The RES-induced Switching Effect Across Fossil Fuels: An Analysis of the Italian Day-ahead and Balancing Prices

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Aim of the Paper

- The intermittent and unpredictable nature of wind and solar production has made the real-time balancing activities more complex and relevant for the continuous matching of supply and demand.
- We show how RES have affected the fuels-electricity nexus in Italy, considering the relationship between fuel prices and between fuels and electricity prices (DAM & BAMs).
- We analyze how the massive introduction of RES has influenced balancing activities and we calculate the incurred costs for balancing needs across hours, technologies and market purposes.

Main focus on balancing sessions

- High RES shares modify the shape of the aggregate supply function in DAM, misplacing gas-fired units.
- BAMs are dominated by conventional technologies (thermal, hydro and pumping) which have the required degree of flexibility and enjoy a higher degree of market power with respect to the DAM.
- In this scenario, we expect two distinct dynamics of the fuels-electricity nexus induced by the growth of RES (less relationship in DAM and a stronger nexus in BAMs).
- We also expect that the new results documented for DAM session may have influenced prices and quantities in real time sessions.

Relevant literature

- Papers about long run dynamics among fuels and fuels-electricity prices (mainly on day-ahead):
  - Erdös (2012) using VECM estimates shows that US natural gas prices have decoupled from European gas and crude oil prices since 2009.
  - Bosco et al. (2010) found strong evidence of a common long-term dynamics between electricity prices and gas prices for the major EU power exchanges. This long run common dynamics is one of the key factors explaining the almost strong integration among price series of the different power exchanges.
  - More recently, this relationship appears to be weakened Gianfreda et al. (2016b), so that the introduction of RES appears to have obstacled the long run convergence of EU prices.

Relevant literature 2

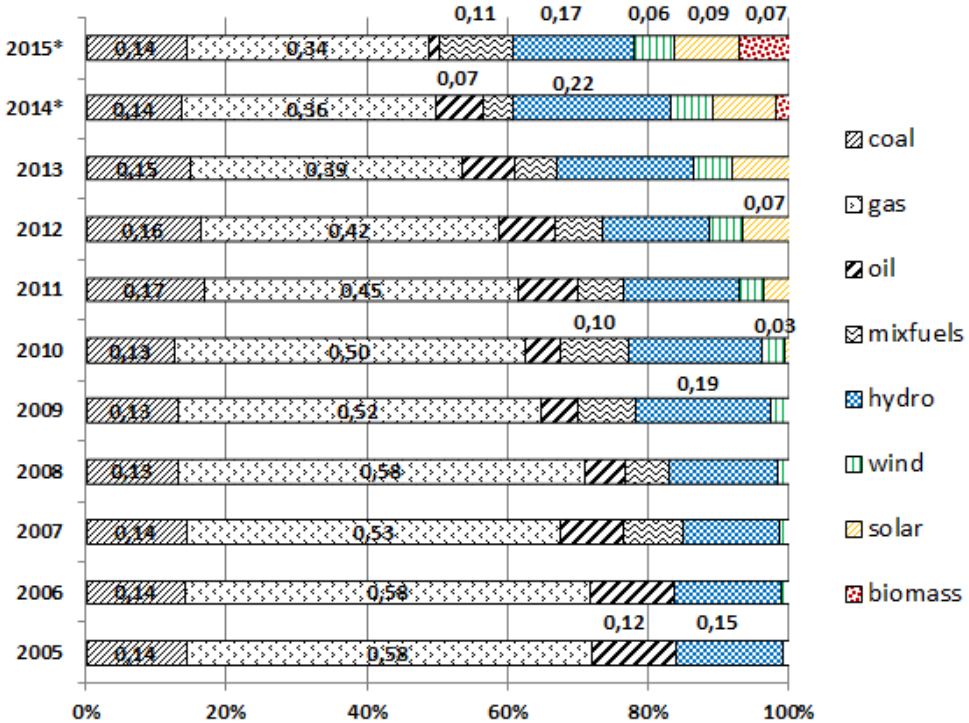
- Papers studying the relationship between RES-E and electricity prices (Texas, Australia, Spain, Denmark, Norway, United Kingdom, The Netherlands and Germany):
  - Woo et al. (2011), Ketterer (2014), Mulder and Scholtens (2013), Mauritzen (2013), Gelabert et al. (2011), and Cruz et al. (2011). However, these recent contributions are mainly devoted to the analysis of day-ahead prices and not on balancing and fuel prices.
  - Hirth and Ziegenhagen (2015) provide a clear description of the main issues regarding balancing activities and relate them to the requirements imposed by the increasing share of variable RES production. They describe the German market data and, surprisingly, notice that while German wind capacity has tripled since 2008, balancing reserves have been reduced by 15% and balancing costs by 50%.

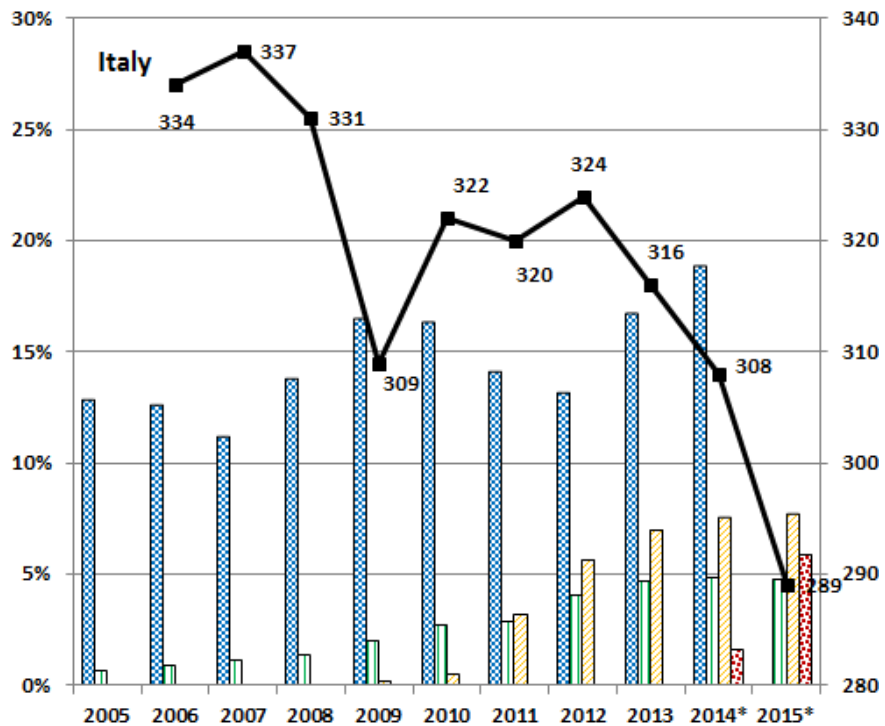
Relevant literature 3

- Papers considering structure and rules for the functioning of balancing markets.
- Papers studying conditions for participation of RES units in the balancing market: Fernandes et al. (2016).
- Papers studying the relationships among spot, adjustment and regulation prices: empirical evidence that the intra-daily sessions are well-functioning and low-cost market tools to ease the introduction of a high share of RES:
  - Gianfreda et al (2016), MI sessions in Italy
  - Chaves-Avila and Fernandes (2015), Spain
- Both papers conclude that market design leaves room to possible strategic behavior across day-ahead and intra-day markets, giving rise to higher system costs.

Evolution of the Italian generation mix

Identification of Two Scenarios: "low" (06-08) and "high" (13-15) RES



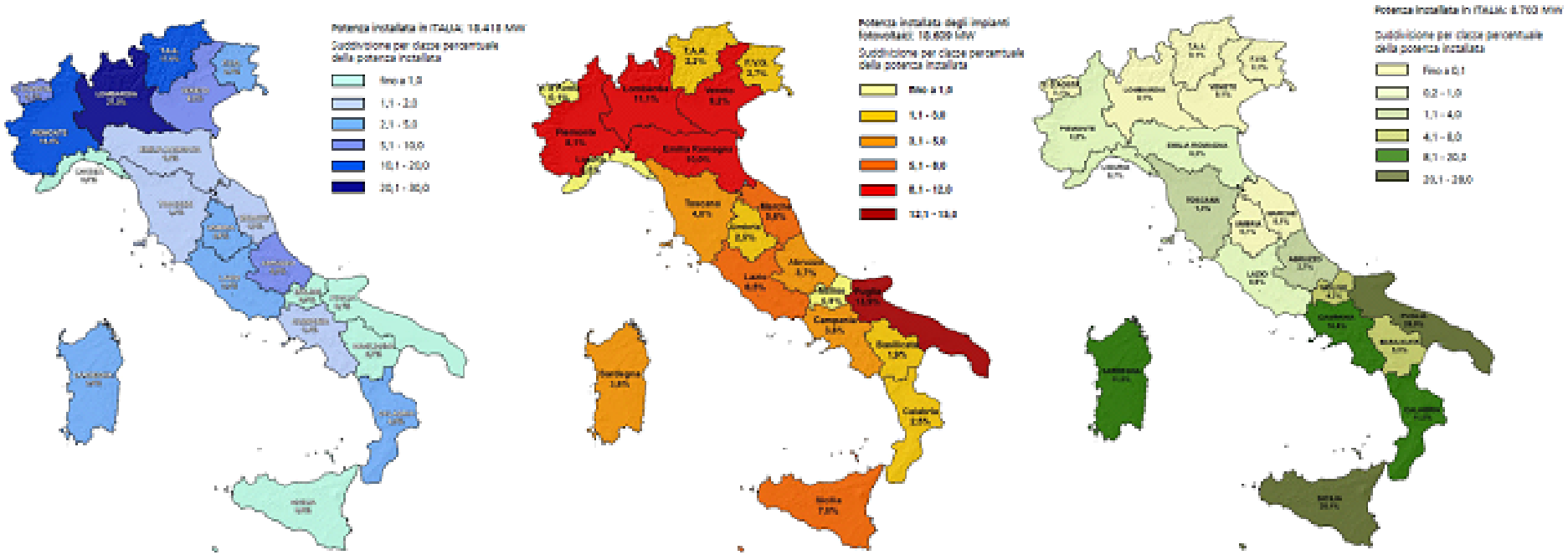


Italian shares by technology generation (on the left), and RES penetration together with Demand levels in TW (on the right)

RES generation in Italy

Selection of the Northern Zone

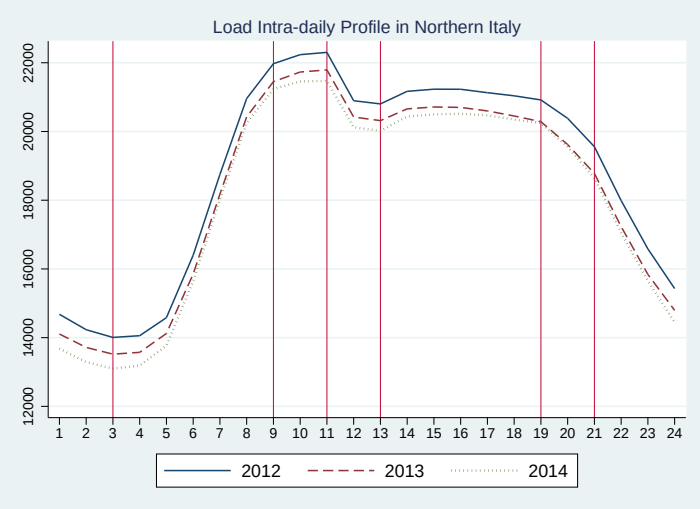
Hydro (left), solar PV (middle) and wind (right) generation

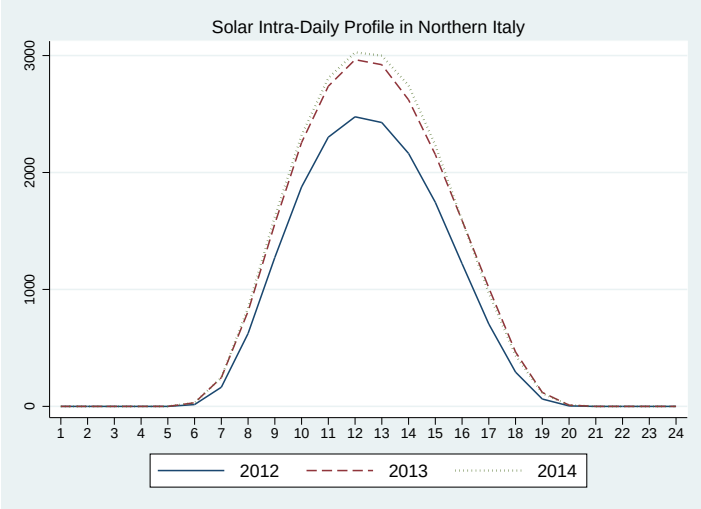


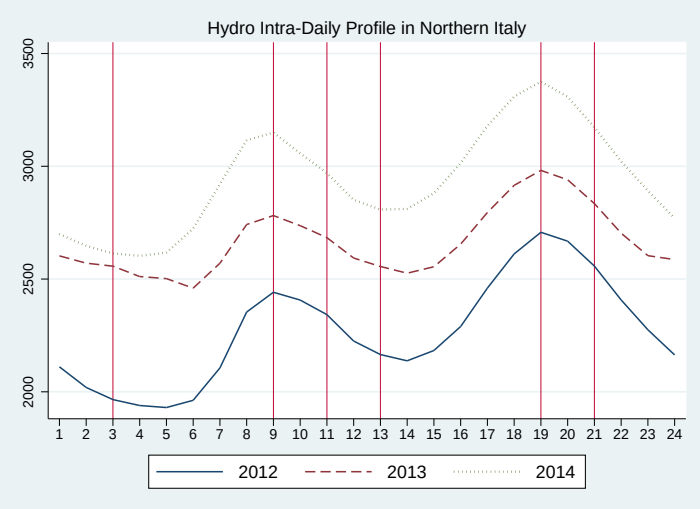
In Northern Italy, there is the majority of hydro and solar PV. Whereas, most wind power is generated in Southern Italy.
However, there are only few observations in Southern BAMs.

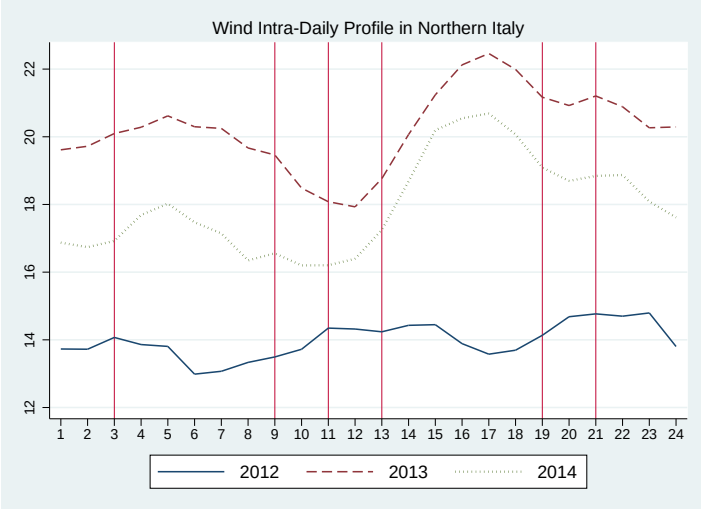
Inspection of Intra-daily Profiles

Selection of Hours: 3–9–11–13–19–21

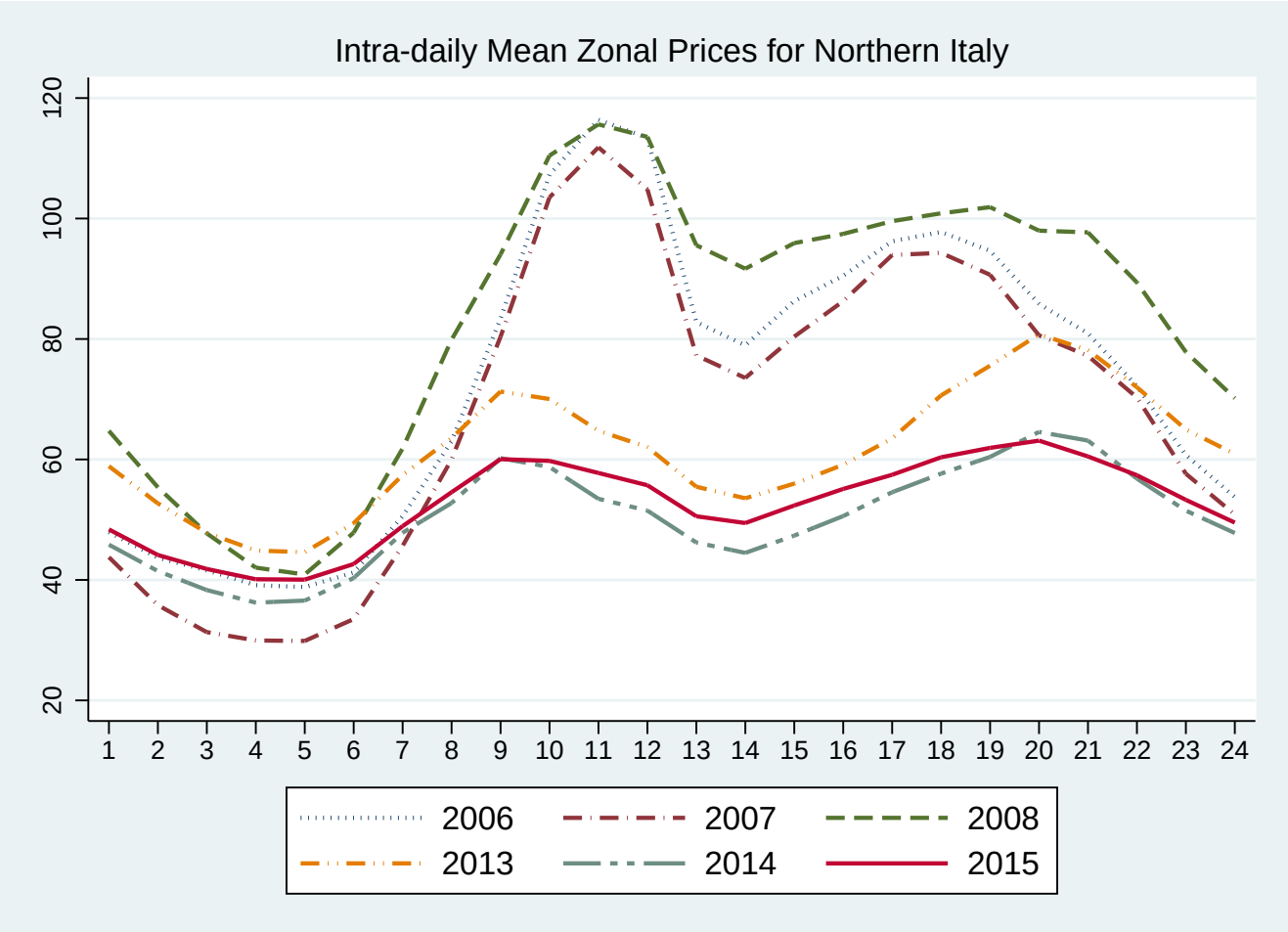






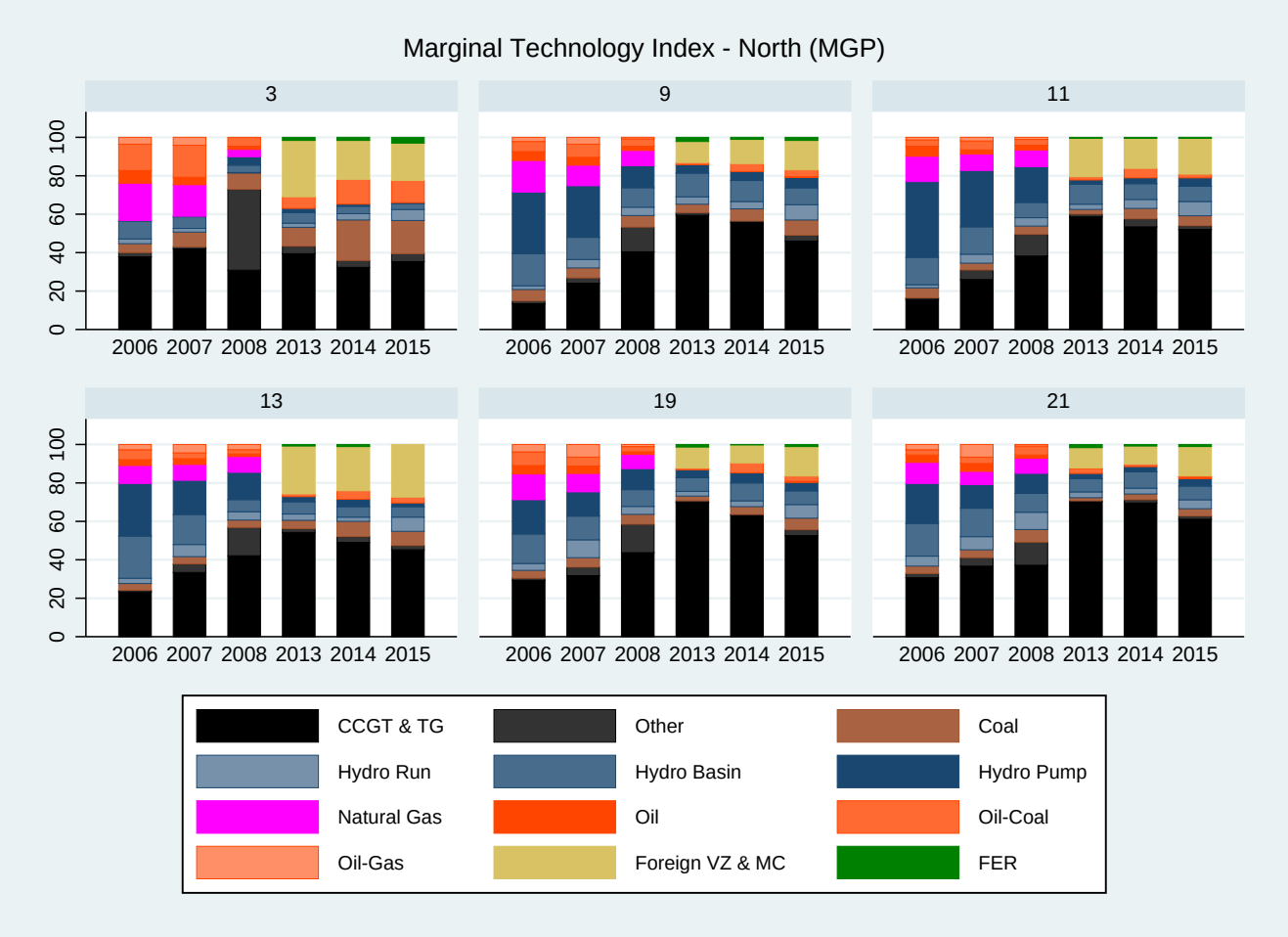


Inspection of Intra-daily Profiles



Spread between peak and off-peak: in 2008 peak price was three times the off-peak, whereas in 2015 peak price was only 50% higher.

Marginal technology index, MGP - North zone



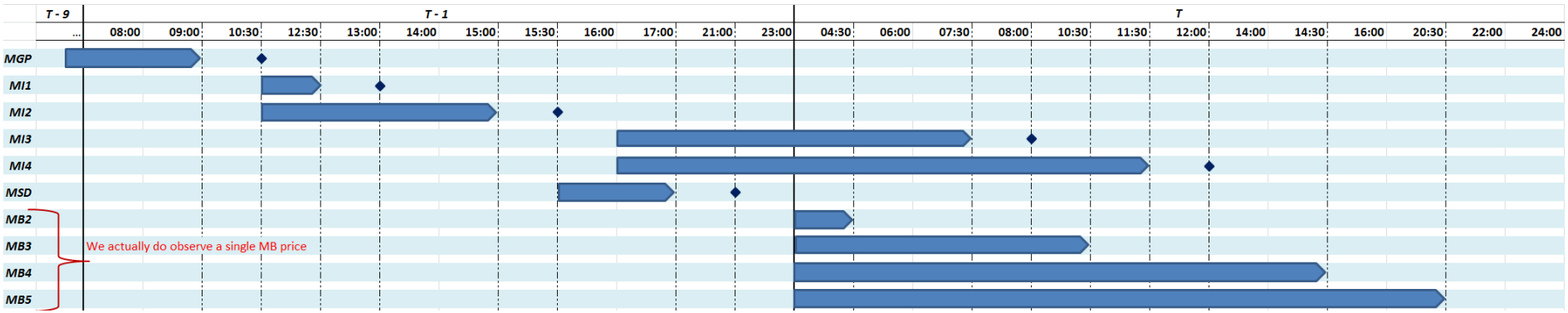
ITM - comments

- Decreasing role of gas
- Coal maintains or even increases its role (see in particular h3)
- Foreign zones are marginal with high frequency
- RES start to be the marginal technology even if with very low frequency

Real time markets

- Ancillary services markets have a scheduling sub-stage (ex-ante MSD with 4 sessions) and a balancing market (MB) with 5 sessions.
- MSD is the marketplace where the Italian TSO, Terna, negotiates all resources necessary to guarantee the system security, including dispatching services useful for resolving intra-zonal congestions, the establishment of an adequate reserve and real time balancing.
- During MB sessions, Terna accepts energy demand bids and supply offers in order to provide secondary control and to balance energy injections into and withdrawals from the grid in real time.
- The ex-ante MSD and MB are based on the pay-as-bid pricing mechanism (a reference price usually calculated as the weighted average of all accepted bids, both for purchases and for sales).
- Italian suppliers of balancing power are obliged to deliver energy under fixed technical conditions, like time of response, ramp rates and duration.

Timing of transactions in different market sessions



Bids submitted in MB sessions can only contain **better economic conditions** with respect to MSD bids, otherwise ex-ante MSD bids remain valid.

Balancing products

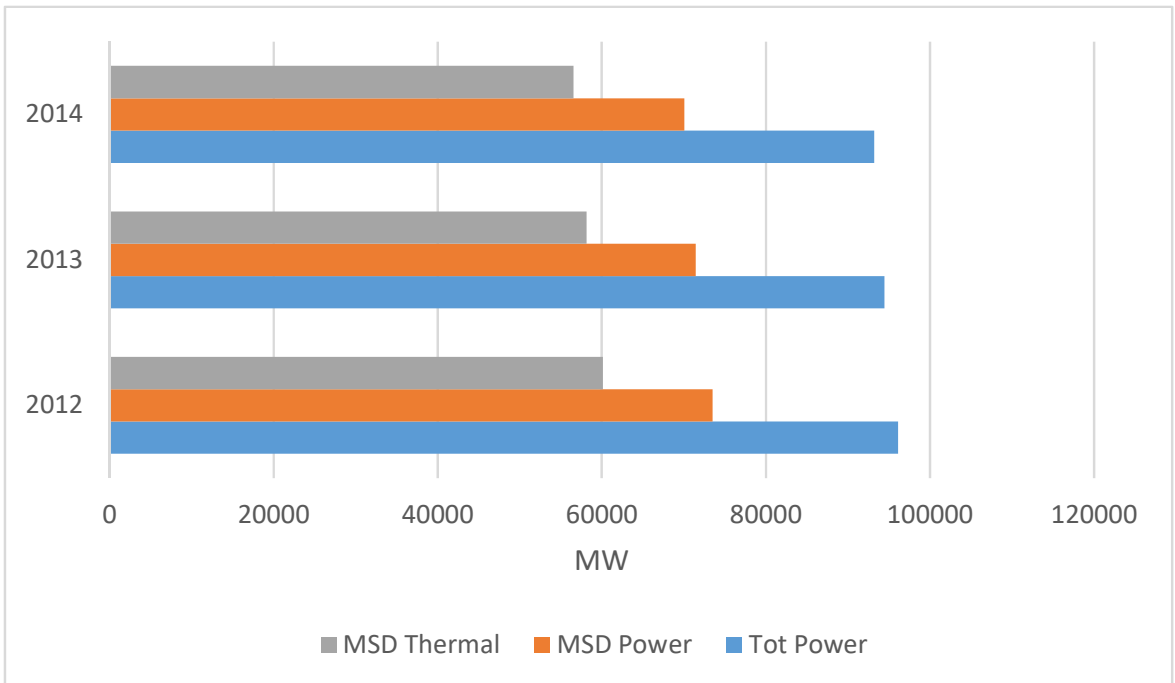
- Balancing products can be divided into two main categories:
  1. balancing capacity, not committed in other markets
  2. balancing energy, which refers to the actual variation of generation (or consumption) with the purpose of reestablishing the balance between generation and demand in real time
- Market purpose: 'upward' reserve (for balancing capacity/energy procured to compensate a negative imbalance) and 'downward' reserve (for balancing capacity/energy procured to compensate a positive imbalance)
- Participants are obliged to comply with the production/consumption program established in the day-ahead and in the intra-day markets and they are financially responsible for any deviations with respect to their market schedules.

Participants to balancing sessions

Balancing sessions are more concentrated than DAM session.

- Thermal
- Pumping units
- Hydro units

In recent years we notice a reduction of capacity entitled to bid into balancing session, expecially in the thermal segment (-5,7%).



Balance of TERNA operations

- Negative balance of Terna's operations (cost for the system covered by the so-called uplift component). Its value was 3.82€/MWh in 2009, but it almost doubled in 2014 (being equal to 6.25€/MWh).
- The main cost components are represented by:
  1. 'the planning of services' (approvvigionamento servizi) concerning activities in the ex-ante MSD sessions, which was mainly stable around one billione across years;
  2. the 'energy component' (componente energia) taking into account all realized imbalances (a cost of €459 M in 2014);
  3. contracts to secure upward reserves (stable across years)
  4. Start-up and status change cost (*gettone di avviamento*) introduced in 2014 (€82 M in 2014)

We concentrate on the two first components.

Data Description and Providers

- Two samples: 2006–2008 and 2013–2015
- Zonal day-ahead electricity prices (GME)
- Balancing prices as weighted averages of awarded quantities under the 'pay-as-bid' rule (on both MSD & MB), and at disaggregated level (GME)
- Oil, Coal and ICE UK Natural Gas prices (Datastream)
- Actual Load as proxy for Demand (ENTSO-E for Italy & Terna for North zone, but only from 2010)

Methods: VECM

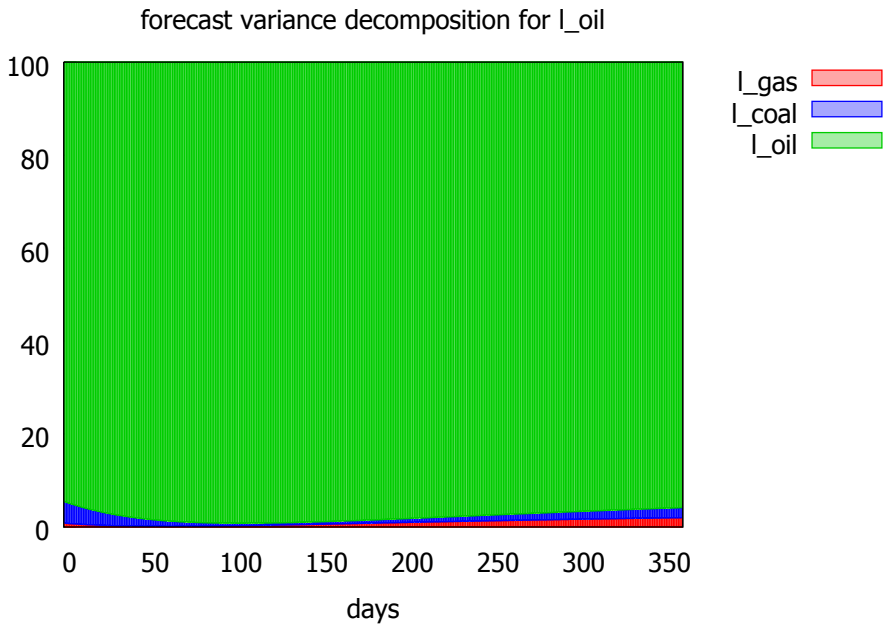
- We decided to keep all the time series at their original (daily) frequency and treat the seasonal components with a data pre-processing.
- All time series of electricity, coal and gas prices were tested for a unit root using the ADF test
- Johansen's test: for each considered hour and for each subsample, we tested for the presence of cointegration among the logarithms of electricity and fuels prices.
- We estimated a vector error correction model (VECM) for each hour, coherently with the number of cointegrating relations found by Johansen's test.

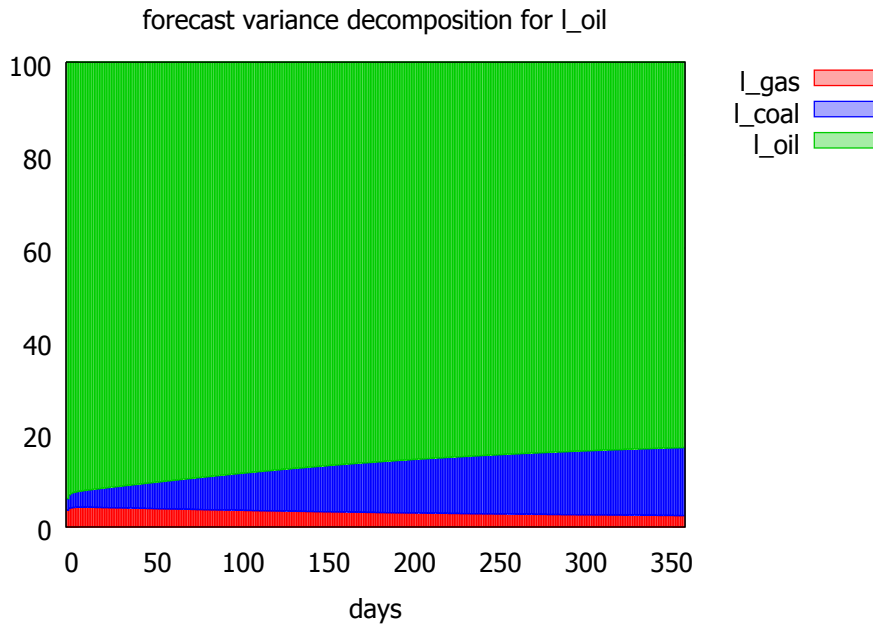
Methods: FEVD

- In the VECM, the best way to assess the role that fuel prices play in influencing electricity prices in the long-run is by the *forecast error variance decomposition*, (FEVD), which allows to determine how much of the forecast error variance of each variables can be explained by exogenous shocks to the other variables
- The relationship among fuel prices (oil, gas and coal) is firstly tested
- Then, the influence of fuel prices on electricity prices is considered at both the day-ahead and balancing levels

Forecast Error Variance Decomposition: OIL

Oil prices became largely independent from shocks affecting other fuels

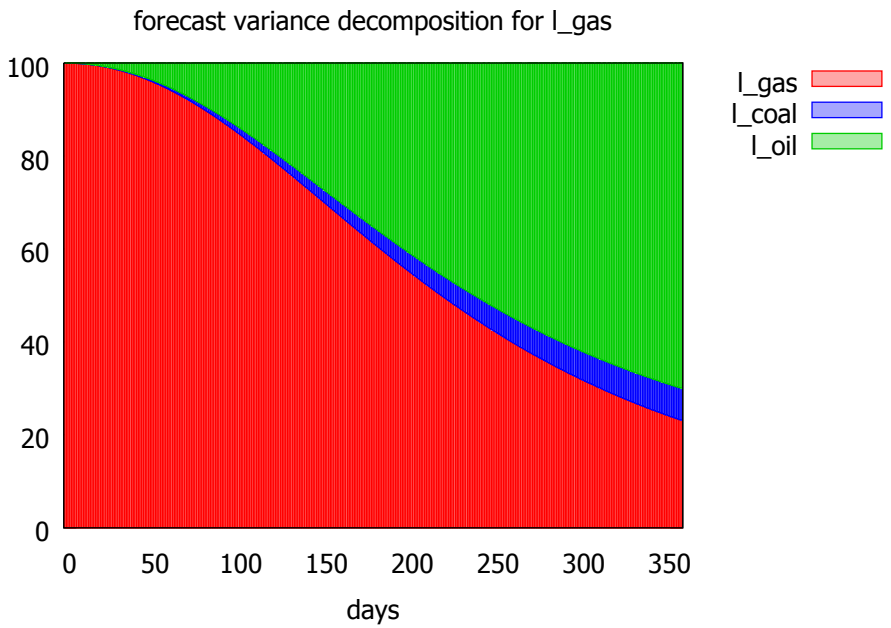


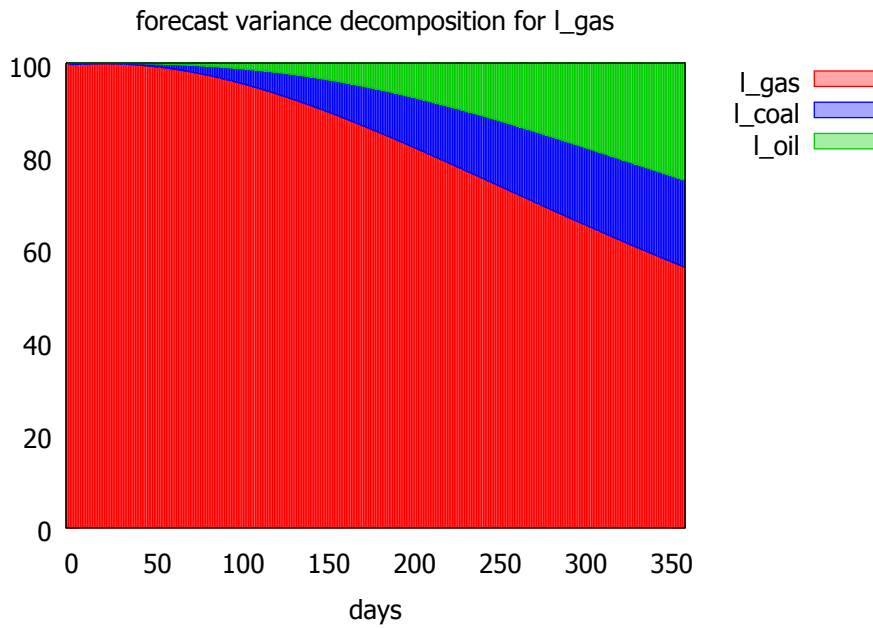


2006-2008 (left) and 2013–2015 (right)

Forecast Error Variance Decomposition: GAS

The role of OIL in explaining the long-run dynamics of gas prices largely decreased (decoupling)

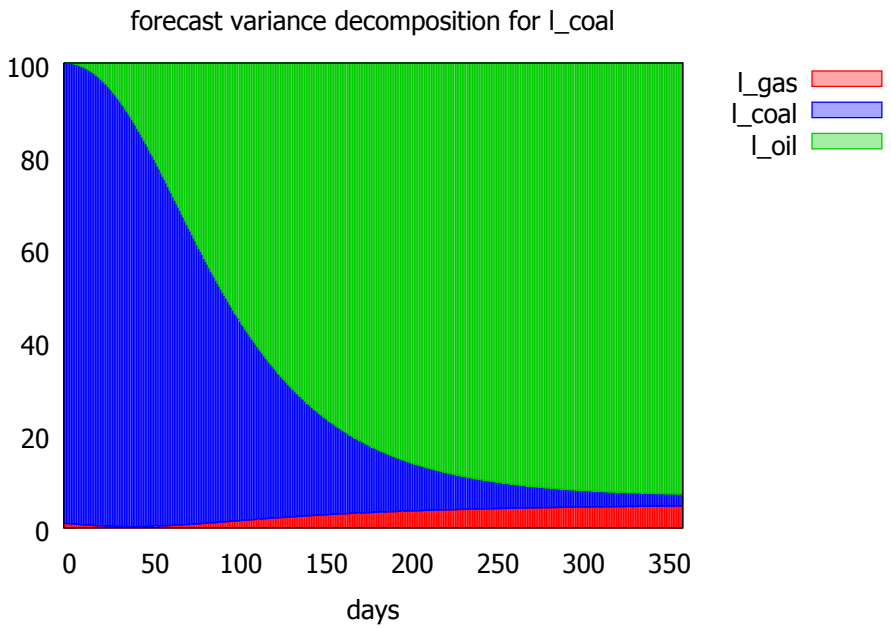


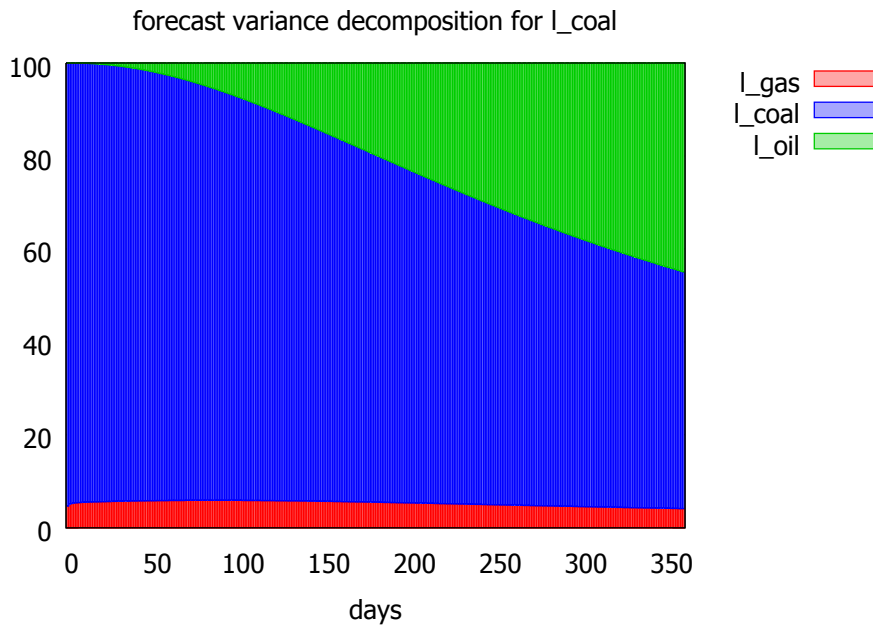


2006-2008 (left) and 2013–2015 (right)

Forecast Error Variance Decomposition: COAL

The role of OIL in explaining the long-run dynamics of coal prices largely reduced

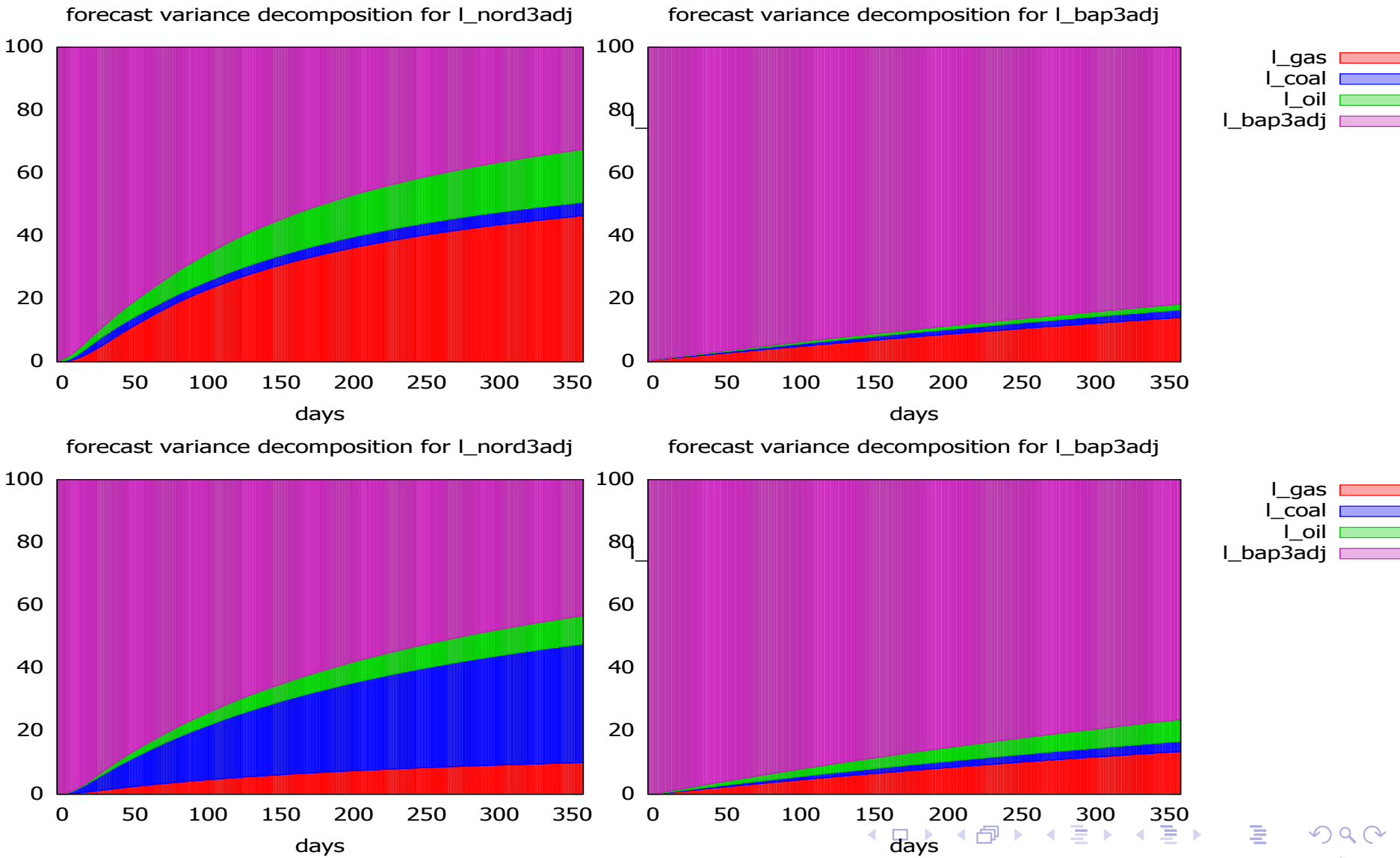




2006-2008 (left) and 2013–2015 (right)

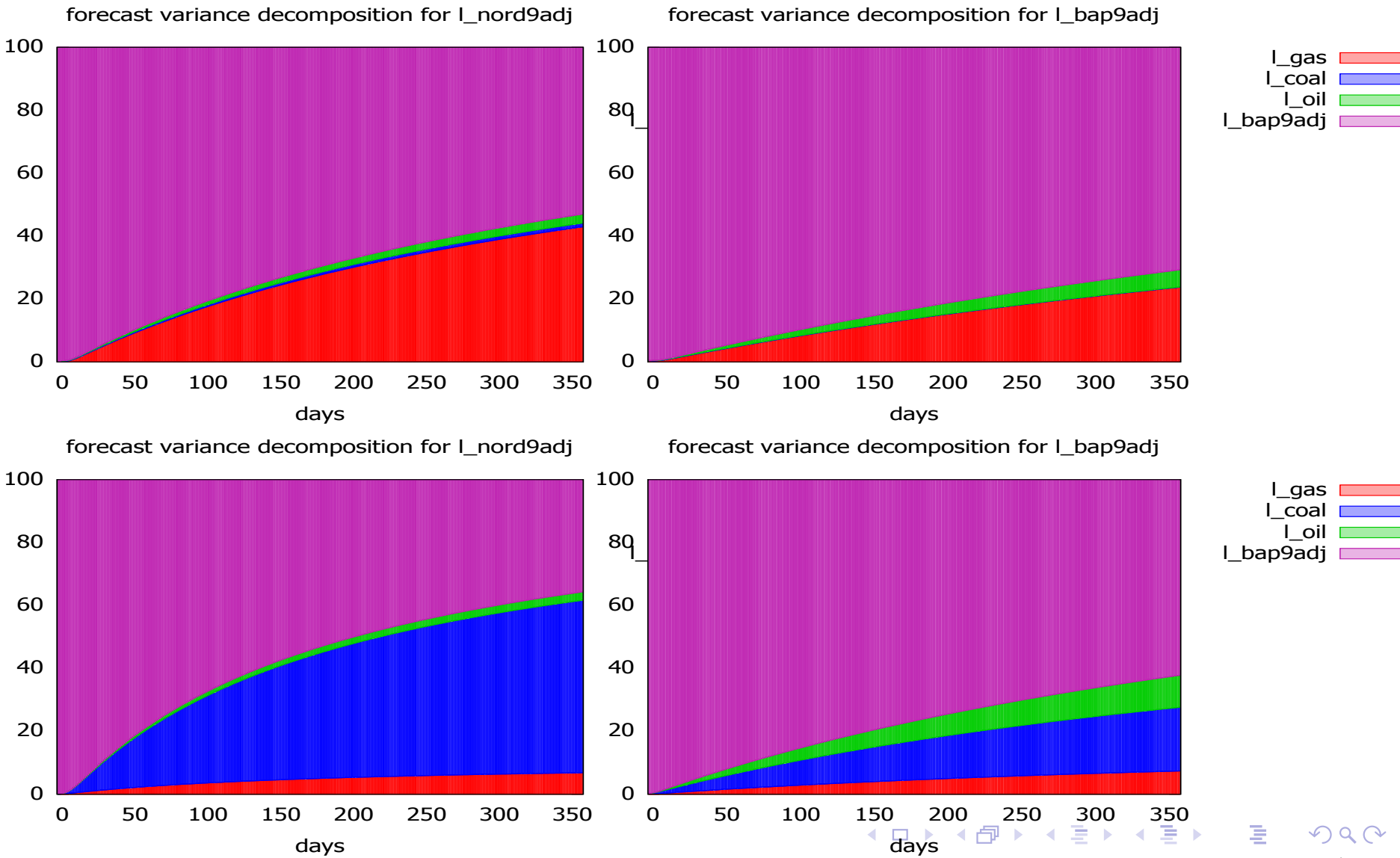
Forecast Error Variance Decomposition: H3

DA (left column), BA (right column), 1^{st} sample (top row), 2^{nd} sample (bottom row)



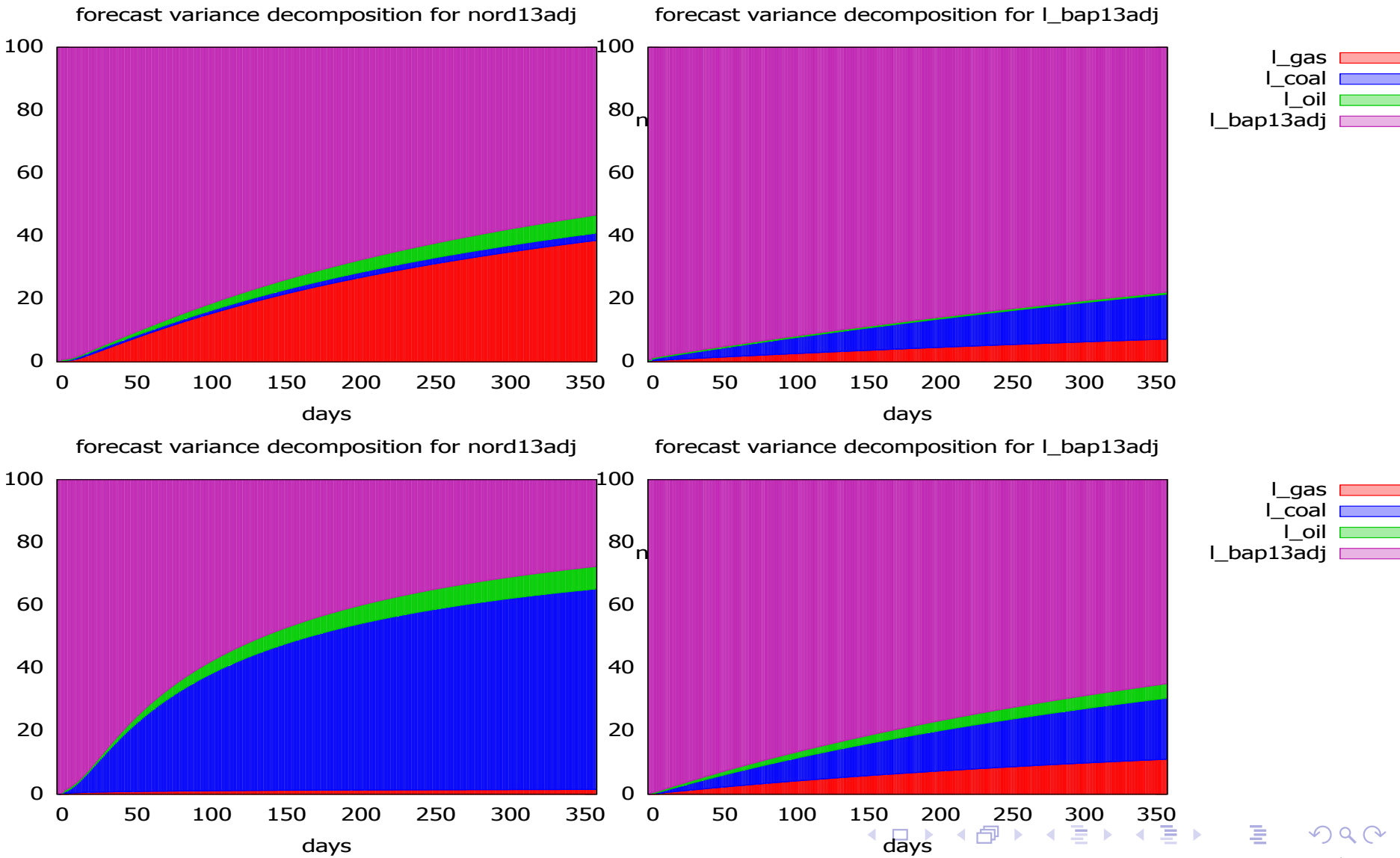
Forecast Error Variance Decomposition: H9

DA (left column), BA (right column), 1^{st} sample (top row), 2^{nd} sample (bottom row)



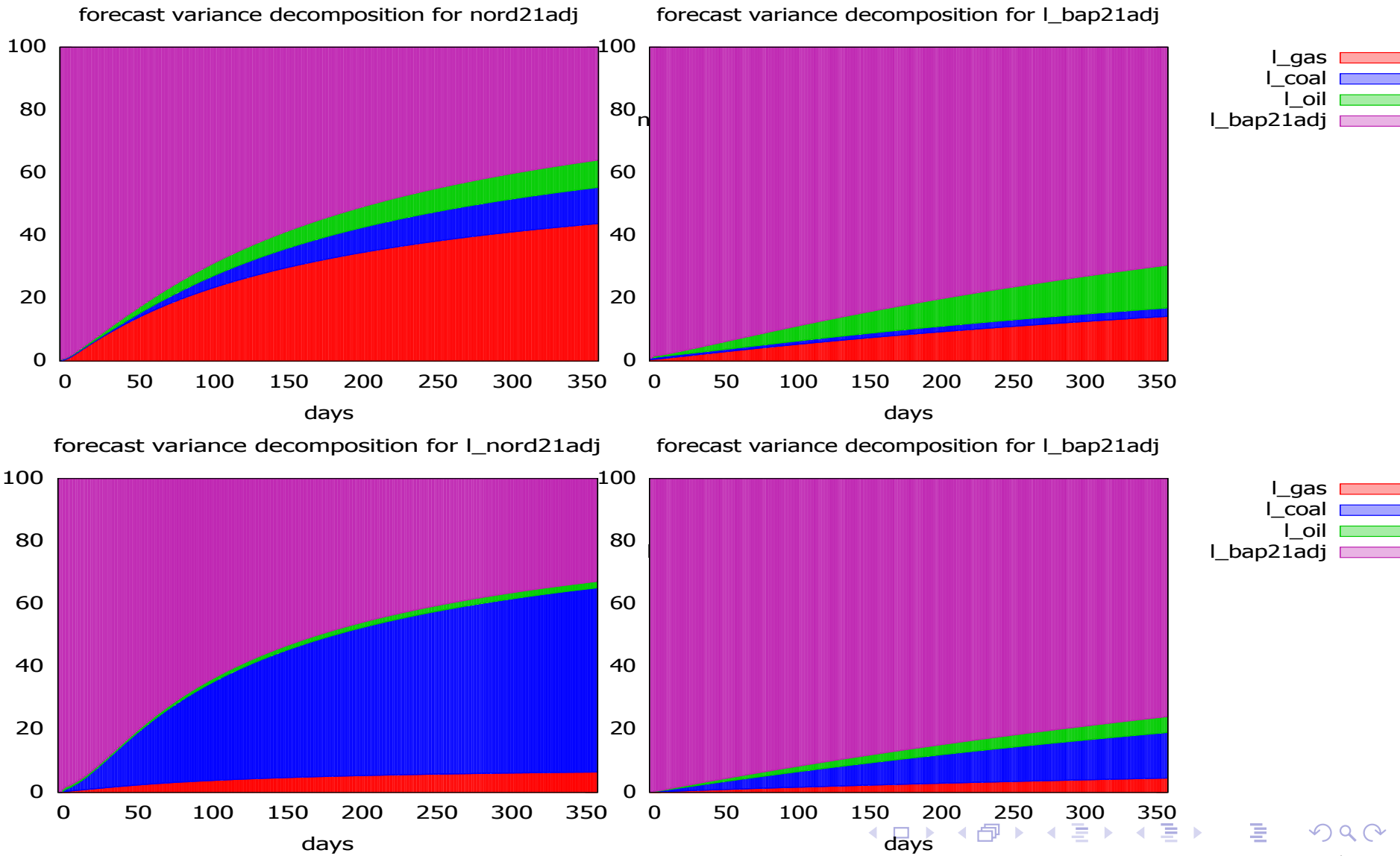
Forecast Error Variance Decomposition: H13

DA (left column), BA (right column), 1^{st} sample (top row), 2^{nd} sample (bottom row)



Forecast Error Variance Decomposition: H21

DA (left column), BA (right column), 1^{st} sample (top row), 2^{nd} sample (bottom row)



Computations

- We compute the actual balancing costs[1] multiplying the awarded prices for corresponding awarded quantities at unit level
- then, we aggregate the information across technologies, hours, years and market 'purpose'
  - "sales" are situations in which Terna buys quantities incurring in 'costs' for the system (represented with negative values) – "up-regulation"

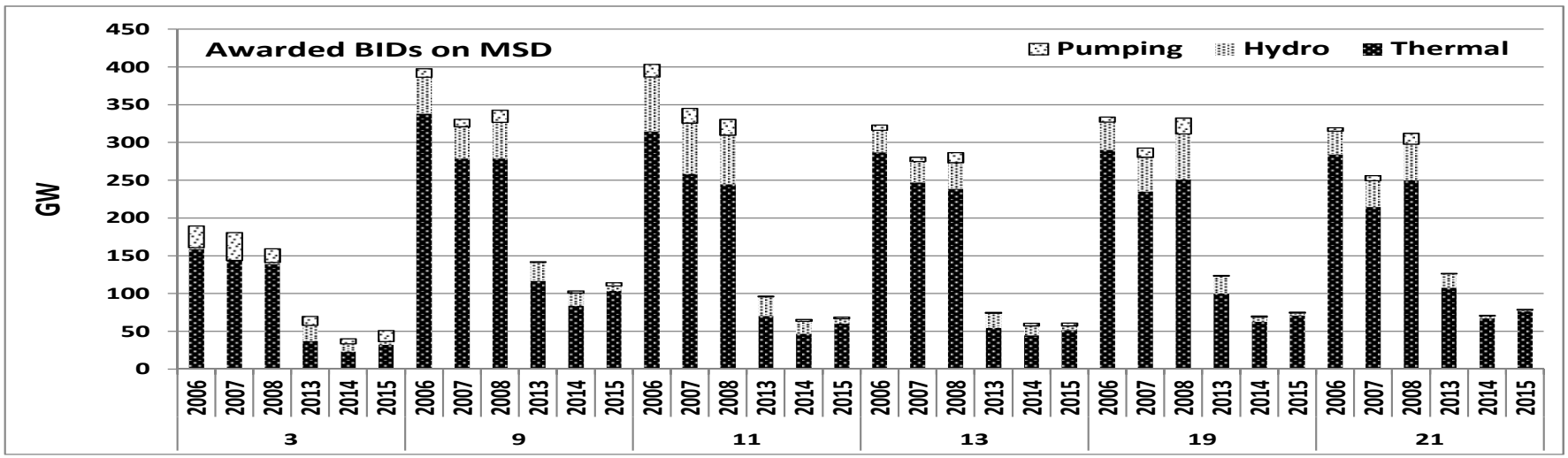
    $\Rightarrow$ general increasing yearly mean prices across the two samples
  - whereas "purchases" are situations in which Terna sells quantities obtaining instead 'profits' (depicted with positive values) – "down-regulation"

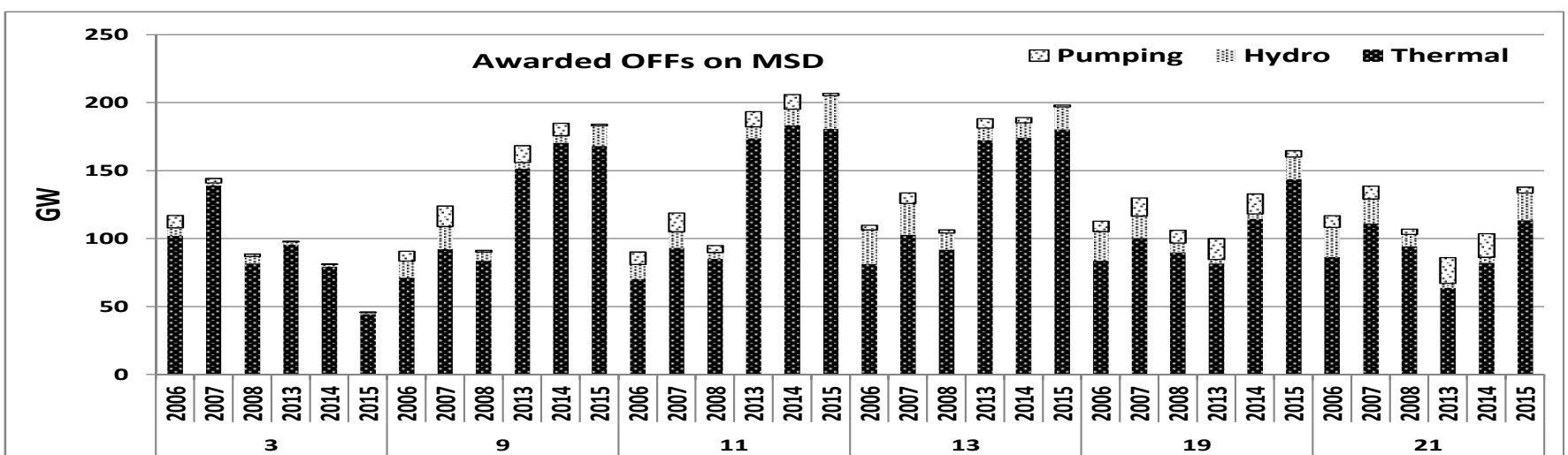
    $\Rightarrow$ decreasing yearly mean prices across the two samples

[1] Focusing only on two components of the *uplift*: the first one is the *planning of services*, which concerns the ex-ante MSD sessions, and the second one is the *energy component* which takes into account all the realized imbalances.

Balancing Quantities in the "ex-ante MSD"

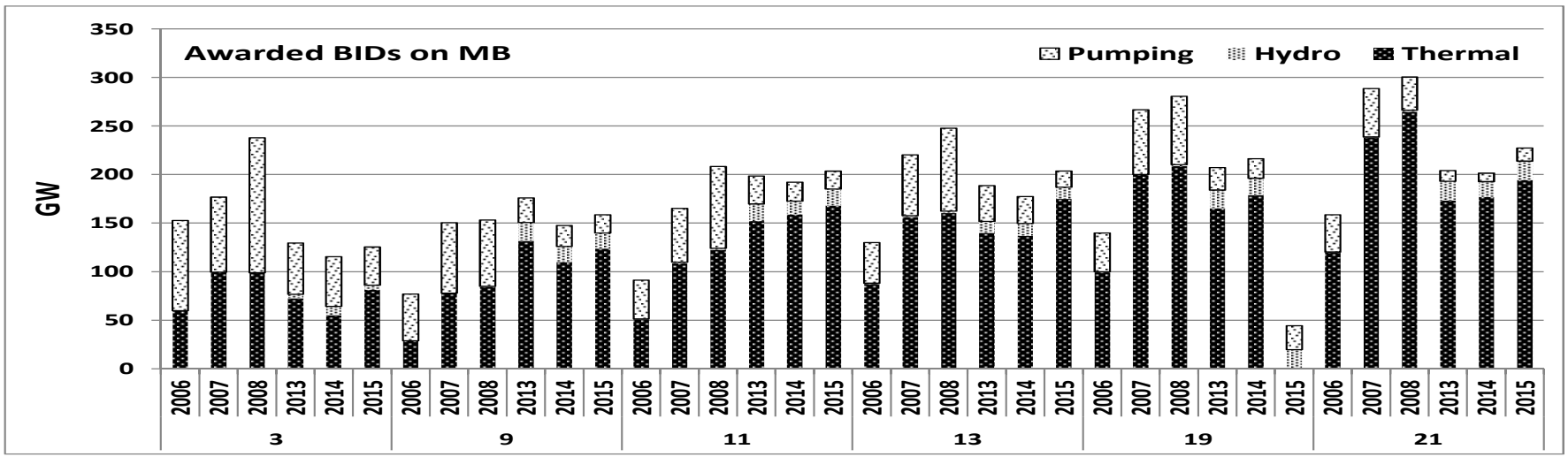
Yearly Sum of Awarded Purchased (on the first row) and Offered or "Sold" (on the second row) Quantities across hours and technologies

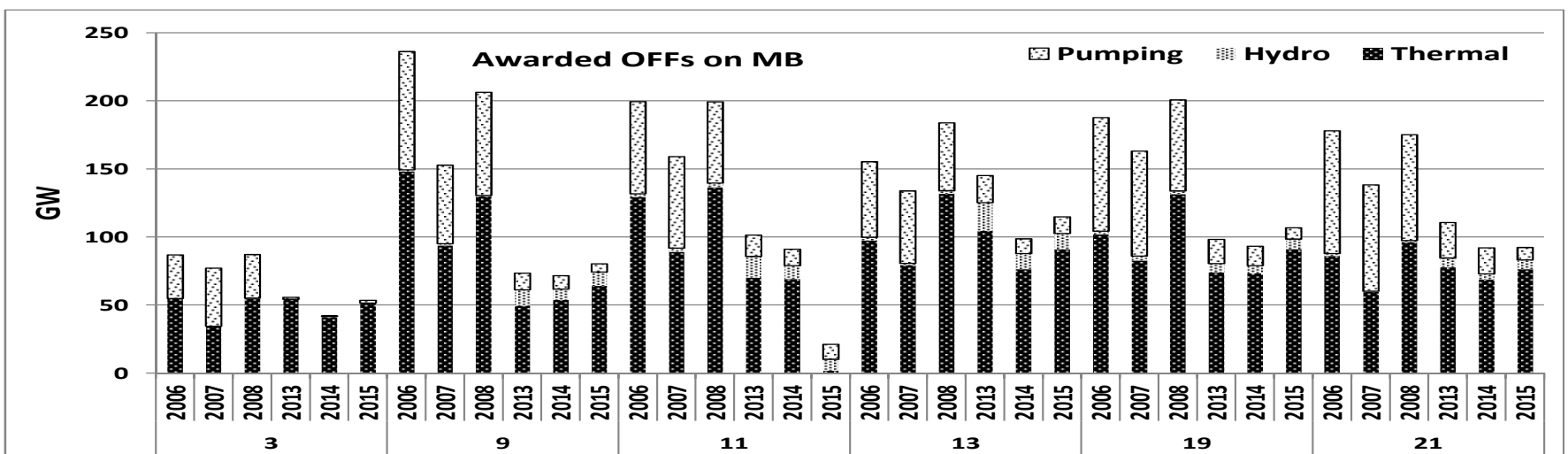




Balancing Quantities in "MB"

Yearly Sum of Awarded Purchased (on the first row) and Offered or "Sold" (on the second row) Quantities across hours and technologies





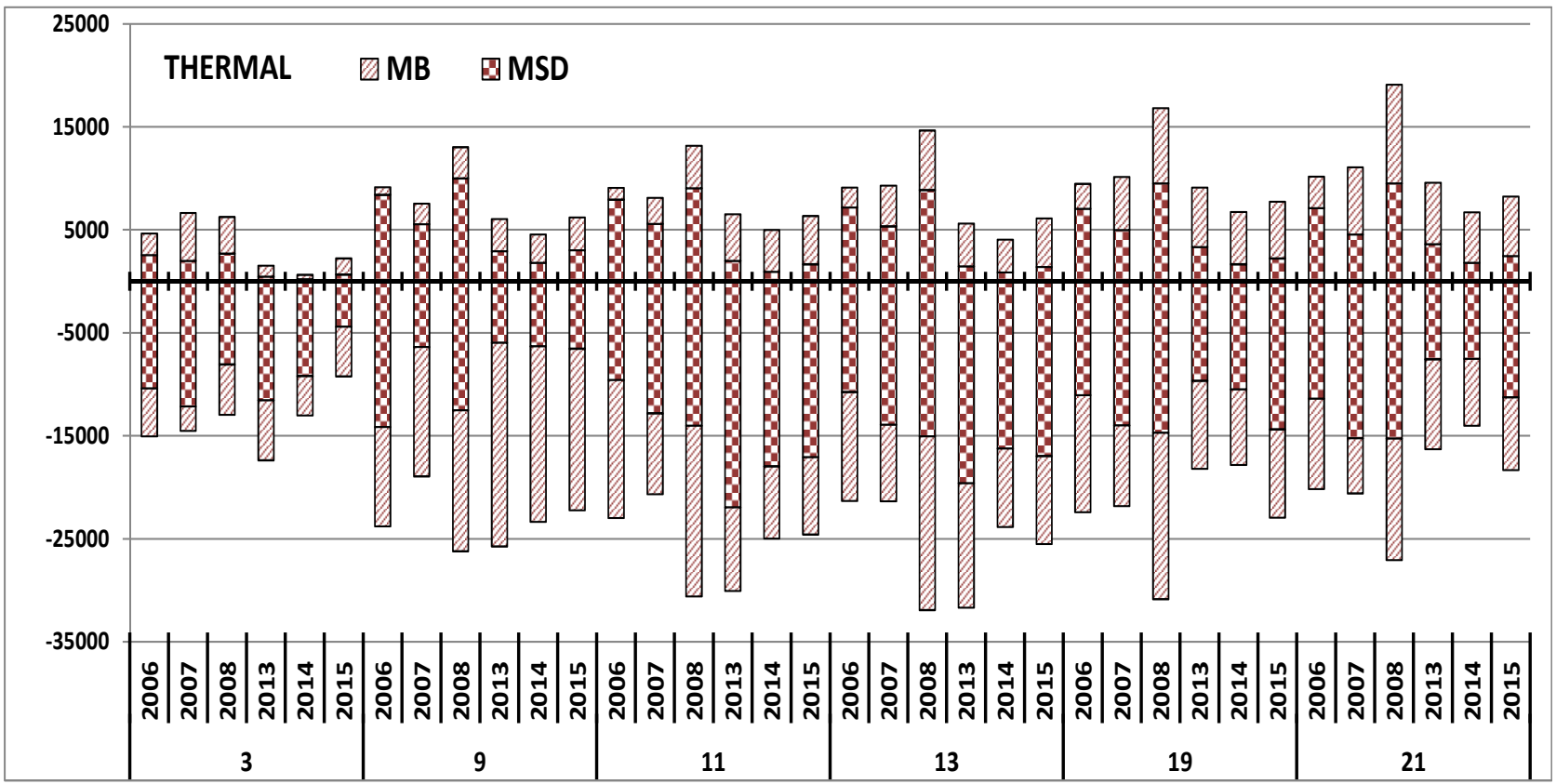
Price variations across the two samples in MSD and MB

	Hydro				Water Pumping				Thermal			
	Max		Mean		Max		Mean		Max		Mean	
Hour	MSD	MB	MSD	MB	MSD	MB	MSD	MB	MSD	MB	MSD	MB
3	↓ 20	↑ 111	↓ 3	↑ 8	↑ 19	↑ 67	↑ 36	↑ 63	↑ 148	↑ **884**	↓ 3	↑ 31
9	↓ 54	↑ 176	↓ 33	↓ 31	↑ 19	↑ 57	↑ 11	↑ 37	↑ 48	↑ 30	↓ 28	↑ 45
11	↓ 12	↑ **1422**	↓ 44	↓ 20	↑ 34	↑ 55	↑ 15	↑ 34	↑ 38	↑ 25	↓ 34	↑ 21
13	↓ 46	↑ 13	↓ 28	↓ 31	↑ 25	↑ 39	⟷	↑ 28	↑ 35	↑ **1717**	↓ 34	↑ 17
19	↑ 22	↑ **1689**	↓ 22	↓ 24	↑ 48	↑ 60	↑ 35	↑ 40	↓ 11	↑ **903**	↓ 33	↑ 18
21	↓ 41	↑ **1922**	↓ 28	↓ 23	↑ 43	↑ 55	↑ 36	↑ 42	↓ 50	↑ 379	↓ 34	↑ 18

Dynamics across samples for the average Maximum and Mean Prices awarded for "Sales" on MSD and MB across hours and technologies, where $\uparrow$, $\downarrow$ and $\leftrightarrow$ represent an average increment, decrement or no changes across the two samples measured by the corresponding amounts expressed in €/MWh.

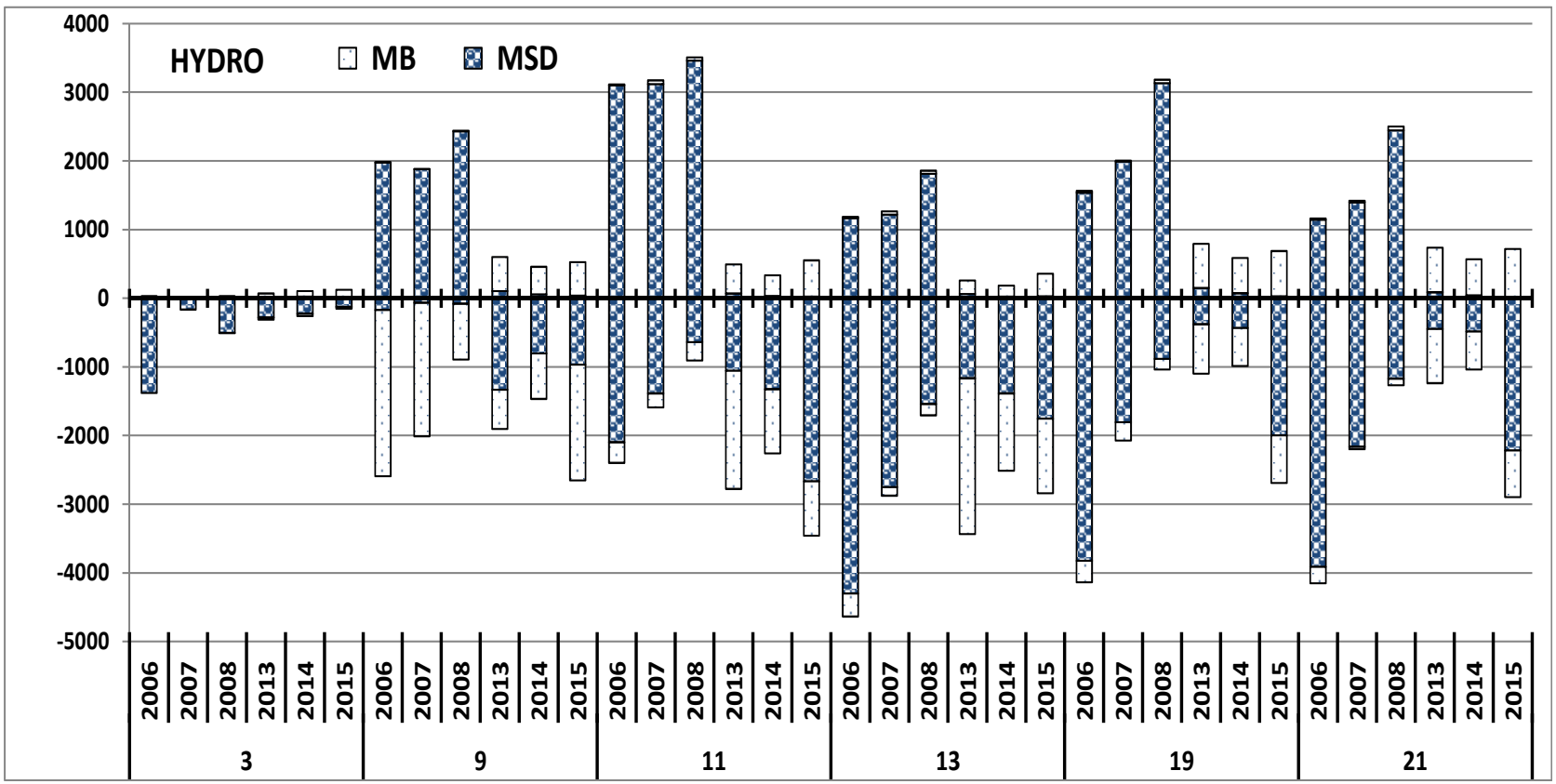
Evolution of balancing costs across technologies

Thermal Costs (in thousands of €)



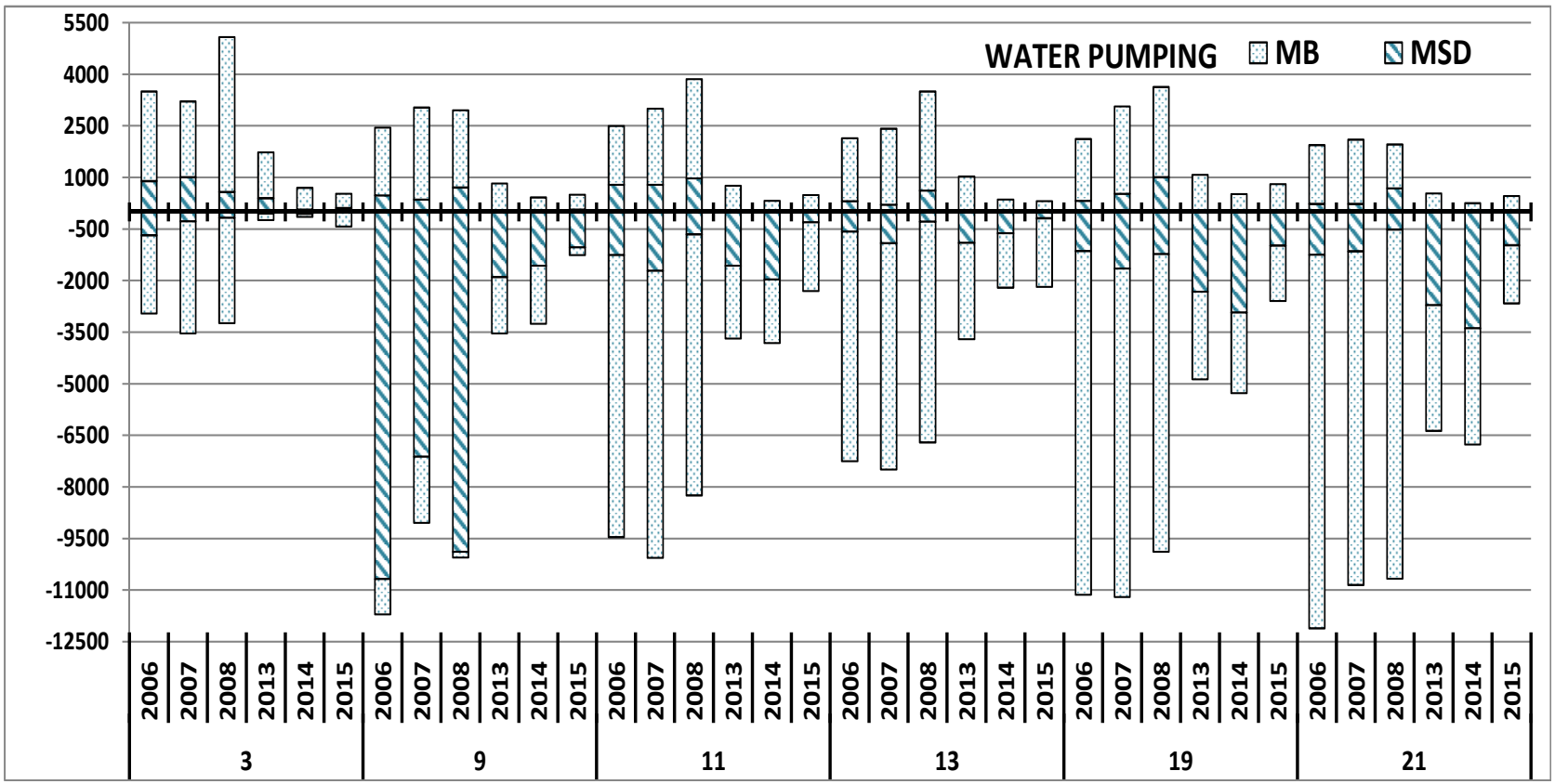
Evolution of balancing costs across technologies

Hydro Costs (in thousands of €)



Evolution of balancing costs across technologies

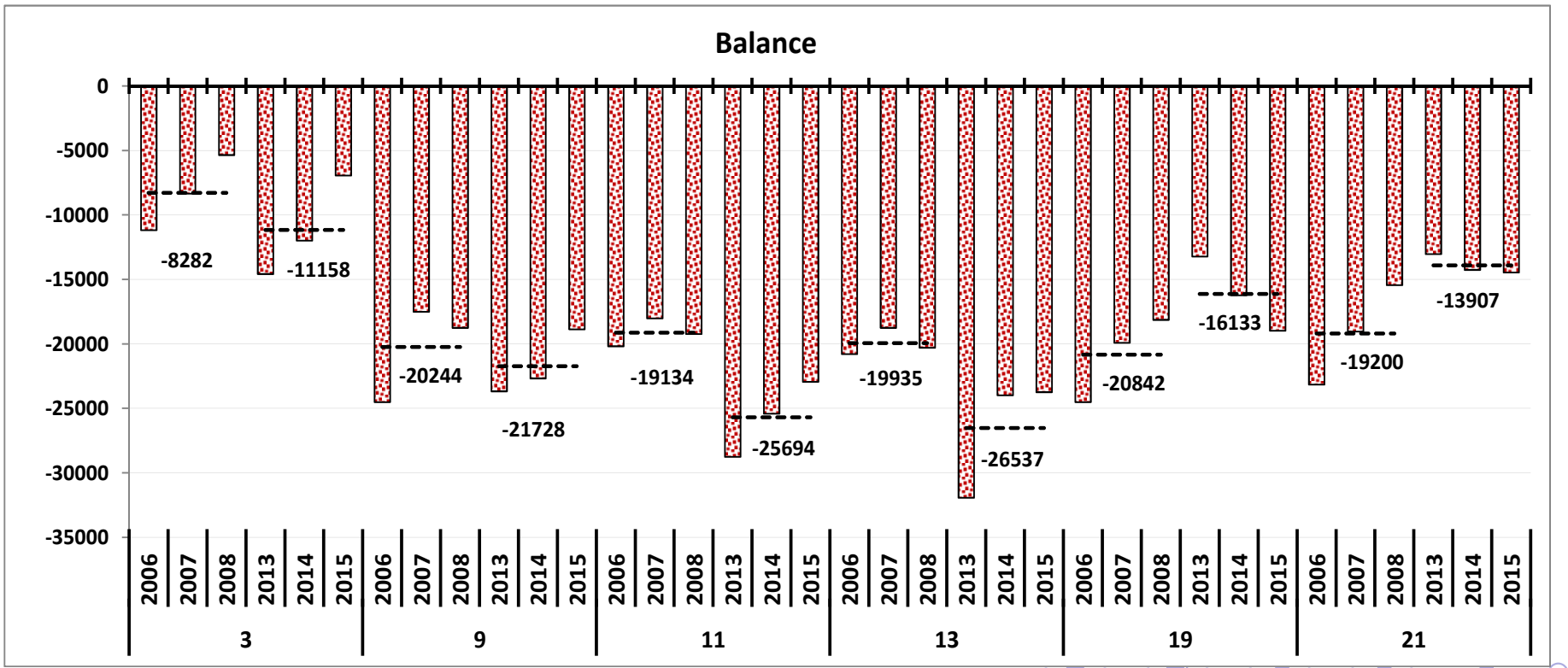
Water Pumping Costs (in thousands of €)



Overall Balance (in thousands of €)

as the difference between profits and costs, faced by the Italian TSO for the Northern zone

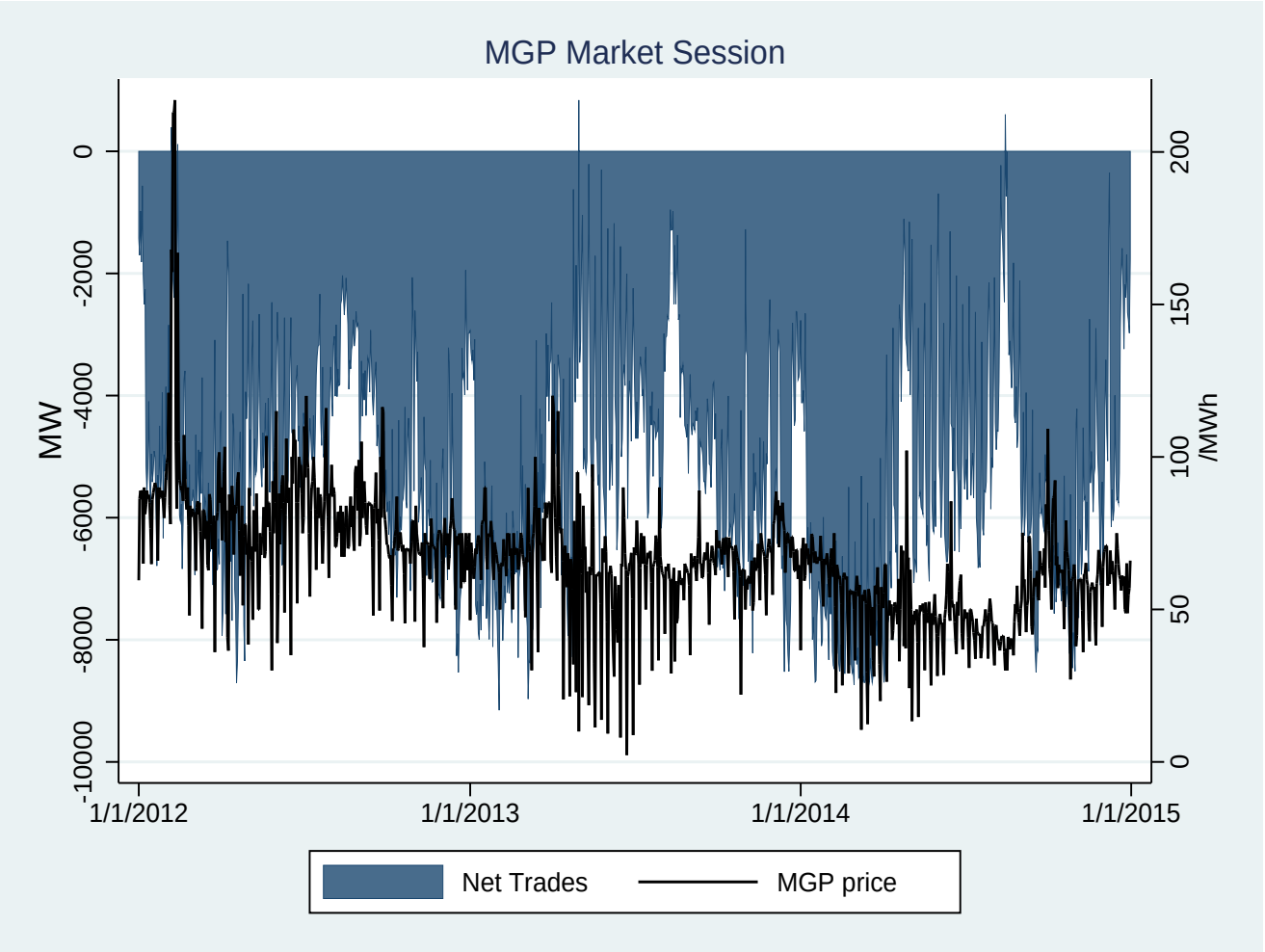
We quantify the overall profits/costs as sum across technologies on both market sessions within a year. Clearly the activities of planning resources and dispatching balancing power are highly costly, and increasing across samples for all hours but H19 & H21



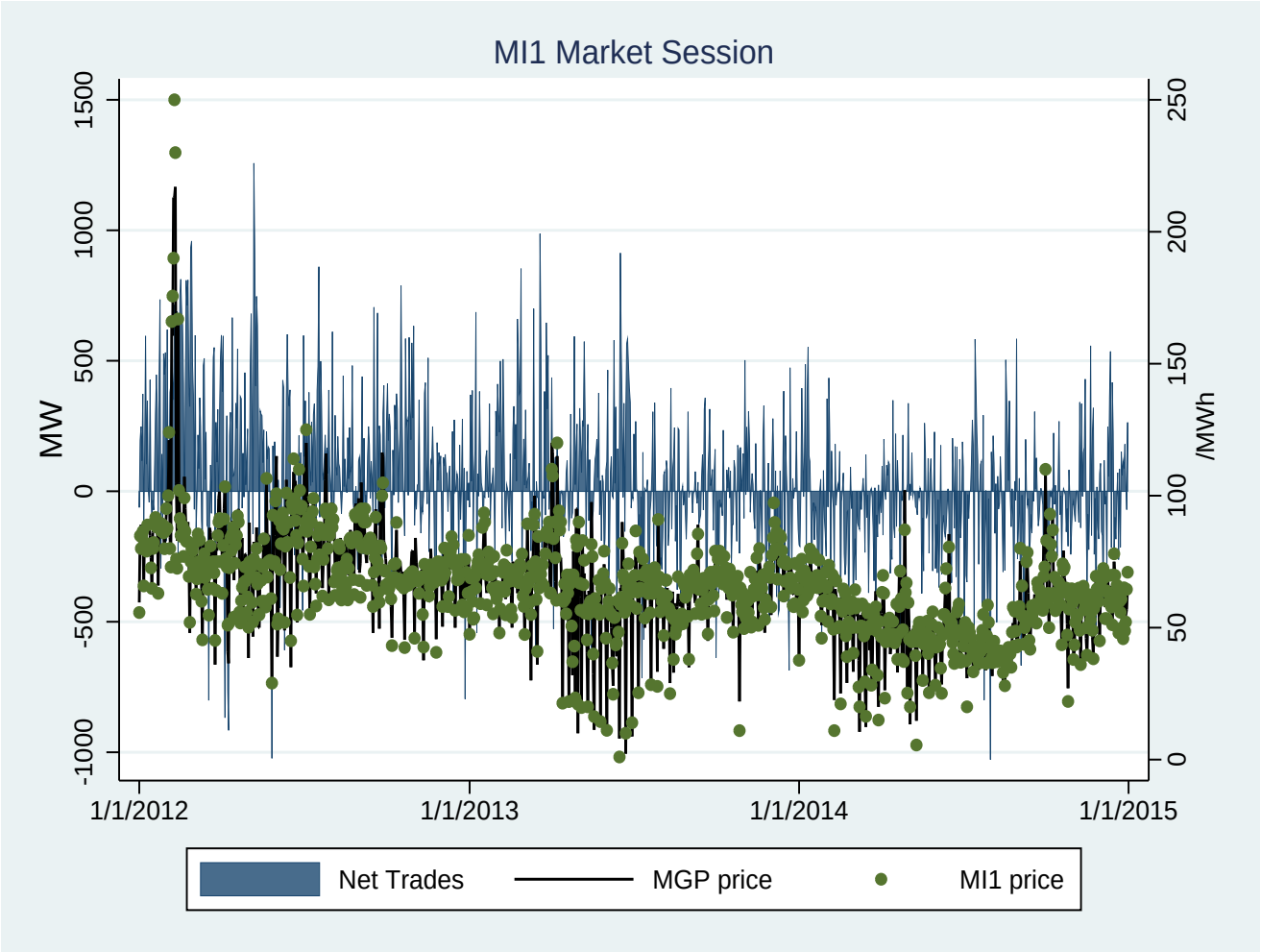
Conclusions

- We documented a decoupling between oil and gas prices in our second sample (2013-15) with respect to the first sample (2006-08)
- We documented a switching effect among fuels in influencing electricity prices
  - the switching effect is remarkable in the day-ahead market
  - the same effect is observed in balancing prices but with a reduced size
- Balancing costs are generally higher in the second sample
- The planning activity executed in MSD is actually a substantial part of computed costs and a migration towards a "capacity market" may be of help for the system

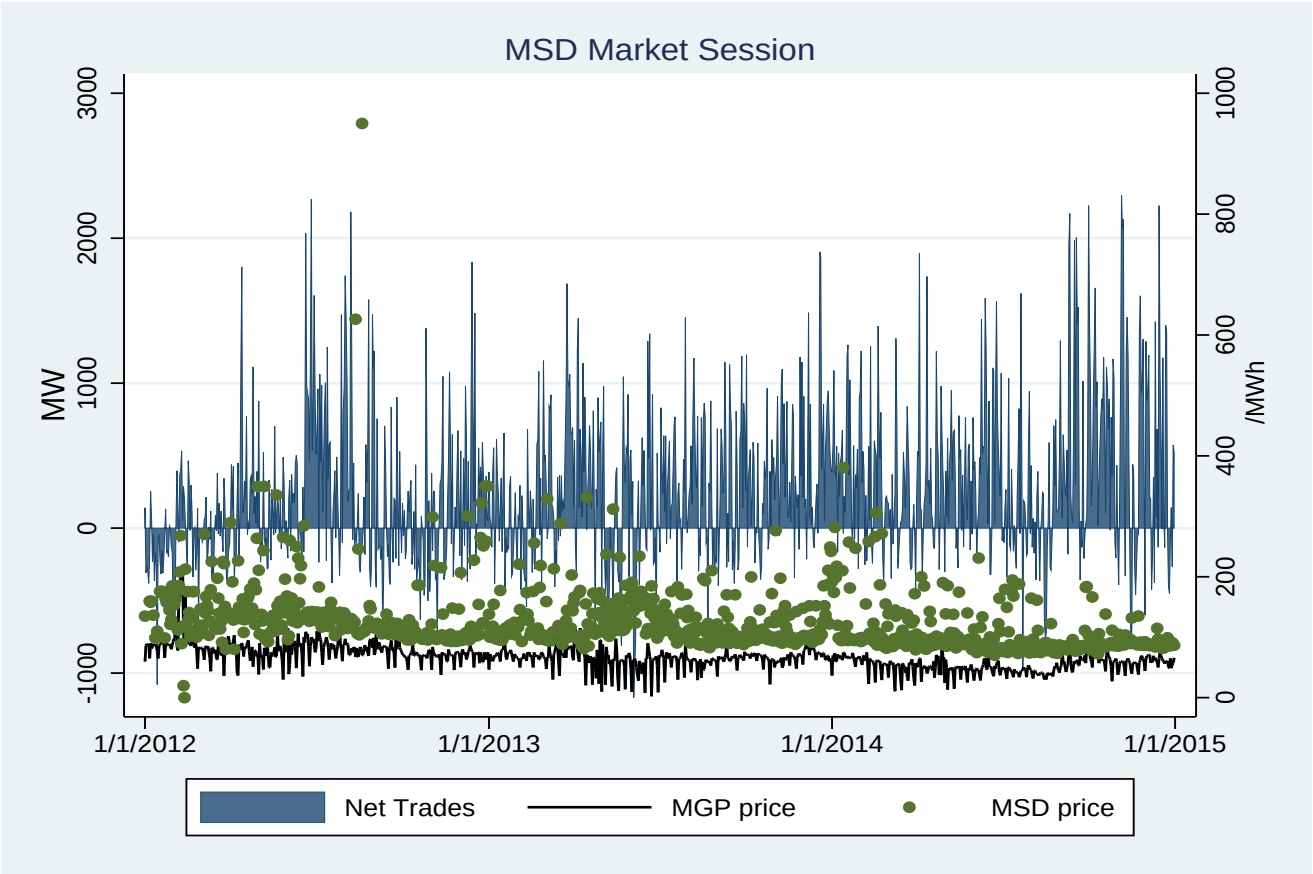
Transactions in North zone at h11 as an example



Results about MI market sessions



Results about MSD market sessions



Results about MB market sessions