, VaasaETT data and DG ENER (Eurostat based) data, 2008 - 2015 (EU (28) plus NO, electricity DC band Euro/kWh



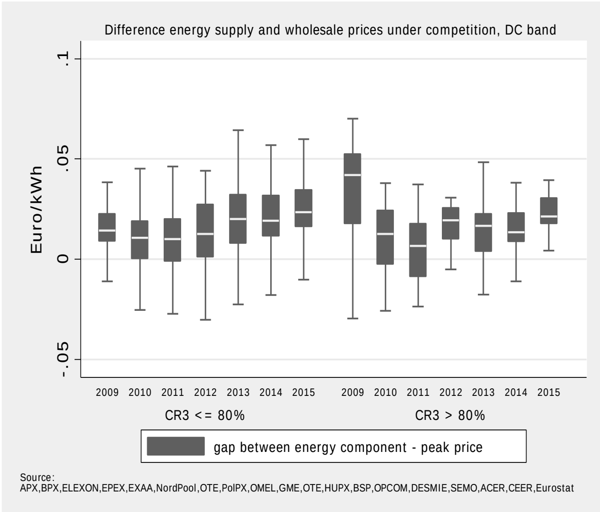


Figure 36: Difference between energy component and wholesale prices by degree of competition, VaasaETT data and DG ENER (Eurostat based) data, 2008 - 2015 (EU (28) plus NO, electricity DC band Euro/kWh

Table 21: Regression results FE estimator for retail prices by regulation, , VaasaETT data

	FE all observations; Hausman: Prob(0.10)	RE	FE deregulated	RE regulated
Number of countries	19	19	11	11
Wholesale price lagged 1 month	0.090***	0.092***	0.185***	-0.002
	(3.72)	(3.84)	(6.26)	(-0.06)
Cooling degree days	0.000	0.000	0.000	0.000
	(0.32)	(0.90)	(1.20)	(1.12)
Heating degree days	0.000	0.000	0.001	0.000
	(0.65)	(0.57)	(0.68)	(0.37)
Exchange rate index	-0.001***	-0.001***	-0.001***	-0.001**
	(-5.88)	(-6.31)	(-3.75)	(-2.42)
Growth index	-0.000***	-0.001***	-0.000*	-0.001***
	(-5.02)	(-5.56)	(-1.78)	(-4.63)
Dummy regulation	0.001	0.001		
	(0.55)	(0.73)		
Constant	0.212***	0.212***	0.149***	0.279***
	(8.83)	(9.40)	(5.75)	(5.07)
Observations	950	950	518	432
Within R2	0.067	0.067	0.123	0.060
Between R2	0.315	0.323	0.257	0.400
Overall R2	0.147	0.154	0.159	0.135

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 22: Regression results FE estimator for retail prices by competition (CR3 equal or below 80%),, VaasaETT data

	FE	RE	RE	RE
	Hausman: Prob(0.11)		competition	No competition
Number of countries	18	18	16	7
Wholesale price lagged 1 month	0.100***	0.104***	0.219***	-0.082*
	(4.16)	(4.31)	(9.11)	(-1.68)
Heating degree days	0.000	-0.000	0.000	-0.000
	(0.02)	(-0.04)	(0.18)	(-0.17)
Cooling degree days	0.000	0.000	0.001	-0.000
	(0.33)	(0.37)	(1.46)	(-0.40)
Exchange rate index	-0.001***	-0.001***	-0.001***	-0.001
	(-7.29)	(-7.44)	(-5.65)	(-0.87)
Growth index	-0.001***	-0.001***	-0.000***	-0.001***
	(-6.94)	(-7.22)	(-3.58)	(-4.67)
Dummy competition	-0.000	-0.000		
	(-0.37)	(-0.34)		
Constant	0.262***	0.253***	0.171***	0.277***
	(10.36)	(10.66)	(7.45)	(3.13)
Observations	869	869	560	309
Within R2	0.108	0.109	0.224	0.083
Between R2	0.282	0.292	0.275	0.051
Overall R2	0.138	0.143	0.284	0.000

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Overall this analysis conveys three significant messages: First, under deregulated and competitive markets, the WS price has a stronger impact than under regulated and less competitive markets. Second, the speed of pass through is difficult to capture, because of the heterogeneity of tariffs offered (indexed, fixed over a year, partly regulated such that the market mechanism is not working). Third, further factors, in particular market specific (customer and supplier specific) factors affect prices, which are not captured by the exogenous variables applied.

3.2.4.2 The gap between wholesale price and retail energy component per country consumption Band DC

The following figures depict the evolution of the wholesale price (peak load) in comparison to the retail price component supply. The latter is based on VaasaETT data (household prices) and plotted without a lag. The gap between these two prices indicates about the potential margins, in non regulated markets the level of retail price competition, in regulated market the potential gains/losses for energy suppliers. The illustrations suggest low margins in Denmark, Finland and Sweden, which points to a strong market competition, while in France the margin seems to be negative, suggesting some price regulation. The figures also highlight that WS price is only one factor out of others explaining RT prices.

Figure 37: Electricity wholesale prices and retail supply component, DC band Euro/kWh

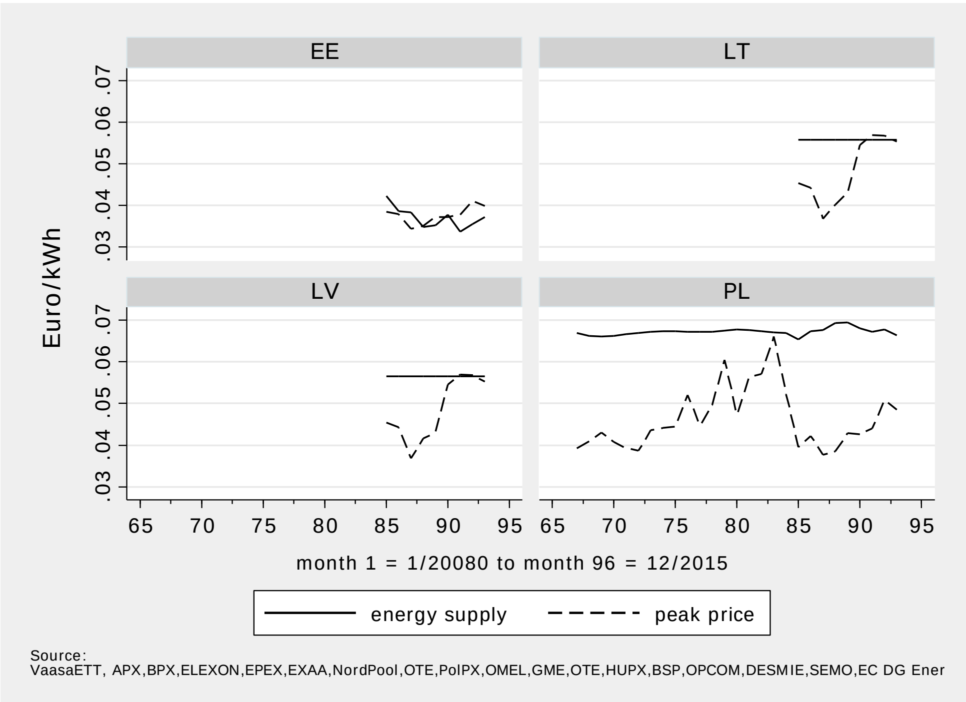


Figure 38: Electricity wholesale prices and retail supply component in LT, PL, LV and EE, DC band Euro/kWh

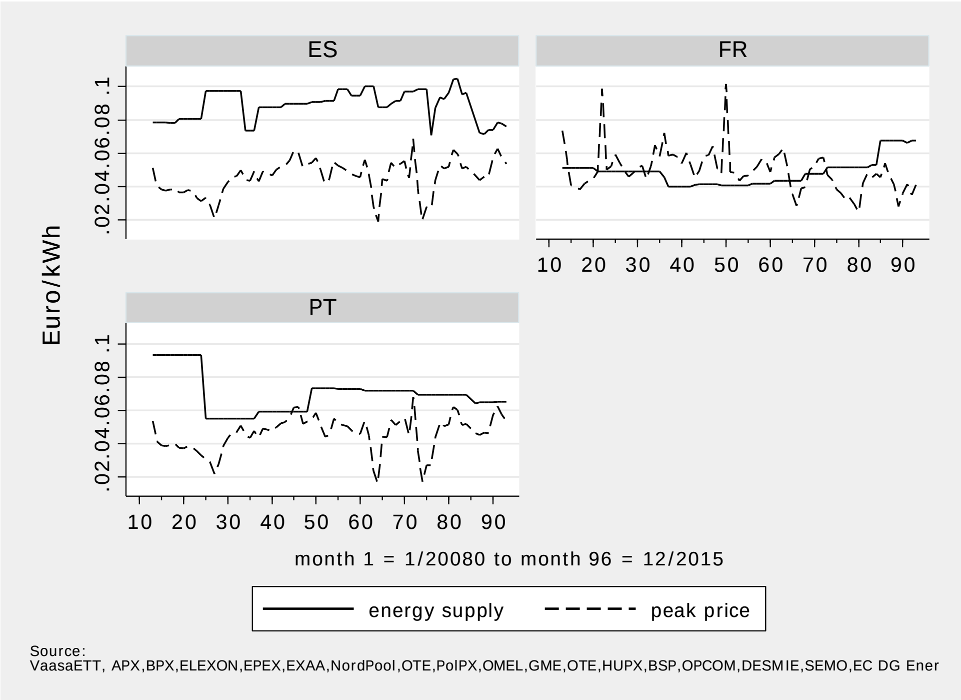


Figure 39: Electricity wholesale prices and retail supply component in ES, FR, PT, DC band Euro/kWh

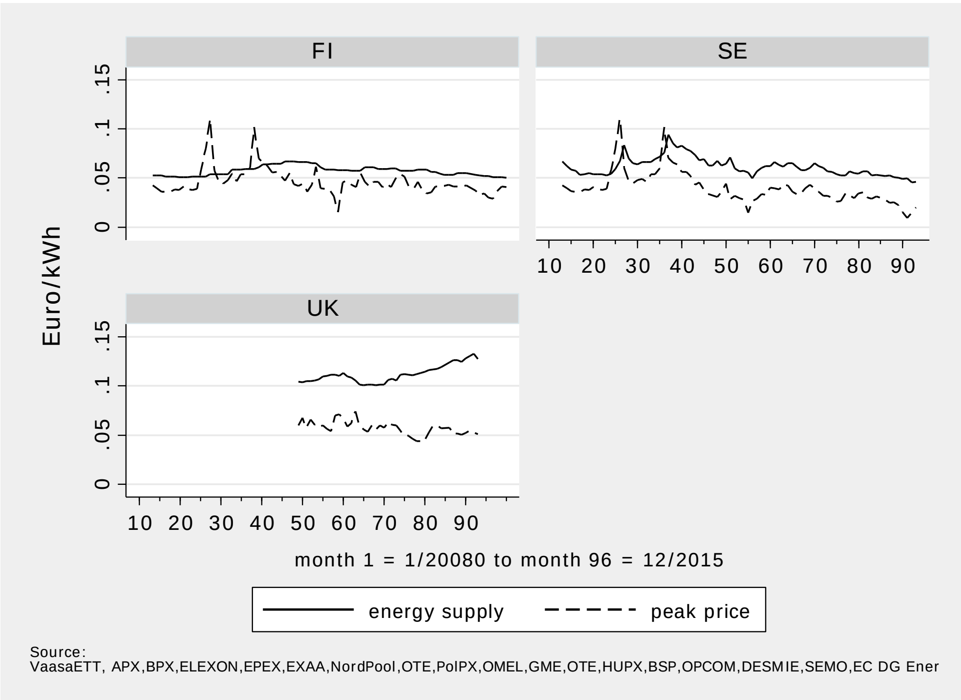


Figure 40: Electricity wholesale prices and retail supply component in FI, SE, UK, DC band Euro/kWh

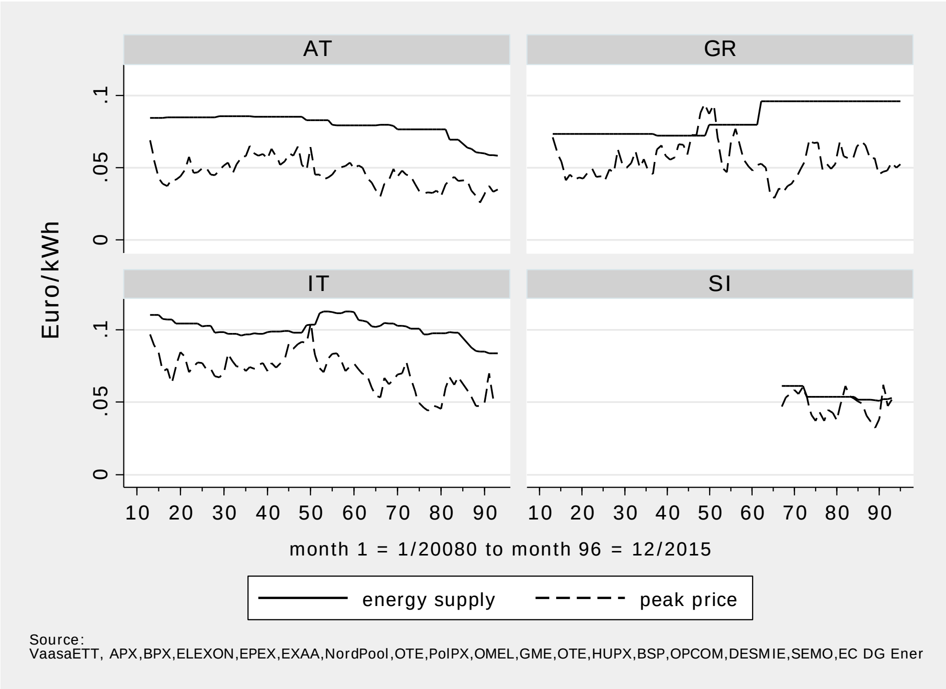


Figure 41: Electricity wholesale prices and retail supply component for AT, IT, GR and SI, DC band Euro/kWh

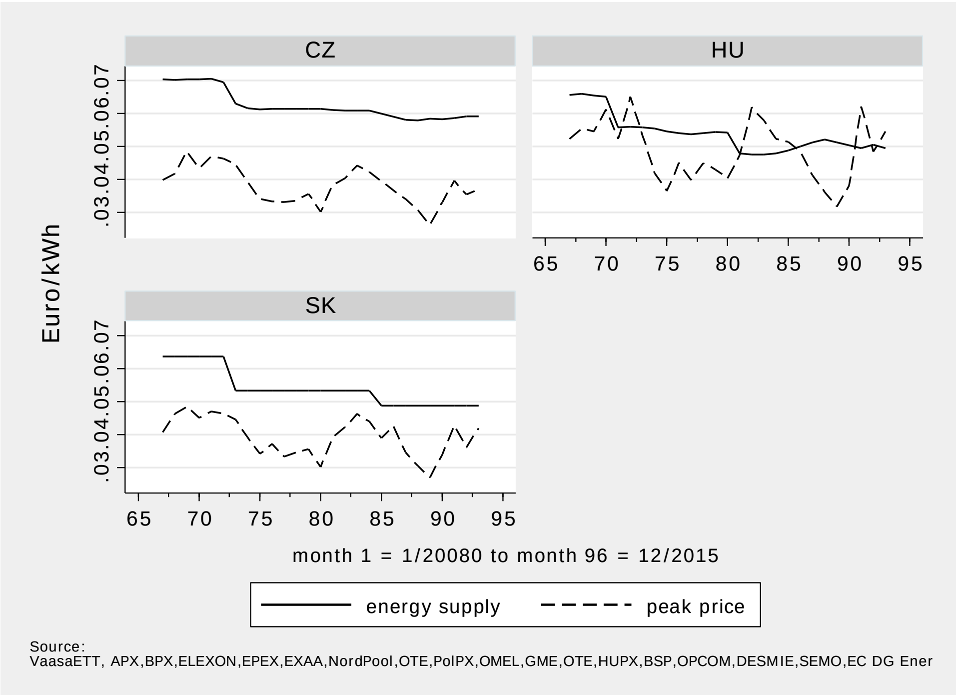


Figure 42: Electricity wholesale prices and retail supply component for CZ, HU and SK, DC band Euro/kWh

3.2.5 Results industry

For the analysis of industry prices, the Eurostat-based data of DG ENER are used because VaasaETT provides no retail price data for industries. Applying the difference between the energy component and the wholesale prices as measure for the degree of competition, it becomes evident from Figure 43 that the margin is smaller, and hence competition is higher for higher consumption levels. This difference between the energy component derived from Eurostat data and wholesale prices is called margin in the following, although it still includes costs for marketing. In both consumption bands the margins decrease and increase again, pointing to changes in market conditions. The spread of margins across countries remains rather constant over time.

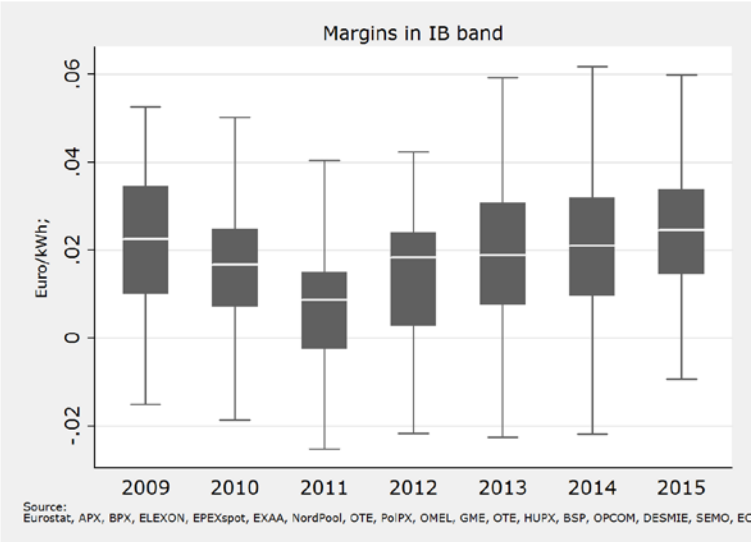


Figure 43: Distribution and evolution of margins between 2008 and 2015, EU, electricity IB band Euro/kWh

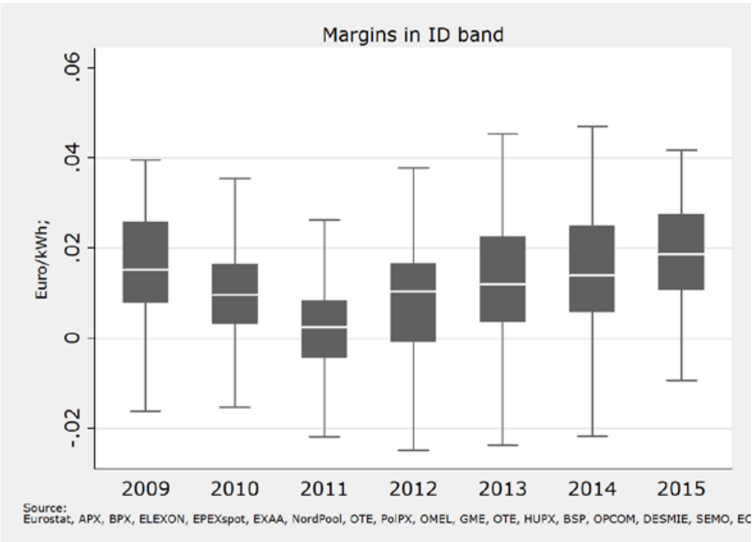


Figure 44: Distribution and evolution of margins between 2008 and 2015, EU, electricity ID band Euro/kWh

Regarding the regression results, wholesale prices and growth and market liberalisation (years as ln) are significant, but only the coefficient of prices is significantly different from zero. Hence energy price components are driven by wholesale prices, but only by a small share, i.e. a decrease of prices by one Eurocent would lead to a decrease by 0.04 Eurocents for band IB. Subsequently, the R^2 is rather low. In contrast, at the ID band even wholesale prices with a lag of one month are insignificant, while other variables, which display a high significance, are hardly different from zero, apart from market liberalisation. Increasing the lag of wholesale price to one year reports a significant coefficient for wholesale prices (alpha at 0.10) but a low impact (0.03), a further increase displays again insignificant results.

Table 23: Fixed and random effects estimator –results for industry IB band by regions, Eurostat data

	FE IB band	FE ID band
Wholesale price lagged 1 month	0.043***	-0.001
	(3.13)	(-0.06)
Cooling degree days	0.000**	0.000
	(2.06)	(1.20)
Heating degree days	0.001	0.000
	(1.60)	(0.72)
Exchange rate index	-0.000	-0.000***
	(-0.06)	(-2.97)
Growth index	0.000**	-0.000***
	(2.03)	(-3.01)
Market liberalization (ln)	0.003***	0.010***
	(2.98)	(5.92)
Dummy Rest		
Constant	0.046***	0.099***
	(4.50)	(5.76)
Observations	1337	1337
Within R2	0.040	0.030
Between R2	0.100	0.053
Overall R2	0.028	0.037

Regarding competition, prices are lower under competition in recent years while margins show a more pronounced decrease and increase over the years. The average prices between markets with higher and lower competition are slightly lower by about one Eurocent under competitive markets (ID band). With respect to regulation no separate analysis has been conducted as information on price regulation of industries have not been available for the analysed period.

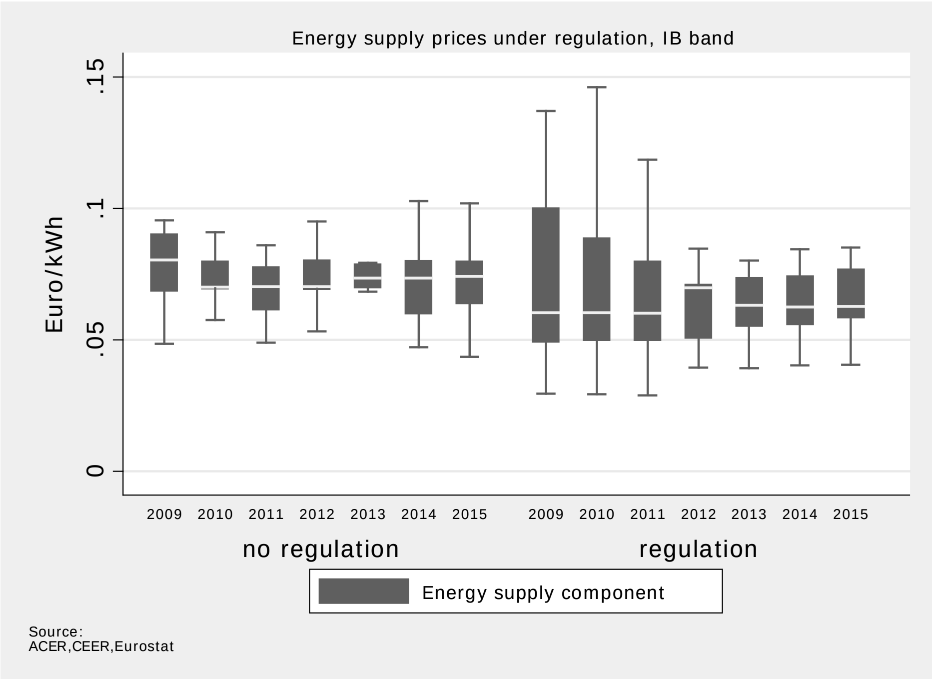


Figure 45: Energy component by status of market regulation, 2008 - 2015, electricity IB band Euro/kWh

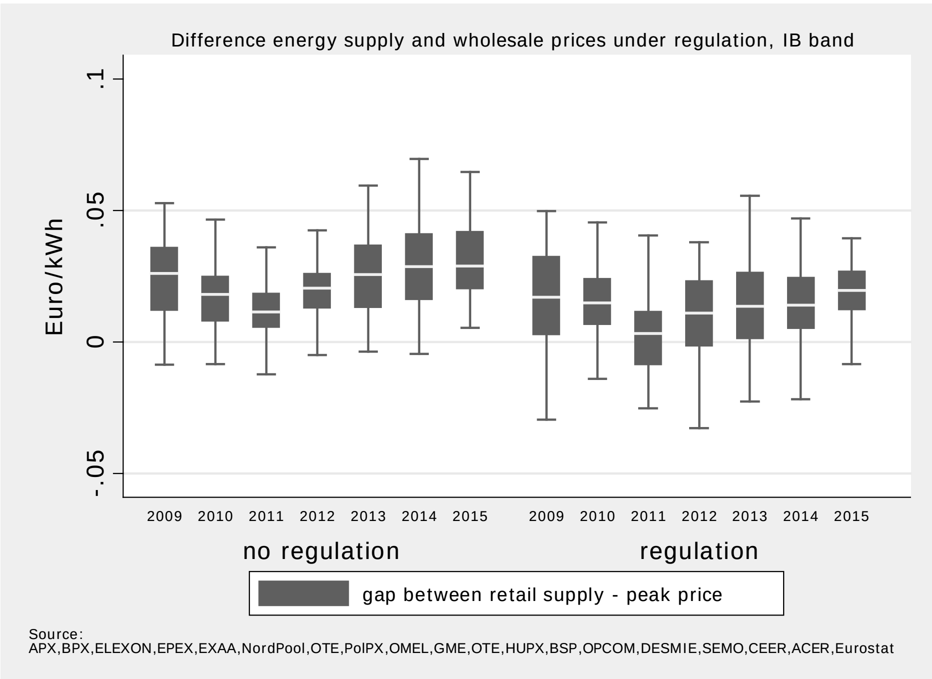


Figure 46: Difference between energy component and wholesale prices by status of market regulation, 2008 - 2015, electricity IB band Euro/kWh

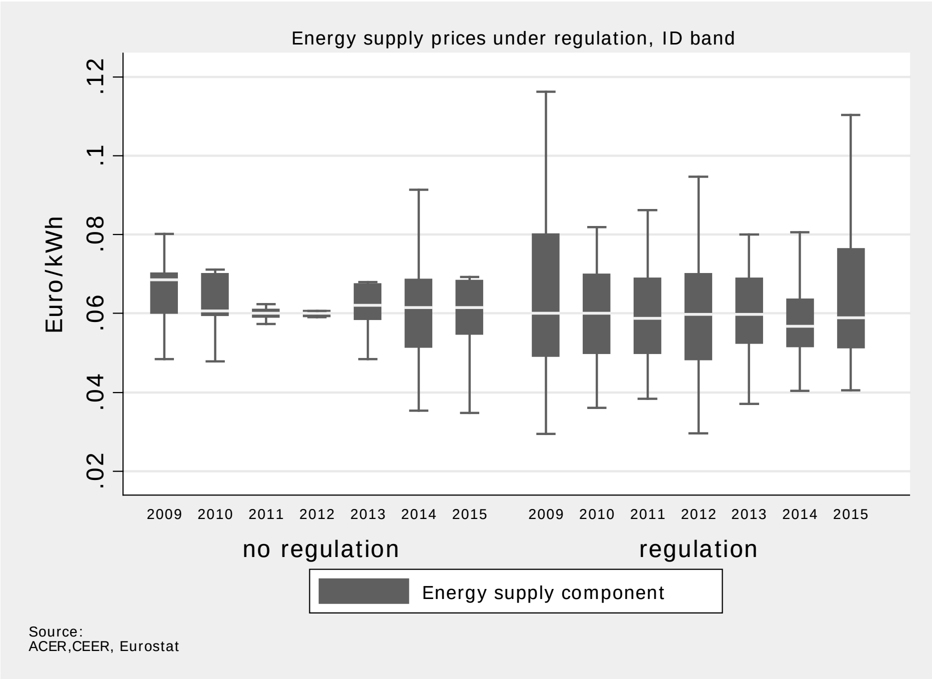


Figure 47: Energy component by status of market regulation, 2008 - 2015, electricity ID band Euro/kWh

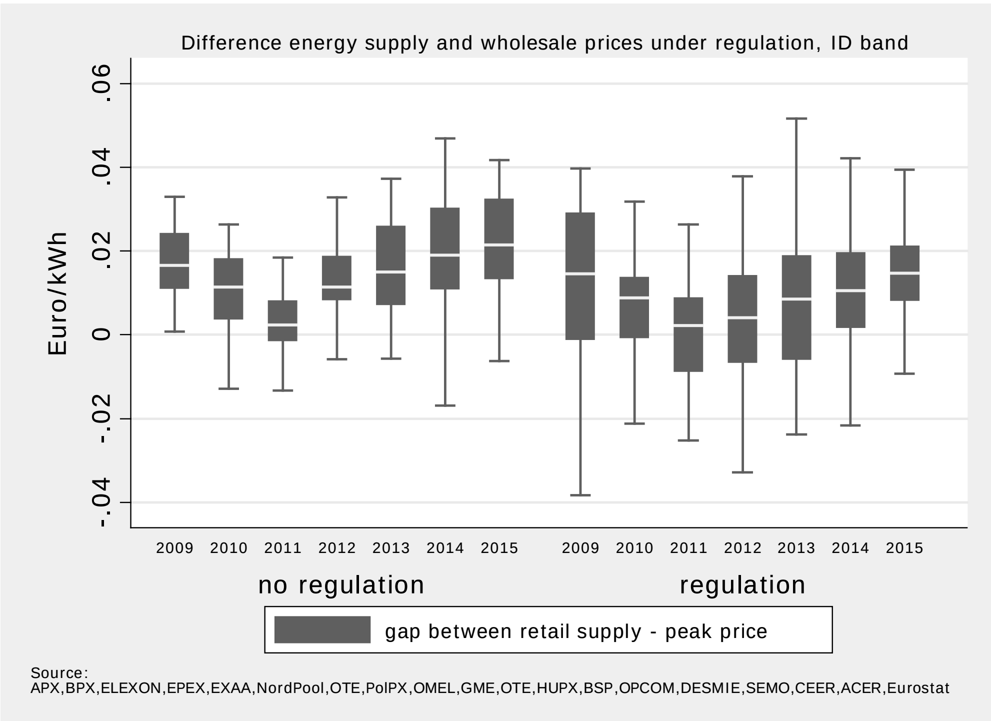


Figure 48: Difference between energy component and wholesale prices by status of market regulation, 2008 - 2015, electricity ID band Euro/kWh

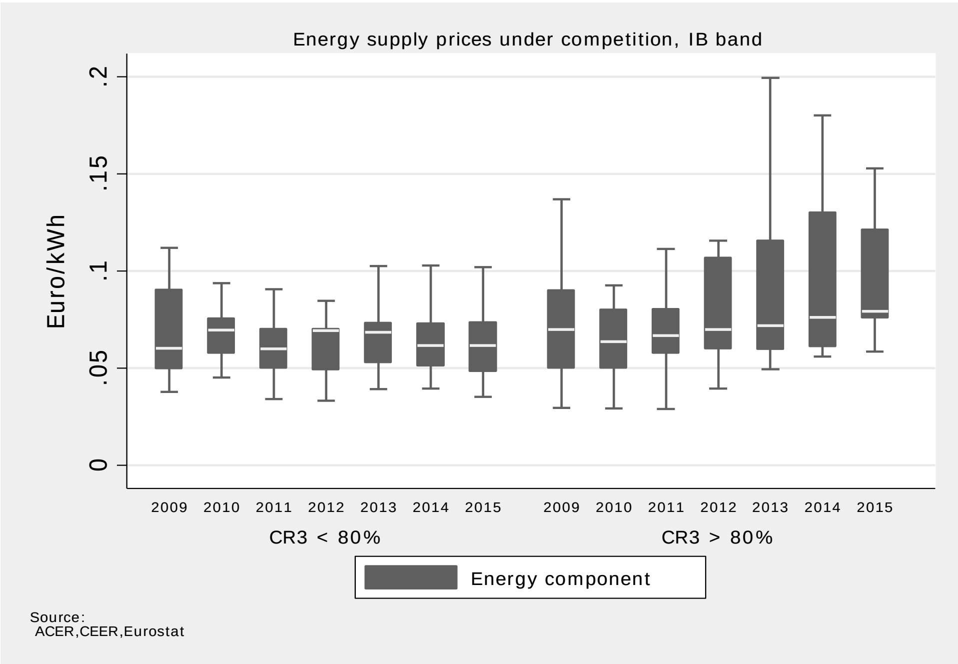


Figure 49: Energy component by competition, 2008 - 2015, electricity IB band Euro/kWh

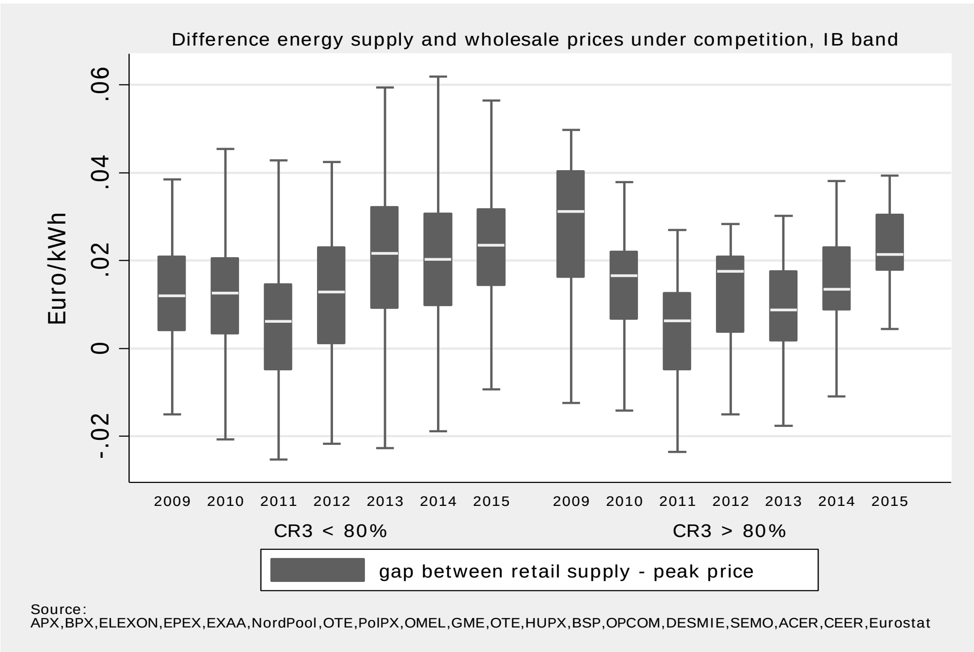


Figure 50: Difference between energy component and wholesale prices by competition, 2008 - 2015, electricity IB band Euro/kWh

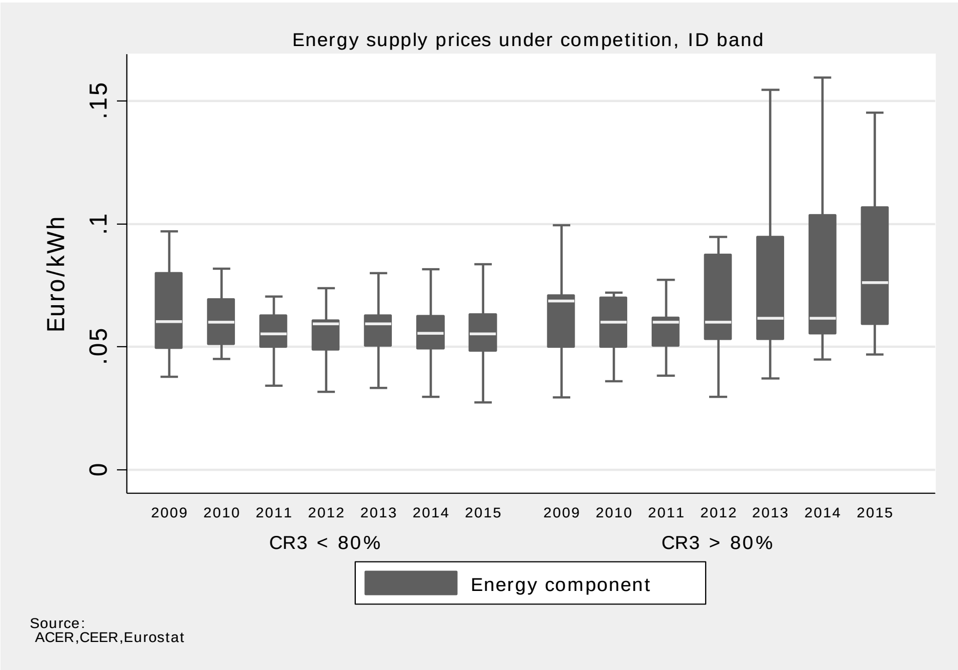


Figure 51: Energy component by competition, 2008 - 2015, electricity ID band Euro/kWh

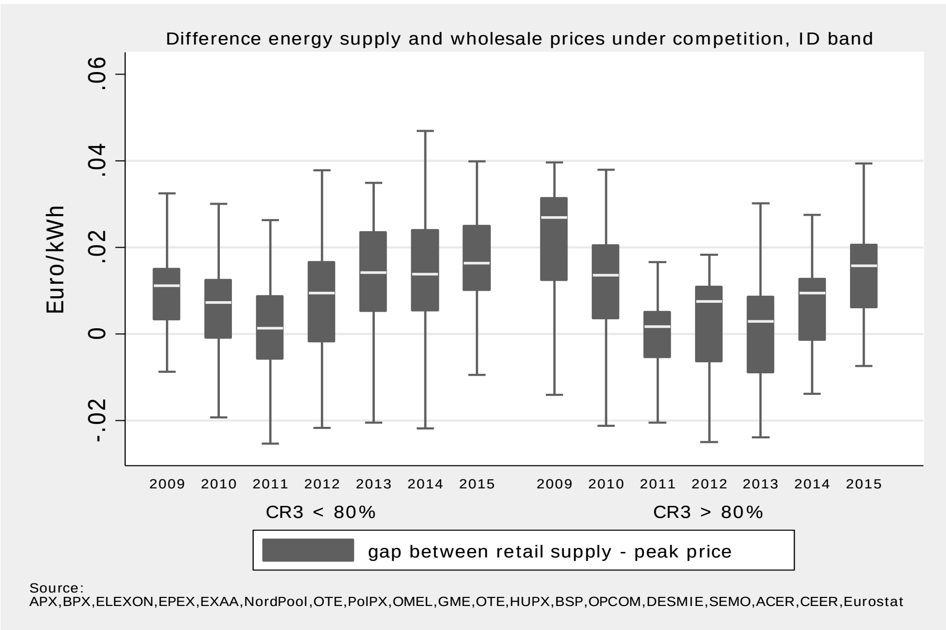


Figure 52: Difference between energy component and wholesale prices by competition, 2008 - 2015, electricity ID band Euro/kWh

3.2.6 Further results

3.2.6.1 A direct depiction of retail price components of different consumption bands displays nicely the differences in this consumption classes.

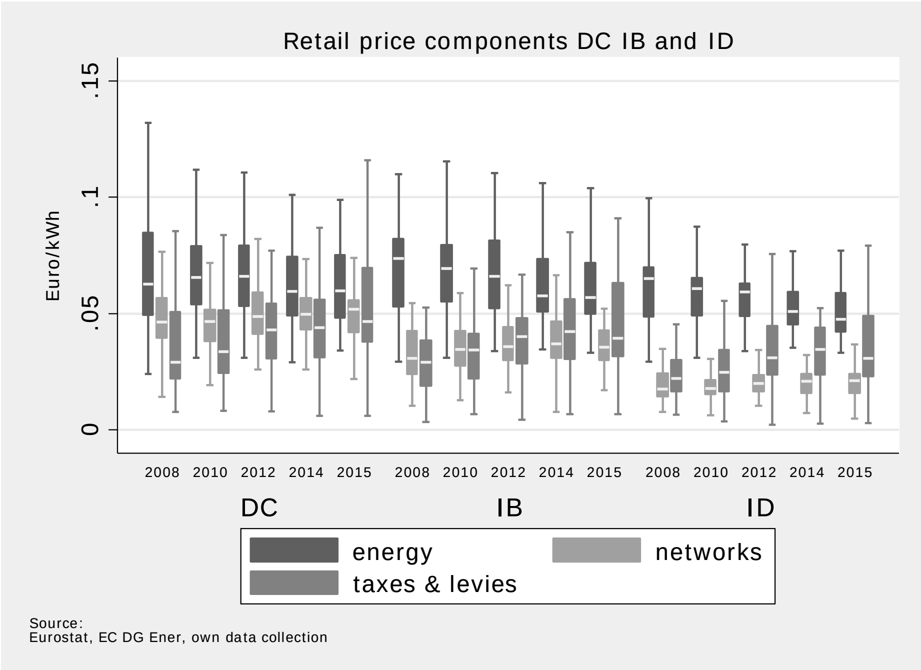


Figure 53: Retail price components 2008 and 2015 in EU countries (electricity DC, IB and ID band, Euro/kWh)

3.2.6.2 Correlation between retail energy price component and wholesale prices by country and database (Eurostat and VaasaETT):

Correlation between retail energy price component and wholesale prices by database (Eurostat (ener) and VaasaETT (ener_vaas)):

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	0.3244	1.0000								
L1.	0.3263	0.7957	1.0000							
L2.	0.3212	0.6679	0.7988	1.0000						
L3.	0.3101	0.5781	0.6718	0.8071	1.0000					
L4.	0.2965	0.4790	0.5823	0.6842	0.8223	1.0000				
L5.	0.2930	0.4141	0.4869	0.5933	0.6923	0.8222	1.0000			
L6.	0.2892	0.3568	0.4275	0.5087	0.6157	0.7083	0.8242	1.0000		
L7.	0.2853	0.3230	0.3709	0.4488	0.5333	0.6300	0.7093	0.8228	1.0000	
L8.	0.2887	0.3292	0.3328	0.3828	0.4571	0.5373	0.6328	0.7104	0.8160	1.0000

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	0.3727	1.0000								
L1.	0.3895	0.7979	1.0000							
L2.	0.3900	0.6610	0.8054	1.0000						
L3.	0.3779	0.5612	0.6702	0.8158	1.0000					
L4.	0.3625	0.4718	0.5775	0.6891	0.8354	1.0000				
L5.	0.3560	0.4055	0.4907	0.5941	0.7021	0.8348	1.0000			
L6.	0.3436	0.3492	0.4308	0.5178	0.6230	0.7174	0.8362	1.0000		
L7.	0.3333	0.3188	0.3737	0.4574	0.5485	0.6425	0.7199	0.8400	1.0000	
L8.	0.3297	0.3219	0.3368	0.3895	0.4688	0.5526	0.6446	0.7211	0.8391	1.0000

VaasaETT prices and wholesale price, by country:

-> id = 1
(obs=80)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	0.4284	1.0000								
L1.	0.4803	0.6286	1.0000							
L2.	0.4547	0.4166	0.6753	1.0000						
L3.	0.4240	0.2608	0.4975	0.7309	1.0000					
L4.	0.3772	0.1086	0.3675	0.5838	0.7980	1.0000				
L5.	0.2869	-0.0772	0.1689	0.3953	0.5715	0.7719	1.0000			
L6.	0.2239	-0.2029	0.0250	0.2540	0.4737	0.6157	0.7721	1.0000		
L7.	0.1931	-0.2197	-0.0775	0.1424	0.3813	0.5462	0.6222	0.7926	1.0000	
L8.	0.1657	-0.1945	-0.1306	0.0159	0.2444	0.4355	0.5598	0.6464	0.8050	1.0000

-> id = 2
no observations

-> id = 3
(obs=25)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	0.7001	1.0000								
L1.	0.4608	0.6630	1.0000							
L2.	0.2928	0.3824	0.6524	1.0000						
L3.	0.2017	0.0251	0.3538	0.6120	1.0000					
L4.	0.0383	-0.1347	0.0101	0.2991	0.6531	1.0000				
L5.	0.0090	-0.2689	-0.1987	-0.0208	0.4271	0.6836	1.0000			
L6.	0.1002	-0.4101	-0.3514	-0.2529	0.0478	0.4057	0.6796	1.0000		
L7.	0.3158	-0.1707	-0.4655	-0.3303	-0.2316	-0.0255	0.3274	0.6560	1.0000	
L8.	0.5564	0.1116	-0.2411	-0.4423	-0.2730	-0.1838	0.0568	0.4407	0.6983	1.0000

-> id = 4
(obs=80)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	0.5872	1.0000								
L1.	0.6905	0.7303	1.0000							
L2.	0.7488	0.6158	0.7305	1.0000						
L3.	0.7912	0.5544	0.6142	0.7333	1.0000					
L4.	0.8190	0.4707	0.5534	0.6162	0.7376	1.0000				
L5.	0.7823	0.3898	0.4691	0.5557	0.6168	0.7469	1.0000			
L6.	0.7380	0.3177	0.3939	0.4756	0.5615	0.6409	0.7530	1.0000		
L7.	0.6489	0.2031	0.3290	0.4063	0.4886	0.5964	0.6530	0.7649	1.0000	
L8.	0.5790	0.1958	0.2077	0.3332	0.4082	0.4947	0.5971	0.6544	0.7625	1.0000

-> id = 5
(obs=80)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	-0.4221	1.0000								
L1.	-0.4563	0.8091	1.0000							
L2.	-0.4874	0.6987	0.8178	1.0000						
L3.	-0.5079	0.6011	0.7000	0.8358	1.0000					
L4.	-0.5411	0.4673	0.6257	0.7421	0.8725	1.0000				
L5.	-0.5517	0.3232	0.4832	0.6396	0.7179	0.8474	1.0000			
L6.	-0.5907	0.2171	0.3668	0.5262	0.6605	0.7324	0.8451	1.0000		
L7.	-0.6474	0.1984	0.2733	0.4315	0.5824	0.6946	0.7360	0.8561	1.0000	
L8.	-0.6970	0.2038	0.2256	0.3003	0.4281	0.5705	0.6985	0.7396	0.8483	1.0000

-> id = 6
(obs=9)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	0.0630	1.0000								
L1.	0.7818	0.4717	1.0000							
L2.	0.5958	0.0521	0.5373	1.0000						
L3.	0.7802	-0.1949	0.5543	0.6941	1.0000					
L4.	0.7355	-0.2961	0.3545	0.7614	0.8230	1.0000				
L5.	0.4570	-0.6125	-0.0017	0.5458	0.6747	0.7645	1.0000			
L6.	0.6447	-0.5423	0.1988	0.4435	0.7870	0.8097	0.6952	1.0000		
L7.	-0.0422	-0.5066	-0.4149	0.4266	0.2089	0.5502	0.7671	0.3208	1.0000	
L8.	-0.0013	-0.6823	-0.4263	-0.3406	0.1472	-0.0125	0.4416	0.3713	0.1366	1.0000

-> id = 7
no observations

-> id = 8
(obs=81)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	-0.1963	1.0000								
L1.	-0.1963	0.7787	1.0000							
L2.	-0.2061	0.5538	0.8047	1.0000						
L3.	-0.2236	0.3707	0.5990	0.8255	1.0000					
L4.	-0.2304	0.2729	0.4324	0.6408	0.8423	1.0000				
L5.	-0.2321	0.2142	0.3386	0.4869	0.6719	0.8547	1.0000			
L6.	-0.2198	0.1423	0.2906	0.4080	0.5347	0.7000	0.8659	1.0000		
L7.	-0.2212	0.0339	0.1955	0.3361	0.4406	0.5589	0.7144	0.8704	1.0000	
L8.	-0.2447	-0.0841	0.0766	0.2299	0.3589	0.4573	0.5700	0.7171	0.8724	1.0000

-> id = 9
(obs=79)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	0.0876	1.0000								
L1.	0.1072	0.6853	1.0000							
L2.	0.0549	0.3980	0.6837	1.0000						
L3.	-0.0740	0.2235	0.4045	0.7009	1.0000					
L4.	-0.2599	0.0785	0.2387	0.4402	0.7161	1.0000				
L5.	-0.2921	0.0335	0.1083	0.2992	0.4909	0.7454	1.0000			
L6.	-0.3592	-0.0478	0.0643	0.1762	0.3577	0.5359	0.7666	1.0000		
L7.	-0.3587	-0.0778	-0.0278	0.1031	0.2133	0.3860	0.5490	0.7679	1.0000	
L8.	-0.3344	-0.1016	-0.0585	0.0063	0.1409	0.2476	0.4006	0.5549	0.7739	1.0000

-> id = 10
(obs=81)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	-0.3545	1.0000								
L1.	-0.3439	0.4410	1.0000							
L2.	-0.3168	0.3102	0.4682	1.0000						
L3.	-0.2744	0.2610	0.3621	0.5236	1.0000					
L4.	-0.2282	0.1348	0.3097	0.4185	0.5993	1.0000				
L5.	-0.2169	-0.0020	0.1485	0.3176	0.4264	0.5944	1.0000			
L6.	-0.2119	-0.0916	0.0410	0.1953	0.3767	0.4669	0.6011	1.0000		
L7.	-0.2179	-0.0797	-0.0332	0.1081	0.2870	0.4353	0.4811	0.6245	1.0000	
L8.	-0.2527	0.0110	-0.0574	-0.0048	0.1398	0.3030	0.4491	0.4898	0.6253	1.0000

-> id = 11
no observations

-> id = 12
(obs=79)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	0.4798	1.0000								
L1.	0.5124	0.8514	1.0000							
L2.	0.5636	0.7321	0.8620	1.0000						
L3.	0.6093	0.6453	0.7615	0.8834	1.0000					
L4.	0.6128	0.5816	0.6691	0.7795	0.9061	1.0000				
L5.	0.6031	0.5172	0.5985	0.6757	0.8064	0.9065	1.0000			
L6.	0.5942	0.4611	0.5573	0.6353	0.7315	0.8233	0.8941	1.0000		
L7.	0.6071	0.4295	0.4858	0.5745	0.6533	0.7308	0.8074	0.8796	1.0000	
L8.	0.6307	0.4086	0.4494	0.4973	0.5837	0.6489	0.7119	0.7867	0.8798	1.0000

-> id = 13
no observations

-> id = 14
(obs=9)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	.									
price										
--.	.	1.0000								
L1.	.	0.5844	1.0000							
L2.	.	0.1126	0.6471	1.0000						
L3.	.	-0.5209	0.2711	0.7164	1.0000					
L4.	.	-0.7633	-0.1639	0.4633	0.8015	1.0000				
L5.	.	-0.8783	-0.3784	0.1686	0.6892	0.9028	1.0000			
L6.	.	-0.8342	-0.4708	0.0126	0.4852	0.8544	0.9166	1.0000		
L7.	.	-0.7899	-0.6084	-0.1610	0.3472	0.7234	0.8924	0.9174	1.0000	
L8.	.	-0.7133	-0.7492	-0.5170	-0.0403	0.3827	0.5953	0.7449	0.8027	1.0000

-> id = 15
(obs=9)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	-0.0000	1.0000								
L1.	0.0000	0.6070	1.0000							
L2.	0.0000	0.1050	0.6648	1.0000						
L3.	0.0000	-0.5111	0.2599	0.7286	1.0000					
L4.	0.0000	-0.7674	-0.1610	0.4517	0.8085	1.0000				
L5.	-0.0000	-0.8702	-0.3857	0.1666	0.6759	0.9071	1.0000			
L6.	0.0000	-0.8265	-0.4652	0.0115	0.4951	0.8588	0.9251	1.0000		
L7.	0.0000	-0.7906	-0.6006	-0.1558	0.3468	0.7375	0.9017	0.9169	1.0000	
L8.	0.0000	-0.7160	-0.7504	-0.5083	-0.0321	0.3867	0.6175	0.7446	0.8020	1.0000

-> id = 22
(obs=80)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	-0.1603	1.0000								
L1.	-0.0543	0.6831	1.0000							
L2.	0.0702	0.3895	0.6984	1.0000						
L3.	0.1902	0.2059	0.4201	0.7252	1.0000					
L4.	0.2941	0.0550	0.2539	0.4696	0.7411	1.0000				
L5.	0.3734	0.0108	0.1184	0.3200	0.5177	0.7708	1.0000			
L6.	0.4531	-0.0655	0.0673	0.1928	0.3784	0.5580	0.7826	1.0000		
L7.	0.5091	-0.0990	-0.0270	0.1170	0.2334	0.4062	0.5707	0.7879	1.0000	
L8.	0.5582	-0.1220	-0.0603	0.0219	0.1615	0.2724	0.4256	0.5822	0.7947	1.0000

-> id = 23
(obs=27)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	-0.0942	1.0000								
L1.	0.0160	0.5327	1.0000							
L2.	0.1239	0.0278	0.5557	1.0000						
L3.	0.1893	-0.2146	0.0285	0.5468	1.0000					
L4.	0.1616	-0.2587	-0.1657	0.0606	0.5691	1.0000				
L5.	0.1629	-0.5146	-0.2372	-0.1450	0.0976	0.5605	1.0000			
L6.	0.1775	-0.5025	-0.5375	-0.2521	-0.1199	0.0501	0.5198	1.0000		
L7.	0.0344	-0.2958	-0.5408	-0.5639	-0.2564	-0.1445	0.0505	0.5612	1.0000	
L8.	-0.1566	-0.0716	-0.3824	-0.5915	-0.5756	-0.2665	-0.1015	0.1577	0.6049	1.0000

-> id = 24
(obs=27)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	0.4877	1.0000								
L1.	0.2954	0.5299	1.0000							
L2.	0.0840	0.1714	0.5522	1.0000						
L3.	-0.0884	-0.1039	0.1711	0.5967	1.0000					
L4.	-0.2537	-0.3785	-0.0746	0.1870	0.7123	1.0000				
L5.	-0.2959	-0.5663	-0.3864	-0.1180	0.3079	0.6823	1.0000			
L6.	-0.2407	-0.5968	-0.5794	-0.4350	-0.0645	0.2525	0.6642	1.0000		
L7.	-0.1622	-0.5702	-0.5876	-0.5709	-0.4032	-0.1032	0.2085	0.6408	1.0000	
L8.	0.0926	-0.2578	-0.5897	-0.6105	-0.6233	-0.4117	-0.0686	0.2548	0.6465	1.0000

-> id = 16
no observations

-> id = 17
(obs=27)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	0.1771	1.0000								
L1.	0.1247	0.4904	1.0000							
L2.	-0.0177	0.1617	0.5127	1.0000						
L3.	-0.0612	-0.1509	0.1495	0.5493	1.0000					
L4.	-0.1245	-0.3343	-0.1102	0.1782	0.6573	1.0000				
L5.	-0.0775	-0.5115	-0.3233	-0.1433	0.2954	0.6217	1.0000			
L6.	0.1035	-0.5119	-0.5109	-0.3598	-0.0833	0.2367	0.5898	1.0000		
L7.	0.2088	-0.5904	-0.5149	-0.5389	-0.3426	-0.1381	0.2053	0.5821	1.0000	
L8.	0.2717	-0.2172	-0.6052	-0.5397	-0.5721	-0.3645	-0.1285	0.2302	0.6020	1.0000

-> id = 18
no observations

-> id = 19
(obs=80)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	-0.1380	1.0000								
L1.	-0.0310	0.7393	1.0000							
L2.	0.1118	0.5770	0.7593	1.0000						
L3.	0.2437	0.4627	0.6227	0.7983	1.0000					
L4.	0.3745	0.2778	0.5291	0.6869	0.8493	1.0000				
L5.	0.4406	0.0687	0.3136	0.5445	0.6654	0.8203	1.0000			
L6.	0.5289	-0.0763	0.1547	0.3822	0.5937	0.6979	0.8205	1.0000		
L7.	0.6223	-0.1251	0.0389	0.2567	0.4839	0.6513	0.7012	0.8367	1.0000	
L8.	0.6997	-0.1363	-0.0452	0.1114	0.3239	0.5162	0.6624	0.7178	0.8420	1.0000

-> id = 20
(obs=80)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	0.6382	1.0000								
L1.	0.6346	0.8248	1.0000							
L2.	0.6137	0.7176	0.8289	1.0000						
L3.	0.5514	0.6067	0.7066	0.8446	1.0000					
L4.	0.5137	0.4756	0.6241	0.7484	0.8791	1.0000				
L5.	0.4881	0.3216	0.4880	0.6340	0.7162	0.8496	1.0000			
L6.	0.4875	0.2274	0.3633	0.5355	0.6629	0.7362	0.8461	1.0000		
L7.	0.4834	0.2088	0.2787	0.4321	0.5961	0.7001	0.7368	0.8584	1.0000	
L8.	0.4936	0.2084	0.2311	0.3017	0.4232	0.5786	0.7033	0.7362	0.8462	1.0000

-> id = 21
(obs=27)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	0.0595	1.0000								
L1.	-0.1846	0.6203	1.0000							
L2.	-0.2643	0.4486	0.6332	1.0000						
L3.	-0.0751	0.3326	0.4695	0.6548	1.0000					
L4.	0.0848	0.1385	0.3549	0.4961	0.6613	1.0000				
L5.	0.4700	0.0386	0.1560	0.3745	0.5004	0.6629	1.0000			
L6.	0.4673	-0.1372	0.0483	0.1792	0.3686	0.4923	0.6612	1.0000		
L7.	0.4202	-0.1410	-0.1242	0.0766	0.1741	0.3603	0.4900	0.6495	1.0000	
L8.	0.3220	-0.1920	-0.1400	-0.1177	0.0674	0.1632	0.3530	0.4836	0.6467	1.0000

-> id = 25
(obs=27)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	0.5993	1.0000								
L1.	0.3922	0.6154	1.0000							
L2.	0.1704	0.2939	0.6475	1.0000						
L3.	0.1189	-0.0221	0.2626	0.6440	1.0000					
L4.	0.0073	-0.2406	-0.0347	0.2260	0.6795	1.0000				
L5.	0.0098	-0.3094	-0.2954	-0.1389	0.3018	0.6707	1.0000			
L6.	0.0884	-0.4457	-0.3658	-0.3869	-0.0815	0.2838	0.6690	1.0000		
L7.	0.2852	-0.1733	-0.4761	-0.4235	-0.3493	-0.0900	0.2878	0.6771	1.0000	
L8.	0.5321	0.0762	-0.2623	-0.5070	-0.3841	-0.2832	0.0549	0.4096	0.7214	1.0000

-> id = 26
(obs=80)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	0.2094	1.0000								
L1.	0.2738	0.6247	1.0000							
L2.	0.3232	0.3636	0.6229	1.0000						
L3.	0.3380	0.2320	0.3603	0.6250	1.0000					
L4.	0.3278	0.1336	0.2244	0.3656	0.6318	1.0000				
L5.	0.3521	0.0897	0.1299	0.2315	0.3765	0.6408	1.0000			
L6.	0.3338	0.0703	0.0867	0.1354	0.2406	0.3869	0.6448	1.0000		
L7.	0.3124	0.0219	0.0675	0.0913	0.1435	0.2504	0.3915	0.6465	1.0000	
L8.	0.2837	0.0051	0.0197	0.0613	0.0804	0.1209	0.2320	0.3769	0.6332	1.0000

-> id = 27
(obs=71)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	0.6853	1.0000								
L1.	0.8769	0.7946	1.0000							
L2.	0.7935	0.6108	0.7892	1.0000						
L3.	0.6800	0.4787	0.6053	0.7859	1.0000					
L4.	0.5814	0.3881	0.4679	0.5994	0.7846	1.0000				
L5.	0.4991	0.3497	0.3907	0.4700	0.6027	0.7915	1.0000			
L6.	0.4221	0.2921	0.3391	0.3862	0.4661	0.6079	0.7880	1.0000		
L7.	0.3657	0.2438	0.2946	0.3400	0.3867	0.4768	0.6102	0.7854	1.0000	
L8.	0.3060	0.2432	0.2556	0.2929	0.3288	0.3743	0.4620	0.5913	0.7750	1.0000

-> id = 28
(obs=44)

	ener_v~l	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener_vaas_el	1.0000									
price										
--.	-0.3805	1.0000								
L1.	-0.4340	0.6636	1.0000							
L2.	-0.4709	0.4916	0.6600	1.0000						
L3.	-0.4931	0.3634	0.4719	0.6513	1.0000					
L4.	-0.5025	0.3333	0.3545	0.4809	0.6519	1.0000				
L5.	-0.5282	0.2309	0.3481	0.3842	0.5006	0.6421	1.0000			
L6.	-0.5541	0.0447	0.2465	0.3536	0.3763	0.4396	0.5853	1.0000		
L7.	-0.5538	0.0263	0.0742	0.2625	0.3392	0.3232	0.3748	0.5643	1.0000	
L8.	-0.5362	0.2462	0.0669	0.0884	0.2479	0.2926	0.2805	0.3850	0.5775	1.0000

Eurostat based monthly retail prices (from DG Ener), by country

-> id = 1
(obs=83)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	0.3298	1.0000								
L1.	0.3858	0.6007	1.0000							
L2.	0.3142	0.3823	0.6645	1.0000						
L3.	0.2016	0.2492	0.4661	0.7215	1.0000					
L4.	0.1348	0.0934	0.3374	0.5787	0.7987	1.0000				
L5.	0.0802	-0.0823	0.1309	0.3861	0.5722	0.7725	1.0000			
L6.	0.0343	-0.1884	-0.0052	0.2424	0.4741	0.6157	0.7773	1.0000		
L7.	-0.0014	-0.2083	-0.0902	0.1382	0.3819	0.5469	0.6271	0.7954	1.0000	
L8.	-0.0402	-0.1818	-0.1355	0.0136	0.2445	0.4353	0.5622	0.6499	0.8073	1.0000

-> id = 2
no observations

-> id = 3
(obs=66)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	0.5279	1.0000								
L1.	0.5262	0.8002	1.0000							
L2.	0.5281	0.7037	0.7990	1.0000						
L3.	0.5267	0.6473	0.7053	0.8026	1.0000					
L4.	0.5074	0.5422	0.6513	0.7083	0.7982	1.0000				
L5.	0.5215	0.5026	0.5430	0.6510	0.7045	0.7972	1.0000			
L6.	0.5296	0.4108	0.5069	0.5490	0.6451	0.6970	0.7969	1.0000		
L7.	0.5703	0.3839	0.4215	0.5229	0.5421	0.6370	0.7023	0.7907	1.0000	
L8.	0.6068	0.4508	0.3892	0.4207	0.5050	0.5293	0.6344	0.6823	0.7679	1.0000

-> id = 4
(obs=83)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	0.5538	1.0000								
L1.	0.6465	0.7418	1.0000							
L2.	0.6248	0.6343	0.7430	1.0000						
L3.	0.5948	0.5777	0.6353	0.7467	1.0000					
L4.	0.5259	0.5006	0.5761	0.6388	0.7539	1.0000				
L5.	0.4901	0.4257	0.4991	0.5829	0.6474	0.7657	1.0000			
L6.	0.4463	0.3598	0.4284	0.5081	0.5953	0.6683	0.7720	1.0000		
L7.	0.3689	0.2473	0.3640	0.4399	0.5242	0.6241	0.6769	0.7813	1.0000	
L8.	0.3012	0.2346	0.2434	0.3659	0.4417	0.5247	0.6198	0.6741	0.7750	1.0000

-> id = 5
(obs=83)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	-0.5286	1.0000								
L1.	-0.5899	0.8015	1.0000							
L2.	-0.6115	0.6944	0.8163	1.0000						
L3.	-0.5856	0.6053	0.7008	0.8399	1.0000					
L4.	-0.5768	0.4740	0.6328	0.7494	0.8750	1.0000				
L5.	-0.5731	0.3413	0.4955	0.6511	0.7242	0.8504	1.0000			
L6.	-0.5919	0.2401	0.3808	0.5466	0.6725	0.7414	0.8546	1.0000		
L7.	-0.6185	0.2222	0.2891	0.4527	0.5971	0.7048	0.7508	0.8643	1.0000	
L8.	-0.6416	0.2272	0.2382	0.3183	0.4440	0.5813	0.7089	0.7479	0.8533	1.0000

-> id = 6
(obs=49)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	0.2206	1.0000								
L1.	0.0460	0.3819	1.0000							
L2.	0.0095	0.3254	0.3865	1.0000						
L3.	-0.0405	0.3044	0.3407	0.3887	1.0000					
L4.	-0.1029	0.0759	0.3159	0.3421	0.3872	1.0000				
L5.	-0.0374	0.0452	0.0546	0.3059	0.3166	0.3620	1.0000			
L6.	-0.1065	0.0385	0.0610	0.0530	0.3009	0.3064	0.3275	1.0000		
L7.	-0.1657	-0.0341	0.0400	0.0534	0.0324	0.2821	0.2704	0.2979	1.0000	
L8.	-0.1604	-0.0658	-0.0509	0.0272	0.0257	0.0013	0.2575	0.2347	0.2615	1.0000

-> id = 7
no observations

-> id = 8
no observations

-> id = 9
(obs=81)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	-0.1340	1.0000								
L1.	-0.0484	0.6819	1.0000							
L2.	0.0343	0.3991	0.6861	1.0000						
L3.	0.0967	0.2344	0.4112	0.7008	1.0000					
L4.	0.1377	0.0919	0.2562	0.4455	0.7214	1.0000				
L5.	0.1735	0.0366	0.1250	0.3062	0.4934	0.7479	1.0000			
L6.	0.2218	-0.0443	0.0705	0.1798	0.3600	0.5347	0.7642	1.0000		
L7.	0.2458	-0.0723	-0.0210	0.1070	0.2190	0.3890	0.5484	0.7684	1.0000	
L8.	0.2855	-0.1049	-0.0552	0.0075	0.1366	0.2429	0.4004	0.5541	0.7711	1.0000

-> id = 10
(obs=82)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	-0.3969	1.0000								
L1.	-0.4203	0.4396	1.0000							
L2.	-0.4398	0.3074	0.4730	1.0000						
L3.	-0.4505	0.2602	0.3658	0.5275	1.0000					
L4.	-0.4706	0.1338	0.3158	0.4274	0.6024	1.0000				
L5.	-0.4735	-0.0020	0.1594	0.3329	0.4319	0.6017	1.0000			
L6.	-0.4748	-0.0913	0.0474	0.2040	0.3807	0.4719	0.6045	1.0000		
L7.	-0.4937	-0.0796	-0.0289	0.1139	0.2898	0.4378	0.4823	0.6259	1.0000	
L8.	-0.5074	0.0110	-0.0571	-0.0046	0.1395	0.3010	0.4424	0.4882	0.6245	1.0000

-> id = 11
no observations

-> id = 12
(obs=81)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	-0.3682	1.0000								
L1.	-0.3281	0.8499	1.0000							
L2.	-0.2683	0.7334	0.8585	1.0000						
L3.	-0.2047	0.6472	0.7632	0.8825	1.0000					
L4.	-0.1682	0.5871	0.6681	0.7813	0.9047	1.0000				
L5.	-0.1481	0.5321	0.5964	0.6747	0.7974	0.9014	1.0000			
L6.	-0.0975	0.4805	0.5613	0.6293	0.7222	0.8126	0.8956	1.0000		
L7.	-0.0582	0.4504	0.4932	0.5720	0.6481	0.7254	0.8152	0.8891	1.0000	
L8.	-0.0345	0.4315	0.4568	0.4974	0.5792	0.6461	0.7274	0.8042	0.8893	1.0000

-> id = 13
no observations

-> id = 14
(obs=20)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	-0.6172	1.0000								
L1.	-0.5474	0.8377	1.0000							
L2.	-0.4216	0.5825	0.8359	1.0000						
L3.	-0.3429	0.2195	0.5747	0.7992	1.0000					
L4.	-0.2624	-0.1562	0.1463	0.3980	0.7400	1.0000				
L5.	-0.1561	-0.4872	-0.1923	0.0601	0.4100	0.7928	1.0000			
L6.	0.0289	-0.6872	-0.5144	-0.2040	0.0815	0.4228	0.7588	1.0000		
L7.	0.2389	-0.6835	-0.7443	-0.5190	-0.2008	0.0649	0.3313	0.7269	1.0000	
L8.	0.3041	-0.4955	-0.7267	-0.7785	-0.5176	-0.1220	0.0428	0.2730	0.6738	1.0000

-> id = 15
(obs=32)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	0.3155	1.0000								
L1.	0.3231	0.7247	1.0000							
L2.	0.2844	0.3822	0.7271	1.0000						
L3.	0.1368	0.1298	0.3927	0.7271	1.0000					
L4.	-0.0105	-0.1292	0.1369	0.3968	0.7280	1.0000				
L5.	-0.1523	-0.4207	-0.1256	0.1480	0.4135	0.7414	1.0000			
L6.	-0.2623	-0.5989	-0.4442	-0.1344	0.1283	0.4066	0.7107	1.0000		
L7.	-0.4582	-0.5622	-0.6227	-0.4536	-0.1176	0.1380	0.3742	0.6678	1.0000	
L8.	-0.5267	-0.3903	-0.5549	-0.6143	-0.4226	-0.1094	0.1086	0.3117	0.6494	1.0000

-> id = 16
no observations

-> id = 17
(obs=55)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	0.5452	1.0000								
L1.	0.5550	0.6647	1.0000							
L2.	0.5634	0.5174	0.6670	1.0000						
L3.	0.5972	0.3556	0.5203	0.6776	1.0000					
L4.	0.5948	0.2253	0.3631	0.5184	0.7085	1.0000				
L5.	0.5765	0.2397	0.2355	0.3599	0.5644	0.6959	1.0000			
L6.	0.5744	0.1739	0.2445	0.2245	0.3871	0.5443	0.6751	1.0000		
L7.	0.5471	0.0918	0.1665	0.2136	0.2354	0.2953	0.4212	0.4883	1.0000	
L8.	0.5587	0.1086	0.0886	0.1580	0.2157	0.2233	0.2828	0.4174	0.3293	1.0000

-> id = 18
no observations

-> id = 19
(obs=83)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	-0.2394	1.0000								
L1.	-0.0891	0.7395	1.0000							
L2.	0.0986	0.5882	0.7645	1.0000						
L3.	0.2544	0.4769	0.6266	0.8017	1.0000					
L4.	0.3958	0.2930	0.5351	0.6920	0.8508	1.0000				
L5.	0.4619	0.1000	0.3259	0.5562	0.6714	0.8223	1.0000			
L6.	0.5400	-0.0359	0.1685	0.3980	0.6027	0.7014	0.8268	1.0000		
L7.	0.6192	-0.0922	0.0535	0.2734	0.4943	0.6571	0.7111	0.8420	1.0000	
L8.	0.6830	-0.1084	-0.0339	0.1271	0.3359	0.5227	0.6693	0.7251	0.8454	1.0000

-> id = 20
(obs=83)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	-0.4191	1.0000								
L1.	-0.3965	0.8208	1.0000							
L2.	-0.3983	0.7158	0.8292	1.0000						
L3.	-0.3974	0.6125	0.7090	0.8482	1.0000					
L4.	-0.4117	0.4842	0.6327	0.7555	0.8810	1.0000				
L5.	-0.4283	0.3415	0.5023	0.6469	0.7224	0.8528	1.0000			
L6.	-0.4450	0.2520	0.3793	0.5549	0.6745	0.7444	0.8548	1.0000		
L7.	-0.4682	0.2332	0.2974	0.4528	0.6095	0.7102	0.7515	0.8659	1.0000	
L8.	-0.4859	0.2313	0.2463	0.3210	0.4397	0.5898	0.7135	0.7459	0.8518	1.0000

-> id = 21
(obs=81)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	-0.1839	1.0000								
L1.	-0.1030	0.6658	1.0000							
L2.	0.0099	0.4423	0.6364	1.0000						
L3.	0.0780	0.3599	0.4208	0.6576	1.0000					
L4.	0.1653	0.1527	0.3209	0.4690	0.6819	1.0000				
L5.	0.2242	0.0454	0.1239	0.3735	0.5123	0.7278	1.0000			
L6.	0.2777	-0.1052	0.0133	0.2169	0.4359	0.6026	0.7650	1.0000		
L7.	0.3101	-0.1708	-0.1192	0.0763	0.2712	0.4979	0.6384	0.7775	1.0000	
L8.	0.3343	-0.2040	-0.1873	-0.0519	0.1392	0.3519	0.5415	0.6666	0.7934	1.0000

-> id = 22
(obs=81)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	-0.1436	1.0000								
L1.	-0.0270	0.6843	1.0000							
L2.	0.0848	0.3920	0.6992	1.0000						
L3.	0.1812	0.2178	0.4237	0.7244	1.0000					
L4.	0.2697	0.0699	0.2594	0.4712	0.7458	1.0000				
L5.	0.3526	0.0150	0.1204	0.3212	0.5178	0.7680	1.0000			
L6.	0.4292	-0.0621	0.0687	0.1937	0.3783	0.5560	0.7827	1.0000		
L7.	0.4845	-0.0935	-0.0244	0.1188	0.2367	0.4078	0.5714	0.7880	1.0000	
L8.	0.5357	-0.1253	-0.0624	0.0201	0.1552	0.2644	0.4236	0.5807	0.7919	1.0000

-> id = 23
(obs=81)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	-0.3914	1.0000								
L1.	-0.3789	0.7742	1.0000							
L2.	-0.3706	0.5637	0.7607	1.0000						
L3.	-0.3711	0.4161	0.5570	0.7737	1.0000					
L4.	-0.3426	0.2862	0.4188	0.5769	0.7847	1.0000				
L5.	-0.2706	0.1780	0.2937	0.4381	0.5920	0.7864	1.0000			
L6.	-0.2346	0.1150	0.1849	0.3092	0.4507	0.5905	0.7816	1.0000		
L7.	-0.2272	0.1059	0.1170	0.1872	0.3082	0.4442	0.5856	0.7815	1.0000	
L8.	-0.2268	0.1375	0.1029	0.0954	0.1641	0.2882	0.4323	0.5807	0.7775	1.0000

-> id = 24
(obs=57)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	-0.5703	1.0000								
L1.	-0.5825	0.6418	1.0000							
L2.	-0.6102	0.5340	0.6418	1.0000						
L3.	-0.6509	0.4207	0.5386	0.6518	1.0000					
L4.	-0.6512	0.2370	0.4175	0.5341	0.6754	1.0000				
L5.	-0.6148	0.2842	0.2268	0.4084	0.5651	0.6629	1.0000			
L6.	-0.5513	0.2132	0.2843	0.2176	0.4338	0.5499	0.6441	1.0000		
L7.	-0.4777	0.1333	0.2065	0.2752	0.2324	0.4182	0.5344	0.6319	1.0000	
L8.	-0.4603	0.1826	0.1229	0.1990	0.2785	0.2250	0.4174	0.5300	0.6309	1.0000

-> id = 25
(obs=61)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	0.7413	1.0000								
L1.	0.7310	0.7720	1.0000							
L2.	0.7051	0.6708	0.7701	1.0000						
L3.	0.6988	0.6223	0.6683	0.7726	1.0000					
L4.	0.6729	0.4687	0.6227	0.6594	0.7753	1.0000				
L5.	0.6441	0.4517	0.4709	0.6084	0.6668	0.7672	1.0000			
L6.	0.6208	0.3895	0.4509	0.4500	0.6093	0.6527	0.7521	1.0000		
L7.	0.6435	0.3455	0.3860	0.4371	0.4491	0.5964	0.6353	0.7400	1.0000	
L8.	0.6836	0.4098	0.3427	0.3801	0.4349	0.4438	0.5987	0.6357	0.7409	1.0000

-> id = 26
(obs=83)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	-0.2193	1.0000								
L1.	-0.3091	0.6265	1.0000							
L2.	-0.2287	0.3680	0.6246	1.0000						
L3.	-0.1451	0.2380	0.3640	0.6270	1.0000					
L4.	-0.0776	0.1444	0.2313	0.3704	0.6356	1.0000				
L5.	0.0640	0.1045	0.1396	0.2394	0.3846	0.6505	1.0000			
L6.	0.0666	0.0854	0.0966	0.1452	0.2510	0.4026	0.6571	1.0000		
L7.	0.0638	0.0370	0.0776	0.1016	0.1562	0.2706	0.4114	0.6568	1.0000	
L8.	0.1115	0.0199	0.0295	0.0714	0.0925	0.1411	0.2549	0.3943	0.6424	1.0000

-> id = 27
(obs=74)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	0.6753	1.0000								
L1.	0.5761	0.8023	1.0000							
L2.	0.4682	0.6281	0.7986	1.0000						
L3.	0.3747	0.5050	0.6256	0.8001	1.0000					
L4.	0.2776	0.4177	0.4952	0.6242	0.8008	1.0000				
L5.	0.2244	0.3776	0.4182	0.4986	0.6274	0.8041	1.0000			
L6.	0.1598	0.3205	0.3661	0.4162	0.4954	0.6267	0.7969	1.0000		
L7.	0.1042	0.2722	0.3218	0.3705	0.4191	0.5016	0.6263	0.7939	1.0000	
L8.	0.0793	0.2684	0.2812	0.3216	0.3601	0.4024	0.4830	0.6057	0.7823	1.0000

-> id = 28
(obs=83)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	0.1008	1.0000								
L1.	0.0515	0.5852	1.0000							
L2.	-0.0374	0.3259	0.6074	1.0000						
L3.	-0.1241	0.2879	0.3969	0.6742	1.0000					
L4.	-0.2336	0.3396	0.3663	0.5143	0.7433	1.0000				
L5.	-0.3051	0.2471	0.4001	0.4573	0.5943	0.7795	1.0000			
L6.	-0.3761	0.1627	0.3301	0.5068	0.5705	0.7128	0.8165	1.0000		
L7.	-0.4215	0.0314	0.2259	0.4018	0.5564	0.6015	0.7384	0.8170	1.0000	
L8.	-0.4686	-0.0367	0.0980	0.3040	0.4615	0.5857	0.6371	0.7485	0.8297	1.0000

-> id = 29
(obs=83)

	ener	price	L. price	L2. price	L3. price	L4. price	L5. price	L6. price	L7. price	L8. price
ener	1.0000									
price										
--.	0.8679	1.0000								
L1.	0.8339	0.8282	1.0000							
L2.	0.7512	0.6756	0.8258	1.0000						
L3.	0.6225	0.5478	0.6709	0.8251	1.0000					
L4.	0.4762	0.3987	0.5381	0.6682	0.8230	1.0000				
L5.	0.3522	0.2938	0.3902	0.5342	0.6631	0.8162	1.0000			
L6.	0.2630	0.2488	0.2831	0.3806	0.5226	0.6469	0.8085	1.0000		
L7.	0.1929	0.2028	0.2386	0.2710	0.3651	0.5010	0.6351	0.8038	1.0000	
L8.	0.1679	0.2075	0.1865	0.2142	0.2387	0.3186	0.4710	0.6170	0.7950	1.0000

4 Drivers of wholesale and retail natural gas prices

4.1 Main drivers of wholesale gas prices

The market structures and pricing mechanisms for wholesale trading of natural gas are quite diverse around the globe but also within the EU. There are three main different pricing mechanisms that coexist on the global scale, sometimes even within the same region, namely government regulated prices (GRP), oil-price escalation (OPE) and spot market pricing in competitive gas markets (GOG). Natural gas is traded partly via bilateral agreements and partly at hubs with shares differing dependent on the region. While OPE is mainly based on long-term contracts (LTC), spot markets with various kinds of time frames (in particular day-ahead, month-ahead, one-year-ahead) exist at trading hubs. The hubs may be physical hubs representing the exchange of gas at network interconnectors or virtual trading points.

4.1.1 Market structures in the EU, North America and Asia

While the EU is slowly but steadily shifting from a dominance of OPE to more GOG (GOG's share increased from 15% in 2005 to 61% in 2014, while OPE declined from 78% to 32%, see IGU 2015), the latter clearly dominates the North American market with fully liquid trading markets in the USA and Canada and the wholesale price in Mexico being referenced to prices in the USA. The markets in Asia Pacific (Japan, Korea) have a dominant share of OPE-traded LNG, but also some GOG. Russia and Central Asia have a diverse mixture of markets with highest share of GRP (see IGU 2015).

In the EU, the Northwestern member states were the first to shift to GOG, both for piped natural gas and LNG. In 2008, hub prices existed in the UK, the Netherlands, Belgium and Germany. In the meantime, also Austria, Denmark, France, and rather recently Finland and Poland have established national hubs and corresponding marker prices. While the transition to GOG is ongoing in central European states, the Baltic and the Southeastern European states are just starting to make use of spot trading. A few of those countries still even have a share of GRP like Romania for its domestic production. The Mediterranean countries (most importantly Spain, France, Greece, Portugal) have dominant import shares of LNG that is still mainly purchased via long-term contracts (IGU 2015).

4.1.1.1 Approach

Hubs usually provide a regional marker price. There are regions without such marker prices though. In this case, border prices have to be used as proxy data for estimating the wholesale prices, as the prices of LTCs are not known to the public. The border price of a country is defined the weighted average price of imported piped natural gas within one month. It can be derived from customs data on total imported volumes and total costs. Thereby a border price reflects both pricing mechanisms

GOG and OPE. However, it is not take into account domestic production and liquefied natural gas (LNG) imports.

However, it does not take into account domestic production and liquefied natural gas (LNG) imports. In general, wholesale gas prices at spot markets can be affected by the following drivers:

- Fundamentally, markets are expected to be driven by the relation between supply and demand, both on the regional and on the global level.
- Moreover, the spot price is influenced by the oil-indexed prices of long-term contracts and should thus show a positive correlation with the global crude oil price lagged in time.
- Local gas storage capacities allow reduced price peaks and should therefore help to avoid peak prices.
- Due to the trade of commodities in fixed currencies, exchange rates can also be of importance.
- There are drivers linked to the market structure such as the shares of GOG in the consumption as well as the share of domestically produced natural gas in total consumption. Here the hypothesis is that a higher share of GOG results in lower prices due to the higher level of completion and a high share of domestic production in lower ones.
- The demand for gas shows strong seasonal variations with low demand in summer and peak-demand times in winter. An important factor is therefore the monthly level of consumption. However, the supply-side is well adapted to the seasonal pattern of demand, in particular by filling up gas storages in summer, and emptying them in winter.
- There may still be deviations from the usual seasonal pattern, e.g. during warm winters or severe cold spells, consumption peaks may result in price peaks. These kind of impacts may be reflected by heating degree days per month on the one hand and a monthly consumption index that measures deviations from the usual seasonal pattern on the other hand. Deviations from the seasonal pattern can have different kinds of impacts, in particular because LTCs commonly include take-or-pay clauses that may result in penalties in case of a demand below the lower limit of expectations.

4.1.1.2 Econometric models and data issues

To assess the drivers of wholesale natural gas prices, an econometric analysis of the drivers has been carried out for the monthly averages of

- spot prices in northwestern Europe (Belgium, Germany, Italy, the Netherlands, United Kingdom; Ireland and Luxemburg linked closely ; insufficient data for Denmark, France and Sweden) and North America (US; Canada and Mexico linked closely),
- border prices of piped natural gas in central European member states (Czech Republic, Germany, Hungary, Italy, Slovakia; insufficient data for Austria and Poland) as well as Baltic and southeastern European member states (Bulgaria, Estonia, Finland, Greece, Latvia, Lithuania, Romania, Slovenia; insufficient data for Croatia; no imports by Cyprus and Malta) and

- LNG landed prices in the EU (Belgium, France, Spain, UK; insufficient data for Greece, Italy, Lithuania, Portugal) and Asia (China, Japan, Republic of Korea).

The corresponding prices were considered as the endogenous variable to be explained by the models and a set of exogenous variables was chosen as the possible drivers according to the discussion of gas-price dynamics above. The hub prices within the EU are strongly correlated and the major US hub price at Henry Hub shows a completely different behavior. Similarly, the LNG landed prices within Asia are strongly correlated, but significantly differ from the hub prices in the EU and the US. For these reasons, time-series analyses were carried out for the individual hub prices and LNG landed prices. For the econometric analyses of the time series, the Dickey-Fuller test suggested a linear regression of first-order differences. There are several parameters, for which a time-lagged impact can be expected, in particular the international hub prices and the crude oil price. In a model of first differences, the significance of certain drivers is quite sensitive to choosing a suitable time lag. The most significant lag structures have been identified, but the results will be presented also for other time lags below to increase the transparency of the results.

With regard to the border prices of piped natural gas within the EU, there are groups of countries with similar developments as explained above, but the individual properties of the countries (e.g. share of GOG and domestic production) result in a diversification of price dynamics. Hence, a panel approach was pursued for two groups of EU member states: the central European states being in transition to GOG and the Baltic and southeastern European states still being dominated by OPE.

As in the case of electricity wholesale prices, we will compare fixed effect and random effect models and also make use of the Mundlak approach to account for heterogeneity of the national prices in the longer term. It is well-known that oil-indexed prices usually are based on the prices of heating and fuel oil with more than one time lag to compensate for volatility (typically six to nine months, see e.g. Platts 2015). We thus pursue a similar approach in the econometric analysis of border prices. Due to data availability, however, we have to stick to the price of crude oil instead of oil products.

The creation of the variables used for the panel data regression for wholesale gas prices and the underlying data sources was based partly on publically available and proprietary data. The details are given in Table 24.

Table 24: Endogenous and exogenous variables for wholesale natural gas market analysis

Variables applied (annual)	Data source	Data creation + normalization
Endogenous and partly exogenous: Hub price for natural gas (day-ahead)	Source: Kaasupörssi Oy, Platts, POLPX Countries: BE, DE, IT, NL, AT, UK, US Time period: monthly, 1/2008 – 9/2015 (1/2010 – 9/2015 in AT)	Creation: unweighted monthly averages per country Normalization: EUR/MWh
Endogenous: Border price for piped natural gas	Source: BAFA, Eurostat Countries: BG, CZ, DE, EE, EL, FI, HU, IT, LV, LT, RO, SI, SK Time period: monthly, 1/2008 – 9/2015 (with gaps depending on the region)	Creation: weighted average of monthly import prices by exporting country (Algeria, Denmark, Netherlands, Norway, Russia); missing months in filled by average of preceding and following month; deleted one low outlier for LT + SK Normalization: EUR/MWh
Endogenous and exogenous: LNG landed price	Source: Thomsen Reuters, Waterborne Countries: BE, FR, ES, UK, CN, JP, KO Time period: monthly, 1/2010 – 9/2015 (1/2011 – 9/2015 in CN)	Creation: unweighted monthly averages per country Normalization: EUR/MWh
Exogenous: Commodity price of crude oil	Source: Platts Countries: Europe (Brent crude), US (WTI), Asia (JPP) Time period: monthly, 1/2008 – 9/2015	Creation: - Normalization: EUR/MWh
Exogenous: monthly consumption index	Source: US Energy Information Administration, Eurostat Countries: EU 28, US Time period: monthly, 1/2008 – 9/2015	Creation: Monthly consumption per average of consumption in the relevant month in 2008 – 2015 Normalization: index with base 100
Exogenous: Heating degree days	Source: US Energy Information Administration, Joint Research Center Countries: EU 28, US Time period: monthly, 1/2008 – 9/2015	Creation: - Normalization: Monthly heating degree days per days per days in month
Exogenous: share of domestic production in total consumption	Source: US Energy Information Administration, Eurostat Countries: EU 28 Time period: monthly, 1/2008 – 9/2015	Creation: moving annual average of total consumption per moving annual average of domestic production Normalization: index with

Variables applied (annual)	Data source	Data creation + normalization
		base 100
Exogenous: Share of GOG in total traded gas	Source: International Gas Union Country: Northwestern Europe, Central Europe, Baltic Europe, Southeastern Europe, North America, Central Asia, Asia Pacific Time period: annual, 2007/09/11/13/14/15	Creation: GOG-traded natural gas in total consumption per sum of GOG- and OPE-traded gas in total consumption Normalization: share between 0 and 100 %
Exogenous: Exchange rate index (base year 2008)	Source: Worldbank Countries: EU 28, US, CN, JP, KO Time period: annual, 1/2008 – 9/2015	Creation: - Normalization: index with base 100

4.1.1.3 Results for the drivers of the wholesale gas prices

Hub prices in northwestern Europe and Italy

As a consequence of increased hub trading, northwestern Europe (NWE) has experienced drastic changes in price formation mechanisms in the last decade. While in 2005 the share of OPE was 72% and the GOG share was 27%, the ratio has more than reversed with 12% OPE and 88% GOG in 2014. The hubs with the by far largest shares of traded volumes are the British NBP and the Dutch TTF. Thanks to the integration of markets, the wholesale prices at both hubs are very strongly correlated, as are those at the Belgian and German hubs (Zeebrugge, GASPOOL, NetConnect).

While the hub prices had been strongly coupled to the oil-indexed LTC prices before 2009, they started to deviate from the oil-indexed development, when both the gas and oil prices significantly dropped due to the low demand in the context of the economic crisis in 2009. This development was fostered by an oversupply of markets due to the rising domestic production in the US (see also the analysis of the US market below). The hub prices recovered to more than 20 EUR/MWh in 2010 and showed a slowly increasing trend in 2011 to 2012. The price level had been significantly higher at the Italian PSV and slightly higher at the Austrian CEGH until the end of 2012, when the improved market coupling resulted in a strong reduction of the price spread lifting the price level in the NWE hubs by about. 3 EUR/MWh. In the mid of 2014, the hub prices dropped significantly again from around 28 EUR/MWh to approx. 20EUR/MWh. This drop and the recovery afterwards can be related to the low demand both in Europe and Asia after a mild winter and the unclear supply situation in the winter 2014/15 due to the gas dispute between Russia and the Ukraine (ACER 2015).

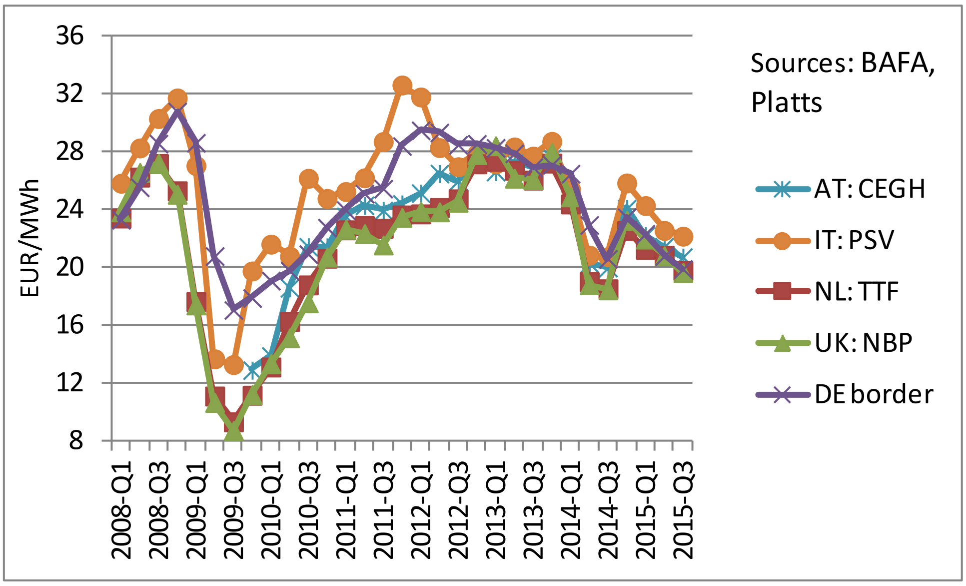


Figure 54: Development of hub prices of natural gas in Northwestern Europe and Italy (2008 – 2015). The German border price is provided as a reference.

For the econometric analyses of the time series of the hub prices in NWE and Italy, the Dickey-Fuller test shows non-stationarity of the price developments suggesting a linear regression of first-order differences. Due to data availability an analysis of the time series of the LNG prices can only be carried out for 2010 to 2015. For comparability reasons, the analysis for the hub prices is also restricted to 2010 – 2015. In 2008 and 2009, the price dynamics were dominated by the economic crisis and the oil price decline. A consequence of excluding 2008 and 2009 is thus that the analysis yields the drivers of the gas prices after the decoupling from the oil price development. The time series is too short to analyse this effect before and after the integration of markets in 2012. We are interested both in the impact of the price of oil-indexed gas in general and the impact of oil-indexed LNG imports to the EU in particular. In order to take into account the evident collinearity of the oil-indexed LNG prices and the crude oil price itself, we carry out two separate analyses: one of the external drivers of the gas markets, which includes the development of the crude oil benchmarks, and another one of the interactions with other gas markets.

The time-series analyses for Belgium, Germany, Italy, the Netherlands, Austria and the UK indicate weakly to moderately significant impacts of the development of the crude oil price (with no lag), see **Table 25**). For Italy, the impact of the crude oil price shows no significance. In addition, there is a strongly significant positive impact of the monthly level of heating degree days in the four northern countries (BE, DE, NL, UK), which provides evidence for the seasonality of hub prices. The integration of the consumption index that reflects deviations from the usual seasonal pattern shows also some but only weak to moderate significance while reducing the significance of the heating degree days because of their correlation. The integration of other possible drivers such as the share of domestic production and available storage capacities does also not produce significant results and reduces the significance of the main drivers. They are thus not included in the model whose results are shown in the **Table 25**.

Table 25: Results of the time series analysis of external drivers for northwestern European and Italian hub prices of natural gas (t statistics in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01)

Hub prices in NWE	**BE**	**DE**	**IT**	**NL**	**AT**	**UK**
OLS first differences	2010 – 15	2010 – 15	2010 – 15	2010 – 15	2010 – 15	2010 – 15
Crude oil price	0.143**	0.129*	0.041	0.140**	0.133*	0.169**
(no lag)	(2.05)	(1.86)	(0.50)	(2.01)	(1.84)	(2.21)
Crude oil price	0.042	0.044	0.011	0.038	0.024	0.033
(lag of 1 month)	(0.54)	(0.59)	(0.11)	(0.51)	(0.28)	(0.37)
Crude oil price	0.063	0.065	-0.031	0.071	0.069	0.040
(lag of 2 months)	(0.74)	(0.80)	(-0.26)	(0.88)	(0.74)	(0.40)
Crude oil price	0.069	0.073	0.135	0.065	0.086	0.077
(lag of 3 months)	(0.80)	(0.87)	(1.46)	(0.78)	(0.89)	(0.89)
Crude oil price	-0.001	-0.007	-0.007	0.004	-0.007	0.015
(lag of 4 months)	(-0.01)	(-0.08)	(-0.07)	(0.05)	(-0.08)	(0.17)
Crude oil price	0.051	0.056	0.109	0.059	0.080	0.052
(lag of 5 months)	(0.45)	(0.55)	(0.96)	(0.57)	(0.75)	(0.50)
Crude oil price	-0.047	-0.035	-0.103	-0.047	-0.046	-0.061
(lag of 6 months)	(-0.51)	(-0.41)	(-1.05)	(-0.53)	(-0.53)	(-0.69)
Crude oil price	0.050	0.020	0.080	0.036	-0.005	0.069
(lag of 7 months)	(0.68)	(0.28)	(0.81)	(0.50)	(-0.05)	(0.94)
Heating degree days	0.200***	0.164***	0.155*	0.198***	0.075	0.311***
per month	(3.37)	(3.20)	(1.86)	(3.33)	(1.44)	(4.27)
Constant	0.140	0.142	0.010	0.144	0.119	0.147
	(0.72)	(0.73)	(0.04)	(0.75)	(0.52)	(0.74)
Observations	69	69	69	69	69	69

Note: When interpreting the results, the low degree of freedom need to be kept in mind.

For the analyses of interactions with international markets, the impacts of the LNG landed price in Spain and of the US gas price at Henry Hub are considered. The former is chosen to reflect the impact of oil-indexed international markets, as the Spanish market is the largest one in Europe and is mainly based on oil-indexation. The US hub price is taken into account to reflect the impact of international spot trading. The impact of the US market is a rather indirect one though because the capacities to export LNG in the US are rather limited due to restrictive export policies by the US authorities. Still, there was a strong interaction of the US and the UK hub markets in 2009, as is clearly visible from Figure 2. It is important to note here that the following analysis concerns 2010 – 2015 and thus does not cover the strong interaction in 2009.

For Belgium, Germany, Italy, the Netherlands, Austria and the UK, the analysis indicates a moderately significant impact of the LNG landed price in Spain both with no lag and a lag of two months (see **Table 26**). The lagged impact shows that the LNG prices are indeed affecting the spot prices, though there is also an impact the other way round (see the analysis of LNG prices below). For Italy, there is no significant impact of the Spanish LNG price, which likely reflects that Italy imports oil-indexed LNG itself but from partly differing sources. The US gas price at Henry Hub is not found to have a significant impact on European spot prices for any kind of lag in 2010 – 2015.

Table 26: Results of the time series analysis of market drivers for northwestern European and Italian hub prices of natural gas (t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)

Hub prices in NWE OLS first differences	**BE** 2010 – 15	**DE** 2010 – 15	**IT** 2010 – 15	**NL** 2010 – 15	**AT** 2010 – 15	**UK** 2010 – 15
LNG landed price ES (no lag)	0.115** (2.24)	0.102** (2.06)	0.111 (1.39)	0.100** (2.01)	0.138** (2.44)	0.123** (2.13)
LNG landed price ES (lag of 1 month)	-0.001 (-0.01)	-0.011 (-0.16)	-0.034 (-0.43)	-0.016 (-0.22)	-0.069 (-0.87)	0.038 (0.54)
LNG landed price ES (lag of 2 months)	0.128** (2.10)	0.123** (2.16)	0.131 (1.31)	0.131** (2.21)	0.128** (1.99)	0.119* (1.79)
LNG landed price ES (lag of 3 months)	-0.130 (-1.59)	-0.120 (-1.53)	-0.129 (-1.14)	-0.133* (-1.68)	-0.107 (-1.21)	-0.133 (-1.59)
Hub price US (no lag)	0.228 (0.99)	0.273 (1.22)	0.185 (0.70)	0.273 (1.22)	0.288 (1.23)	0.172 (0.73)
Hub price US (lag of 1 month)	-0.202 (-0.89)	-0.164 (-0.73)	-0.036 (-0.10)	-0.184 (-0.82)	-0.133 (-0.54)	-0.253 (-1.01)
Hub price US (lag of 2 months)	-0.269 (-1.52)	-0.289* (-1.78)	0.145 (0.57)	-0.299* (-1.77)	-0.242 (-1.36)	-0.309* (-1.67)
Hub price US (lag of 3 months)	-0.013 (-0.07)	0.003 (0.02)	0.091 (0.36)	-0.026 (-0.14)	0.054 (0.29)	-0.097 (-0.50)
Constant	0.054 (0.28)	0.054 (0.28)	0.021 (0.07)	0.052 (0.27)	0.044 (0.22)	0.046 (0.23)
Observations	66	66	66	66	66	66

The hubs in Denmark and France have not been considered due to data limitations, but are expected to show a similar behavior given the strong degree of market integration in NWE. As Ireland, Luxemburg and Sweden import gas from NWE only, the price developments should also be comparable in these countries (no sufficient data on border prices available). Due to the lower level of market integration of Eastern Europe the hub prices in Finland and Poland will be related to the development of border prices in their neighboring countries below.

Border prices in central European member states

According to IGU 2015, gas trading in central Europe has experienced significant changes in the last decade. OPE has declined from 85% in 2005 to 32% in 2014, while GOG has increased from almost zero in 2005 to 53% in 2014, which reflects increased imports of spot gas. Moreover, renegotiations of oil-indexed LTCs took place in the context of high oil prices and significantly lower international gas prices. The regional imports stem from various countries, mainly Algeria, the Netherlands, Norway and Russia, but Italy has also a certain share of LNG from Algeria (Eurostat 2015).

Until 2010, the development of border prices in central European member states roughly mirrored the lagged oil price development with a peak of up to 38 EUR/MWh at the end of 2008 and a drop down to 16 EUR/MWh at the end of 2009. The dynamics started to diversify afterwards, when spot prices for natural gas began to decouple from the oil price development (see Figure 55). While the German border price deviated already in 2010, the Czech and Italian border prices peaked at more than 35 EUR/MWh in 2012 and moved to lower levels only in 2013. In 2015, all border prices in Central Europe as well as the newly established Polish hub price have reached a level of 20 – 24 EUR/MWh after showing a valley in 2014 that correlated with the drop of European spot prices suggesting an increased importance of gas-price indices. Such components are typically based on the British or the Dutch hub price (see ACER 2015).

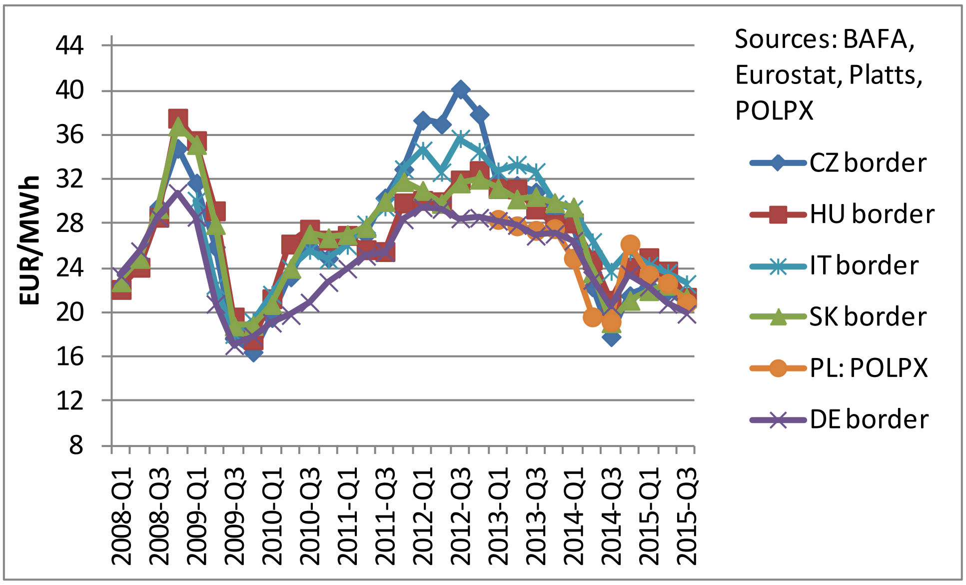


Figure 55: Development of border prices of piped natural gas in Central Europe (2008 – 2015). and the Polish hub price (2013 – 2015). Border prices are the country-specific average import prices reflecting imports from Algeria, the Netherlands, Norway and Russia. The German border price is provided as a reference.

With regard to the border prices of piped natural gas within central European states, we compare fixed effect and random effect models and also make use of the Mundlak approach to account for heterogeneity of the national prices in the longer term. It is well-known that oil-indexed prices usually are based on the prices of oil products with time lags of six months and more (e.g. Platts 2015). To account for this, we include the crude oil price in our model both with a time lag of six and eleven months. A correlation analysis suggests to include the UK hub price with a time lag of two months as well. In order to reflect the fact that there has been a transition from OPE to GOG in the recent years, we split the time period for econometric analysis of the central European border prices (*Czech Republic, Germany, Hungary, Italy, Slovakia)* into two subperiods: 2009 – 2012 and 2013 – 2015.

For the period 2009 – 2012, the Hausman test indicates consistency and efficiency of a random-effect estimator. The random-effect estimator shows a strongly significant positive impact of the crude oil price for medium to long-time lags (six to eleven months), which explain a large part of the dynamics during this period. This indicates the importance of oil-indexed LTCs. However, the marker prices at Northwestern European hubs (e.g. the NBP) also have a strongly significant positive impact, with a shorter time-lag (two to three months) and a smaller coefficient than the oil price though (see **Table 27** below). Here, one has to take into account that the hub prices are partly driven by the oil price themselves (see above) so that the impact of the oil-price is likely to be underestimated in a model that contains also a hub price. Furthermore, the rising share of GOG is strongly significant for comparably lower prices. It mainly explains the lower deviations of prices from a standard oil-indexed price but also a noteworthy part of the difference between the countries (with Germany having a high share of GOG and Italy having a comparably low share). A Mundlak model shows no significance of the mean GOG share though.

For the period 2013 – 2015, the Hausman test indicates the inconsistency of a random-effect estimator. In the fixed-effect estimator, the crude oil price stays a strongly significant driver, but the medium-lagged part of oil-price indexation becomes less important. On the other hand, the strongly significant impact of hub prices from Northwestern Europe has more than doubled. This provides important evidence that renegotiations of LTCs have led to the introduction of gas-indexed components. At least for 2013 – 2014, the relative share of GOG still has a significant decreasing impact on the regional price levels (no data available for 2015)

Table 27: Results of the panel analyses of external drivers for Central European border prices of piped natural gas (t statistics in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01)

Border prices in CE (CZ, DE, HU, IT, SK)	2009 – 2012 fixed effect	2009 – 2012 Mundlak	2013 – 2015 fixed effect	2013 – 2014 Mundlak
Crude oil price (lag of 6 months)	0.287*** (8.73)	0.288*** (8.73)	0.059*** (2.72)	0.120 (1.33)
Crude oil price (lag of 11 months)	0.130*** (6.50)	0.129*** (6.43)	0.273*** (5.88)	0.222*** (3.78)

Hub price UK (lag of 2 months)	0.309*** (4.66)	0.311*** (4.67)	0.814*** (21.52)	0.745*** (16.77)
GOG-share in gas consumption	-0.100*** (-4.63)	-0.105*** (-4.85)		-0.091*** (-4.63)
Mean GOG-share in gas consumption		0.025 (0.89)		0.032 (1.34)
R^2 overall	0.81	0.81	0.81	0.87
R^2 within	0.81	0.79	0.86	0.87
R^2 between	0.77	0.81	0.89	0.96
Hausman (prob>chi^2)	1.00		0.00	
Observations	240	240	165	120

The border prices in AT and PL as well as the newly established hub price in PL have not been considered due to data limitations. AT is expected to show a similar behavior as DE given the strong degree of market integration. In view of **Figure 54** and **Figure 55**, the same can be expected at least for the hub-traded gas in PL.

Baltic and southeastern member states

In the recent years, GOG has slightly started to gain importance in Baltic and Scandinavian countries. OPE has declined from 73% in 2010 to 54% in 2014, while GOG has increased from almost zero to 15% in 2014 (IGU 2015). The remaining share is used in enhanced oil recovery and refineries in Norway. The imports to the Baltic states mainly originate from Russia, but Lithuania also imports a certain share of LNG from Norway (Eurostat 2015). OPE was still the dominant pricing mechanism in Southeastern Europe in 2014. Croatia was the only country with a non-zero but small share of GOG in 2014. Romania has a special role in the region, as it has a high share of domestic production with a price, which is regulated based on the cost of service. The main imports stem from Russia and Algeria, but GR also imports a certain share of LNG from Algeria (Eurostat 2015).

As for the central European member states, the border prices in the Baltic countries roughly followed the time-lagged oil price development until 2010 (see Figure 55). In 2011, the border price of Estonia and Latvia significantly deviated to lower levels, while the Lithuanian border price continued to evolve similar to an oil-indexed price and reached a level of more than 36 EUR/MWh. In the sequel, the spread between the Estonian and Lithuanian price remained relatively constant. On the contrary, the Latvian price deviated to even lower levels in 2013 and moved in parallels afterwards. This price level at the Finnish hub, which was established in 2013, shows the same order of magnitude as the Latvian price. With the dropping oil price in 2015, the regional price spread has shrunk significantly resulting in a price level of 22 – 25 EUR/MWh. The shifted but qualitative similar development in the Baltic countries suggests that LTCs have been renegotiated in Estonia and Latvia, though still staying oil-indexed. This would match with the fact that Lithuania has been offered a retro-active discount on imports from Russia, which is not reflected by the shown figures (Quarterly Report 3/2015).

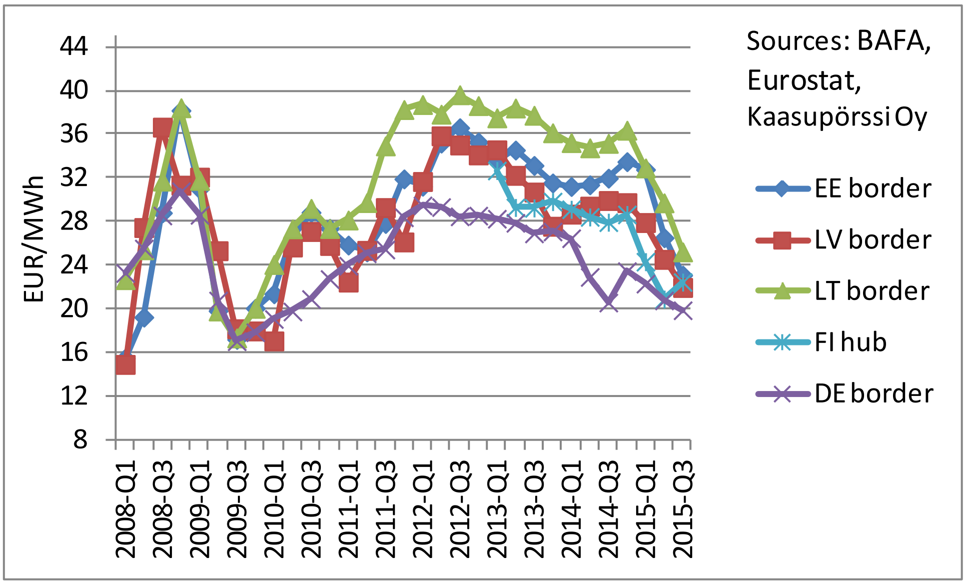


Figure 56: Development of border prices of piped gas in the Baltics (2008 – 15) and at the Finnish hub (2013 – 15). Border prices are the mean import prices that include imports from Algeria, NL, Norway and Russia. A retro-active discount on the Lithuanian import price is not reflected by the figure. The DE border price is provided as a reference.

Similar to the other central and eastern European member states, the development of border prices in southeastern European countries (*Bulgaria, Greece, Romania, Slovenia, no data for Croatia)* mainly reflected the time-lagged oil price development until 2011 (see Figure 55). After 2011, the border price of Romania, which corresponds to imports from Russia only, developed quite differently from the remaining countries. Until the end of 2012, the price steadily decreased to a level of 28 EUR/MWh (comparable to the German border price), which resulted in a large spread as the border prices of Bulgaria and Slovenia strongly peaked at more than 40 EUR/MWh following the peak of oil prices. In this context, it is important to note that the imports to Romania significantly increased from a low level in 2011 and declined again in 2013, as demand was mainly met by domestic production before and afterwards. In 2013, Bulgarian and Slovenian prices relaxed to a price level of 28 – 32 EUR/MWh comparable to the Baltic prices. At the end of 2014 the Romanian border price returned to the price level of the other southeastern European countries, which all significantly dropped in 2015 as did the oil price.

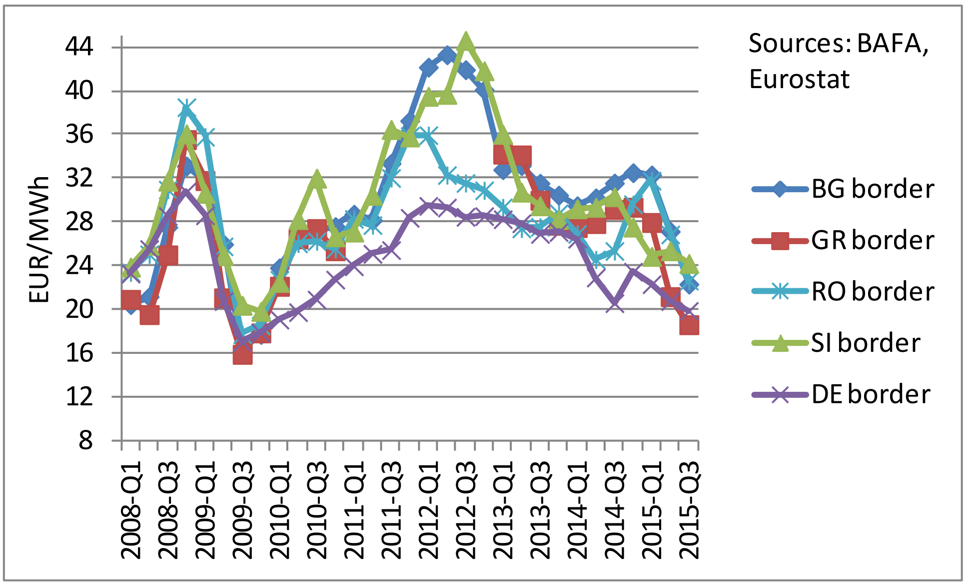


Figure 57: Development of border prices of piped natural gas in Southeastern Europe (2008 – 2015; no data for Greece in 2011/12). Border prices are the country-specific average import prices reflecting imports from Algeria, the Netherlands, Norway and Russia. The German border price is provided as a reference.

In order to shed some light on the roughly comparable but still significantly different developments in the Baltic and southeastern member states, we carry out a panel analysis of border prices of piped natural gas in Bulgaria, Estonia, Greece, Latvia, Lithuania, Romania and Slovenia. In consistence with the analysis of the central European member states, we split the period 2009 – 2015 into two sub-periods and include the crude oil price in our model both with a time lag of six and eleven months as well as the UK hub price with a time lag of two months.

For the period 2009 – 2012, the Hausman test again indicates consistency and efficiency of a random-effect estimator. The analysis of the random-effect mod shows a strongly significant positive impact of the crude oil price for medium to long-time lags (six to eleven months), which explain a large part of the dynamics during this period. On the contrary, the hub prices in Northwestern Europe have a much weaker and less significant impact (see **Table 28**). This is in accordance with the low share of GOG. The different shares of GOG in the Baltic and the southeastern European countries have a significant negative impact on the price dynamics, as has the monthly consumption index. The latter might reflect that the quite low consumption during that period was penalized by the existing LTCs to a certain extent. Integrating both the share of GOG and the consumption index as drivers in the model allows explaining the different price levels of countries to a large part. The share of domestic production within the last year is insignificant to the monthly dynamics during that period.

For the period 2013 – 2015, in order to arrive at meaningful results, it is crucial to look at Mundlak-type model that contains the means of those exogenous drivers that differ across the countries. This reflects the divers developments during this period described above. Still, the results of the panel analysis provide less explanation of the total price dynamics (see **Table 28**). The crude oil price stays a strongly significant driver, but the long-lagged part of oil-price indexation becomes insignificant. Moreover, the hub prices in Northwestern Europe show no significant impact on price dynamics anymore. This may suggest that gas-indexed components haven't been introduced to the major share of LTCs yet. The impact of the consumption index is still significant but now with a positive impact, which may reflect peak prices in months of peak demands. The different shares of GOG in the Baltic and the southeastern European countries do not have a significant impact on the price dynamics anymore. The share of domestic production, however, becomes a driver with a significant negative impact, which partly explains the differences between the countries for 2013 – 2015.

Table 28: Results of the panel analyses of Central European border prices of piped natural gas (t statistics in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01)

Border prices in Baltic & SEE (BG, EE, GR, LV, LU, RO, SI)	2009 – 2012 random effect	2009 – 2012 Mundlak	2013 – 2015 fixed effect	2013 – 2015 Mundlak
Crude oil price (lag of 6 months)	0.426*** (11.78)	0.428*** (10.86)	0.357*** (13.58)	0.357*** (10.00)
Crude oil price (lag of 11 months)	0.095*** (4.67)	0.094*** (4.26)	0.079 (1.30)	0.087 (1.05)
Hub price UK (lag of 2 months)	0.155** (2.16)	0.134* (1.72)	0.032 (0.65)	0.029 (0.43)
Domestic share of annual consumption	0.007 (0.20)	0.074 (0.72)	0.246*** (4.33)	0.246*** (3.23)
Monthly consumption index	-0.034*** (-3.31)	-0.032*** (-2.95)	0.026** (2.23)	0.029* (1.86)
Mean domestic share of annual consumption		-0.094 (-0.94)		-0.301*** (-3.68)
Mean GOG share in gas consumption		-0.294*** (-5.27)		-0.050 (-0.99)
R^2 overall	0.76	0.78	0.00	0.54
R^2 within	0.80	0.80	0.65	0.65
R^2 between	0.53	0.72	0.18	0.25
Hausman (prob>chi^2)	0.93		0.01	
Observations	240	240	165	120

The border prices in FI and HR as well as the newly established hub price in FI have not been considered due to data limitations. Given that FI is solely depending on imports from Russia, it likely shows similar price dynamics as the Baltic states, as also **Figure 55** indicates. HR imports piped gas via AT and HU and already has a certain share of GOG (Eurostat 2015, IGU 2015). This might suggest that the price dynamics are closer to those of the central European member states, but there is no data at hand to verify this.

LNG in EU member states

LNG imports play an important role mainly in the Southern European member states with highest share in Spain. In Mediterranean countries (*Greece, Italy, Portugal, Spain, Turkey)*, OPE has declined from 100% in 2005 to around 64% in 2014 and GOG has risen from nothing to around 30%. This initially reflected spot LNG imports in the sub-region and some spot pipeline imports into Italy, as well as changes in the pricing of domestic production in Italy. However, in 2014 this was further enhanced by the renegotiation of the main Russian contract into Italy.

While the LNG prices in Spain correlate with those in France and LNG prices in Belgium correlate with those in the UK (0.99 for the monthly averages in 2010-2015 in both cases), the correlation between the two markets is somewhat lower (0.76 – 0.85). This is because, the prices in Spain and France still reacted quite sensitively to fluctuations of the crude oil price (in 2011 – 2014), whereas the prices in Belgium and the UK mainly correlate to the spot market prices in the EU.

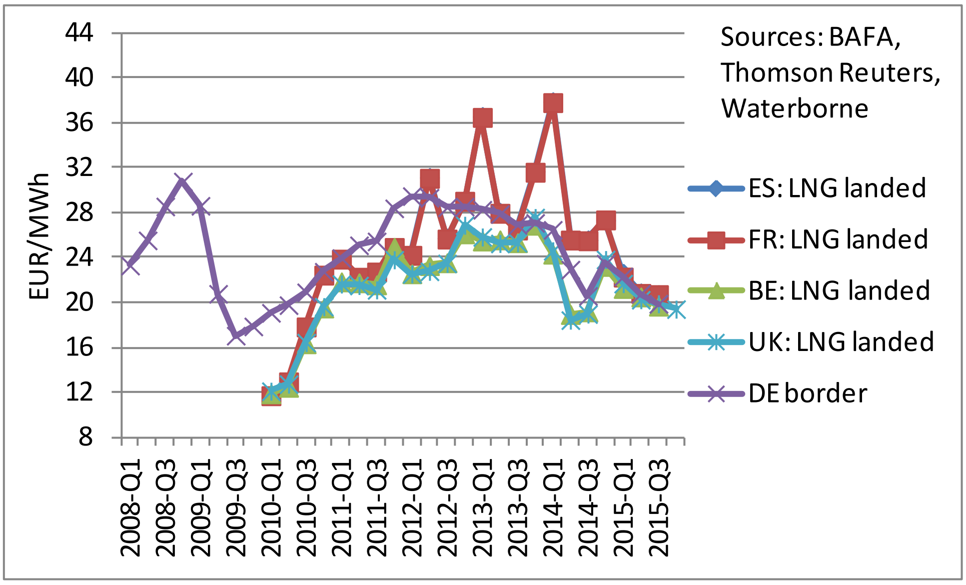


Figure 58: Development of the LNG landed prices in Western Europe (2010 – 2015). The German border price is provided as a reference.

With regard to the econometric analyses of the time series, the Dickey-Fuller test indicates non-stationarity of the price developments requiring a linear regression of first-order differences. Due to data availability, an analysis of the time series of LNG prices can only be carried out for BE, ES, FR and the UK for 2010 to 2015. Again we carry out two analyses: one of the external drivers of the gas markets, which includes the development of the crude oil benchmarks, and one of the interactions with other gas markets. This avoids multi-collinearity between gas prices and the crude oil price. For ES and FR we find a modest and only weakly to moderately significant positive impact of the crude oil price with a time lag of one month (see Table 30). Longer time lags don't show significant impacts. For BE and the UK, there is no significant impact of the crude oil price. These results reflect the fact that LNG in ES and FR is traded via oil-indexed long-term contracts, while LNG is traded on spot markets in BE and the UK. Furthermore, we find a moderately significant impact of the monthly heating degree days, which indicates a seasonality of prices that can be explained by the seasonal variation of demand for heating purposes.

Table 29: Results of the time-series analysis of external drivers for Western European LNG prices (t statistics in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01)

LNG prices in the EU OLS first differences	**ES** 2010 – 2015	**FR** 2011 – 2015	**BE** 2010 – 2015	**UK** 2010 – 2015
Crude oil price	0.047	0.103	0.059	0.103
(no lag)	(0.36)	(0.69)	(0.74)	(1.10)
Crude oil price	0.271**	0.288**	0.071	0.020
(lag of 1 month)	(2.03)	(1.98)	(0.80)	(0.19)
Crude oil price	0.078	0.185	0.015	0.015
(lag of 2 months)	(0.46)	(0.90)	(-0.17)	(0.17)
Crude oil price	0.155	0.130	0.121	0.139
(lag of 3 months)	(0.88)	(0.62)	(1.27)	(1.34)
Crude oil price	0.006	0.042	-0.020	-0.007
(lag of 4 months)	(0.04)	(0.20)	(-0.25)	(-0.08)
Crude oil price	0.046	0.091	0.006	0.020
(lag of 5 months)	(0.27)	(0.43)	(0.06)	(0.20)
Crude oil price	0.167	0.188	-0.017	-0.011
(lag of 6 months)	(1.07)	(1.04)	(-0.18)	(-0.11)
Crude oil price	-0.018	-0.086	0.046	0.067
(lag of 7 months)	(-0.13)	(-0.49)	(0.52)	(0.61)
Consumption index	-0.028	-0.020	0.010	-0.048*
	(-0.36)	(-0.44)	(0.84)	(-1.78)
Heating degree days	0.343**	0.332**	0.091	0.231**
per month	(2.36)	(2.05)	(1.05)	(2.14)
Constant	0.171	0.315	0.118	0.120
	(0.47)	(0.68)	(0.56)	(0.56)
Observations	68	51	68	68

As LNG is traded on spot markets in BE and the UK, the LNG prices in BE and the UK are strongly correlated to the hub prices in NWE. Therefore the corresponding coefficient is larger as for ES and FR and there is an impact of varying significance also for a lag of one month in BE and the UK (see Table 30). This provides evidence that the European hub prices, indeed, drive the LNG prices, while for ES and FR the direction of the impact remains unclear.

The US hub price at Henry Hub does not a significant impact for any kind of lag structure. Here it is important to note that the main known impact on LNG prices took place in 2009, which is not covered by the available time series. The LNG prices in ES and FR are strongly correlated with the Asian LNG prices because both are based on oil-indexed LTCs and markets are interconnected via shipping. Thus it is not surprising that the Asia LNG landed prices are shown to have a strongly significant impact in a linear regression of first differences, however only without a time lag on the monthly scale. And the same is true the other way round so that an analysis of the detailed interconnections would require a much more elaborated kind of model, which is out of the scope of this study.

Table 30: Results of the time-series analysis of market drivers for Western European LNG prices (t statistics in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01)

LNG prices in the EU OLS first differences	**ES** 2010 – 2015	**FR** 2011 – 2015	**BE** 2010 – 2015	**UK** 2010 – 2015
Hub price UK	0.420***	0.505**	0.681***	0.749***
(no lag)	(3.04)	(2.55)	(8.28)	(7.58)
Hub price UK	0.021	-0.133	0.260***	0.226*
(lag of 1 month)	(0.09)	(-0.39)	(2.81)	(1.89)
Hub price UK	-0.180	-0.046	-0.108	-0.109
(lag of 2 months)	(-0.72)	(-0.14)	(-0.93)	(-0.84)
Hub price UK	0.288	0.225	0.004	0.002
(lag of 3 months)	(1.39)	(0.85)	(0.04)	(0.02)
Hub price US	-0.317	-0.062	-0.195	-0.211
(no lag)	(-0.96)	(-0.13)	(-1.48)	(-1.34)
Hub price US	0.320	0.469	0.222	0.205
(lag of 1 month)	(0.93)	(0.80)	(1.49)	(1.22)
Hub price US	-0.331	-0.609	-0.036	-0.041
(lag of 2 months)	(-1.06)	(-1.30)	(-0.22)	(-0.22)
Hub price US	-0.264	-0.173	0.114	0.094
(lag of 3 months)	(-0.77)	(-0.29)	(0.70)	(0.44)
LNG landed prices Japan	0.538***	0.568***	0.089**	0.084*
(no lag)	(4.55)	(3.94)	(2.17)	(1.78)
LNG landed prices Japan	0.082	0.019	-0.051	-0.050
(lag of 1 month)	(0.70)	(0.12)	(-1.11)	(-0.94)
LNG landed prices Japan	-0.068	-0.006	-0.027	-0.029
(lag of 2 months)	(-0.74)	(-0.06)	(-0.48)	(-0.47)
LNG landed prices Japan	-0.056	-0.103	-0.006	0.000
(lag of 3 months)	(-0.51)	(-0.79)	(-0.12)	(0.01)
Constant	-0.036	0.111	0.051	0.054
	(-0.12)	(0.27)	(0.33)	(0.28)
Observations	66	52	66	66

Due to insufficient data availability the LNG price developments in EL, IT and PT could not be analysed. Since their imports originate from a less diverse set of exporting countries, namely Algeria and for PT also Nigeria (Eurostat 2015), the price dynamics may be quite different for these countries. In particular, DG ENER (2015) reports significantly higher prices in IT and EL than in ES and FR. We finally note that Eurostat lists no gas imports to CY and MT at all.

North American and East Asian Markets

GOG clearly dominates the North American markets with fully liquid trading markets in the USA and Canada and the wholesale price in Mexico being referenced to prices in the USA. The markets in Asia Pacific (Japan, Korea) have a dominant share of OPE-traded LNG, but also some GOG. China has a diverse mixture of pricing mechanisms with a high share of GRP but also OPE-traded LNG (see IGU 2015). While the Asian markets are interconnected with the European markets both via the shipping of LNG and Russia as a supplier of piped natural gas, the interconnection of both the Asian and the European markets with the US markets is mainly one-sided. The US imports LNG from a diverse set of countries, but exports LNG to countries without free-trade agreements only in exceptional cases.

In the context of the economic crisis and the resulting lower energy demand, the price for natural gas at the Henry Hub has dropped in accordance with the oil price development. Due to the the rising domestic production of shale gas, the hub price has completely decoupled from the oil price development after 2009. The price more than halved until the beginning of 2012, which reflects the lack of opportunity to export LNG (ACER 2015). After recovering in 2012 and 2013, the prices peaked during a severe cold spell especially in the Midwest at the beginning of 2014 (Quarterly Report 3/2014). In the sequel, the price has halved again (see **Figure 59**).

At the beginning of 2010, the Asian LNG landed prices were at low levels due to the low international demand, which was a consequence of the economic crisis on the one hand and the rising domestic share in the US on the other hand. Reflecting the high share of oil-indexed contracts in Asia Pacific, the LNG import prices in Japan, China and South Korea have stayed strongly correlated to the oil price. Gas demand has also risen in the region due to economic growth in China and South Korea, and the switch from nuclear to gas plants after the Fukushima incident in Japan (Energy prices report 2012). Hence, the LNG prices increased by more than 150 % until the beginning of 2014 while undergoing high volatility in between, partly due to the seasonality of demand. Afterwards the prices fell again to the level of 2010 within one year, following the global crude oil price development (see **Figure 59**).

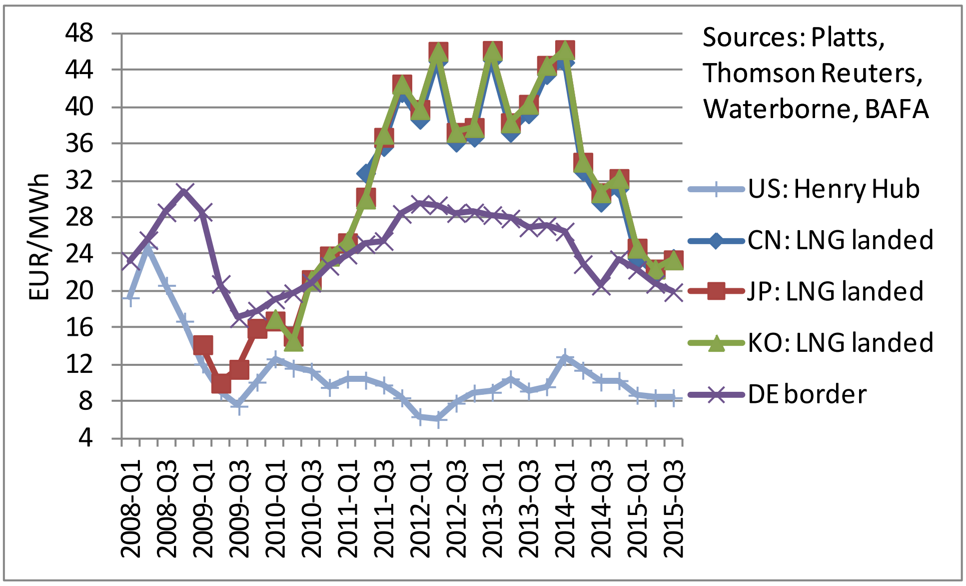


Figure 59: Development of the US hub price at Henry Hub (2008 – 2015) and of the LNG landed prices in Eastern Asia (2010 – 2015). The German border price is provided as a reference.

For the econometric analyses of the time series of the US hub price and the East Asian LNG landed prices, the Dickey-Fuller test again shows non-stationarity of the price developments suggesting a linear regression of first-order differences. Due to data availability an analysis of the time series of the East Asian LNG prices can only be carried out for 2010 to 2015. For comparability reasons, the analysis for the US is also restricted to 2010 – 2015. In 2008 and 2009, the price dynamics were dominated by the economic crisis and the oil price decline. A consequence of excluding 2008 and 2009 is thus that the analysis yields the drivers of the gas prices after the decoupling from the oil price development. Again we carry out two analyses: one of the external drivers of the gas markets, which includes the development of the crude oil benchmarks, and another one of the interactions with other gas markets. This avoids multi-collinearity between gas prices and the crude oil price.

With regard to the US hub price at Henry Hub in 01/2010 – 09/2015, the crude oil price shows no significant impact for diverse lags (see **Table 31**). However, a moderately significant positive driver has been the index of the monthly level of consumption that indicates deviations from the usual seasonal pattern of demand. This provides clear evidence for the impact of extraordinary cold spells such as the one in the Midwest in 2014 and underlines the import role of demand fluctuations in the US, which may be a consequence of the lack of LTCs in the context of dominance of GOG. The rising share of domestic production shows neither a significant impact itself nor of moving averages. It is important to note, however, that considering first order differences removes the quite significant downward trend from the time series of the hub price. In a linear regression model with absolute values instead of first-order differences, the moving average of the domestic share in consumption shows a strongly significant negative impact when applied in combination with the index of monthly consumption. The importance of the domestic situation can also be seen from the rather weak impacts of international markets discussed below.

For the LNG landed prices in Japan, Korea and China we analyze the monthly time series starting in 2010 (in 2011 for China). We find a modest positive impact of the crude oil price, which is moderately significant without a time lag (see **Table 31**). Longer time lags don't show significant impacts. The coefficient is a bit higher for China, which is most likely due to the lack of price data for China for 2010, when the volatility of the oil price was particularly large. The impact of the oil price is an important factor to explain the significantly higher LNG prices in Asia because the Asian benchmark prices for crude oil have been exceeding those at the North Sea. The seasonality of Asian LNG prices could not be tested due to the lack of both heating degree days and consumption data on the monthly time scale.

Table 31: Results of the time-series analysis of external drivers for the hub price in the US and LNG landed prices in East Asia (t statistics in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$)

International hub & LNG landed prices	**US: Henry Hub**	**Japan: LNG landed**	**South Korea: LNG landed**	**China: LNG landed**
OLS first differences	2010 – 2015	2010 – 2015	2010 – 2015	2011 – 2015
Crude oil price	0.042	0.367**	0.352**	0.483**
(no lag)	(0.72)	(2.06)	(1.98)	(1.98)
Crude oil price	-0.071	0.099	0.102	0.027
(lag of 1 month)	(-1.26)	(0.43)	(0.44)	(0.08)
Crude oil price	0.057	0.114	0.112	0.136
(lag of 2 months)	(0.99)	(0.41)	(0.41)	(0.32)
Crude oil price	0.022	0.171	0.170	0.168
(lag of 3 months)	(0.38)	(0.53)	(0.52)	(0.42)
Crude oil price	-0.078	-0.039	-0.048	0.026
(lag of 4 months)	(-1.33)	(-0.17)	(-0.22)	(0.11)
Crude oil price	0.011	0.096	0.087	-0.002
(lag of 5 months)	(0.24)	(0.49)	(0.43)	(-0.01)
Crude oil price	0.024	-0.314	-0.307	-0.353
(lag of 6 months)	(0.40)	(-1.13)	(-1.12)	(-1.01)
Crude oil price	0.008	-0.111	-0.120	-0.210
(lag of 7 months)	(0.14)	(-0.45)	(-0.49)	(-0.64)
Monthly consumption index	0.072** (2.57)			
Monthly index of domestic production	-0.027 (-1.14)			
Constant	-0.083	-0.068	-0.092	-0.141
	(-0.65)	(-0.15)	(-0.20)	(-0.24)
Observations	69	59	59	43

The LNG landed price of ES exerts a strongly significant but only modest positive impact on the US hub price with a time lag of one month reflecting the interconnection of markets via shipping of LNG (see **Table 32**). Furthermore, we find a strongly significant impact of the exchange rate between the

US Dollar and the Euro, both for an index of nominal prices and for an index of deflated prices. The impact's magnitude reflects the US price level of roughly 10 EUR/MWh in 2010 – 2015. The strengthening of the US Dollar in 2015 has therefore also driven the recently rising spread with regard to the European prices.

As discussed already in the analysis of the LNG prices in ES and FR, the latter are strongly correlated with the East Asian LNG prices because both are based on oil-indexed LTCs and markets are interconnected via shipping. It is thus not surprising that we find a strongly significant and high impact of the LNG landed price in ES on the East Asian LNG prices(see **Table 32**). There is, however, no lag on the monthly time scale so that the mutual impact do not become evident from the analysis. An analysis of the detailed interconnections is out of the scope of this study. As for the European LNG landed prices, the US hub price at Henry Hub does not show a significant impact for any kind of lag. We note again that the main known impact of the US hub price on LNG prices took place in 2009, which is not covered by the available time series. The local currency's exchange rate shows a significant impact neither for indices of nominal prices nor for deflated prices

Table 32: Results of the time-series analysis of market drivers for the hub price in the US and LNG landed prices in East Asia (t statistics in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01)

International hub & LNG landed prices OLS first differences	**US: Henry Hub** 2010 – 2015	**Japan: LNG landed** 2010 – 2015	**South Korea: LNG landed** 2010 – 2015	**China: LNG landed** 2011 – 2015
Deflated exchange rate index	0.151***	0.114	0.065	0.147
	(2.71)	(1.19)	(0.30)	(0.89)
LNG landed prices ES (no lag)	0.031	0.829***	0.794***	0.908***
	(0.40)	(7.75)	(6.87)	(7.41)
LNG landed prices ES (lag of 1 month)	0.137***	0.188	0.196	0.204
	(2.75)	(1.13)	(1.07)	(1.24)
LNG landed prices ES (lag of 2 months)	0.046	-0.088	-0.094	-0.061
	(0.78)	(-0.62)	(-0.63)	(-0.37)
LNG landed prices ES (lag of 3 months)	0.098	0.236	0.219	0.273
	(1.40)	(1.53)	(1.47)	(1.56)
LNG landed prices Japan (no lag)	-0.002			
	(-0.03)			
LNG landed prices Japan (lag of 1 month)	-0.066			
	(-1.44)			
LNG landed prices Japan (lag of 2 months)	0.008			
	(0.17)			
LNG landed prices Japan (lag of 3 months)	-0.079			
	(-1.35)			
Hub price US (no lag)		0.151	0.145	-0.317
		(0.41)	(0.37)	(-0.74)
Hub price US		-0.340	-0.303	-0.636

(lag of 1 month)		(-0.94)	(-0.82)	(-1.39)
Hub price US		0.062	0.025	0.212
(lag of 2 months)		(0.17)	(0.06)	(0.38)
Hub price US		0.219	0.117	0.329
(lag of 3 months)		(0.63)	(0.32)	(0.73)
Constant	-0.104	0.010	-0.010	-0.240
	(-0.77)	(0.03)	(-0.03)	(-0.68)
Observations	65	65	65	51

The price dynamics in Canada and Mexico could not be evaluated due to the lack of sufficient data. The strong interconnection of markets in North America including Mexico (see IGU 2015), however, suggests that prices show a similar behavior also in Canada and Mexico. Since the Indian gas markets rely on gas imports via oil-indexed long-term contracts with export countries very similar to Chinese markets, the price development can be expected to be comparable. However, there is no data available to underpin this statement. For all other remaining G20 countries, the available data is also insufficient to carry out a similar econometric analysis for the dynamics of wholesale prices of natural gas. We thus refrain to discuss the gas price developments for those countries.

Summary of the findings for drivers of wholesale gas prices

During the period 2008 – 2015, wholesale pricing of natural gas in the EU has undergone remarkable changes. At the beginning of 2008, the shares of GOG and OPE were already quite diverse across the member states with close to 100 % of GOG in the UK and a vanishing share in the Baltic and Southeastern European member states. The level of prices, however, was not so different due to the persistence of a strong coupling to the oil price dynamics. In 2009/10, the gas price dynamics at the European hubs decoupled driven by an oversupply of international markets. The oversupply was a consequence of the low international demand for energy induced by the economic crisis and the particularly lower gas imports to the US because of the shale gas boom. In the following years, more and more member states were trying to profit from the low hub prices by both increasing the share of GOG and renegotiating the existing oil-indexed LTCs. The interplay of this development with the hub price dynamics itself has led to a diversification of gas price dynamics throughout the EU. **Figure 60** shows the price development for selected member states, which roughly represent the whole spectrum of price dynamics in the period 2008 – 2015.

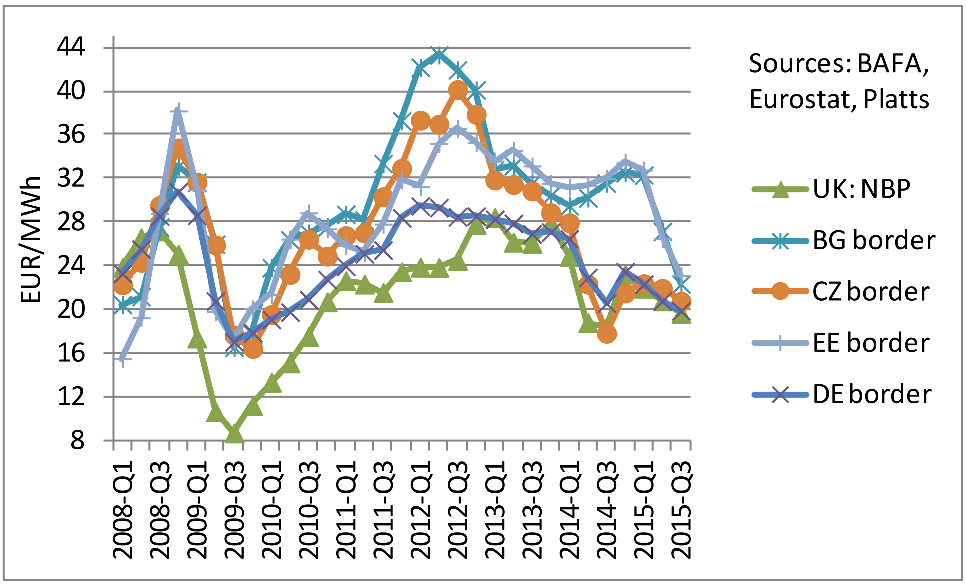


Figure 60: Development of hub and border prices of natural gas in selected member states of the EU (2008 – 2015). Border prices are the country-specific average import prices reflecting imports from Algeria, the Netherlands, Norway and Russia.

For the hub prices in Northwestern Europe, represented by the British NBP hub in **Figure 60**, the econometric analysis has found a weakly to moderately significant impact[4] of the non-lagged crude oil price and a moderately significant impact of the European import price of oil-indexed LNG (both non-lagged and with a lag of two months). While the former reflects the impact of oil-indexed LTCs on the spot markets, the latter is an indication of the indirect interconnection of markets via the trade of LNG. The impact of the crude oil (with an increase by one unit raising the hub price by €0.13 - 0.17 /MWh on average) is only half as big as the total impact of the LNG import price (€0.23 - 0.27). This indicates a persisting decoupling of the hub prices from the crude oil price, as the impact of the crude oil price is significantly higher for oil-indexed prices (see below). In addition, the analysis provided evidence for a strongly significant impact of deviations from the usual seasonal patterns of demand on the European hub prices.

The development of prices in central European member states was more divers, as can be seen from the comparison of the German and the Italian border price in **Figure 60**. There is, however, clear evidence from the econometric analysis that the rising share of GOG in central European member states has significantly decreased the impact of oil price on the border prices for natural gas: while the average impact of an increase of the US hub price by 1 EUR on the border prices of 0.33 EUR in 2009 – 2012 more than doubled in 2013 – 2015, the impact of the crude oil price has reduced from 0.42 EUR to 0.34 EUR in the same period. As a consequence, central European member states were able to profit from the drop of hub prices in 2014.

For the Baltic and southeastern European states – represented by the Estonian and the Bulgarian border price in **Figure 60** – the main drivers are less clear. Given the still high share of OPE, it is not surprising that the analysis indicates the still high importance of the crude oil price (average impact of 0.44 EUR in 2013 – 2015). On the contrary, there is also moderate evidence that the impact is decreasing and that also hub price dynamics have been affecting the border prices, which might be explained by the introduction of gas components in oil-indexed LTCs and the installation of a LNG terminal in Lithuania in 2014. Moreover, other factors like the share of domestically produced gas turned out to have had notable impact in the econometric analysis. All in all, this has led to diverse price developments in 2012 – 2014.

Recently, the strong drop of crude oil prices in 2015, however, has reduced the price spreads not only among the Baltic and southeastern European member states but throughout the EU in general. In the context of the seemingly persisting low level of the crude oil prices, hence, the questions arises whether the diversity of gas price dynamics is replaced by a situation similar to 2008 again.

LNG landed prices in southwestern Europe and in Asia are highly correlated with each other and both are still strongly driven by the oil price development, but our analyses indicate that the price development at European hubs has gained a significant impact, too. For the US hub price at Henry Hub, the covered time period (2010 – 2015) did not provide evidence for a significant impact on the LTC-based LNG prices. Furthermore, the econometric analysis suggests that the seasonal change of demand persists to be an important driver of LNG prices.

The development of wholesale gas prices in the US itself has been quite different from the one in the EU. This is commonly attributed to the rising share of domestically produced natural gas in combination with the existing export restrictions for natural gas that allow exports to countries without a free-trade agreement with the US only with a special permission. The econometric analysis could provide indirect evidence for the impact of the rising domestic production by indicating that the impact of the crude oil price is insignificant and the impact of the European LNG prices is weak (€0.14 /MWh with a lag of one month). On the contrary, it clearly indicated an impact of international LNG prices on the US market itself. Finally, there is some evidence of the impact of the exchange rate between the US Dollar and the Euro as well as of deviations from the usual seasonal pattern of demand, which may result in high peak prices during periods with extraordinary high demand. The latter suggests that a complete shift to GOG as in the US that on the one hand allows reducing the risk of price volatility may also partly increase volatility due to the lower importance of LTCs. Here, it should be noted that the general level of hub prices is only half as big as in the EU though.

4.2 Main drivers of natural gas retail prices

In this section, we look at the factors affecting retail prices and the energy retail price component of gas. Similar to the electricity retail price, the gas retail price consists of three main components, the energy component, network fees, taxes and levies. While taxes and levies are price components directly set by regulation and governments, network fees are mainly determined by infrastructure costs and are supervised by a regulation body. The price of the energy component includes costs for supplying and marketing of gas, in some cases costs for measuring and grid as well as a profit. The price of the energy component depends on wholesale prices but also on market features such as the degree of market liberalisation.

The objective of this section is to show how the retail price component has evolved over time, and analyse which factors drive the energy component. This includes analysing how strongly wholesale prices affect the energy component and what the role is of market liberalisation, regulation or competition.

The econometric analysis builds on data from VaasaETT and Eurostat. The latter are compiled by DG ENER, which used biannual data and monthly gas price indices to derive monthly data. However, the energy and network components are not separately depicted in this statistics. In addition, for descriptive purposes, the adhoc statistical data collection is used. This has been organised by DG Energy with the help of ESTAT and national statistical institutes. Data from Eurostat and the adhoc data collection are differentiated into gas consumption bands D2 (household annual consumption) and I5 (industrial annual consumption), while data from VaasaETT only include household's prices in (capital) cities.

4.2.1 Methodology and Data

To assess the pass through-effect of wholesale prices on retail prices, a panel analysis based on fixed and random effects is conducted (linear specification, selection of random vs fixed effects estimator via a standard Hausman test). This analysis allows incorporating time variant variables and country specific characteristics. In addition a correlation with lagged wholesale prices is conducted and the evolution of wholesale price and energy supply price is depicted.

To explain changes in retail prices, wholesale prices and demand are applied as exogenous variables. In addition, market characteristics, such as liberalisation and price regulation and competition might also affect the retail price component energy. The exogenous and endogenous variables are variables are depicted in Table 33, the sources are depicted in Table 1.

Table 33: Variables applied to analyse drivers in the retail electricity market

Variables	Description	Available Data
Retail price component energy	Endogenous energy component, monthly data	Ad-hoc data collection, covering household and industrial consumer bands for electricity and natural gas; 2008 2010, 2012, 2014, 2015, Eurostat data: monthly data derived from biannual data (used only for industry analysis) VaasaETT data, monthly, only for households
Wholesale price	Exogenous wholesale prices, monthly	See Task 1.1
Heating and cooling degree days	Account for demand	See task 1.1
Exchange rate index	To account for changes in domestic currency to euro	See task 1.1
Growth rate index	To account for changes due to growth	See task 1.1
Market regulation Market liberalisation	To account for market features	Annual data (2012-2014) ACER/CEER MMR 2015, DG ENER

4.2.2 Results

The evolution of gas retail price components is depicted in Figure 61 for households and in Figure 62 for industries:

- The energy component is decreasing from 2012 to 2015, but is more costly for households.
- The spread of the energy component is larger in the household segment.
- Network fees, taxes and levies are significantly higher for households and are slightly increasing till 2015.
- While for the industry network fees remain rather constant, taxes and levies are increasing over time as well as the spread between countries.

Overall, similarly to the electricity sector, taxes and levies become the main drivers of retail prices. For households, network fees also contribute to augmenting retail prices. In contrast to electricity, the energy price component is clearly the highest among the three components. Therefore, factors driving the energy component are of utmost interest.

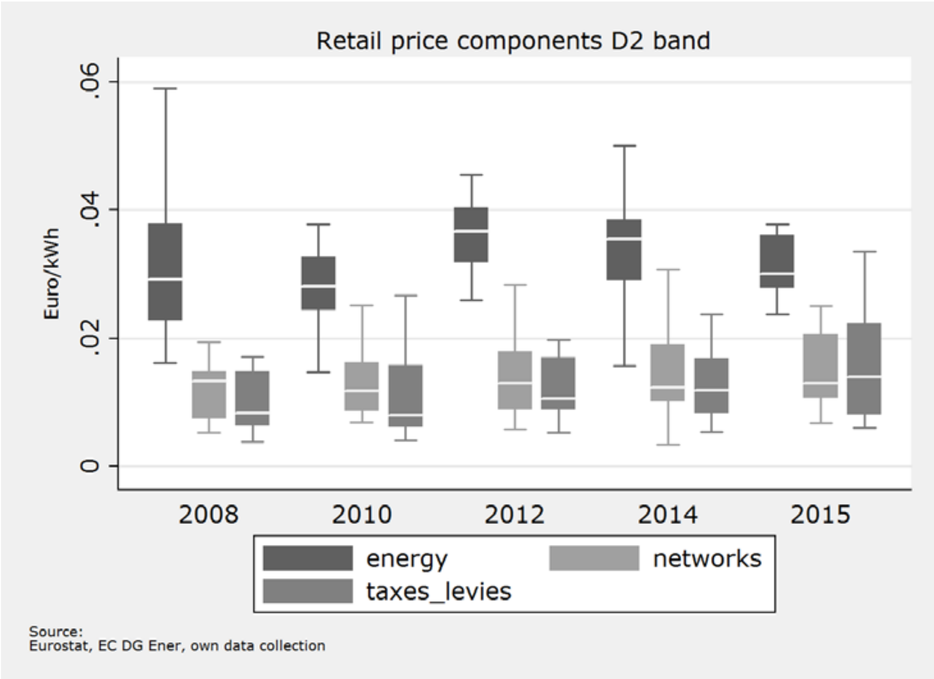


Figure 61: Annual gas retail price components, households between 2008 and 2015 of EU member states, (Euro/kWh)

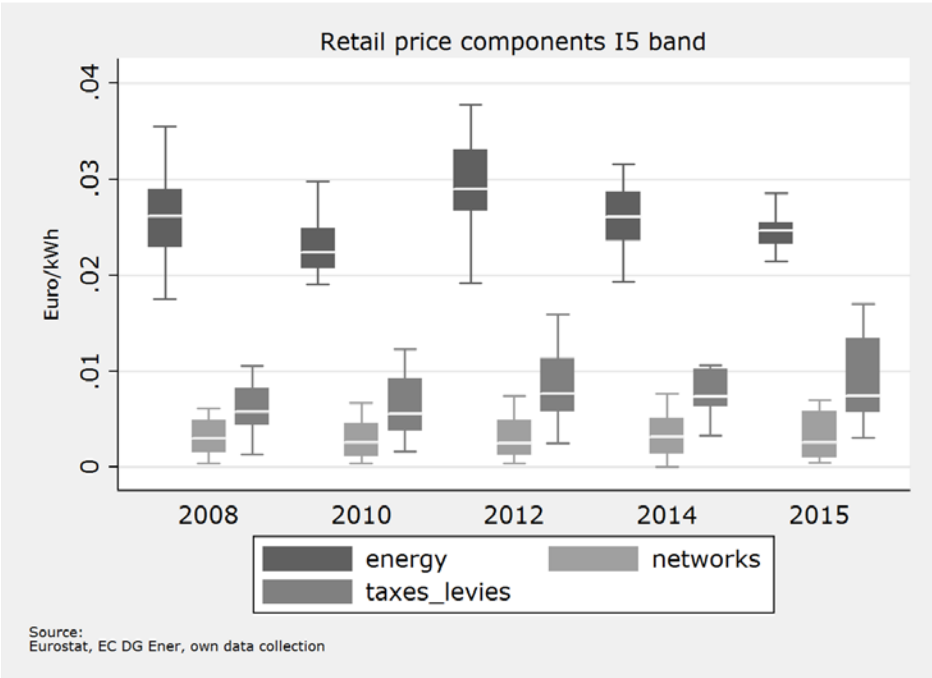


Figure 62: Annual gas retail price components, industries between 2008 and 2015 of EU member states, (Euro/kWh)

For the FE/RE estimator, the wholesale price is lagged by 2 months, lags larger than 2 months do not increase the impact or significance of the analysis. Data of VaasaETT are used for prices of households, Eurostat data are applied for analyses of industrial consumer prices. Overall, the econometric results are similar to the electricity retail price analysis and are depicted in Table 34:

- Wholesale gas prices drive the retail energy component while other factors display no impact under the given variables: A change by one Eurocent of wholesale gas prices affect retail energy by about 0.4 Eurocents.

Table 34: Results of the FE/RE model - drivers in the retail gas market

	FE households VaasaETT energy	RE industry Eurostat energy&networks
Number of countries	20	19
Cooling degree days	0.000	0.000*
	(0.36)	(1.94)
Heating degree days	-0.000	-0.000
	(-0.54)	(-0.31)
Exchange rate index	-0.001***	0.000***
	(-9.98)	(4.07)
Market liberalization (ln)	0.002***	0.000***
	(5.53)	(3.54)
Wholesale price lagged by 2 months	0.369***	0.438***
	(13.00)	(31.48)
Constant	0.086***	0.006**
	(12.68)	(2.14)
Observations	892	1568
Within R^2	0.311	0.417
between R^2	0.290	0.291
Overall R^2	0.289	0.347

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

It is assumed that in addition to wholesale prices other factors such as market conditions determine retail energy prices. To address these factors, the difference between the retail energy component and wholesale price is used. In the following it is called margin and is supposed to be a measure for the degree of competition. However, this margin should not be considered as the profit margin, because it still covers costs for marketing and metering, distribution and transportation (industry prices). Nevertheless, this margin is used to show the evolution of market competition in the retail sector. A small margin points to a strong competition, changes in margins point to changes in market conditions. The depicted evolution of the margins across time (Figure 63 and Figure 64) confirms the findings of the analysis: margins are lower in the industrial consumer segment, even though the margin might still cover part of the grid fees. This reveals a strong market power of industrial consumers. In some countries, margins are very large, in others they are negative. This can be explained by differing pricing and regulation mechanisms.

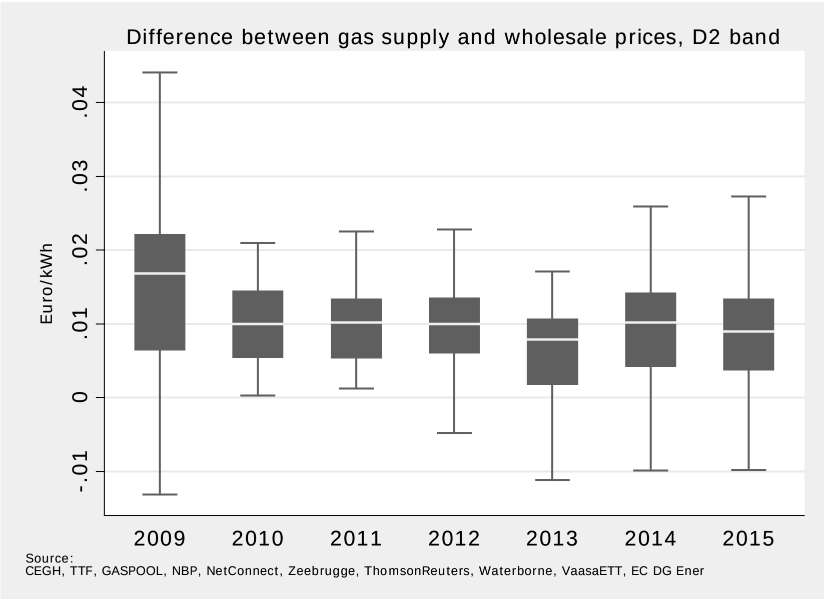


Figure 63: Margin in household segment: difference between gas retail price and wholesale price, 2009 and 2015 of EU member states, (Euro/kWh)

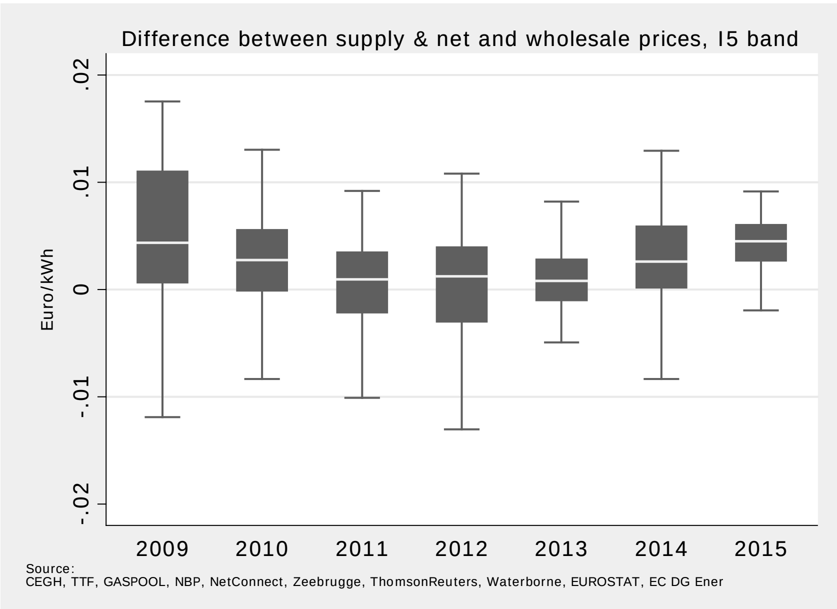


Figure 64: Margin in industry segment: difference between gas retail price and network components and wholesale price, 2009 and 2015 of EU member states, (Euro/kWh)

There are regional differences in prices, which could be explained by different market characteristics such as retailer concentration, number of suppliers, households' switching behaviour, but also by different wholesale prices.

4.2.2.1 Regional markets

When differentiating between border and spot market prices, the analysis shows that spot market prices have a significant impact on energy price components of households, while border prices show very minor impacts, even with lags up to one year (Table 35). All other factors show no or minor impacts on energy prices. Thus, regional differences are determined by wholesale and retail market features. Similar results are obtained for industries: the energy price component is influenced by spot market prices while countries with border gas prices display very small coefficients for wholesale gas prices.

Table 35: Results of the FE/RE estimator by regions- drivers in the retail gas market for households (VaasaETT)

	FE BG, RO, SI, EL border	FE CZ, HU, SK, border	RE AT, DE, PL spot	FE UK, NL, BE spot
Number of countries	4	3	3	3
Cooling degree days	0.000	0.000	-0.000	-0.003
	(0.09)	(0.81)	(-0.11)	(-1.08)
Heating degree days	-0.000	0.000	-0.000*	-0.000
	(-0.73)	(0.72)	(-1.66)	(-0.93)
Exchange rate index	-0.000	-0.000***	-0.000***	-0.001***
	(-0.18)	(-7.00)	(-9.84)	(-8.51)
Market liberalization (ln)	0.002***	-0.003***	-0.001	-0.003***
	(3.16)	(-2.77)	(-1.28)	(-4.08)
Wholesale price border lagged by 2 months	0.001***	-0.000		
	(6.62)	(-0.58)		
Wholesale price spot lagged by 2 months			0.164***	0.672***
			(2.77)	(10.17)
Constant	0.036	0.078***	0.074***	0.118***
	(0.25)	(11.03)	(18.98)	(11.25)
Observations	135	106	180	200
Within R2	0.288	0.662	0.066	0.440
Between R2	0.127	0.633	0.985	0.786
Overall R2	0.135	0.566	0.396	0.034

The difference between the energy price component and the wholesale gas prices (for industry the energy price component also includes networks fees) is also depicted by regions. This country specific illustration of margins underpins the assumption that market features play a role (see Figure 65, Figure 66, Figure 67, Figure 68).

- Although the data basis differs and contains network fees in the industry segment, margins in the household sector are larger than in the industry segment pointing to bargaining power of larger consumers
- There are huge differences between countries (households): low margins in HU and NL
- There are high margins in some years, low in others (UK, BE)

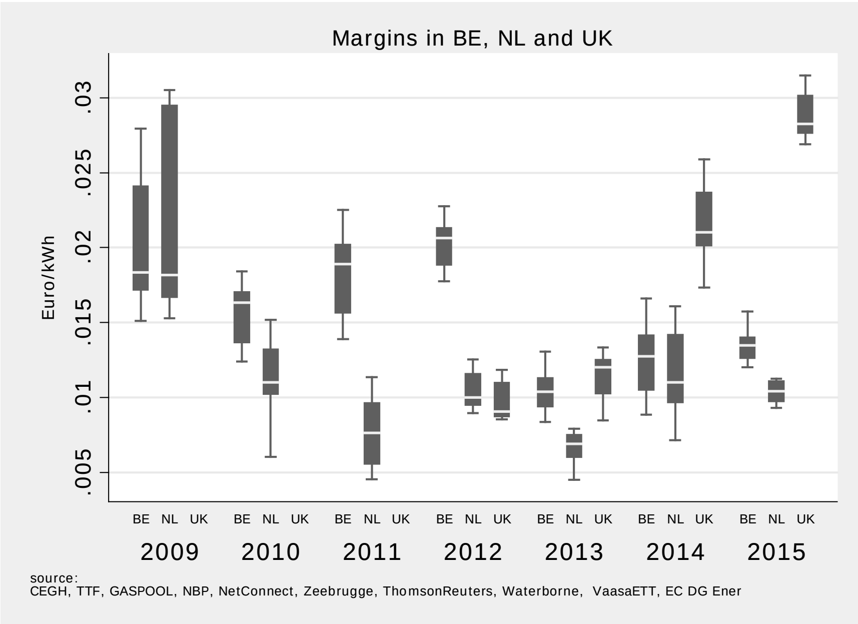


Figure 65: Margin in household segment of Western EU countries: difference between gas retail price and wholesale price, 2009 and 2015 of EU member states, (Euro/kWh)

The evolution of the margins in BE, NL and UK is heterogeneous, as the wholesale price (spot price) of these countries is almost identical, but the retail supply price and hence the margin is not. Subsequently, the differences in margins can only be explained by retail market structures, be it that they have different lags to the spot market, offer different products, or differ in their degree of competition (Figure 65 and Figure 67). Similarly, there are huge differences in margins in CZ, HU and SK for households while in the industry segment margins have converged recently (Figure 66 and Figure 68).

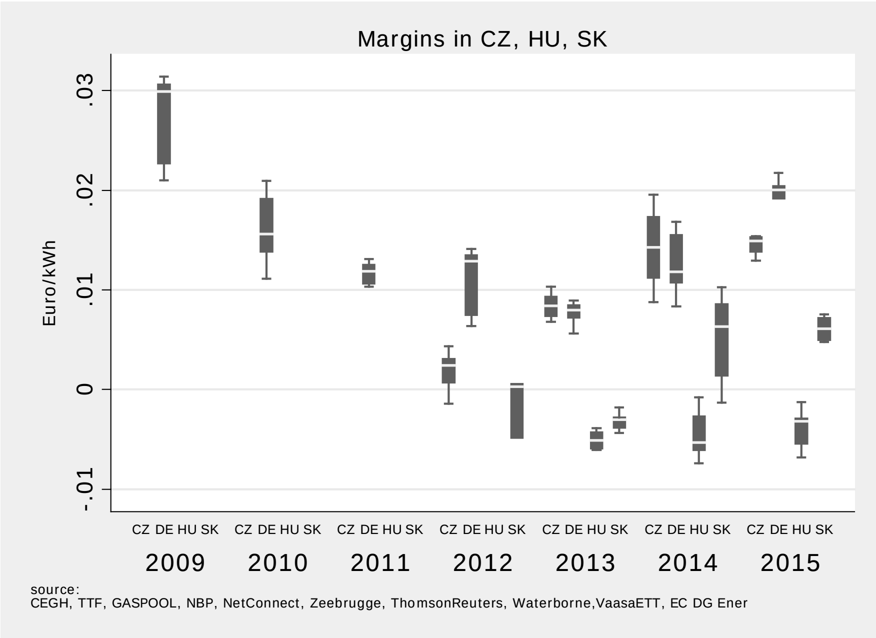


Figure 66: Margin in household segment of Eastern EU countries: difference between gas retail price and wholesale price, 2009 and 2015 of EU member states, (Euro/kWh)

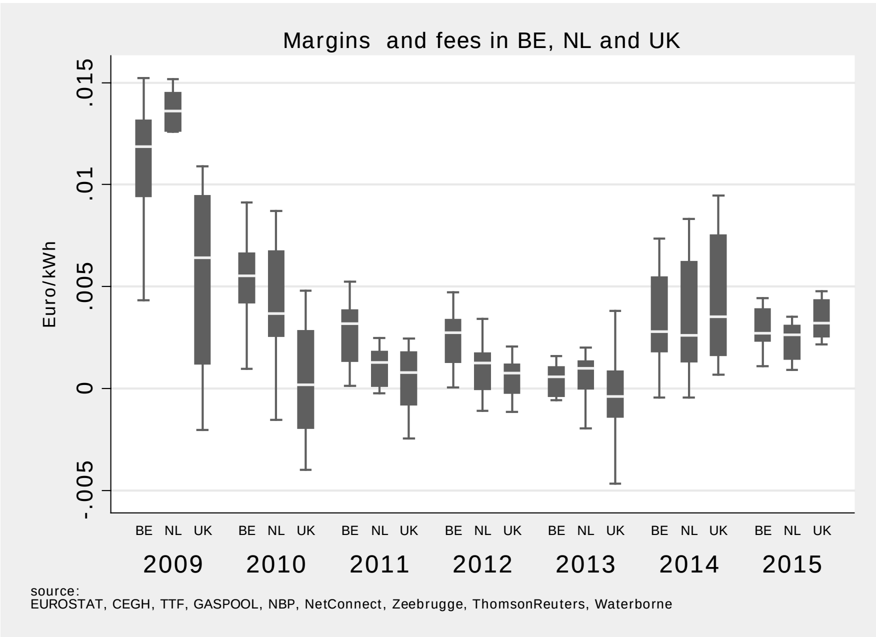


Figure 67: Margins in industry segment of Western EU countries: difference between gas retail price and network components and wholesale price, 2009 and 2015 of EU member states, (Euro/kWh)

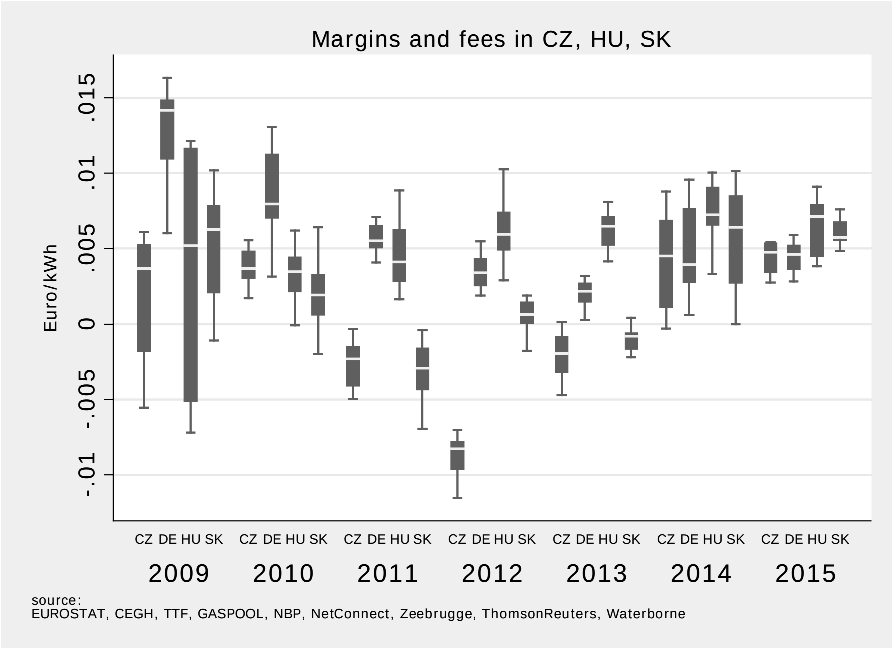


Figure 68: Margins in industry segment of Eastern EU states: difference between gas retail price and network components and wholesale price, 2009 and 2015 of EU member states, (Euro/kWh)

4.2.2.2 Supply price by status of regulation and liberalisation and degree of competition

Regional differing wholesale prices fail to explain regional differences in retail prices. It is assumed that market conditions play a crucial role: retail prices differ by their degree of competition, regulation (price setting or controlling by authorities) and liberalisation (free entry and exit) status. Data on these market features are incomplete for the time period under analysis (2008 to 2015). Therefore some assumptions are made: example, for 2015 it is assumed that the degree of competition has not changed much compared to 2014. Similarly, the status of regulation and liberalisation is assumed to be the same if no update information were available. The energy prices of markets with different status of regulation, liberalisation and competition are depicted in Figure 71, Figure 69, Figure 73, Figure 72, Figure 74 and Figure 70.

Countries with liberalised markets display less changes over years (household) but a larger spread of supply prices. However the average energy prices of liberalised and non-liberalised markets reveals no differences. For industrial consumers the prices are in average slightly lower (less than 0.5 Eurocents lower) in liberalised markets.

Countries with regulated retail markets tend to display lower supply prices in the household segment (about one Eurocent), but their variances are heterogeneous as well. In the industry segment regulated prices seem to be slightly higher than in deregulated markets, but the average energy prices are not significantly different.

Countries with a higher degree of competition display lower prices (about one Eurocent, but no homogeneous variances) than those with market shares of the three top suppliers above 80% in the household segment. In the industry segment the average prices differ by about 0.2 Eurocents, but the variances are heterogeneous.

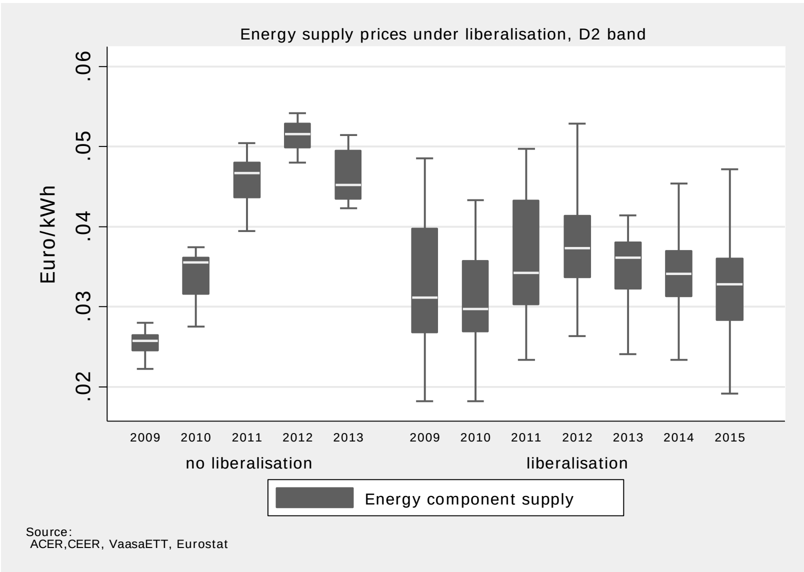


Figure 69: Households' energy prices by liberalization, between 2008 and 2015, EU countries (Euro/kWh)

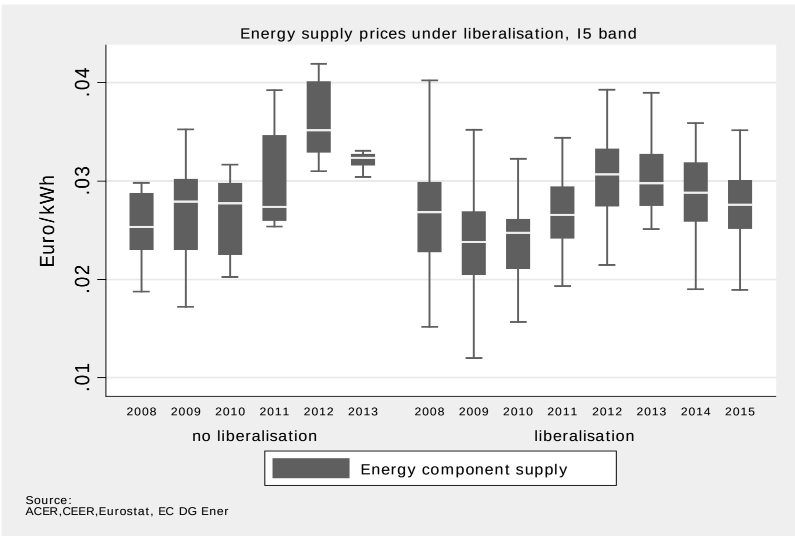


Figure 70: Industries' energy prices by liberalization status, between 2008 and 2015, EU countries (Euro/kWh)

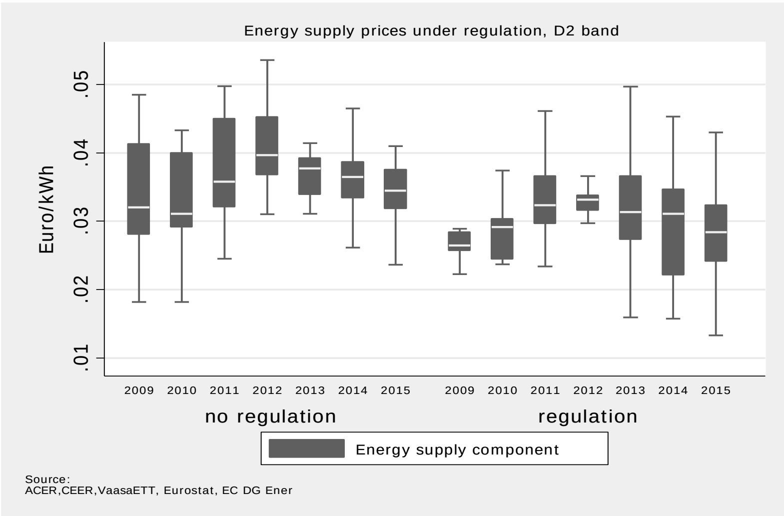


Figure 71: Households' energy prices by regulation, between 2008 and 2015, EU countries (Euro/kWh)

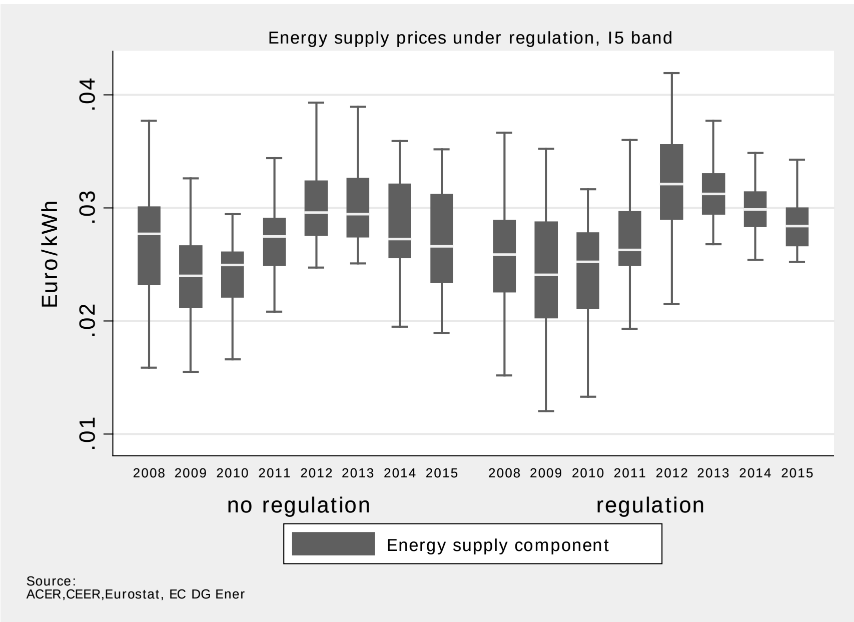


Figure 72: Industries' energy prices by regulation status, between 2008 and 2015, EU countries (Euro/kWh)

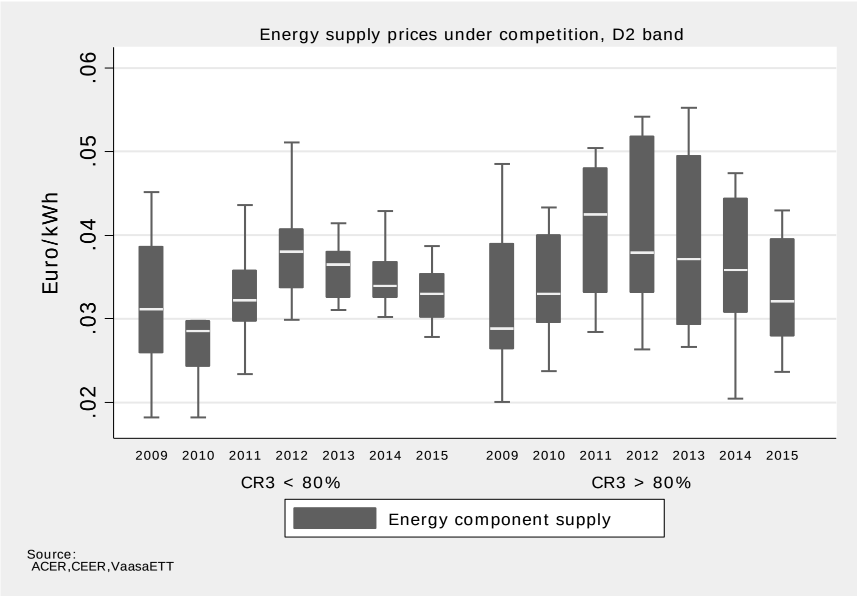


Figure 73: Households' energy prices by competition (competition if CR3 share <= 80%), between 2008 and 2015, EU countries (Euro/kWh)

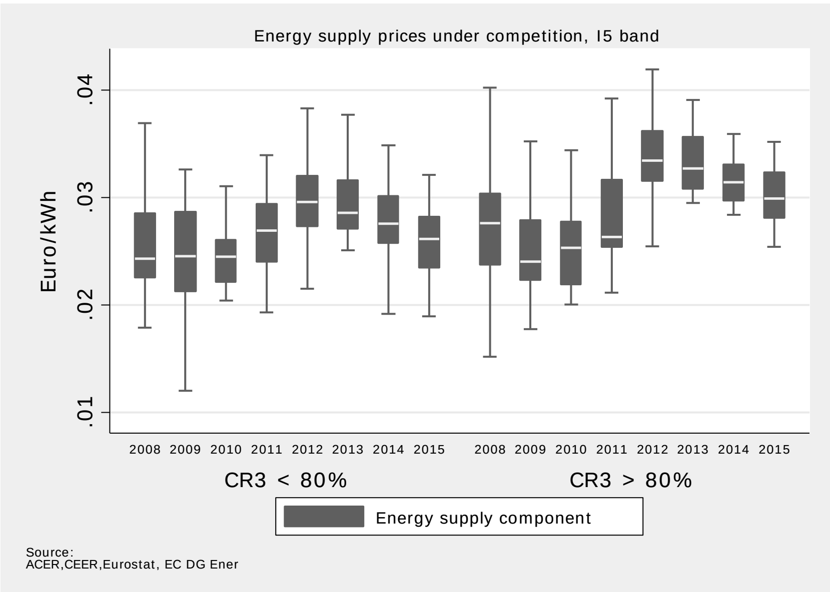


Figure 74: Industries' energy prices by competition (competition if CR3 share <= 80%), between 2008 and 2015, EU countries (Euro/kWh)

4.2.3 Additional results

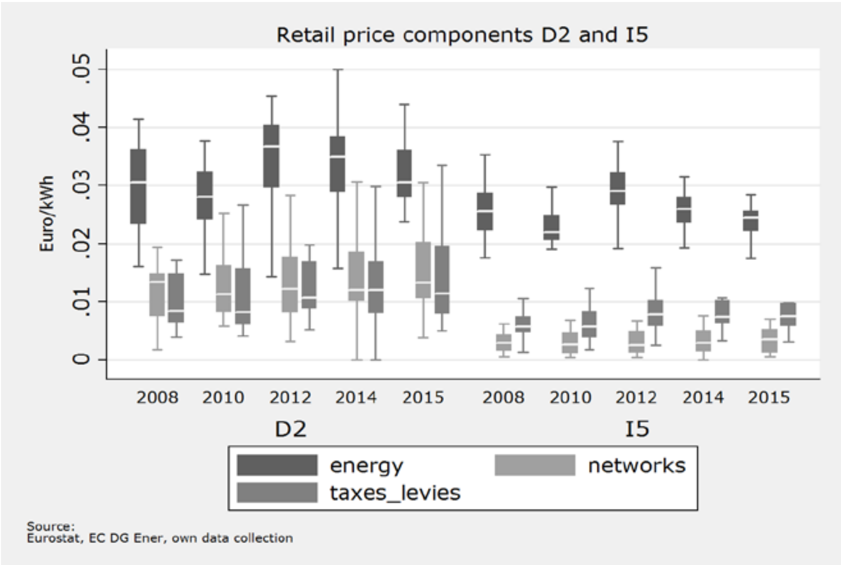


Figure 75: Retail price components in the retail gas market between 2008 and 2015 for households and industry in the EU (D2 and I5, ad-hoc data base), Euro/kWh

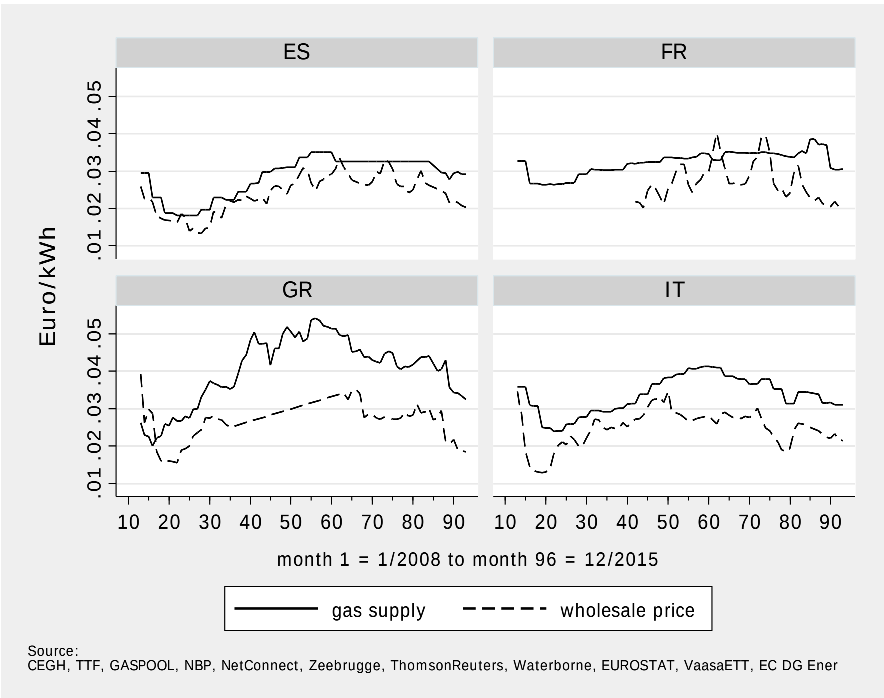


Figure 76: Energy price component (households) and wholesale gas price of selected EU member states, (Euro/kWh)

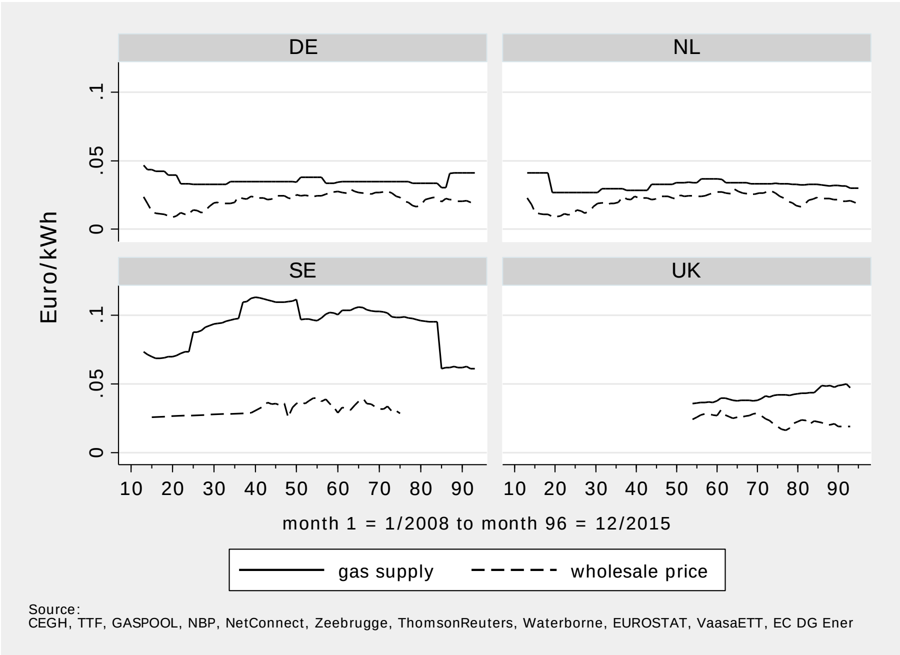


Figure 77: Energy price component (households) and wholesale gas price of selected EU member states, (Euro / kWh)

5 Drivers of the network fees – electricity and gas

The network component covers costs for transportation of electricity and natural gas. Major sub-components of this component are costs for transmission and distribution. Beside costs of capital and operation of grid, this component includes compensations for grid losses, and costs back-up systems to ensure system security. Some countries also report costs of metering services under this headline. As shown in Section 3.1 if the main report, the spread of network fees is small for all consumption levels suggesting that infrastructure costs are more homogenous within Europe than the other two components.

There are three potential factors to calculate network costs: A lump sum for the connection of an installation, a capacity fee for the connected capacity (kW) and a consumption fee based on the usage of the network. In most countries, households only pay a consumption fee, sometimes there is a lump sum fee for the connection. For industries, the capacity fee for the connected capacity (or peak load) often is more important. By basing the network costs on capacity, the network operators provide an incentive for "flat" consumption, a low peak load in comparison to the total consumption, or – described from a different perspective – high full load hours of consumption. In some countries, these incentives are provided by grid operators to maximise the usage of existing (transmission) grid capacity, in some countries, there are additional regulatory measures to reduce network costs for large energy-intensive industries with high full load hours. In general, network fees are lower for industrial consumers with large consumption, they are more often connected to medium and high voltage levels and therefore do not need to pay fees to use distribution grids.

Increasing fees for transmission and distribution over time mainly depend on the expected long-term development of grids. Transmission and distribution system operators plan investments in long periods based on the information about future developments in their covered region. Transmission grid operators are encouraged to increase capacity for international exchange of electricity and gas. The European association of transmission system operators for electricity (ENTSO-E) and gas (ENTSO-G) provide lists of projects of common interest for European grid extension. These projects are generally aimed at increasing the capacity of interconnectors or facilitating transport via longer distances. Often, the increasing and intermittent share of renewable energies is also mentioned as drivers for the projects of common interest for electricity. Centres of wind and solar generation capacity need to be connected to other regions in Europe to supply in times of strong wind and sun and to back up local demand in times of low in-feed.

Similarly, distribution grid operators have to justify their more local investments. In the electricity grid in particular, increasing costs for distribution grid operation are assigned to distributed generation of electricity, mainly by wind power plants and solar photovoltaic.

In this section, the impacts of tariff structures, remuneration schemes and the penetration of RES on the network component of retail prices of electricity and natural gas is analyzed for the EU member states, as far as sufficient data is available. Network fees are usually correlated with the density of consumers within the network (the number of connection points per length of the network), as the maintenance cost of the network is distributed to the relevant consumers. However, network fees are regulated by authorities because of the natural monopoly of the grid infrastructure. Therefore the characteristics of the regulation may have an impact on the level of network fees, in particular the tariff structure and the remuneration schemes. With regard to the tariff structure, the main differences concern capacity-based and fixed price components, which do not exist in all member states or partly only for some consumer bands. With regard to renumeration scheme, a key issue is the kind of risk allocated to the grid operator. If revenues are collected depending on the transport volume, there is a risk that revenues fail to meet the costs. This risk is transferred to the grid operator in some member states. In some cases, there is an ex-post-assessment of the investments' usefulness that affects the revenues. This allocates an additional risk to the grid operator. Furthermore, the integration of renewable electricity generation into the electricity grids may be expected to increase grid fees due to additional investments in connecting lines.

As a measure for the penetration of RES, we use the annual share of electricity generation from RES sources per country. The annual share of electricity generation from RES per country is available for all EU member states for 2008 – 2015. The latter allows for a quantitative assessment of the impact of RES penetration based on the panel of all EU member states. There is data/information on network characteristics in 18 to 20 of the member states in refE, mercados and indra 2015, but solely for the year 2013. Hence, the data is far from being sufficient for a meaningful quantitative analysis. We therefore restrict ourselves to a descriptive analysis. Still, as the adhoc data on network fees cover only 2012 and 2014, we have to assume that those network characteristics are the same in 2012 and 2014, which results in two observations of the parameters per country. That assumption seems plausible because the regulation of network fees is changing only slowly. Still, all the descriptive results on the tariff structure and the remuneration schemes should be interpreted very carefully. In particular, the number of observations is not high enough for statements of statistical significance.

5.1 Electricity

The level of electricity grid fees in the years 2008, 2010, 2012, 2014 and 2015 is available for households and industrial consumers in all EU member states from the adhoc data collection. The parameters used in the analyses are listed in Table 36: Variables applied to analyse drivers of the network component of retail electricity prices in the EU.

Table 36: Variables applied to analyse drivers of the network component of retail electricity prices in the EU

Variables	Description	Available Data
Retail price component network	Endogenous n component, annual data for 2008, 2010, 2012, 2014, 2015	Ad-hoc data collection, covering household and industrial consumer bands for electricity (DC, IB, ID), 2008 2010, 2012, 2014, 2015 in all 28 EU member states
Share of electricity generation from renewable sources	%, electricity generation from renewable sources is divided by the total generation	ENTSO-E: Total generation and per technology for 2008 – 2015 in all 28 EU member states
Capacity-based and fixed price component of network fees	Dummy variables (1: capacity-based / fixed price component exists; 0: no capacity-based / fixed price component)	refE, mercados and indra: total, capacity-based and fixed price network fees for household and industrial consumer bands for electricity (DC, IB, ID), 2013 in 18 EU member states
Regulatory lag	Time lag in the adaptation of remuneration levels in years	refE, mercados and indra: regulatory lag in years, 2013 in 18 EU member states
Volume risk	Dummy variables (1: risk of the volume component's magnitude is partly or fully carried by the network operator; 0: no volume risk for the grid operator)	refE, mercados and indra: qualitative information on volume risks, 2013 in 18 EU member states
Assessment of investments	Dummy variables (1: ex-post assessment of the usefulness of investments by the regulator affects the revenues; 0: no assessment of usefulness of investments)	refE, mercados and indra: qualitative information on the assessment of usefulness of investments, 2013 in 18 EU member states

5.1.1 Grid fees and penetration of RES

We have divided the network fees into two groups according to different levels of RES penetration. The levels of grid fees are depicted for RES generation shares above and below 15% for the DC band (Figure 78). The number of 136 observations allows the application of standard statistical tests, which indicate that the grid fees are significantly lower for an RES generation share below 15 %. The statistical significance remains for a split at 10 %, but disappears at 20 %.. Therefore the significant differences suggest that in average across all years and countries higher RES penetration has gone hand in hand with increased grid fees in the past. When looking at annual grid fees, the relation between grid fees and RE generation shares becomes less evident. The results also suggest that the increase of grid fees does not continue in a linear fashion for higher shares. Overall, grid fees can be driven by several factors, such as replacements (investments) of existing equipment, substitution or new infrastructures, number of connections, and by RES generation shares.

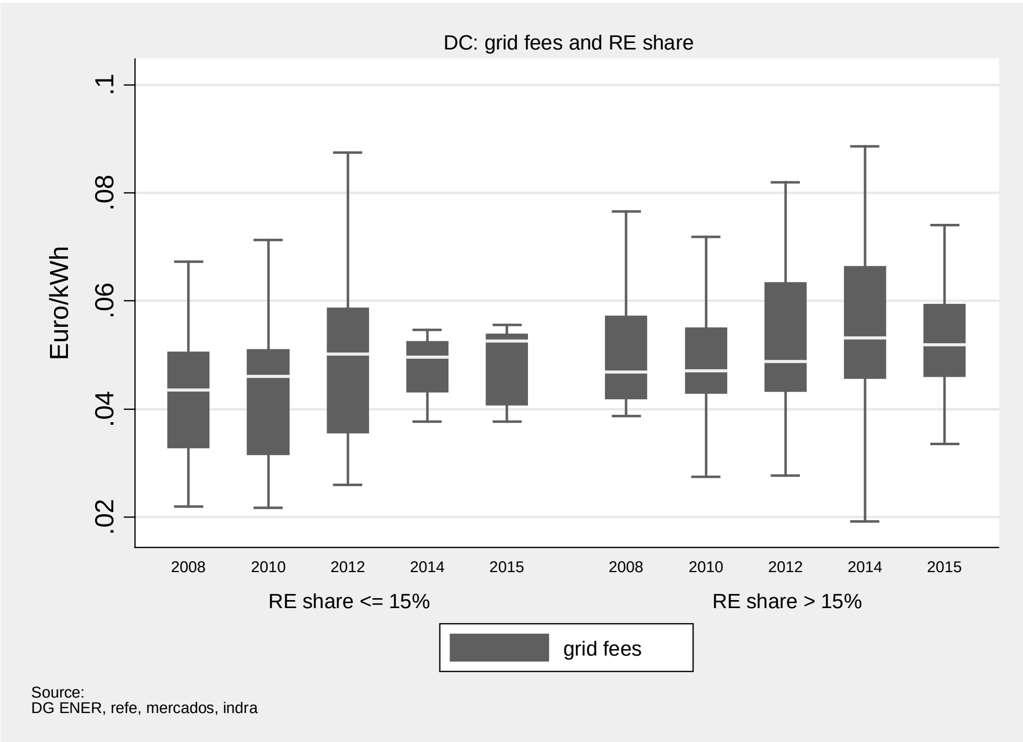


Figure 78: The level of electricity grid fees for households (DC band) in EU member states depending on the current share of RES electricity generation.

5.1.2 Grid fees and tariff structure

As characteristics of the tariff structure, we look at the existence of fixed price and a capacity-based price component based on the information in refE , mercados and indra 2015 and as explained above assume that it is valid for 2012 – 2014.

The network fees are divided into two groups according to the existence of fixed price and a capacity-based price component. The level of grid fees depending on the existence of capacity-based component is depicted for the DC band in Figure 79. The figure reveals that the network fees are lower in countries, where a capacity-based price component exists both in 2012 and 2014. This effect is not visible for industrial consumers. The existence of a fixed price component does not show a clear impact, either. There is no immediate explanation why the existence of a capacity charge should correlate with lower prices. In particular, it is usually the total amount of revenues that is regulated by the regulating authority. As the effect is visible only for the DC band, the split of fees between different consumer bands may play a role. The available data is insufficient to make any judgement here.

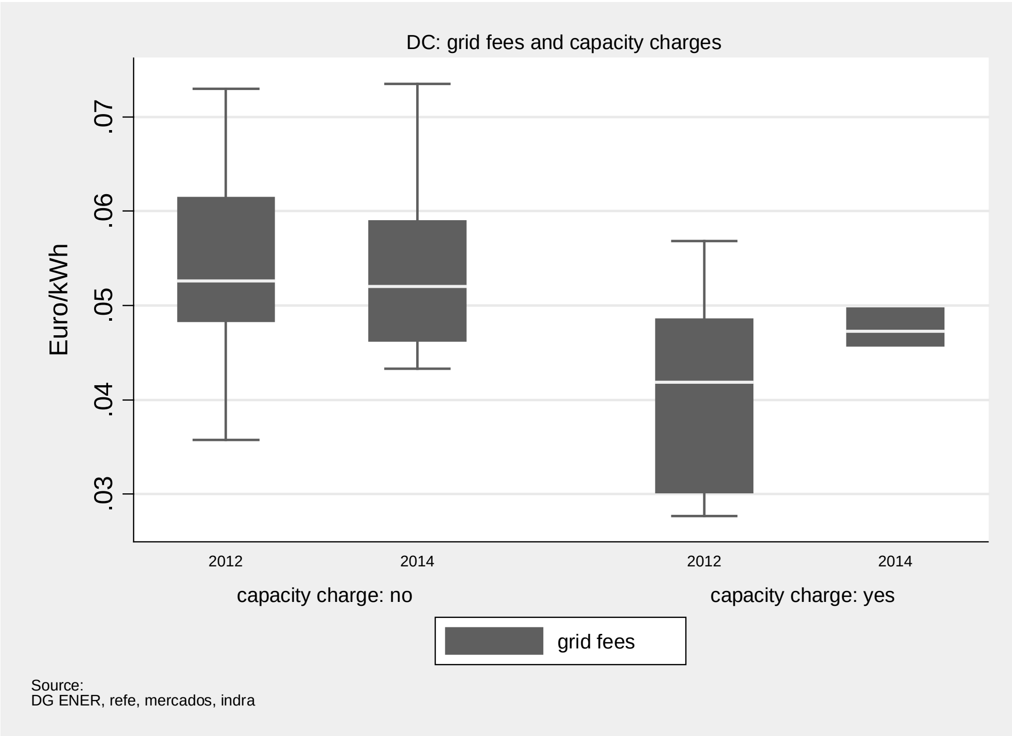


Figure 79: The level of electricity grid fees for households (DC band) in EU member states depending on the existence of a capacity-based price component.

5.1.3 Grid fees and remuneration schemes

As characteristics of the remuneration schemes, we use the facts whether the risk of the volume component's magnitude is at least partly carried by the network operator and whether there is an ex-post assessment of the usefulness of investments by the regulator. Furthermore, we look at the time lag in the adaptation of remuneration levels. For all three characteristics, we use the information contained in refE , mercados and indra 2015 and as explained above assume that it is valid for 2012 – 2014.

The levels of grid fees are grouped by regulatory lags above and below three years for the IB band in Figure 80. Under the given limitation of the data set, the figure shows that the network fees are lower in countries, where the regulatory lag is not longer than three years both in 2012 and 2014. The effect is even more prominent for countries, where the level of remuneration is adapted on an annual basis. It also occurs for the ID band but not for households.

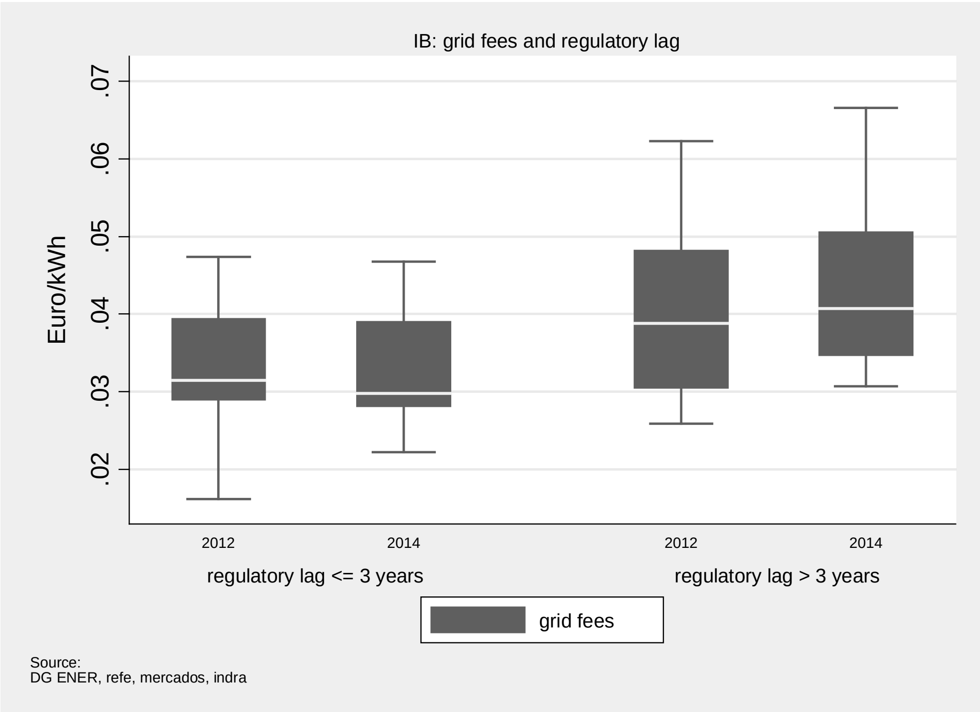


Figure 80: The level of electricity grid fees for industrial consumers (IB band) in EU member states depending on the regulatory lag.

The level of grid fees is depicted for the DC band in Figure 81depending on the allocation of the volume risk. Given the available data set, the figure reveals that the network fees are higher in countries, where the risk of the volume component's magnitude is carried by the network operator both in 2012 and 2014. This effect also occurs for the ID band but not for households. The existence of an ex-post assessment of the usefulness of investments by the regulator does not show a clear impact on electricity grid fees for all considered consumer bands.

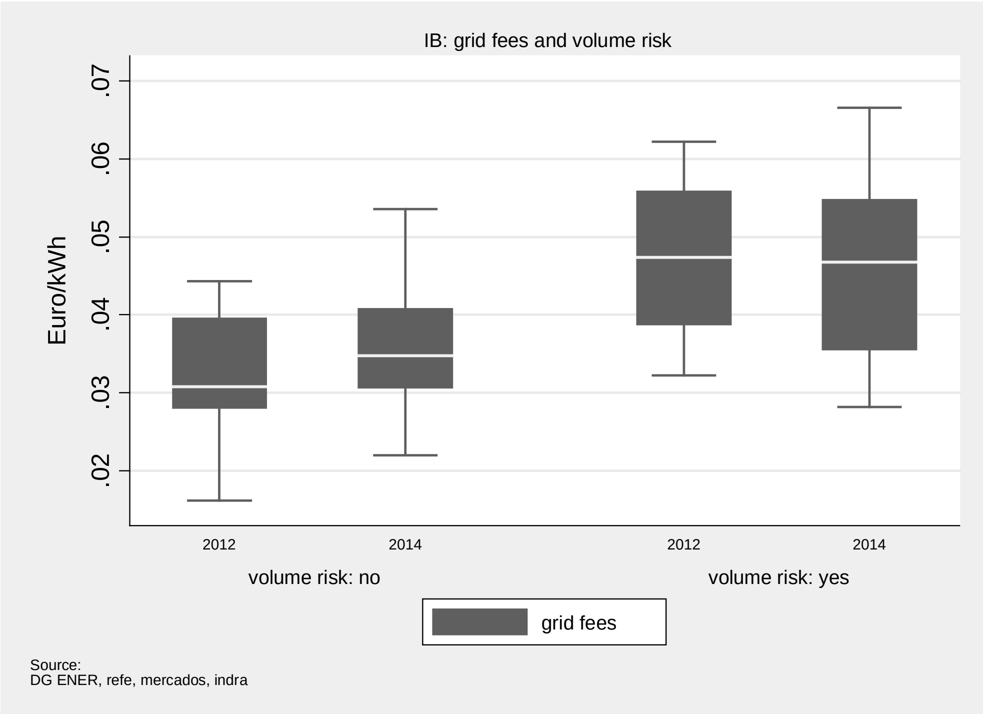


Figure 81: The level of electricity grid fees for industrial consumers (IB band) in EU member states depending on the fact whether the risk of the volume component's magnitude is carried by the grid operator.

5.2 Natural gas

The level of network fees in the years 2008, 2010, 2012, 2014 and 2015 is available for households and industrial consumers in 21 and 19 EU member states respectively from the adhoc data collection. The parameters used in the analyses are listed in Table 37.

Table 37: Variables applied to analyse drivers of the network component of retail electricity prices in the EU

Variables	Description	Available Data
Retail price component network	Endogenous n component, annual data for 2008, 2010, 2012, 2014, 2015	Ad-hoc data collection, covering household and industrial consumer bands for electricity (DC, IB, ID), 2008 2010, 2012, 2014, 2015 in 19 – 21 EU member states
Capacity-based and fixed price component of network fees	Dummy variables (1: capacity-based / fixed price component exists; 0: no capacity-based / fixed price component)	refE, mercados and indra: total, capacity-based and fixed price network fees for household and industrial consumer bands for electricity (DC, IB, ID), 2013 in 20 EU member states
Regulatory lag	Time lag in the adaptation of remuneration levels in years	refE, mercados and indra: regulatory lag in years, 2013 in 20 EU member states
Volume risk	Dummy variables (1: risk of the volume component's magnitude is partly or fully carried by the network operator; 0: no volume risk for the grid operator)	refE, mercados and indra: qualitative information on volume risks, 2013 in 20 EU member states
Assessment of investments	Dummy variables (1: ex-post assessment of the usefulness of investments by the regulator affects the revenues; 0: no assessment of usefulness of investments)	refE, mercados and indra: qualitative information on the assessment of usefulness of investments, 2013 in 20 EU member states

5.2.1 Network fees and tariff structure

As characteristics of the tariff structure, we again look at the existence of fixed price and a capacity-based price component based on the information in refE , mercados and indra 2015 and as explained above assume that it is valid for 2012 – 2014.

The network fees are divided into two groups according to the existence of fixed price and a capacity-based price component. The level of grid fees depending on the existence of fixed price component is depicted for the D2 band in Figure 82. The figure reveals that the network fees are higher in countries, where a fixed price component exists both in 2012 and 2014. This effect is not visible for industrial consumers. The existence of a capacity-based price component also does not show a clear impact.

As for the case of capacity-based components of electricity grid fees, there is no immediate explanation why the existence of a fixed price charge should correlate with higher prices. As the effect is visible only for the DC band, the split of fees between different consumer bands may play a role. The available data is again not sufficient to make any judgement here.

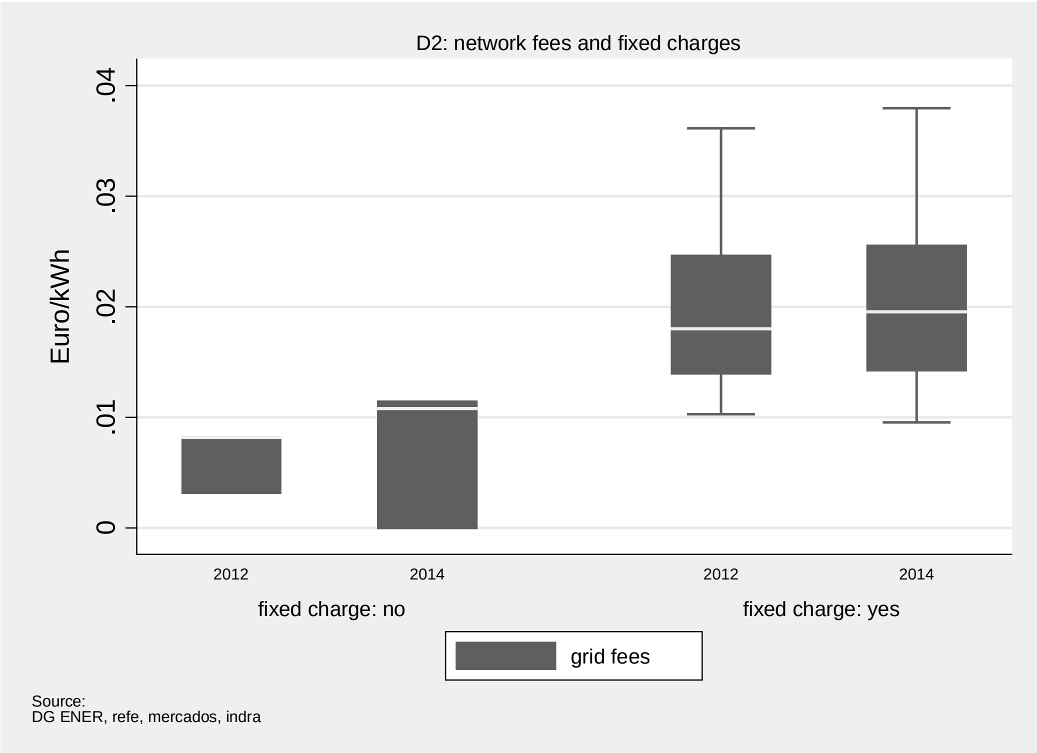


Figure 82: The level of gas grid fees for household (D2 band) in EU member states depending on the existence of fixed price component.

5.2.2 Network fees and remuneration schemes

As characteristics of the remuneration schemes, we again use the facts whether the risk of the volume component's magnitude is carried by the network operator and whether the usefulness of investments is assessed by the regulator. Furthermore, we a look at the time lag in the adaptation of remuneration levels. For all three characteristics, we use the information contained in refE , mercados and indra 2015 and as explained above assume that it is valid for 2012 – 2014.

The level of grid fees is depicted in Figure 83 for the I5 band depending on the assessment of investments by the regulator. The figure reveals that the network fees are lower in countries, where the usefulness of investments is assessed by the regulator, both in 2012 and 2014. This effect does not occur for households. The allocation of the volume risk to the grid operator seems to increase grid fees for households but not for industrial consumers. The regulatory lag does not show a clear impact on gas grid fees for all considered consumer bands.

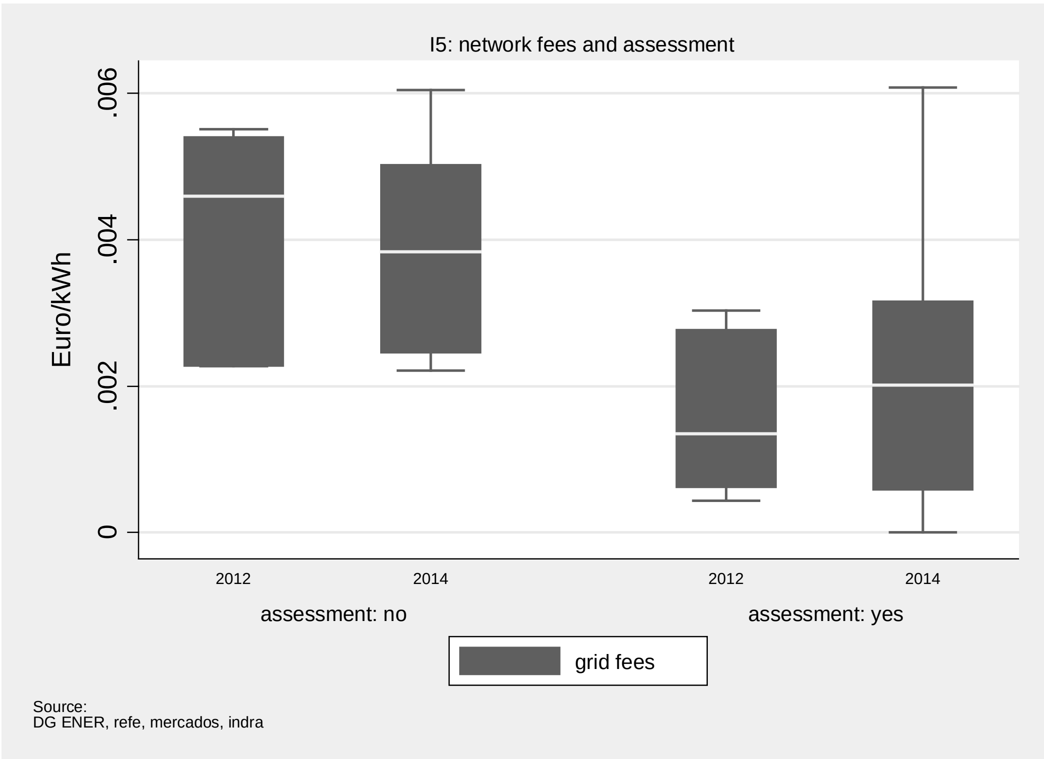
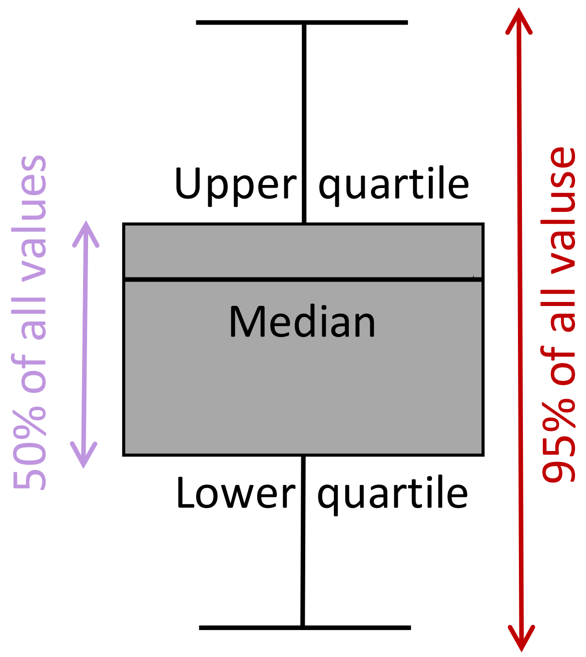


Figure 83: The level of gas grid fees for industrial consumers (I5 band) in EU member states depending on the fact whether there is an assessment of the usefulness of investments by the regulator.

In summary, there is evidence that the increasing RES penetration and electricity grid fees go hand in hand, though seemingly in a non-linear fashion. Furthermore, the descriptive analysis of the role of tariff structures and remuneration schemes suggests the plausible relations that shorter regulatory lags tend to correlate with lower prices, while higher remuneration risks for the grid operator tend to correlate with higher prices. However, all the descriptive results on the tariff structure and the remuneration schemes should be interpreted very carefully due to the lack of data for statistical significant statements.

6 Explanations

6.1 Box plot



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