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Abstract

The massive introduction of RES in electricity markets is recognized to have induced a merit order effect on wholesale prices. While day-ahead prices are likely to decline as RES-E production increases, the effects on balancing market sessions are more ambiguous. Taking into account the Northern Italian zone characterized by a high solar PV and hydro penetration, we provide empirical evidence that balancing quantities decreased while costs increased between two samples associated with low (2006-08) and high (2013-15) RES levels. We estimate balancing costs for different technologies and compare their dynamics across specific hours. We find evidence of increasing balancing prices in particular market conditions, that we interpret as a signal of strategic use of real time sessions by conventional producers prone to the merit order effect in the day-ahead market. We compare our results to those obtained in the German market (where, on the contrary, balancing costs have decreased) and postulate that the different market designs may explain these results. Our findings suggest that Italian policy makers should carefully monitor all trading sessions, especially those close to real time, to avoid the exercise of market power by few operators allowed to guarantee system security and, additionally, to promptly adopt a capacity market.

JEL codes: D04, D24, L1, O13, Q41, Q42

Keywords: Electricity market, Merit order effect, Balancing Cost, Up-regulation, Down-regulation, Uplift

Contents

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1. Introduction

In this paper we show how the massive introduction of renewable energy sources (RES) in the Italian electricity market has affected balancing prices and associated costs. The intermittent and unpredictable nature of wind and solar production has made the real-time balancing activity of electricity systems more complex and relevant for the continuous matching of supply and demand. In this connection, we show that balancing costs have increased while balancing quantities have been reduced. We quantify the incurred costs across hours, technologies and market purpose (that is up- and down-regulation) and compare them across the two low/high RES scenarios. We analyze the most relevant portion of the Italian market as a reference case, namely the Northern zone, historically characterized by high hydro shares and, in the last few years, by high solar PV penetration. Another interesting case would be the Southern zone, because of its high wind penetration. However, we observed an extremely low number of trades in balancing market sessions for this zone and this does not allow us a reliable empirical analysis.

We focus on a time span from 2006 to the end of 2015 during which we observed a progressive increment of RES generation from low, or even absent, to high penetration. We have divided the time series into two samples: the first one (2006-2008) representing the scenario for low RES penetration, whereas the second one (2013-2015) represents the scenario with high RES penetration. Furthermore, relevant regulatory changes were introduced between the two considered time spans.

Balancing sessions are dominated by conventional technologies (thermal, hydro and water pumping), which have the required degree of flexibility. Hence, units supplying regulation services usually enjoy a higher degree of market power in balancing than in day-ahead (and intra-day) sessions, where they compete with RES producers. As a consequence, in the last years we find that thermal plants had the incentive to sell in less competitive balancing sessions to recover the lower margins gained on the day-ahead market.

The flexibility necessary for the deployment of variable RES-E production is usually costly for the system and weights on the consumers' electricity bill. [4] point out that balancing costs need to be considered when computing the economic impacts of an increasing penetration of variable RES-E on electricity markets, in particular when they entail significantly higher volumes of ancillary services. All things considered, the achievement of EU 2020 targets may be very expensive for consumers since it is composed by RES incentives allowed by the State and higher costs for the ancillary services. It must be emphasized that a final evaluation of RES impact on the system may be calculated only contrasting lower wholesale prices (coming from the merit order effect) with higher costs due to direct support and balancing activity.

This paper contributes to the literature providing a deeper understanding of balancing costs, which are disentangled for hours, market purpose and most importantly by technologies, showing firstly how different players on the balancing sessions react to flexibility needs and secondly how prices are affected.

The Italian balancing sessions are managed by the Transmission System Operator (TSO, in Italy Terna S.p.A.), which is the formal responsible of system security, grid stability and instantaneous balance between inflows and outflows. Terna negotiates regulation services in balancing market sessions with producers and/or consumers, remunerating increments or decrements in production and consumption. Balancing power differs on the basis of activation time, purpose and activation rules. From a regulatory point of view, while day-ahead sessions are quite homogeneous across EU, intra-day and real time market design as well as power characteristics vary across countries. Indeed, the Agency for the Cooperation of Energy Regulators (ACER) is considering a harmonization of rules and products to facilitate the coupling of balancing markets[1].

Balancing markets are attracting a growing interest both in the literature and in the regulatory practice. A number of recent papers consider different institutional designs and their ability to respond to highly increasing RES penetration. [15] provide a clear description of the main issues regarding balancing activities and relate them to the requirements imposed by the new shares 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%. This finding is quite interesting because it suggests that an increase in RES production can be obtained without incurring in extra costs for the system. The so-called "German Paradox" has been explained by [19], who refer to two new flexible trading options in the market and to the national and international Grid Control Cooperations, which augmented system flexibility making costly reserves less necessary.

Some papers consider the functioning of balancing markets and different regulations across EU countries with particular attention devoted to the change of market design and rules due to the increasing RES shares. Countries like Germany, France, Belgium and the Netherlands introduced more system flexibility by allowing negative prices[2], as described in [7].

Another stream of literature considers the conditions for participation of RES units in balancing markets. Indeed, [22] and [24] proved that wind has the required potential flexibility to operate in balancing sessions for both up- and down-regulation and for reducing thermal ramping and wind curtailment. Moreover, [13] analyze the current Spanish market design and suggest provisions for the adaptation of balancing arrangements to the participation of renewable producers. In Spain, where more than 20% of the total electricity is supplied by wind generators, the government recently launched a new remuneration scheme that provides renewable generators strong incentives to an active participation in electricity markets, including balancing sessions.

[17] analyze the institutional market design in German balancing power markets, where bidders submit simultaneously a capacity price bid and an energy price bid. Bids are selected starting from the lowest capacity price bid under the pay-as-bid pricing rule, and the activation of balancing power, if needed, is requested from procured capacities, starting from the lowest accepted energy price (where again "pay-as-bid" is used). Within a sufficiently competitive environment, they show that a settlement rule based on uniform pricing ensures efficient energy calls in the balancing power market, whereas a scoring rule based on capacity prices only ensures an efficient production schedule. Thus, both rules together with rational

[1]In the Recommendation No 03/2015 of 20 July 2015, ACER suggests a number of changes on the network code with the objective to ensure the efficient integration and functioning of electricity balancing markets. Integrated balancing markets at the EU level imply cooperation between two or more TSOs with respect to i) the exchange of balancing services, ii) sharing reserves, or iii) operating the imbalance netting process. [18] estimate that the potential benefit of coupling interconnectors for increasing the efficiency of trading in balancing services across borders amounts at 3.9 billions of Euros per year at the EU level. About one third of this amount comes from shared balancing, which, therefore, appears to be highly valuable.

[2]Negative prices emerging in day-ahead, intra-day and balancing markets are considered as signals of scarce downward flexibility, occurring when low load is combined with high non-programmable RES supply.

bidding ensure simultaneous efficiency on the balancing power market and on the wholesale electricity market.

[9] and [14] analyze the Spanish and the Italian markets, two EU cases of organized adjustment market sessions. Both show that the intra-day markets have effectively contributed to balance renewable generation even if market design leaves room to possible strategic behavior across day-ahead and intra-day markets, giving rise to higher system costs. In particular, [14] study the dynamics of day-ahead and balancing prices looking at long-run inter-relationship motivated by the time of market sessions, trying to explain the price spread in terms of electricity generated by hydro, wind, solar and geothermal sources.

Several other studies have investigated the effect of RES on power systems, see for instance [3], [5], [6], [8], [16], [20], [21] and [23]; among many others. However, only few contributions focussed on the quantification of costs incurred for planning and dispatching balancing power, which has important and interesting policy implications and it has recently attracted the regulators' interest. In Italy, we assisted to a recent judgment of the Administrative Court (TAR, 28 June 2016) canceling the tariff increase established by the Italian energy regulator (AEEGSI) after the complaints of consumers' associations. On one side, the increment of 4.3% in the electricity bill was motivated by higher energy prices registered on balancing sessions in the preceding months; on the other side, consumers complained an alleged strategic sellers' behavior which induced a significant cost increase in dispatching services. Therefore, our analysis also contributes to the understanding of this issue.

The paper is structured as follows: Section 2 describes the structure of the Italian power market and its sessions, whereas data and the overview of balancing prices and quantities are presented in Section 3. Section 4 quantifies balancing costs before and after RES introduction. Finally, Section 5 concludes and draws policy implications.

2. Background on Italian Power Market and its Balancing

Wholesale electricity markets are platforms where bids for demand and supply of physical energy are submitted and production/consumption programs are defined under a cost minimizing objective. They are organized in a sequence of several sessions starting with the day-ahead market and closing near the delivery time. The final session is the balancing market, where TSOs refine any deviations from production and consumption plans that occur after the gate closure of the intra-day market[3]. Balancing activities have been traditionally considered by TSOs as "security mechanisms" to maintain grid stability. In recent years, this view has been partially abandoned in favor of a new balancing market design that enhances cost efficiency. Moreover, the increase in variable and intermittent RES generation across EU countries has challenged the design of balancing markets; [4] and [15] present detailed explanation of ancillary services and balancing activities.

The Italian balancing market is structured in a programming phase (ex-ante MSD, with 4 organized sessions) and a balancing phase (MB, with five organized sessions)[4]. The MSD and MB are based on the "pay-as-bid" pricing mechanism, whereas day-ahead and intra-day market sessions are based upon the marginal pricing rule. In both balancing market

[3]Intra-day negotiations can be conducted in organized auction sessions or with continuous trading. The recent EU position calls for harmonization of national rules.

[4]For a detailed description of IPEX, its structure and functioning see [14].

sessions, a reference price is usually calculated as the weighted average of all accepted bids, both for purchases and for sales (that is for up- and down-regulation respectively). In the programming phase (ex-ante MSD), Terna accepts energy demand bids and supply offers in order to relieve congestions and to create reserve margins. During the balancing phase (MB), Terna accepts energy demand bids and supply offers in order to provide its service of secondary control and to balance energy injections and/or withdrawals into/from the grid in real time. Bids submitted in MB sessions can only contain better economic conditions with respect to MSD bids, otherwise MSD bids remain valid. Italian suppliers of balancing power are obliged to deliver energy under fixed technical conditions, like time of response, ramp rates and duration.

RES-E production is sold on the day-ahead market by the *Gestore dei Servizi Energetici*[5] (GSE), and it enjoys priority dispatch. Therefore, the relevant portion of demand open to competition of all other conventional units is residual with respect to quantities allocated first to RES. As a consequence, residual demand for mid-merit units becomes very tight in a scenario of increasing RES-E production. The same effect is common to other EU countries, see for example [11].

RES have added uncertainty to planned volumes on the day-ahead market, given that it opens nine days before the day of delivery and closes at 12:00 p.m. of the day before delivery. Then, the quantity bid by solar and wind units are based on forecasts, while the effective load is known only in real time. This determines a higher level of volatility in production in connection with uncertainties in consumption and the mismatches have to be hedged with the reserves for real time balancing. However, five intra-day market sessions (MIs) take place between day-ahead and balancing sessions. They represent a good instrument used by non programmable RES sources to adjust their production program; for a detailed description and analysis see [14].

The Italian power generation mix has substantially changed in the last five years. Its evolution is depicted in Figure 1, where the shares of technology generation and RES penetration levels are shown together with the yearly dynamics of demand (in TW on the right axis of the panel on the right). A part from hydro and a very small percentage of wind generation, RES sources were absent in 2006, whereas they covered around 39% of gross electricity production in 2015. Solar production gained a share of more than 9% of Italian demand for electricity in few years and similarly wind covered around 6%. Hydro production remained stable through years with supply varying according to water availability. At the same time, the share of conventional thermal power plants dropped from a share of 80% at the beginning of 2012 to 48% in 2015 because of the priority dispatch given to RES in the day-ahead market and of the drop in demand. Among fossils, gas primarily drives the generation, followed by coal, oil and mixed fuels, whereas no nuclear generation is available.

The analysis of the Italian generation mix suggests us to conduct our study considering two separate samples: 2006-2008, where non-programmable RES-E generation was absent, and 2013-2015, where RES-E generation becomes significant. Moreover, a relevant institutional change occurred between the first and the second sample. Before 2009 transactions after the gate closure of the day-ahead market were conducted in the "adjustment market".

[5] GSE is a public company acting on behalf of the Italian Ministry of Economic Development. It manages all the activities related to RES, from the units' qualification as "green producers" to the selling of electricity produced by RES units in the day-ahead market.

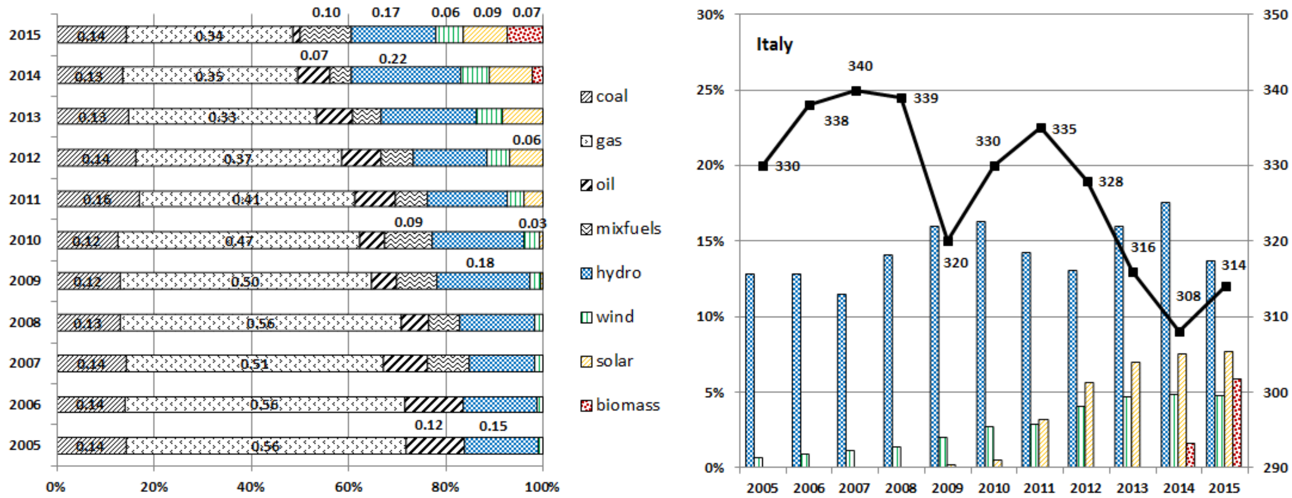

Figure 1: Italian shares by technology generation (on the left), and RES penetration together with Consumption levels in TWh (on the right). Data Source: ENTSO-E.

In 2009, this was replaced by a number of intra-day market sessions (from two to five, with the fifth session introduced in March 2015) open to RES-E producers in order to adjust their schedules on the basis of better weather forecasts.

The outcomes of the Italian real time market in the recent past have been influenced by the sharp increase of solar PV and wind generation, the former one especially in the Northern zone and the second one in the Southern zone. The results of up- and down-regulation in the MSD market are different for the physical zones and are related to location and characteristics of RES capacity. A geographically balanced portfolio may result in the smoothing of variations and RES output forecast errors. The Northern zone of Italy appears to be subject to a systematic overestimation of PV generation capacity sold in the day-ahead market. Hence, up-regulation is necessary to restore equilibrium and it is generally more costly than down-regulation. The seasonality of solar production lowers the demand directed to conventional technologies during hours of irradiation and requires a strong increase in programmable and flexible production at sunset. For this reason, the evening ramp has increased from 8,250 MW in 2012 to 11,050, MW in 2014, a fact that produced a significant impact in the balancing market.

Notwithstanding the increase in RES-E generation that would call for a parallel increase in eligible balancing capacity, we recently assisted to the dismissal of a number old thermal units, not replaced by new and more efficient ones. As pointed out by [2], the RES supporting policy eased high RES penetration but heavily affected price volatility. As a consequence, the investments in new combined cycle power plants were stopped with serious implications for the availability of flexible capacity. This induced a reduction of capacity entitled to act in the balancing markets (with the thermal segment registering the main reduction) and an increase of market concentration and market power. The combined effect of increasing RES and decreasing balancing capacity had economical consequences in terms of cost for the system. The significant increase in the electricity bills paid by consumers motivates the attention of policymakers and the necessity of a deeper understanding of sources and reasons of balancing cost increase.

Indeed, the electricity bill includes a component known as *uplift*, which exhibited values growing from 3.82€/MWh in 2009 to 6.25€/MWh in 2014 and, finally, 8.8€/MWh in the fourth quarter of 2016. The uplift accounts for four factors: 1) 'the planning of services' (*approvvigionamento servizi*) concerning planning activities in the ex-ante MSD sessions, which was mainly stable around one billion€ across years; 2) the 'energy component' (*componente energia*) taking into account all realized imbalances, which turned from being a profit to represent an increasing substantial cost from 127 Mln€ in 2011 to 459 Mln€ in 2014; 3) 'contracts' to secure (mainly upward) reserves for 3 GW in 2014, with stable costs in the last years; 4) 'the start-up and status change' (*gettone di avviamento e cambio assetto*) determining a cost of 90 Mln€ in 2013 and 82 Mln€ in 2014. This last factor clearly represents a reward granted to flexible generators for a secure and stable power system, as discussed in [12]. Therefore, over a total cost of 1,756 Mln€ in 2014, the 'start-up and status change' represents only 4.7% of total costs, whereas the 'energy component' represents a larger share of 26%; according to the latest available report of the Italian regulatory authority [1]. For this reason, we concentrate mainly on the 'energy component' in addition to the necessary 'planning of services' when quantifying balancing costs occurred in Italy in the two RES scenarios.

3. Data Description

Our analysis is conducted on the Italian Northern zone. It accounted for 12,524 GWh of electricity consumed in 2015 (more that half of the Italian production), and its zonal balancing market sessions are liquid enough (in terms of volumes exchanged and number of trades) to provide a good dataset for our analysis. We could not conduct a similar investigation for the Italian Southern zone (where the highest share of wind power is located) because only few price observations[6] are available.

We consider electricity prices determined at specific hours to isolate effects on prices induced by demand from those generated by RES production. Therefore, to construct and inspect the intra-daily profiles, we use the actual load for Northern Italy as recorded by Terna, whereas RES-E generation data have been obtained from the Italian market operator, *Gestore dei Mercati Energetici*.

Figure 2 shows the lowest load at hours 3-5, the midday peak at hours 11-12 and the evening peak at hours 18-20. Then, to detect the effect of solar PV and hydro, we have selected hours 11, 13, 19, whereas hour 3 allows us to control for low values of load and RES-E generation. Furthermore, we consider hours 9 and 21 to include the ramp-up and -down hours, during which demand noticeably increases/decreases, as shown in the top left panel of Figure 2. At these hours, we can detect the solar effect, since irradiation is increasing at hour 9 and decreasing at hour 19. In addition, while RES generation is quickly falling at

[6] In Southern MB sessions, "accepted" and "no revoked" type of auctions were available only for hours: 1-3, 8, 13-15, 17-24 during 2013; hours 1, 20-24 during 2014; and hours 9, 13-24 during 2015. Therefore, this information was not sufficient to compute balancing costs for all hours. Furthermore, the inspection of MSD and MB data shows that these market sessions for accepted bids/offers were very thin. For instance, considering just offers, the total accepted quantities awarded on MSD were 196 GW in 2006, 158 GW in 2007 and 216 GW in 2008; whereas we find 23 GW in 2013 and 2014, and just 8 GW in 2015. Moving to the MB sessions, we observed 792 GW in 2006, 810 GW in 2007, 1,017 GW in 2008 in sharp contrast of scale for 186 MW in 2013, 895 MW in 2014 and 830 MW in 2015.

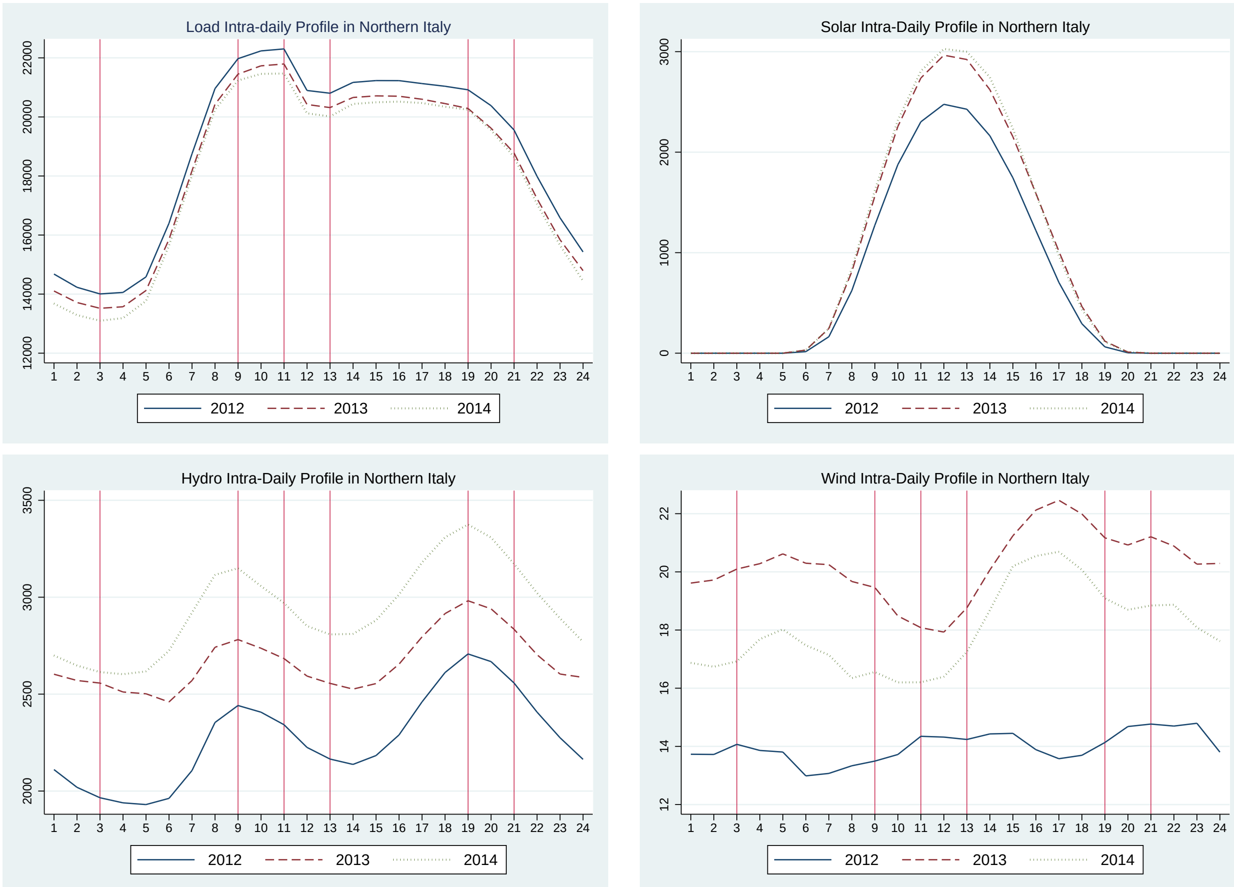

Figure 2: Intra-daily profiles for the Northern zone in selected years.

sunset, electricity demand is still high so making flexible generation resources essential for balancing the system.

The Italian TSO acts as a central counterpart in both planning and balancing sessions (ex-ante MSD and MB respectively). In situations of up-regulation, Terna buys electricity for procuring power necessary to balance the system (the Italian *chiamate a salire*). In this case, she bears costs on the basis of sale prices asked by generators injecting energy in the system (or consumers lowering demand). On the contrary, in down-regulation Terna sells electricity and realizes profits determined by purchase prices (the Italian *chiamate a scendere*). Therefore, for explaining the behavior of balancing costs across samples, we first analyze the total balancing quantities per hour, year and market purpose (that is up- and down-regulation) accounting also for the two balancing phases and then we concentrate on balancing prices.

Looking at the balancing quantities, their amount (expressed in MW) is computed as sum of the awarded quantities on the ex-ante MSD and MB for each market purpose, namely up- or down-regulation. In details, only "non revoked" bids have been considered in our analysis, firstly, because those "revoked" and "of netting" represent only small percentages over the total of auctions[7] and, secondly, because the information on type was not available in our first sample of years 2006-2008.

The yearly dynamics of awarded quantities across MSD and MB sessions in Northern Italy are presented in Figure 3. In the first two rows we find quantities *sold by* Terna for down-regulation. We can notice that they dramatically reduced in the MSD planning sessions during the second sample (2013-15), whereas they slightly increased in MB sessions (but only at hours 9 and 11). Thermal units maintain the highest market share in both samples.

In the last two panels of Figure 3 we register quantities *sold to* Terna for up-regulation. We find an opposite dynamics: quantities increased in MSD whereas decreased in MB, especially for peak hours. As for MSD, it is interesting to notice that we observe a decreasing trend at the beginning of our second sample in years 2013 and 2014. The trend is reverted from 2014 to 2015, when we observe noticeable increments, especially at hours 19 and 21. Given that the Northern zone has been characterized by a strong solar PV penetration starting from 2012, we believe that the increasing balancing needs registered at hours 19 and 21 can be explained on the basis of up-regulation necessary to replace solar production at sunset. On the contrary, decreasing balancing needs at 9 (both for up- and down-regulation) can be explained by the increasing solar PV production at that time.

Next, considering the share of the three different technologies in the supply of balancing energy, it is interesting to observe that water pumping heavily lost market shares during the second sample. The reduction is evident for all considered hours in the MB session. We explain the latter finding referring to the impact of RES on the intra-daily profile of the day-ahead market price. Indeed, the spread between maximum and minimum prices has decreased substantially from the first to the second sample as it is evident from Figure 4, where a flatter dynamics of the intra-daily profiles of zonal prices is observed. Since water pumping units buy electricity off-peak and then sell it during peak hours, the new intra-daily profile of zonal prices makes this technology less competitive as the spread diminishes and so their arbitrage opportunities. On the contrary, thermal and hydro production maintain their shares from the first to the second sample and we note an increase in thermal production at hours 19 and 21 for up-regulation needs.

Summing up across hours and market purposes, we derive an overall reduction of balancing quantities negotiated by Terna. For this reason, and in line with other studies, we observe that the strong increment of RES did not require more balancing, which is an unexpected result supporting, however, the findings obtained by [15] for Germany. Also, we interestingly observe that behind an overall decrease, we find a different profile depending upon hours and technologies. Therefore, we aim at answering to the open question about the impact that these changes have on market outcomes and costs.

To this end, we calculate balancing prices disaggregating observations for hours, technologies and market purpose.

Taking into account the *pay-as-bid* pricing mechanism applied in all real time auction

[7]The preliminary analysis of the balancing market sessions shows how the percentages of total accepted quantities on MB were: 1) for “revoked” auctions only 6% in 2013, 7% in 2014 and 5% in 2015 for purchases, whereas for sales 7%, 6% and 7% in 2013, 2014 and 2015; 2) for “netting” auctions only 2% in 2013 and 2014, and 1% in 2015 for purchases, whereas for sales 6% in 2013 and 8% in 2014 and 2015. Then, this classification of balancing “type” of auctions introduced after 2009 may induce some overestimation of our balancing costs in the second sample, but we believe that it is negligible.

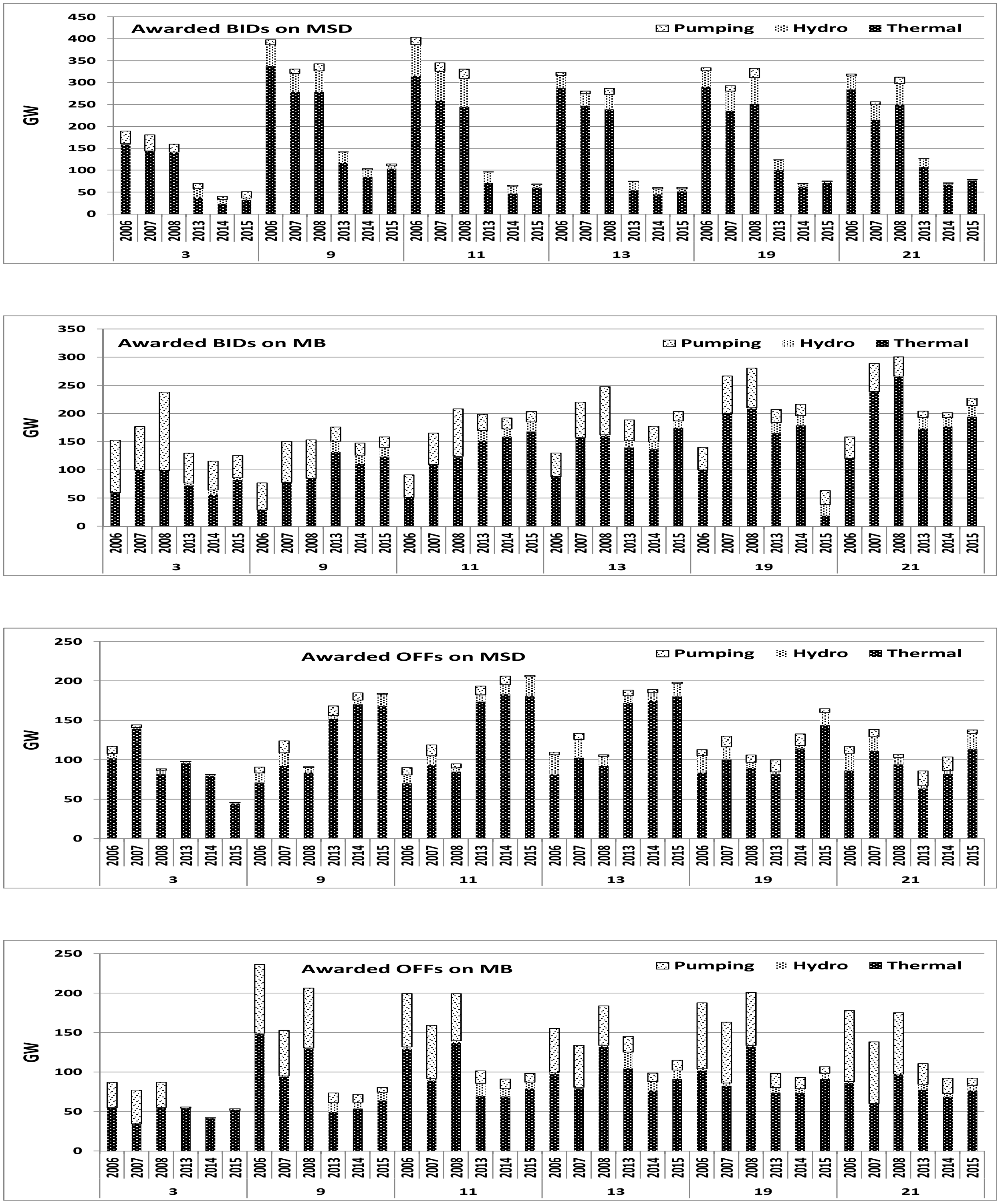

Figure 3: Yearly Sum of Awarded Purchased (by Terna, 'Bids' on the first two rows) and Offered or Sold (to Terna, 'Offs' on the last two rows) Quantities on MSD and MB balancing market sessions in Northern Italy; across technologies, selected hours and years.

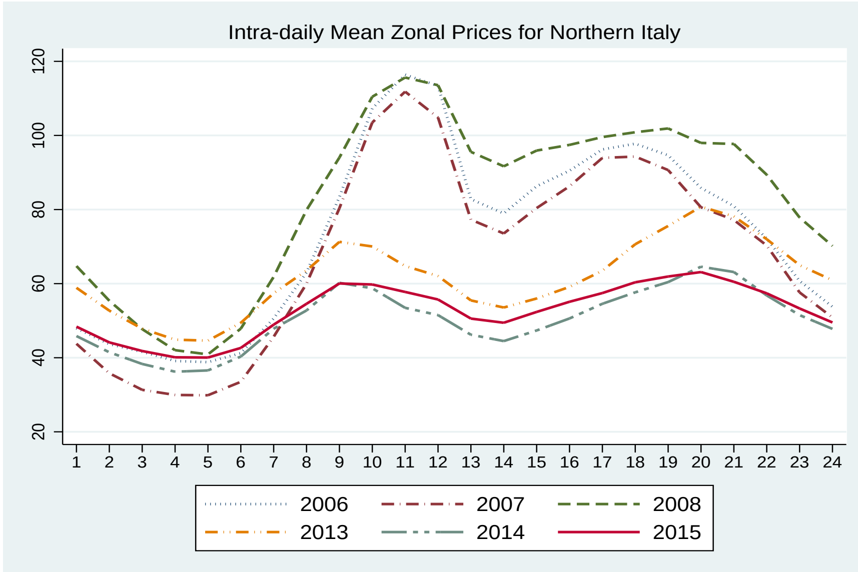

Figure 4: Intra-daily profiles of zonal prices in Northern Italy for considered years.

sessions, we calculate balancing prices as sum of accepted bids, weighted for the corresponding quantities, within each technology, hour and day. We repeated this aggregation for purchases and sales awarded on MSD and MB sessions, computing weighted awarded prices using bids “accepted” on the planning session and “not revoked” on the balancing one.

Considering each single unit across market purpose and within a technology group, we are able to detect the maxima, minima and average prices for both up- and down-regulation. These data are obtained for each specific hour considered in the two sample periods. Tables 1 and 2 present a comparison between the two samples, whereas Tables 3 and 4 in the Appendix report full details.

On average, yearly mean prices awarded to each technology for down-regulation remained almost constant or registered moderate reductions from the first to second sample in both market sessions. Maximum awarded prices decreased for hydro units especially in MSD with substantial differences for hours 9, 11 and 13 (respectively, 84, 73 and 82€/MWh of reduction from the first to the second sample). Thermal power reduced maximal bids up to 201€/MWh in MB at hour 19 and 21. However, while maxima were shaved, mean prices registered a moderate increase at those hours.

Completely different dynamics are observed for the sale of up-regulation power. We notice quite different trends for mean/average and maximum prices in both balancing sessions. Hydro units decreased mean bids in MSD and MB, and maximum bids in MSD. On the contrary, maximum awarded bids increased substantially in MB, especially at hours 11, 19 and 21 (determining a strong increase in balancing costs for hydro units as shown later in Figure 5). Water pumping units increased mean and maximum bids from the first to the second sample. Thermal units decreased mean bids in MSD sessions while increased them in MB.

This data inspection conducted at the single transaction level, clearly highlights a sort of coordinated and complementary bidding strategy for the two technologies, hydro and thermal power. Hydro generation shows a dramatic increase in maximum prices at hours 11, 19 and 21, with average increments of 1422, 1689 and 1922 €/MWh in the second sample with respect to the first sample. On the contrary, thermal units set their maximum price at hour 13 (with an increment of 1717 €/MWh) and at hour 19 (with an increment of 903 €/MWh). However, the increase of maximum bids might also be explained as scarcity of flexible generation capacity in specific hours when balancing activity is crucial due to the decreasing solar PV production.

Our detailed analysis provides the empirical evidence of a strong increment of up-regulation prices, observed over the second sample, following the increasing RES penetration. On one side, more variable RES-E production requires continuous balancing (with observed decreasing quantities) to meet demand and supply; on the other side, conventional operators explore market power opportunities increasing their prices on the structurally concentrated balancing sessions to recover profits lost on the day-ahead market.

	Hydro				Water Pumping				Thermal			
	Max		Mean		Max		Mean		Max		Mean	
Hour	MSD	MB	MSD	MB	MSD	MB	MSD	MB	MSD	MB	MSD	MB
3	↓ 10	↑ 28	↓ 8	↑ 9	↑ 8	↓ 24	↓ 12	↓ 14	↓ 38	↓ 128	↓ 3	↓ 32
9	↓ 84	↑ 30	↓ 37	⟷	↓ 1	↓ 55	↓ 23	↓ 15	↓ 86	↓ 178	↑ 3	↓ 6
11	↓ 73	↓ 44	↓ 43	↓ 4	↓ 1	↓ 72	↓ 28	↓ 18	↓ 109	↓ 200	↑ 5	⟷
13	↓ 82	↓ 57	↓ 40	↓ 9	↓ 16	↓ 64	↓ 34	↓ 18	↓ 72	↓ 190	↑ 4	↓ 3
19	↓ 64	↓ 72	↓ 32	↓ 3	↓ 3	↓ 36	↓ 17	↓ 7	↓ 94	↓ 201	↑ 9	↑ 1
21	↓ 62	↓ 28	↓ 30	↑ 5	↓ 16	↓ 46	↓ 26	↓ 7	↓ 98	↓ 201	↑ 10	⟷

Table 1: High level summary dynamics across samples for the average Maximum and Mean Prices awarded for down regulation on MSD and MB across hours and technologies, where ↑, ↓ and ↔ represent an average increment, decrement or no changes across the two samples measured by the corresponding amounts expressed in €/MWh.

	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

Table 2: High level summary dynamics across samples for the average Maximum and Mean Prices awarded for up regulation on MSD and MB across hours and technologies, where ↑, ↓ and ↔ represent an average increment, decrement or no changes across the two samples measured by the corresponding amounts expressed in €/MWh.

4. Quantification of Balancing Costs and Cost Analysis

Our main interest is to verify whether the high RES penetration, especially from non programmable sources, observed during the sample 2013-2015 has influenced quantities allocated in the real time and their associated costs with respect to the period 2006-2008.

To analyze this issue, we first compute the balancing costs as product of awarded prices and corresponding awarded quantities at unit level. In this way, we obtain disaggregated costs for technologies, hours and market purposes. Finally, we aggregate the information to obtain the final balance. As before, "sales" represent situations in which Terna buys quantities incurring in 'costs' for the system and so for final consumers (these are represented with negative values), whereas "purchases" amount to situations in which Terna sells quantities obtaining instead 'profits' (registered with positive values).

Focusing only on two components[8] of the *uplift*, we study profits and costs for hydro, water pumping and thermal power respectively, considering both the ex-ante MSD and MB sessions. In Figure 5, we register profits (positive bars) and costs (negative bars) for the three technologies considered.

We can observe that profits (earned by Terna from down-regulation) decreased for all hours over the second sample, in particular for hydro and water pumping, whereas, we observe moderate reductions for thermal power.

Looking at the costs (incurred by Terna from up-regulation), we register a substantial decrease between the two samples for energy bought from water pumping. This was expected because of the decreasing market share of this technology. On the contrary, there is an unclear overall trend for hydro and thermal power. In particular, we registered a cost decrease at the beginning of the second sample with respect to years 2006-2008, whereas we calculate a noticeable increment of costs in 2015 with respect to 2014. Furthermore, the majority of hydro costs originate into MSD sessions, whereas costs of thermal power are spread on both MSD and MB sessions. We observe sustained costs for thermal units across years, again with a significant increase from 2014 to 2015, especially at hours 19 and 21. This result is particularly relevant since the solar production suddenly decreases in the evening and flexible units become necessary to the system and are able to exploit a high degree of market power.

We believe that increasing balancing costs for hydro and thermal technologies in the last years is the result of a coordinated strategic reaction of producers with respect to the new market conditions generated by high RES penetration. Conventional producers become victims of the "merit order effect" in the day-ahead market and, at the same time, they are aware of the increasing market power opportunities in real time sessions (given the high concentration) resulting in a high-price bidding strategy for targeted hours. In this way, they are able to recover some profits lost on the day-ahead market due to the priority of dispatch of RES units. In order to implement this strategy, generators manage to have spare capacity at the end of day-ahead and subsequent intra-day sessions to be able to sell it in balancing sessions[9]. In fact, we observe that the spread between price bids for up- and down-regulation in the Northern zone was increasing and equal to 100€ at the end of 2015.

Starting from this plant-level analysis, we are able to quantify the overall profits/costs, as sum across technologies on both market sessions within a year. Results show that Terna earned the largest share of profits on the ex-ante MSD in the first sample and on the MB in

[8] Let us recall that the first component is the *planning of services* which concerns the ex-ante MSD session, and the second one is the *energy component* which takes into account all realized imbalances. See Section 2 for details.

[9] [14] document this situation of excess demand and/or under-supply especially for the Italian Northern zone.

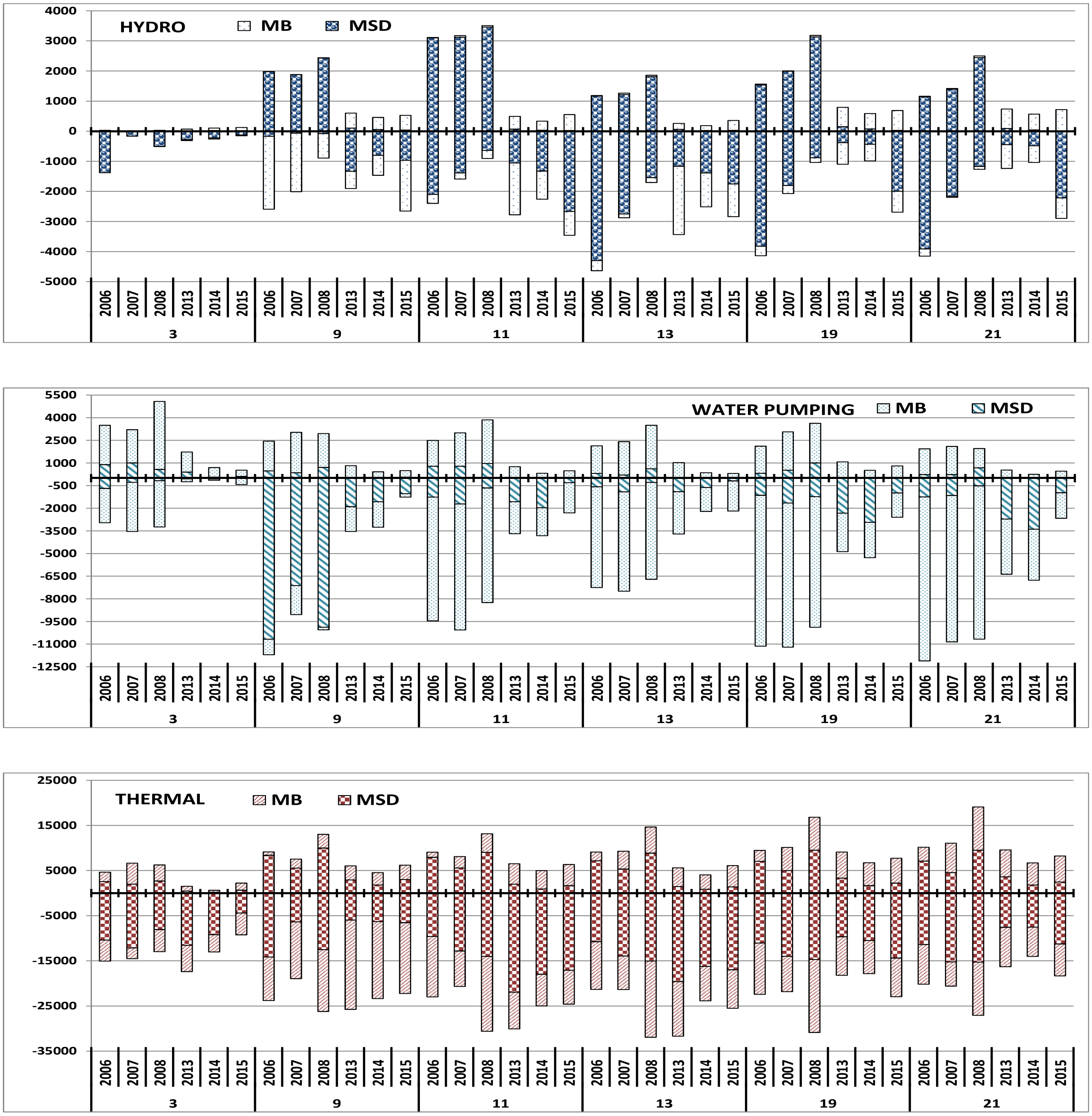

Figure 5: Evolution of balancing costs (in thousands of €) in Northern Italy across years and selected hours for Hydro (on the first row), Water Pumping (on the second row) and Thermal Power (on the third row) distinguishing between profits (purchases from Terna) and costs (sales to Terna).

the second sample (see Figure 6). Costs were almost equally spread between the two market sessions, with higher shares in MSD than in MB (apart at hour 9 when MB costs represented 69% of average costs in the second sample). As a consequence, the planning activity executed in the ex-ante MSD is actually a substantial part of computed costs.

Finally, the overall balance is computed as the difference between profits and costs faced by the Italian TSO for the Northern zone. In Figure 7, we clearly observe that the planning

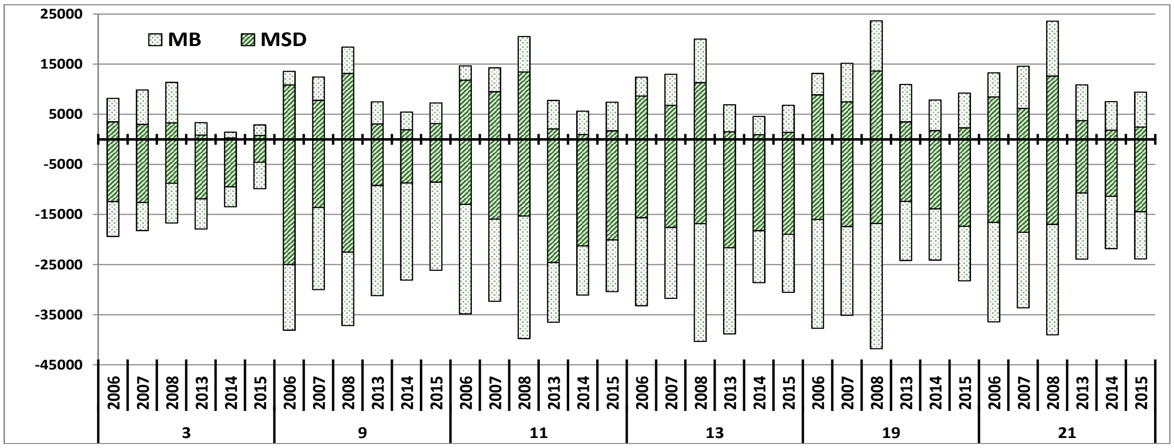

Figure 6: Evolution of Profits and Costs (as sums across technologies, in thousands of €) on MSD and MB in Northern Italy.

of energy resources and balancing activities are highly costly.

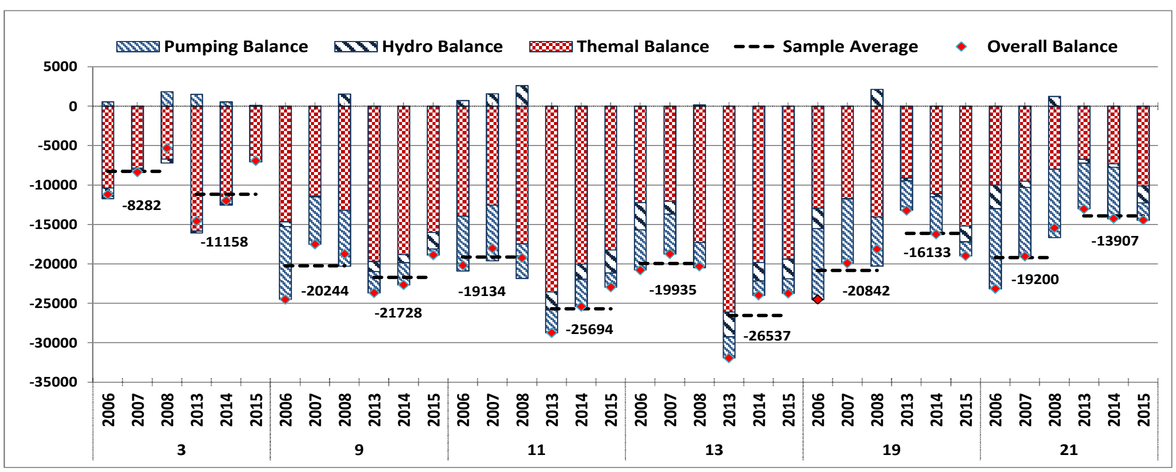

Figure 7: Balance between Profits and Costs across Technologies (in thousands of €) in Northern Italy.

The average costs increased in the second sample at hours 3, 9, 11 and 13 with the highest costs observed at hour 13 and equal, on average, to 26.5 Mln € during the period 2013-2015[10]. Increasing costs are interestingly observed at hour 3, when both demand and RES generation are at their lowest levels and, simultaneously, both water pumping and thermal units implement a price strategy of high maximum prices (increments across the two samples go from 19 to 67 €/MWh for water pumping, and from 148 to 884 €/MWh for thermal units, see Table 3). This supports the idea that thermal units are recovering in balancing sessions

[10]For comparisons, note that Terna incurred in costs equal to 1,723 Mln € in 2013 and 1,756 Mln € in 2014 for the whole Italian market; according to the Italian energy regulator [1].

their profits lost on the day-ahead market, especially in off-peak hours, when the competition from hydro and water pumping is low or even absent in the second sample (see their intra-daily profiles in Figure 2 and bottom panels for awarded offers in Figure 3). Indeed, [10] already observed that 'the merit-order effect' (daytime switch between solar and gas) has pushed gas producers to concentrate their supply of electricity during off-peak hours of the day-ahead market. Reduced costs are surprisingly observed at hour 19 (when demand is still high and RES-E is low) and at the ramp-down hour 21 (when again both demand and RES are decreasing) because of the competition in quantity from hydro and water pumping units (see again bottom panels for awarded offers in Figure 3, especially for the MB session).

We additionally observe significant cost increases for hydro and thermal power from 2014 to 2015 especially at hours 19 and 21, not well captured in the dynamics of the overall balance. This suggests that market operators may have initially followed old strategies and then some learning mechanisms have taken places supporting the hypothesis that speculations are occurring in the Italian balancing markets.

Overall, our results provide a simple and clear empirical evidence that the strong impact of RES in the generation mix actually induced higher costs for balancing needs for almost all considered hours (excluding hours 19 and 21). We found that thermal and hydro producers are able to exert market power but only at specific hours so that they probably apply a differential strategy related to the strength they have on different market session.

5. Conclusions

Despite the regulatory concerns and the attention paid in the recent "winter package", balancing markets have not been analyzed in deep by the literature. Indeed, there is an open ongoing debate about the supposed increase in balancing needs, and hence in costs, induced by the high RES penetration. Moreover, a system largely based on RES generation requires careful monitoring and planning to avoid unwanted reduction in investments, instabilities in supply and consequent excessive price variability, as postulated by [2].

This paper provides some new and interesting insights based on a careful an detailed analysis of the Northern zone of the Italian electricity market and it contributes to the literature in two ways. Firstly, we answer the question whether the increasing RES-E production has consequently increased balancing quantities and costs. We show that balancing quantities have decreased as the RES-E production has increased in Italy, as occurred in Germany, while balancing costs have dramatically increased. Secondly, studying balancing quantities and prices and computing balancing costs for up- and down-regulation with respect to available technologies, we are able to detect interesting RES effects on possible strategies available to bidders allowed to act in all market sessions and competing in the final highly concentrated ones. We find that the high and sudden RES penetration has reshaped the competitive conditions in the electricity market: RES are pushing gas units out of the merit order in the day-ahead market and, therefore, they revert to real time sessions where they still enjoy a leading role. We also detect differential bidding strategies of producers (especially thermal but also hydro units), which are able to exploit their pivotal position at sunset, when solar PV units stop production.

We emphasize that the computation of costs for technologies, hours and TSO's market position helps the understanding of the dynamics occurring into the balancing market sessions and better tailor any regulatory intervention.

Energy regulatory authorities should carefully monitor the whole electricity market trying to avoid excessive concentration in all market sessions, as occurred in Northern Italy with the closing of a number of gas units relevant for balancing purposes.

In addition, our findings clearly show that the prompt adoption of a capacity market is the best policy option to reduce costs associated to the planning of balancing activities: we indeed document that costs associated to the activities on the planning sessions (i.e., ex-ante MSD) represent a substantial proportion of total costs. Moreover, we detected an increasing trend of costs from 2014 to 2015 suggesting operators' learning mechanisms and perhaps some coordinated bidding strategies.

The Italian authority understood this lesson too late and decided to prosecute a number of firms only during 2016, when the phenomenon documented in this paper became impressive and evident also to consumers who assisted to high balancing costs transferred in the uplift component of their electricity bills. Therefore, when talking about the cost for supporting RES-E production, it is more appropriate to include subsidies paid to RES producers (as incentives) and regulation costs incurred by the TSO and paid by final consumers.

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Appendix

		Hydro								Water Pumping								Thermal							
		Max		Min		Mean		Std. Dev.		Max		Min		Mean		Std. Dev.		Max		Min		Mean		Std. Dev.	
Hour	Years	MS	MB	MS	MB	MS	MB	MS	MB	MS	MB	MS	MB	MS	MB	MS	MB	MS	MB	MS	MB	MS	MB	MS	MB
3	2006	47	5	0	5	9.0	5.0	13.8		52	84	4	0	27.3	26.7	11.5	13.6	101	218	0	0	15.2	33.6	10.7	42.9
	2007	45		0		10.1		15.0		47	84	13	0	25.2	28.6	7.2	10.1	110	186	0	0	15.8	53.0	9.2	46.3
	2008	60	41	0	0	9.5	6.8	14.8	16.7	38	101	0	0	27.6	32.4	6.7	6.8	94	200	0	0	19.0	38.0	11.7	37.5
	2013	50	57	0	0	0.2	15.7	2.1	19.0	57	65	0	0	33.3	21.9	22.6	20.6	45	110	0	0	14.3	9.9	12.0	12.5
	2014	35	34	0	0	1.5	7.4	4.8	8.7	50	49	0	0	6.0	10.9	11.8	15.2	100	56	0	0	8.2	5.6	11.2	8.3
	2015	39	61	0	0	3.7	21.4	7.8	16.0	53	81	0	0	5.0	13.1	12.8	17.9	46	55	0	0	18.9	13.1	13.4	12.4
9	2006	194	54	0	0	38.9	34.4	21.6	15.2	65	123	0	0	42.8	40.1	12.6	13.0	160	320	0	0	17.7	18.4	16.3	27.8
	2007	133	45	0	0	41.1	23.1	19.9	18.4	68	177	6	0	39.3	34.7	14.3	22.5	166	300	0	0	17.6	25.0	13.5	31.6
	2008	123	46	0	0	43.6	18.8	19.7	15.4	59	132	0	0	44.3	32.8	11.6	7.7	166	235	0	0	32.3	32.3	13.5	27.3
	2013	75	75	0	0	4.9	27.9	11.0	23.9	64	99	15	0	39.3	23.7	14.4	23.8	124	115	0	0	26.7	17.5	14.1	16.4
	2014	55	89	0	0	3.6	21.9	9.9	18.9	35	72	0	0	7.3	15.0	11.8	18.6	63	110	0	0	22.0	18.2	14.2	14.9
	2015	68	71	0	0	5.0	28.0	11.5	16.7	89	96	0	0	11.6	24.9	24.2	19.4	47	95	0	0	29.2	22.2	10.0	12.0
11	2006	170	51	0	0	42.9	34.0	21.6	16.6	66	123	0	0	44.7	40.6	12.0	13.2	160	320	0	0	17.7	17.5	16.6	24.5
	2007	121	170	0	0	44.5	33.0	18.8	29.3	68	177	10	0	41.0	36.3	12.9	24.6	166	300	0	0	19.3	22.8	14.1	28.1
	2008	119	125	0	0	49.7	21.2	15.5	23.5	59	137	30	0	47.7	34.1	6.5	12.7	219	290	0	0	33.8	31.2	13.4	24.3
	2013	85	67	0	0	3.0	27.8	7.9	23.7	60	77	0	0	37.0	19.1	20.4	21.8	124	130	0	0	33.6	25.8	14.4	17.1
	2014	55	76	0	0	1.8	19.9	7.1	19.1	31	66	0	0	2.7	12.0	6.8	17.9	48	90	0	0	22.4	20.8	13.8	13.8
	2015	50	71	0	0	4.6	28.7	10.9	16.9	100	77	0	0	8.1	27.0	22.2	21.5	46	90	0	0	28.4	24.8	10.7	11.3
13	2006	170	54	0	0	37.9	23.8	19.3	19.4	65	123	0	0	41.3	40.5	13.5	11.2	160	320	0	0	17.2	19.2	16.5	26.0
	2007	111	170	0	0	41.2	34.8	18.1	33.5	68	133	10	0	40.5	32.8	12.1	14.5	166	300	0	0	18.7	24.8	13.6	29.5
	2008	130	135	0	0	50.2	20.7	16.2	23.5	59	132	0	0	46.8	33.0	8.9	7.4	166	230	0	0	34.0	33.0	12.9	26.4
	2013	72	67	0	0	3.7	18.5	7.7	21.1	49	77	0	0	17.1	21.3	15.8	18.3	115	123	0	0	32.5	25.0	15.8	17.4
	2014	43	55	0	0	1.4	12.0	5.5	15.4	43	58	0	0	6.6	11.0	12.0	16.0	92	87	0	0	22.1	18.6	15.4	14.1
	2015	50	65	0	0	4.2	22.9	9.2	17.9	50	61	0	0	3.3	20.6	10.5	19.2	69	69	0	0	27.0	23.9	12.2	12.1
19	2006	121	124	0	0	39.0	32.9	22.8	29.5	65	123	0	0	42.5	40.5	13.8	14.1	160	320	0	0	16.8	20.3	16.1	26.6
	2007	180	151	0	0	39.7	31.7	20.2	38.9	68	177	17	0	42.1	36.1	12.6	23.1	166	323	0	0	19.0	25.2	13.5	30.2
	2008	106	179	0	0	48.0	28.3	13.9	30.4	59	137	24	0	48.6	35.3	6.8	17.6	219	280	0	0	34.4	31.9	13.7	25.5
	2013	99	71	0	0	6.1	31.5	13.0	23.6	58	122	0	0	44.7	35.8	14.6	27.2	115	140	0	0	37.5	30.6	12.0	17.0
	2014	61	86	0	0	11.5	23.1	18.4	20.0	52	117	0	0	6.2	23.3	12.1	24.2	100	110	0	0	28.7	24.0	13.2	13.3
	2015	54	81	0	0	11.6	29.0	14.9	17.1	72	91	0	0	31.1	30.7	28.0	23.3	46	69	0	0	31.7	26.4	7.7	11.0
21	2006	131	66	0	0	35.4	23.7	18.6	21.0	66	123	0	0	43.4	41.0	13.8	12.7	160	320	0	0	16.7	20.6	16.0	26.2
	2007	111	95	0	0	37.7	24.2	16.0	22.0	68	132	17	0	39.2	34.8	13.9	19.0	166	315	0	0	18.4	27.3	13.6	32.7
	2008	101	125	0	0	47.8	29.7	14.1	29.0	59	137	24	0	48.3	34.1	6.4	13.6	219	230	0	0	34.4	32.2	13.2	26.2
	2013	50	68	0	0	6.0	34.2	11.7	22.8	49	117	0	0	28.5	36.2	19.4	25.2	104	123	0	0	37.5	30.3	11.7	16.0
	2014	51	68	0	0	12.2	26.8	16.2	18.7	41	71	0	0	4.3	21.3	11.7	20.0	100	68	0	0	29.0	24.2	10.4	13.0
	2015	55	65	0	0	13.1	30.4	16.5	16.7	55	65	0	0	19.3	32.7	20.7	18.7	47	70	0	0	32.2	27.1	6.3	10.4

Table 3: Descriptive Statistics of Prices awarded for Purchases on MSD and MB; across hours, years and technologies.

		Hydro								Water Pumping								Thermal							
		Max		Min		Mean		Std. Dev.		Max		Min		Mean		Std. Dev.		Max		Min		Mean		Std. Dev.	
Hour	Years	MS	MB	MS	MB	MS	MB	MS	MB	MS	MB	MS	MB	MS	MB	MS	MB	MS	MB	MS	MB	MS	MB	MS	MB
3	2006	500		50		223.3		121.7		297	170	49	23	116.2	72.4	81.3	14.2	400	500	29	0	102.8	81.6	34.2	41.3
	2007	170		40		86.2		31.8		98	179	79	16	84.0	77.4	4.0	25.6	315	500	35	0	95.0	70.3	30.5	49.7
	2008	230	160	50	46	96.3	101.2	25.3	42.9	101	179	65	30	88.4	95.2	13.2	21.0	200	499	40	0	102.3	72.9	20.8	48.8
	2013	287	215	0	69	146.3	116.4	50.7	29.3	112	142	108	65	110.3	109.8	2.1	22.6	500	650	70	66	106.9	115.0	31.2	57.0
	2014	302	200	70	55	134.7	97.9	52.3	29.0	186	286	60	60	124.3	130.8	71.3	61.5	460	500	69	64	98.5	102.2	42.0	35.0
	2015	250	399	59	51	115.4	113.4	41.1	64.3	255	300	69	60	162.0	192.4	131.5	76.3	400	3000	0	57	87.1	101.4	33.2	59.5
9	2006	495	500	70	11	207.6	153.6	106.6	115.4	295	196	88	23	156.6	120.9	62.6	14.0	320	500	58	0	121.6	96.2	34.6	56.6
	2007	177	500	50	25	120.2	121.0	20.2	107.1	177	229	77	18	124.0	125.1	20.6	20.0	315	500	70	0	122.6	59.0	37.9	64.3
	2008	230	230	67	42	135.4	137.6	29.1	63.5	180	229	82	26	120.4	128.7	26.6	19.4	400	499	0	0	161.2	99.7	50.9	64.0
	2013	241	999	0	64	135.3	116.0	40.1	46.4	199	265	90	65	129.5	165.2	31.7	48.4	370	650	74	35	128.0	131.1	51.1	53.4
	2014	249	260	65	55	116.1	104.3	40.1	45.3	231	290	87	60	170.8	168.1	52.0	71.9	460	500	62	50	98.2	141.1	39.2	60.7
	2015	250	500	59	49	111.4	99.0	31.5	39.4	279	270	60	60	134.6	151.0	78.1	68.8	350	440	62	45	96.0	117.9	28.7	46.5
11	2006	495	500	75	11	211.0	142.0	109.1	85.8	295	196	66	23	144.4	120.6	59.3	13.5	320	400	60	0	121.4	101.3	35.6	55.4
	2007	175	500	50	23	122.2	114.7	18.5	96.2	177	230	77	28	122.2	126.0	14.6	20.7	315	499	70	0	126.0	69.9	41.6	68.8
	2008	230	230	90	31	142.7	107.9	28.7	65.9	153	229	82	31	124.5	128.4	15.4	20.9	500	500	82	0	169.5	108.0	53.0	69.8
	2013	259	1499	0	53	126.2	111.5	34.9	52.1	199	260	90	65	129.9	151.1	32.1	43.6	370	650	70	35	122.0	125.7	47.1	48.8
	2014	295	2999	60	55	108.1	97.6	33.5	101.6	250	271	87	60	157.6	153.9	54.6	64.3	460	463	69	45	96.5	114.3	36.3	40.3
	2015	308	999	59	49	108.8	96.4	32.9	48.5	279	290	60	60	148.6	171.1	80.8	76.3	420	360	62	45	96.6	103.5	31.0	30.7
13	2006	495	500	34	26	176.9	144.4	87.8	64.2	291	196	106	43	164.5	120.7	58.4	14.0	320	500	60	0	117.2	102.5	32.9	56.5
	2007	190	290	40	25	120.2	122.9	21.0	51.1	149	230	88	28	116.7	124.8	15.7	19.9	315	500	69	0	123.4	72.5	39.7	72.1
	2008	250	230	69	35	137.5	133.0	30.4	68.3	164	229	83	31	125.1	129.5	19.9	19.2	500	499	82	0	163.6	108.5	51.1	72.0
	2013	260	300	0	53	127.3	112.0	35.5	35.8	198	212	90	65	124.4	151.0	30.0	40.0	361	650	73	66	114.4	123.4	32.4	45.1
	2014	286	260	60	55	113.0	100.8	42.6	37.7	231	259	87	65	155.3	148.9	54.9	61.7	460	3000	61	45	94.3	111.6	25.1	69.7
	2015	250	499	59	51	109.6	93.4	35.1	33.5	250	300	60	60	125.7	158.8	68.5	70.6	420	3000	60	45	94.3	100.4	31.2	42.1
19	2006	500	500	45	43	190.8	145.3	97.5	57.4	295	199	86	37	152.5	120.0	61.1	14.1	320	500	58	0	116.4	103.9	29.2	57.6
	2007	178	500	50	24	117.4	124.9	21.6	67.7	177	230	88	18	121.2	125.5	15.4	19.4	323	500	69	0	125.4	77.5	41.6	73.5
	2008	235	230	69	10	136.7	118.9	30.1	62.2	137	229	82	30	121.1	129.0	17.9	19.4	500	400	82	0	166.1	108.5	53.5	69.5
	2013	326	299	0	35	138.2	115.3	44.0	37.4	199	260	65	65	144.0	152.0	37.2	41.9	356	3000	80	35	115.9	123.5	34.2	56.9
	2014	302	2998	65	52	118.9	100.0	40.3	82.4	255	279	65	63	197.4	163.9	36.2	63.2	403	500	65	45	92.0	115.6	25.3	41.6
	2015	352	3000	59	45	122.0	103.1	42.5	144.7	300	300	60	75	157.1	178.7	82.5	69.9	350	610	63	40	101.7	105.0	34.9	38.3
21	2006	499	500	34	14	183.5	147.4	100.3	79.8	295	206	86	46	147.6	120.4	57.3	14.1	400	500	60	0	119.0	99.3	32.4	54.7
	2007	200	500	40	29	121.3	136.6	25.8	76.0	149	230	88	38	118.7	125.9	11.8	16.9	500	500	70	0	123.5	78.5	39.8	67.3
	2008	230	230	70	10	137.5	135.1	28.8	64.9	137	229	85	31	121.5	130.0	16.5	15.3	356	400	48	0	161.3	107.4	51.1	58.3
	2013	259	999	0	60	134.3	118.9	45.1	52.5	199	260	90	86	139.4	148.7	37.0	43.3	356	500	80	35	112.3	120.5	34.5	45.5
	2014	279	2997	60	52	109.8	118.5	40.3	148.1	255	271	65	65	186.7	172.9	45.7	61.5	400	368	65	50	89.7	114.2	25.7	40.2
	2015	269	3000	59	45	113.0	113.8	33.4	160.5	255	300	60	60	168.3	182.1	82.3	73.8	350	1670	63	40	100.7	105.0	36.0	53.9

Table 4: Descriptive Statistics of Prices awarded for Sales on MSD and MB; across hours, years and technologies.