The electricity price drop

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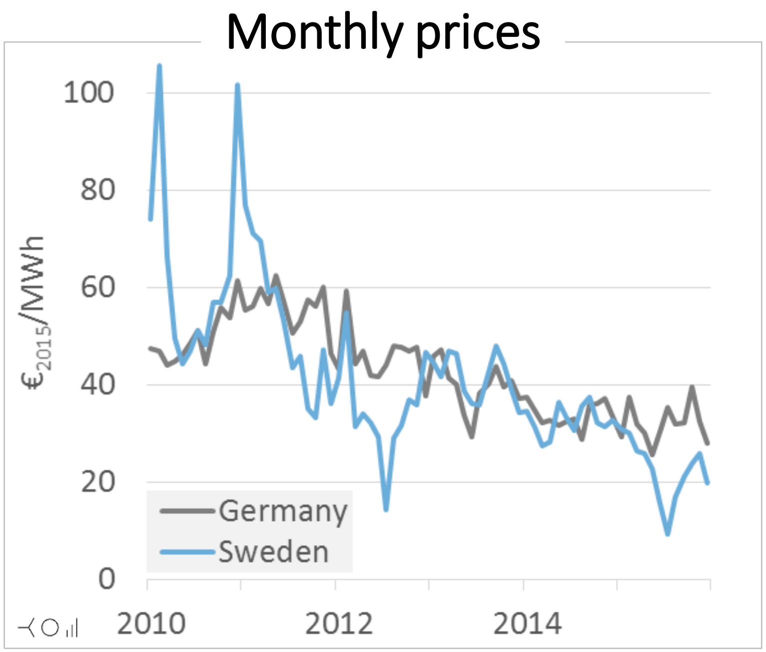
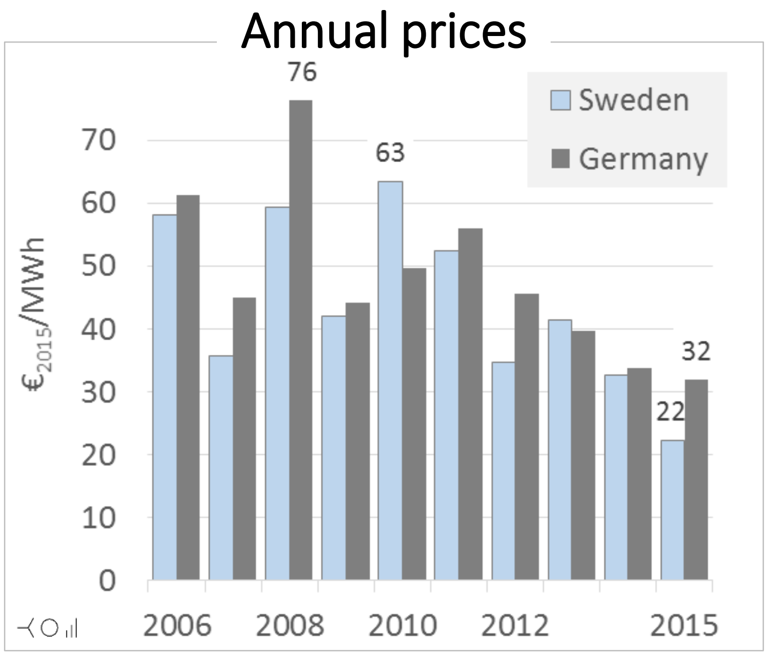
Ex-post analysis

- Econometric analyses study the past
- Analyses that use fundamental models often study the future – in form of projections or scenarios
- Today: let us study the past
- More specifically: quantify the impact of one or more factors on the historical development of a variable of interest
- Variables of interest
  - wholesale electricity price
  - CO_2 certificate price
  - Stock market value of energy companies

Motivation: the electricity price plunge



Neon analysis based on EPEX Spot and Nordpool Spot data.

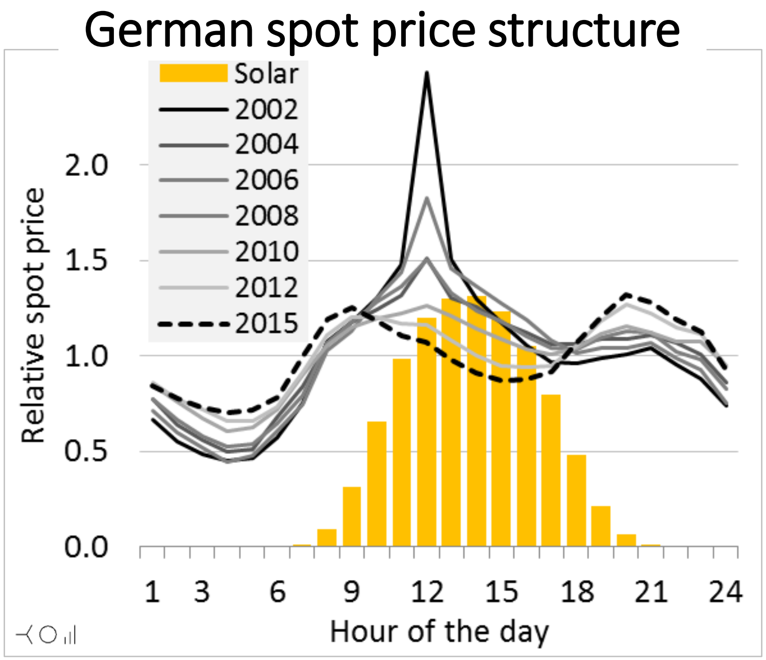


Neon analysis based on EPEX Spot and Nordpool Spot data.

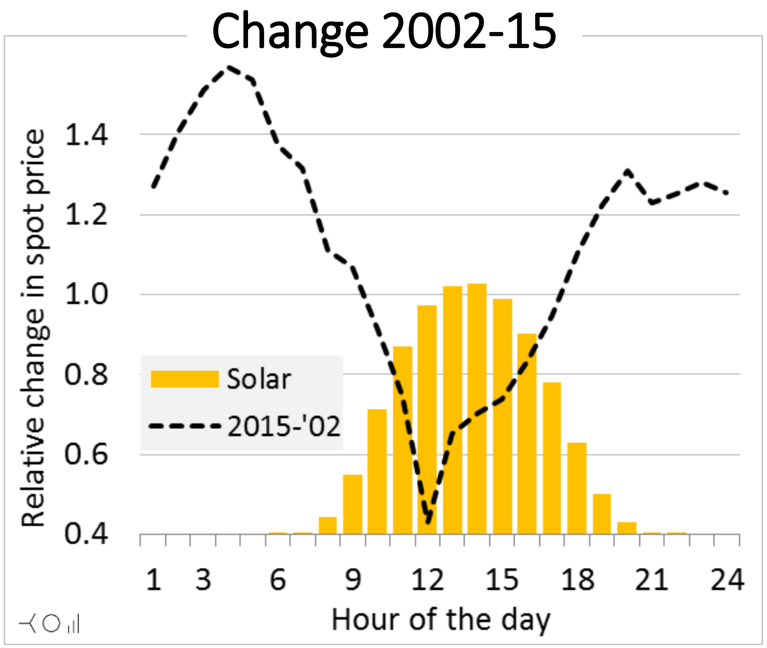
Since 2010, Swedish prices declined even faster than German prices.

Electricity prices have declined about 60% from their peak in 2008-10 (day-ahead base price, inflation-adjusted).

The price structure has changed as well



The diurnal structure of German day-ahead spot price during summer months 2002-15.
Neon analysis based on data from TSOs and power exchanges.



The change of price structure between 2002 and 2015.
Neon analysis based on data from TSOs and power exchanges.

The price structure of German prices changed dramatically with the rise of solar.

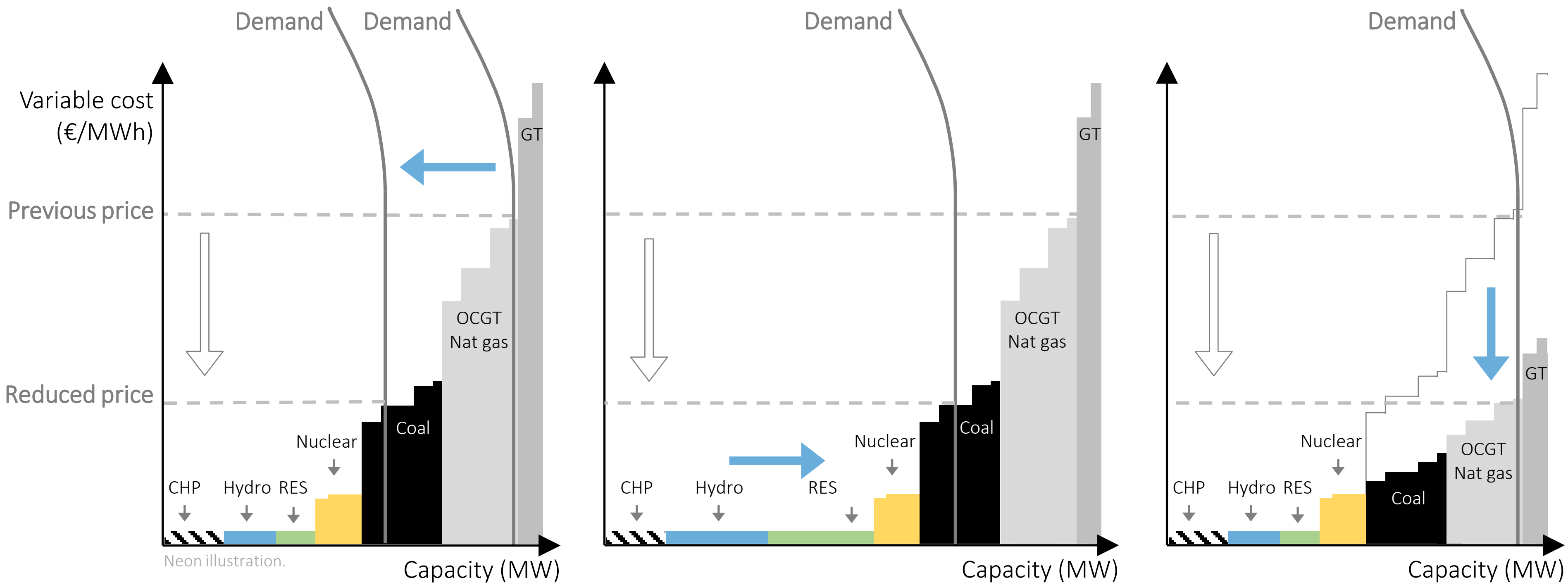
Sunny hours became relatively much cheaper, and night hours more expensive.

Some price recovery

- CAL18 base future hit a low of 21 €/MWh in February 2016 and recovered by 50% to 31 €/MWh today
- Spot prices during the winter reached 100 €/MWh
- Nevertheless, prices remain far below long-term sustainable levels, where contribution margins are sufficient to cover capital costs

Three drivers of falling prices

illustrative



1 Reduced electricity <u>demand</u>

2 Increased low-variable cost <u>supply</u>

3 Reduced variable <u>cost</u>

Potential drivers in detail

1 Reduced demand

- Decline in final demand for electricity
- Reduced export capacity, particularly from the Nordic region to the Continent

2 Increased low-cost supply

- Additional thermal capacity (mostly coal-fired plants)
- Year-to-year variation of water inflow to hydro reservoirs
- Additional wind, solar, and biomass capacity
- Availability of (Swedish) nuclear power
- Decommissioning of conventional plants
- Nuclear phase-out (in Germany)

3 Reduced variable cost

- Declining coal price
- Declining CO_2 price
- Improved thermal fleet efficiency (heat rate)
- Increased natural gas price

Which electricity prices are we interested in?

One can analyze *spot* or *financial markets*. On average, they should be identical, but in the past years they often deviated significantly for extended periods of time.

Spot (day-ahead) markets

- How did *realized prices* develop?
- How did *market fundamentals* (supply, demand, costs) change?

Financial (future) markets

- How did *expectations* develop?

A spot market analysis is easier to interpret, and data availability is better (expectations are private information) → we study spot prices.

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The plunge in German electricity futures prices – Analysis using a parsimonious fundamental model

Thomas Kallabis*, Christian Pape, Christoph Weber

Chair for Management Science and Energy Economics, University of Duisburg-Essen, Campus Essen, Germany

Kallabis, Pape, Weber (2016)

What Caused the Drop in European Electricity Prices? A Factor Decomposition Analysis

*Lion Hirth**

Hirth (2018)

An analysis of the decline of electricity spot prices in Europe: Who is to blame?

Andreas Bublitz[a,*], Dogan Keles[a], Wolf Fichtner[a]

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Bublitz, Keles, Fichtner (forthcoming)

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Article

OXFORD

Politics vs markets: how German power prices hit the floor

Martin Everts, Claus Huber and Eike Blume-Werry*

ABSTRACT

Everts, Huber, Blume-Werry (2016)

What caused the drop in European electricity prices?

A factor decomposition analysis

The Energy Journal (open access)

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Research question

In short:

Why did the power prices drop?

More precisely:

Which factors contributed by how much to the drop of the Swedish and Germany electricity day-ahead base prices between 2010 and 2015?

Methodology

Methodology

1. Replicate prices for the years 2010 and 2015

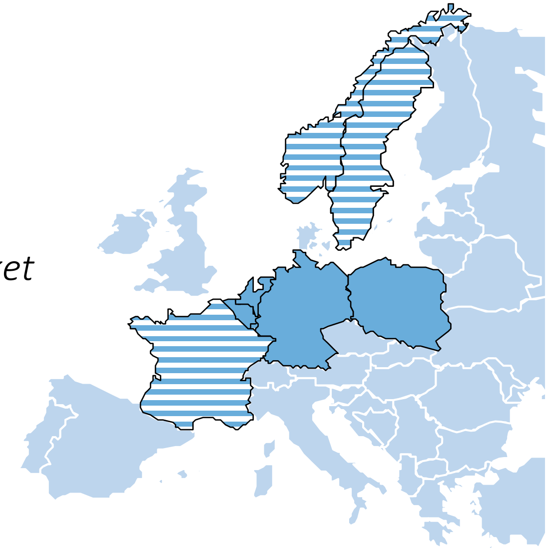
- With a fundamental power market model
- Using the full set of input factors of the respective year (electricity demand, RES generation, hydro inflow, fuel prices, ...)
- → Model check: can prices be replicated?

2. Quantify impact of individual factors

- Substitute one individual factor (e.g. coal price) from 2010 with 2015 value
- Leave all other factors (e.g., RES generation, hydro inflow, fuel prices, ...) unchanged at 2010 values
- By how much did the modeled 2015 price change vs modeled 2010 price?
- Replicate this procedure for each factor one-by-one
- → Estimate the impact of individual factors on price drop

The Electricity Market Model EMMA

Numerical partial-equilibrium model of the European interconnected power market



Objective: minimize system costs

- Capital costs
- Fuel and CO2 costs
- Fixed and variable O&M costs
- ... of thermal and hydro power plants, storage, interconnectors

Decision variables

- Hourly dispatch
- Yearly investment
- ... of plants, storage, interco's

Constraints

- Energy balance
- Capacity constraints
- Volume constraints of storage/hydro
- Balancing reserve requirement
- CHP generation
- (No unit commitment, no load flow)

Resolution

- Temporal: hours
- Spatial: bidding areas (countries)
- Technologies: eleven plant types

Input data

- Wind, solar and load data of the same year
- Existing plant stack

Equilibrium

- Short-/mid-/long-term model (= dispatch / capacity expansion / greenfield)
- Equilibrium ("one year") rather than a transition path ("up to 2030")

Economic assumptions

- Price-inelastic demand
- No market power
- Carbon price

Implementation

- Linear program
- GAMS / cplex

Applications

- Four peer-reviewer articles
- Various consulting projects
- Copenhagen Economics

Open source

Conceptual remarks on the methodology (1)

1. Sum of individual effects does not equal joint effect

- If a change in a non-linear system is de-composed into individual factors, the sum of the individual factor in general do not equal the joint effect
- Hence the “interaction effect”
- An interpretation: the interaction effect represents the balancing forces of markets
- An illustrative example
  - Increase in RES is estimated to reduce prices by 20 €/MWh and decline in demand by another 18 €/MWh.
  - The joint effect of both changes simultaneously is likely to be less than 38 €/MWh, as the power market adjusts to the larger (joint) shock by adjusting dispatch and trade. (Let us assume, the joint effect is 30 €/MWh.)
  - Then the interaction effect is positive. (In the example, 8 €/MWh.)

Conceptual remarks on the methodology (2)

2. Alternative benchmarks

- The two following questions are not identical
- "What would be reduction of the electricity price if all parameters are at 2010 levels, only RES supply is increased to 2015 levels?" (2010 benchmark)
- "What would be the increase of the electricity price of all parameters are at the 2015 level, only RES supply is decreased to 2010 levels?" (2015 benchmark)

Conceptual remarks on the methodology (3)

3. Individual ("separate") vs. cumulative ("added") effect

- We test factors individually, starting always with the 2010 parameter set
- In other words, we test each effect individually, always holding all other effects at 2010 levels
- A different approach would be to add changes on top of each other

4. Cumulative ("added") effect: order matters

- If effects are added one on the other, order of effects impacts their size
- For example:
- Start with 2010 parameters, decrease demand first, increase RES supply then
- Start with 2010 parameters, increase RES supply first, decrease demand then
- This is the reason we do not follow such an approach

Data

market data

Crucial parameters 2010 vs. 2015 in the model region

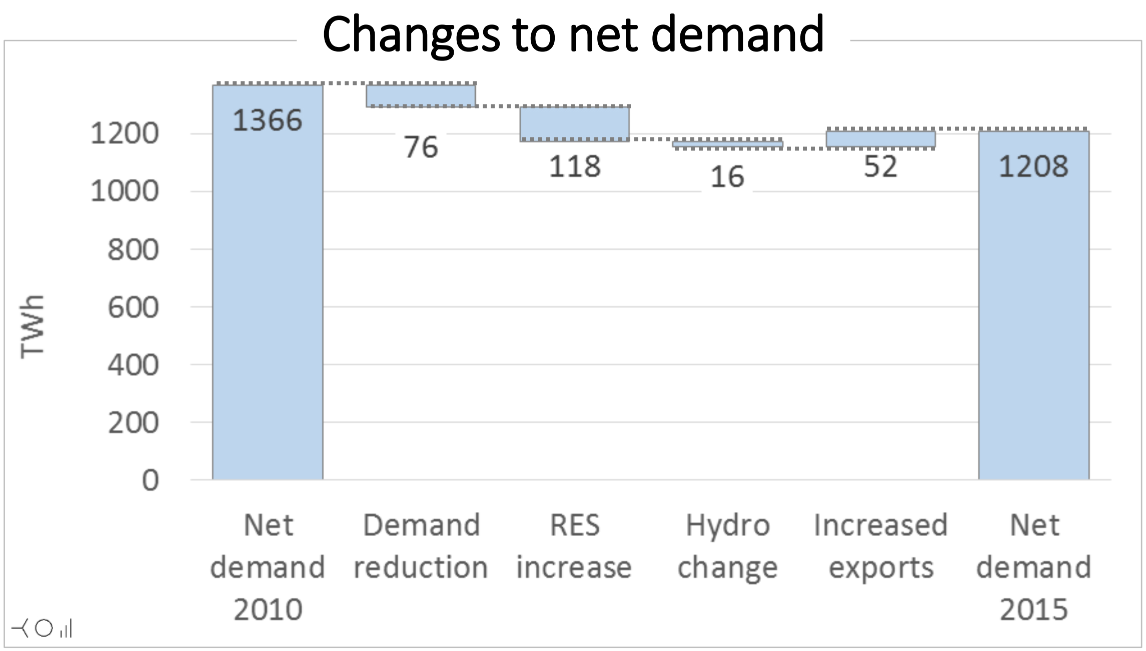
Parameter	2010	2015	Data source
Electricity demand	1723 TWh	1647 TWh	IEA Monthly electricity statistic
Wind + solar generation	75 TWh	193 TWh	IEA Monthly electricity statistic
Hydroelectricity output	282 TWh	302 TWh	IEA Monthly electricity statistic
Net exports of model region	38 TWh	90 TWh	ENTSO-E Statistical factsheet
Net demand (demand minus wind, solar, hydro, net imports)	1404 TWh	1246 TWh	Own calculation
Coal price	92 $/t 8.4 €/MWh	59 $/t 6.4 €/MWh	IHS McCloskey Northwest Europe Marker Price
Natural gas price	21 €/MWh	22 €/MWh	IMF German border import price
CO_2 price	16 €/t	6 €/t	EUA price

Conventional capacity includes nuclear and hydro power as well as all fossil fuel generators. Numbers are shown for the entire model region (Sweden, Norway, Germany, France, Poland, Belgium, The Netherlands). Electricity consumption and wind/solar generation is estimated based on Nov 2015 data, because Dec data are not published yet. All prices are nominal values (not inflation-adjusted). Dollar-denominated prices were converted into Euro using exchange rate data from the ECB. ATC values are used until the introduction of flow-based market coupling.

market data

First observations: volume changes

Electricity demand from power plants with positive marginal costs (thermal plants) declined by 158 TWh (9%).



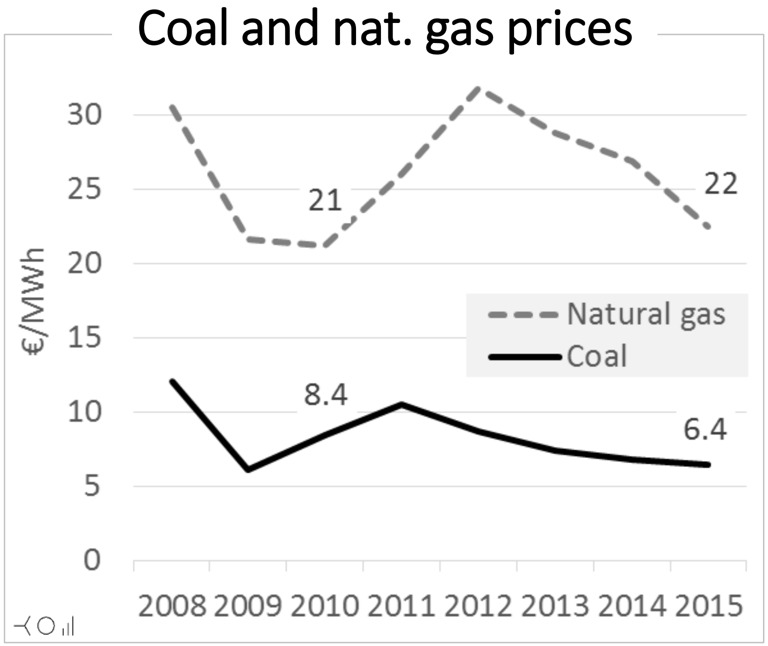
Neon analysis.

First observations: price changes

Fuel prices fluctuated widely, but net change 2010-15 is pretty small. The carbon price declined strongly during the same period.

Some fuel prices declined, while others remained stable

- Coal -24%
- Natural gas + 5%
- CO_2 -63%
- (Fuel prices in nominal terms denominated in Euro)
- → It is pretty obvious that a 24% decline in coal prices can, by itself, not explain a 65% decline in electricity prices.

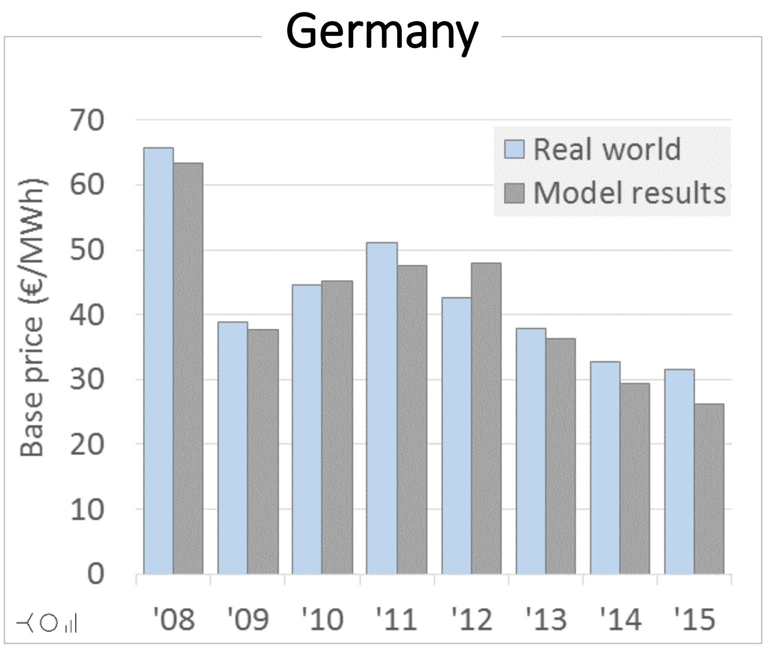


Neon analysis.

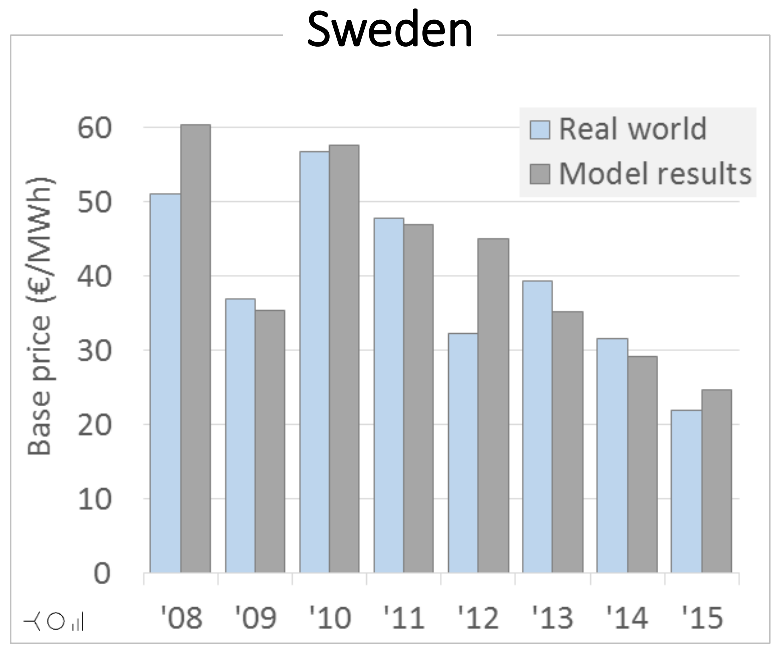
Replicating historical prices (Step 1)

The model is able to replicate historical prices...

model results



Neon analysis.



Neon analysis.

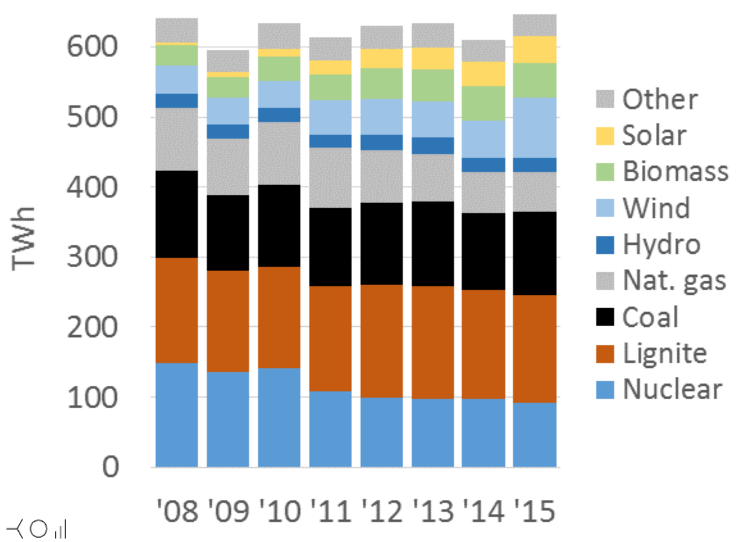
... as well as German prices.

Swedish prices are replicated quite well ...

... as well as historical generation pattern

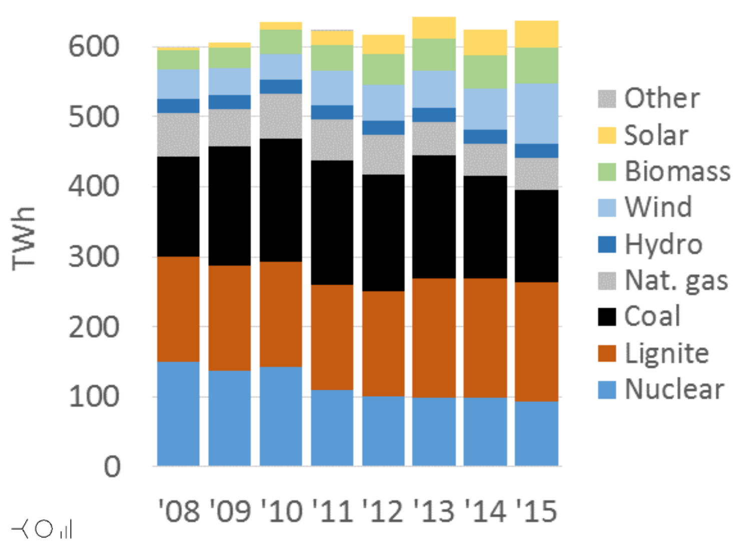
model results

Real world (GER)



Neon analysis.

Model results (GER)



Neon analysis.

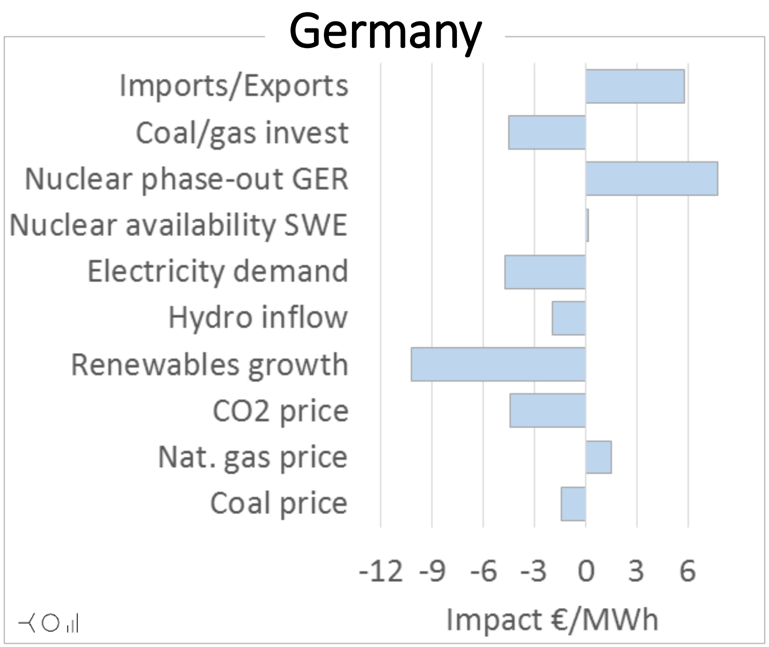
Observed generation mix in Germany.

Modeled mix. The model overstates coal generation somewhat, but replicates structural shifts well.

Factor decomposition
(Step 2)

The impact of individual factors: Germany

model results



Neon analysis.

Driver	Share in price drop
Renewables growth	54%
Final electricity demand	25%
Coal/gas invest	24%
CO_2 price	24%
Hydro inflow	10%
Coal price	8%
Nuclear availability SWE	-1% (increasing)
Nat. gas price	-8% (increasing)
Imports/Exports	-31% (increasing)
Nuclear phase-out GER	-41% (increasing)

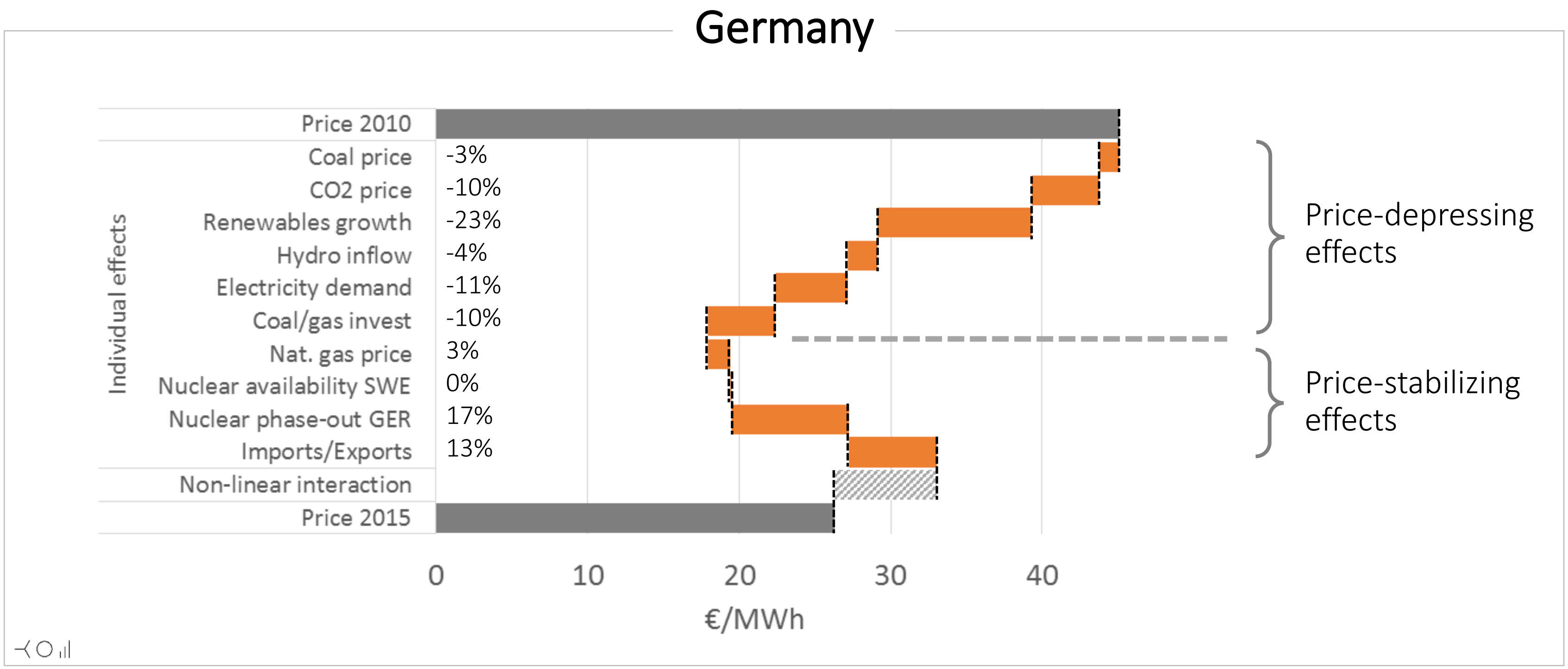
Neon analysis. The share in price drop is the effect of the individual effect relative to the total drop modeled. Renewables comprise wind power, solar PV, and biomass – hydroelectricity is listed separately.

Increased exports and the nuclear phase-out stabilized prices most.

How to read: if the only change was the decline in CO_2 prices, the electricity price drop would have been a quarter of the actual drop.

The impact of individual factors: Germany

model results

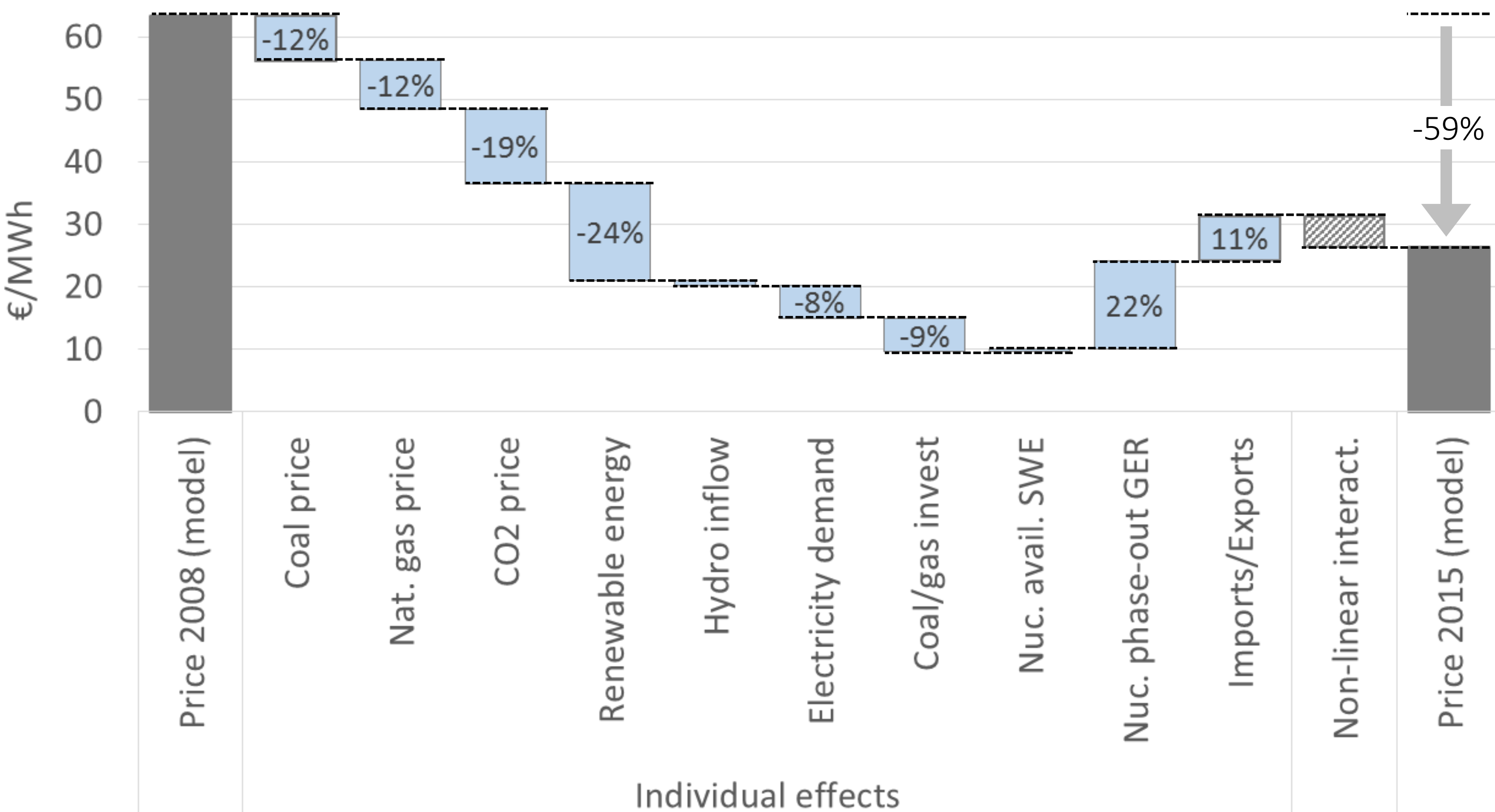


Neon analysis. Price impact relative to 2010 price level.

Six factors reduced the electricity price, four increased it. The decline of coal prices by itself would have reduced prices by 3%, the decline of the CO_2 price by 10%. The additive decomposition into individual effects works quite well: the non-linear interaction term is small.

The impact of individual factors: Germany

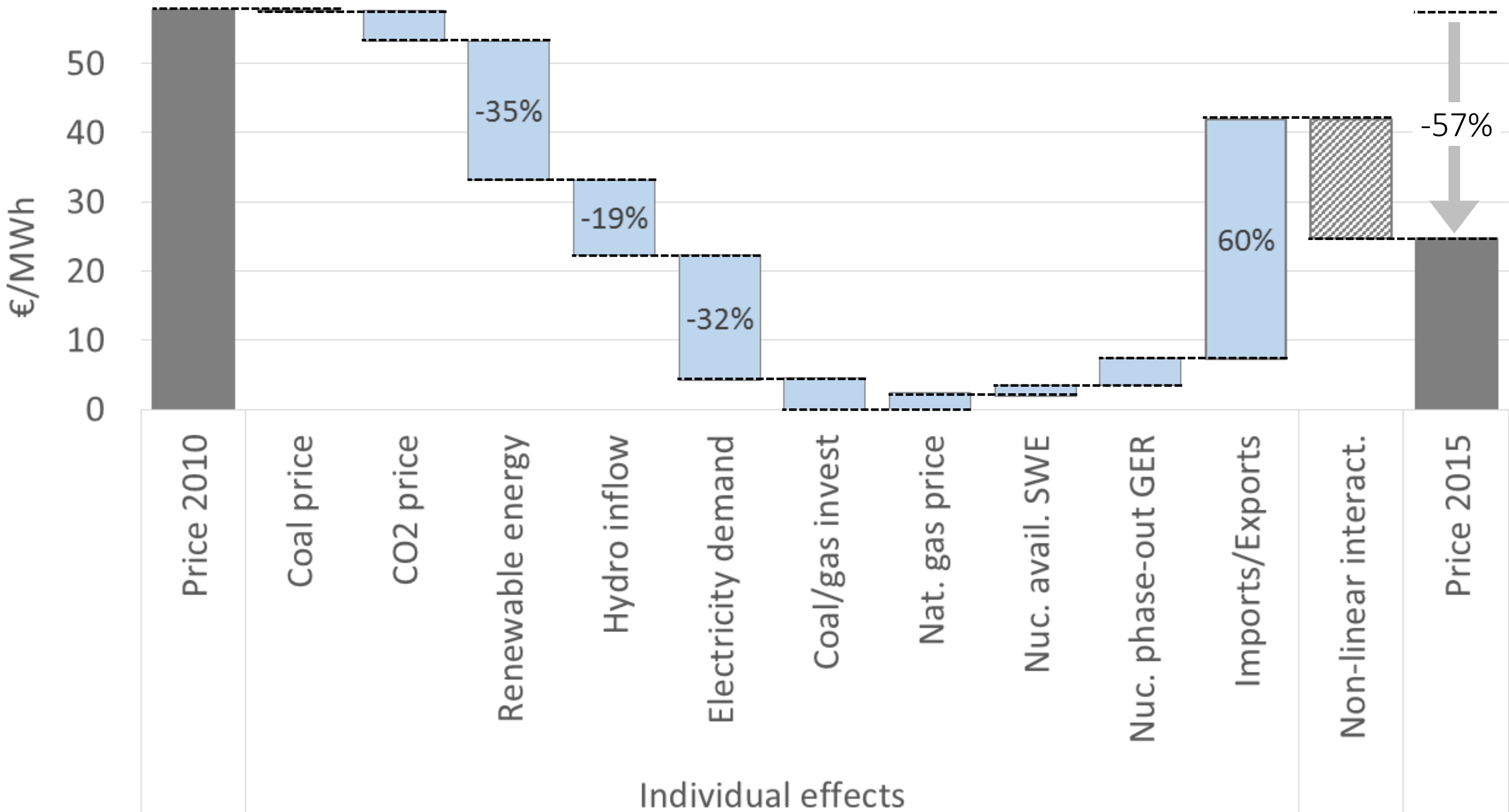
model results



7 factors reduced the electricity price, 3 increased it. The decline of coal prices by itself would have reduced prices by 12%, the decline of the CO_2 price by 19%. The additive decomposition into individual effects works quite well: the non-linear interaction term is small.

The impact of individual factors: Sweden

model results

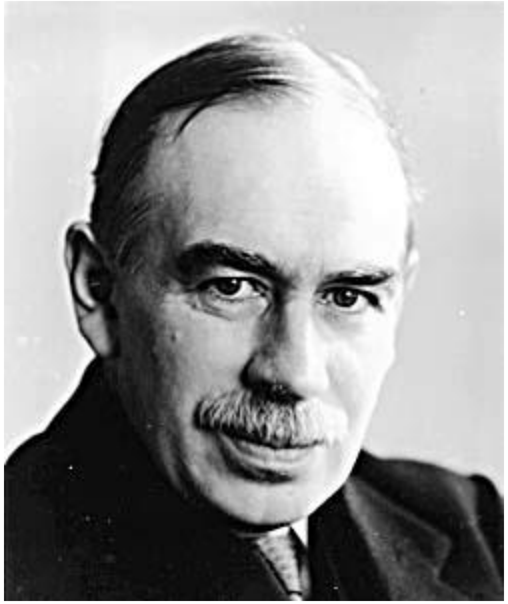


Swedish price are much more sensitive to changes in fundamentals. This is the nature of a hydro system where small changes in the yearly energy balance can lead to large shifts of prices. An additive decomposition leads to a significant residual.

Conclusions

Most impacts are transitory – but might take a while

- A cost shock (e.g. a change in fuel or CO_2 prices) can have a lasting impact, if most (or all) price-setting technologies are affected
- A volume shock (e.g. decrease of demand or increase of RES supply) affects the wholesale electricity price temporarily, as it triggers market exit which re-establishes long-term equilibrium price levels
- → Crucial question: *how long is "long-term"?*
- → In power systems with long-living assets and little demand growth (like Sweden), reaching the long-term equilibrium can take decades
- → In power systems with assets near the end of their live-time and/or strong demand growth, it will be reached sooner



"In the long term, we are all dead" – John Maynard Keynes

Summary and conclusions

- Wholesale power prices throughout Europe have declined substantially
- Several factors depressed, several increased the price
- The Nordic system, where most electricity is generated in zero-marginal cost plants (hydro, nuclear, CHP) is more sensitive to volume changes: they have a larger price effect

Germany: important price drivers

- Downward: RES growth was largest driver; demand, new investments and the CO_2 price were about half in size
- Upward: nuclear phase-out, followed by increased exports

Sweden: important price drivers

- Downward: RES growth and demand decline about the same size; followed by hydro inflow
- Upward: increase exports (very large effect)

What caused the drop in European electricity prices?

A factor decomposition analysis

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Why do studies differ?

- **Time horizon**: This paper covers 2008-15, while Kallabis et al. cover 2007-14, Everts et al. 2008-14, and Bublitz et al. 2011-15. Important input parameter differ significantly between these time periods. During 2015 the CO_2 price somewhat recovered, which helps explain why Kallabis et al. attribute a larger impact on carbon prices than this paper does.
- **Geographic coverage**: Kallabis et al. and Everts et al. model the German market, while Bublitz et al. and this study include a broader set of countries. The latter two studies consistently report that changed net export had a strong effect, something the former two studies miss out by design.
- **Type of electricity price**: Kallabis et al. model future prices while the three other papers model spot prices. As outlined in section 2.1, future prices reflect expectations while spot prices reflect fundamentals. If market fundamentals change but these changes are anticipated by market actors, spot prices will change but future prices will not.
- **Other assumptions**: the studies also differ in other crucial assumptions. Only Bublitz et al., for example, assumes market power to be present.