Impact of Renewables Resources into the Italian Intraday Electricity Market

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Abstract: Intermittent resources such as wind and solar are nowadays strongly approaching the energy markets. European authorities are responsible to find the optimal way to integrate them efficiently into the power system to follow the decarbonization process. Market rules penalize traders who close their position in the market without being able to respect it in real market operation. At this regard, the possibility of being able to exchange energy closer to the real time operation helps players to solve forecasts problems. To this aim, a new design of intraday market has been carried at European level focused on the possibility to trade energy continuously until one hour before the delivery. The Italian energy market, historically based on seven auctions, taking part to the Single Intra Day Coupling (SIDC) Market, implemented a hybrid system composed by three auctions and continuous trading. Consequently, the whole system had to face significant changes that impacts on volumes, prices of energy exchanged and agent's behavior. This paper aims at investigating how the efficiency of the market changes in terms of liquidity and price volatility and the new strategies adopted by players throughout statistical analyses that compare the past structure of intraday Italian market and the current one.

Key words: Renewable energies, intraday market, power system

1. Introduction

The Paris agreement, stipulated by 196 parties at COP26 in December 2015 aiming at limiting the global warming [1], has further pushed an increase of renewable energy resources such as wind and solar in all energy sectors [2]. Following this path, the electricity market is facing a considerable challenge trying to maximize the penetration of renewables in the market contest. The main drawback that must be solved, due to the intermittent nature of renewable energy sources, is the difficulty to forecast the real energy profile, in order not to incur in penalties related to energy imbalances [3]. Wind and solar energy profiles are very volatile [4] and consequently, the energy trades during the so-called short-term markets, divided into day ahead (DAM) and intraday (ID) market is growing significantly [5]. Although the biggest volumes of energy are managed during the day ahead session [6], in [7] is stated that the imbalance costs can be reduced by smartly participating in the ID market. Intraday session is useful overall for renewables energy producers that have the possibility to adjust their positions after updating their energy production forecast [8]. Due to the fact that the participation of intermittence resources in energy market contest is growing significantly, the efficiency of intraday market of all European countries has to be enhanced in order to provides better conditions for players in terms of liquidity and information efficiency. These two characteristics are well defined by [9] respectively as the feature by which a lot of market participants are able to exchange energy quickly without affecting the products price or incurring in high transaction costs and the capacity on

translated new external information into market adjustment. So, to improve the market efficiency, the Agency for the Cooperation of Energy Regulators (ACER) established, through the CACM guidelines [10]to sets out minimum harmonized rules for the ultimately single day-ahead and intraday coupling of all European countries involved in this process under a single platform called Single Intraday market Coupling (SIDC) by which agents can sell or buy energy continuously among different bidding zones as long as there is enough transmission capacity available [11]. Continuous trading provides an appropriate information efficiency for renewables agents since they can submit a bid as soon as they forecast any changes in external conditions [12] but, on the other hand, the first-come-first-served rule typical of this market scheme [13] in not able to provide a sufficient liquidity level [14]. In [15] is stated that liquidity in markets based on auctions mechanism is higher than in markets based on continuous trading while in [16] is argued that auctions guarantee a better allocation of cross zonal capacity fundamental to trade efficiently among different bidding zones. Therefore, many European countries decided to introduce the possibility to trade energy with auctions besides continuous trading. The Iberian Peninsula inserted 6 auctions alongside the continuous mechanism and, nowadays, it is viewed as one of the most liquid intraday markets in Europe [17] while the German market has increased the liquidity significantly after the launching of one auction inside the continuous system [5]. So, the new target is to understand which could be the correct number of auctions that can ensure the optimal structure of the European SIDC [8]. ACER designed a future of ID market based on continuous trading punctuated by three pan-European auctions [18]. So far, Italy is the only nation that implemented the hybrid system proposed by ACER since September 2021, data in which Italy join the SIDC platform. In this work, throughout statistical analyses, the main changes in terms of volumes and prices of energy exchanged by players in the Italian ID market from the previous structure based on seven auctions and the actual one is highlighted to better understand if the new market design led to a better market efficiency. Even considerations about renewables agent's behaviour who have to quickly adapt their strategies from a market structure historically based on the auction mechanism to a strongly different one is provided. The paper is structured as follow: in chapter II the previous and the actual structures of the Italian ID market are accurate explained. In chapter III all statistical analyses are presented with the corresponding considerations. Conclusions and discussions are reported in chapter IV.

1.1. Related works

With the growth of intraday trading and the introduction of the SIDC project, the literature on the intraday market activities has been recently increased. [13] investigates the intraday trading of ELBAS that include the northern European countries (Finland, Sweden, Denmark, Norway, and Germany) and shows how the SIDC facilitate the integration of renewable resources into the energy context and underline how continuous trading is used overall by power plants (like solar and wind) that need to keep their position balanced after a new forecast of energy production. In [19] is stated that the introduction of continuous cross border trading in the Greek contest will help the renewable resources to better update their position constantly reducing the risk of imbalances. [5] and [20] explain that the German ID market, historically based on continuous trading, significantly increased its liquidity and thus its efficiency after the introduction of one auction besides continuous activities. On the other hand, [21] shows that the Iberian ID market historically based on auctions is one of the most liquid markets in Europe after the introduction of the continuous trading mechanism. In [22] is presented how the ID market efficiency is increased after the introduction of SIDC market into the Great Britain context while in [23] is shown how the volumes exchanged in the France ID market increased after the introduction of a hybrid model composed by auctions and continuous trading. [24] summarize the status quo of different intraday European market that join the SIDC project. This paper aim at analyzing the impact of the SIDC project and the introduction of continuous trading in the Italian context.

2. Italian ID Market

Prior to presenting the main aspects of the Italian ID structure before and after the introduction of the single intraday market coupling some general aspects about the Italian market are explained. GME is the Nominated Electricity Market Operator (NEMO) and TERNA is the Transition System Operator (TSO). The first one is responsible for the wholesale energy market, and it is the central counterpart for sell and buy energy in the day-ahead and intraday markets [25]. The second one is responsible for planning and developing the national transmission grid as well as the managing of the electricity flow and the eventual congestions [26]. Taking into account the structural transmission constraints, TERNA divided the national territory into seven different bidding zones: Northern Italy, Central-Northern Italy, Central-Southern Italy, Southern Italy, Sicily, Sardinia and Calabria. Agents can trade energy among different zones as long as there is enough available transmission capacity. The day-ahead market ends at 12 a.m. of the day before the delivery (D-1) and then, players can start trading during the intraday market.

2.1 ID structure before September 2021 – Auction model

Before the introduction of SIDC, the Italian ID market was organized with seven implicit auctions called respectively as: MI1, MI2, MI3, MI4, MI5, MI6, MI7 that allow agents to trade energy no less than four hours before the delivery (as shown in Table 1). The first three sessions were performed the day before the effective delivery of energy (D-1) while the other four were held during the delivery day (D). Agents could submit hourly products and all accepted bids/offers were remunerated with a zonal clearing price [27]. In Table 1 information about the structure of the auctions is provided [28].

Table 1. Structure of the previous Italian ID market

	MI1	MI2	MI3	MI4	MI5	MI6	MI7
Gate opening	12:55 (D-1)	12:55 (D-1)	17:30 (D-1)	17:30 (D-1)	17:30 (D-1)	17:30 (D-1)	17:30 (D-1)
Gate closing	15:00 (D-1)	16:30 (D-1)	23:45 (D-1)	03:45 (D)	07:45 (D)	11:15 (D)	15:45 (D)
Time horizon	00:00-24:00 (D)	00:00-24:00 (D)	04:00-24:00 (D)	08:00-24:00 (D)	12:00-24:00 (D)	16:00-24:00 (D)	20:00-24:00 (D)
Products available	H	H	H	H	H	H	H

2.2 ID structure after September 2021–Hybrid model

In September 2021 the Italian authorities of electricity market decided to replace the previous seven auctions entering in the SIDC platform and introducing the continuous trading mechanism. Precisely, following the ACER decision mentioned in section 1 [18], the ID market has been structured with a hybrid model divided into continuous trading and three implicit auctions allowing players to trade until one hour before the real time overlapping to the national ancillary services market. During the auction's session, the interconnection capacity is allocated among all the Italian bidding zones and the other areas interconnected with the Italian territory. Auctions and continuous session are held sequentially without overlapping in the following order: MI-A1, continuous session 1, MI-A2, continuous session 2, MI-A3, continuous session 3. In Table 2 the new structure of the Italian ID market is reported [21].

Table 2. Structure of the new Italian ID market

	MI-A1	Continuous session 1	MI-A2	Continuous session 2	MI-A3	Continuous session 3
Gate opening	12:55 (D-1)	15:30 (D-1)	12:55 (D-1)	22:30 (D-1)	12:55 (D-1)	10:30 (D)
Gate closing	15:00 (D-1)	21:40 (D-1)	22:00 (D-1)	H-1/09:40 (D)	10:00 (D)	H-1
Time horizon	00:00-24:00 (D)	00:00-24:00 (D)	00:00-24:00 (D)	00:00-24:00 (D)	13:00-24:00 (D)	12:00-24:00 (D)
Products available	H	H	H	H	H	H

From the introduction of SIDC, Italian market attended the Local Implementation Project 14 (LIP 14) which coupled the continuous and auctions sessions with the countries bordering Italy [29]. In this scenario the three ID auctions take the name of Cross Border Intraday Auctions (CRIDA), and they are currently able to exchange energy between the connection of Italy and Slovenia, Italy and Greece and among the Italian bidding zones. Moreover, in continuous, Italy is coupled with the same countries mentioned above plus France and Austria bidding zones. Pointed out the two different settings in which market agents compete to solve their imbalances, a comparison of the results in terms of prices and volumes are presented in the next chapter.

3. Analyses of the Behavior of Market Operators

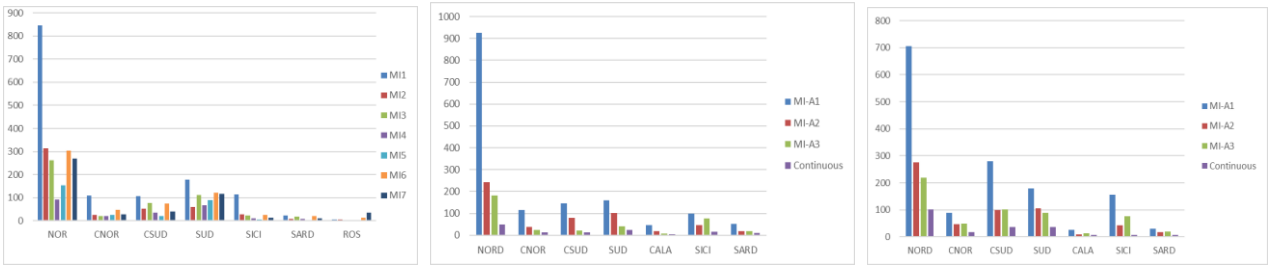
3.1. Sources

Analyses have been carried out through to the data available in the Italian Nominated Electricity Market operator (GME: Gestore del Mercato Elettrico) website in which all prices and volumes of the transactions occurred in the Italian electricity market are stored. In particular, results regarding the volumes and prices of the seven auctions of the previous ID market and the results of the continuous trading plus the three implicit auctions of the current ID market design have been taken into considerations [30].

3.2. Analyses developed

In this section, historical data of the Italian ID market are analyzed throughout statistical analyses of prices and volumes gathered before and after September 2021 (October 2020,2021 and 2022). This lead to investigate how agents have changed their behavior in front of two ID different market models as well as to compare the liquidity and the price volatility (that measure the uncertainty of prices) of the new ID model with the previous scheme.

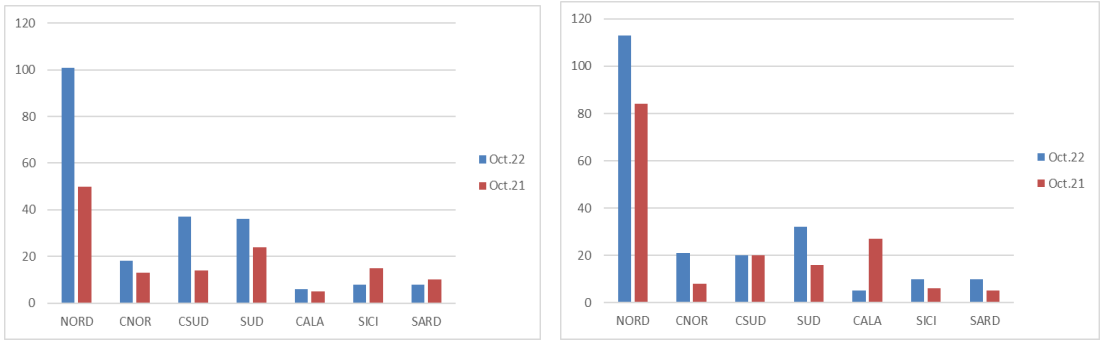
The first analyses report the volumes of energy (MWh) purchased in October 2020, October 2021, and October 2022 in the different session of the ID market for each Italian bidding zone. Results are shown in Fig. 1.



(a) (b) (c)

Fig. 1. (a) volumes purchased (MWh) in October 2020; (b) October 2021; (c) October 2022.

All plots show that volumes of energy are purchased mostly during the first auction, representing consequently the most liquid session of the market, and the value of MWh decrease constantly for every other session reaching the lowest point in continuous. The trend is even stronger during October 2021 probably because players are still not able to trade with the new market and they prefer to use the first auction to exchange energy like in the past. This behavior has been registered also in the Iberian market when it joined the SIDC platform in 2018 [31]. In figure 1.c is noticeable that agents start trading bigger volumes in the other sessions of the market because they are more practical on trading close to the real time. Focusing on trading in continuous, Fig. 2 shows the variation of volumes exchanged continuously in all bidding zones in October 2021 and October 2022.

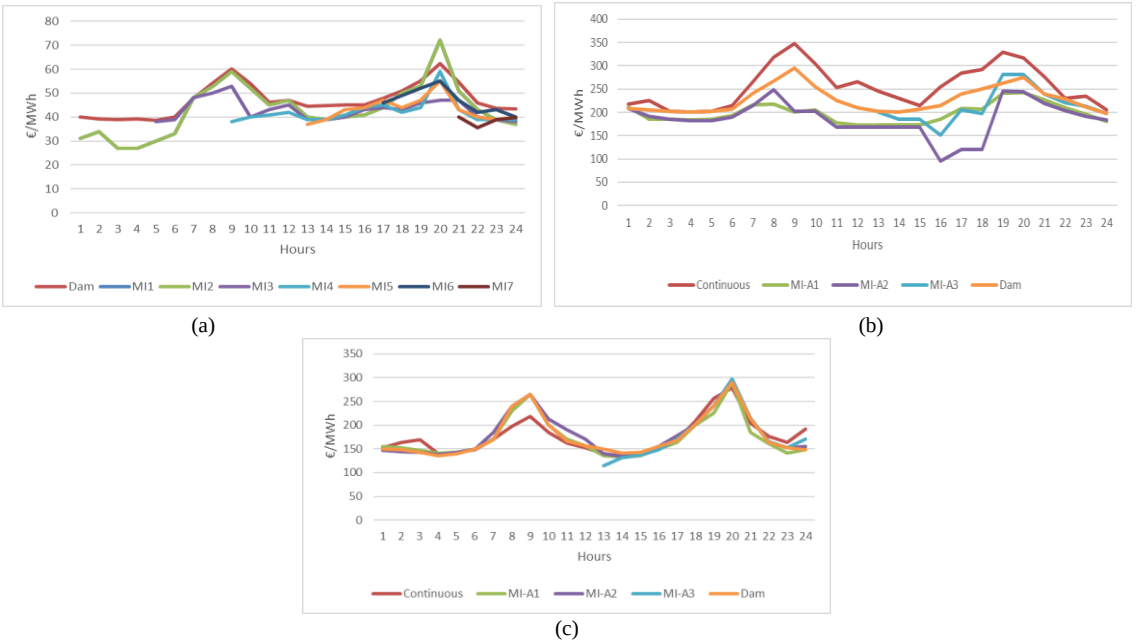


(a) (b)

Fig. 2. (a) Comparison of volumes purchased (MWh) in continuous; (b) Comparison of volumes sold (MWh) in continuous Data provided by [30]

For almost all bidding zones, the volumes treaded in continuous increase one year after the introduction of SIDC for buyers and sellers. This is also a signal that solar and wind power plant are participating more active in the market thanks to the possibility to trade until one hour before the delivery time.

In the second analyses, how the price strategy formulation has changed after the SIDC market is investigated. To do that, the analyses of trend prices from the day-ahead market until all session of the ID market for the 24 hours of the same day in October 2020, 2021, and 2022 has been carried out. Results are displayed in Fig. 3.



(a) (b)

(c)

Fig. 3. (a) trend of prices for the 20/10/2020; (b) trend of prices for the 19/10/2021; (c) trend of prices for the 21/10/2022. Data provided by [30]

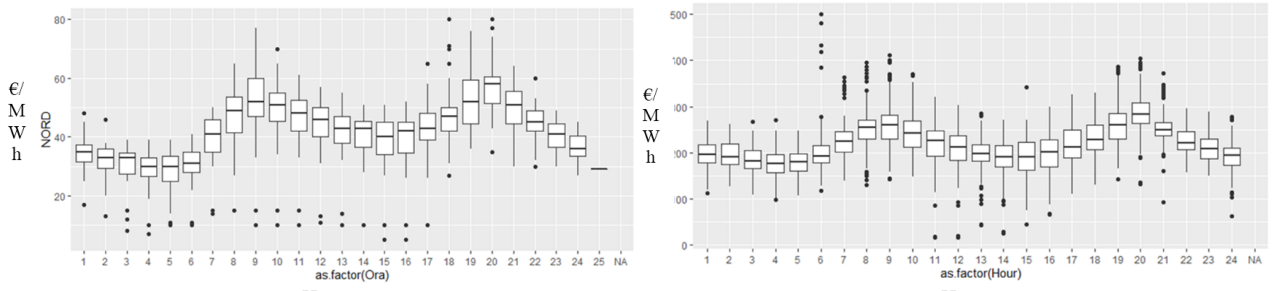
The plot shape of Fig. 3.a demonstrates that prices of the ID market follow the prices levels of the transactions that come out from the day-ahead market and the volatility is very low. Immediately after the introduction of the SIDC market (Fig. 3.b), a big variation of prices under the different session of the market is registered. Probably agents try to maximize their profit or minimize their expenses submitting offers and bids at different prices apparently without a specific strategy. As results prices that come out from the CRIDA are different from each other, players don't understand likely how to use continuous trading to buy energy and the transaction values increase significantly. It is clear that, comparing the trend of Fig. 3.b with the one in Fig. 3.c after one year using the new mechanism, players are more capable to trade in SIDC market intercepting cleverly the price signal given by the day-ahead market. Consequently, the liquidity increases because agents can estimate better which offer has to be submitted in order to obtain a transaction and non-dispatchable agents can use the continuous trading efficiently. An analog behavior is obtained also in the German ID market [32].

The box plot of prices of transactions occurred in the first auction of October 2020 and for the continuous trading of October 2021 and, 2022 are highlighted in the last analyses. Box plot is a graphical method to demonstrate the spread of numerical data throughout quartiles. In particular the graph reports a box of the range of number distributing from the first quartile, which is the middle number between the smallest number and the median of the data set, to the third quartile, which is the middle number from the median to the highest number of the data set. This statistical method helps the analyses to exclude the outline numbers that could affect the results and the spread of the majority of data prices help to understand the volatility of the market. In Table 3 the lowest first quartile and the highest third quartile of the transaction prices registered along the whole months are reported to better highlight the price fluctuation.

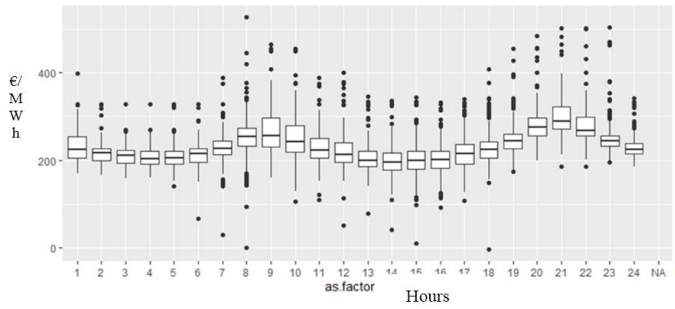
Table 3. Second and third quartile of prices in different session of ID market in October

	October 2020	October 2021	October 2022
Lower bound	26 €/MWh	152 €/MWh	180 €/MWh
Upper bound	60 €/MWh	310 €/MWh	320 €/MWh
Difference	34 €/MWh	158 €/MWh	140 €/MWh

Results help to understand how the volatility changes in the different market session. Table 3 shows that the volatility is very low in a market composed by auctions in respect to the continuous trading. In Fig. 4 the entire box plot of all values in between the first and the third quartile of a series of numbers, is reported hour by hour. In the same plots there are represented lines extending from the box indicating variability outside the upper and lower quartiles. They can help to figure out in which market session players submit more offers far from the average market price trying to maximize their revenues



(a) (b)



(c)

Fig. 4. (a) quartile of prices averages of October 2020; (b) quartile of prices averages of October 2021; (c) quartile of prices averages of October 2022. Data provided by [30]

These three plots underline the impact of the continuous trading on the price volatility compared to the auctions. Focusing on the range of the y-axes it can be seen that in the previous market with seven auctions (Fig. 4.a): the volatility of prices is very low, and outliers are mostly prices lower than the average and the 50% price ranges approximately between 25€/MWh to 35€/MWh in the less volatile hour (5:00) and between 45€/MWh and 60€/MWh in the more volatile hour (19:00). During continuous trading the volatility increase extremely. Fig. 4.b presents a consistent number of outliners with high prices of transactions and the price range of the box plot has a variation of more than 50€/MWh for most of the hours and a total variation of 158€/MWh during the whole month. It is interesting to investigate the trend after one year of SIDC operation (Fig. 4.c) because players are exploiting the opportunity of trading in continuous with more consciousness. As an outcome the number of outliners is very high compared to Fig. 4.a and Fig. 4.b but the range of values among the first and the third quartile decreases compared to Fig. 4.b. The reason is immediately suggested: after one year of continuous trading players know better how to find a match following the prices that come out from previous auctions, so most of the transactions occur around the "reference" auction's prices and the volatility decreases consistently. On the other hand, well-prepared players obtained the ability to predict when they can achieve a profitable match submitting offers with high prices to the disadvantages of the players that, very close to the delivery time, are forced to buy energy in order not to occur in very expensive penalties imbalances.

3.3. Summary results

Analyses show that auctions are the mechanism more utilized by players to trade in the ID market but since the participation to the SIDC project, continuous trading is becoming more exploited every year by players. This reflects the growth of renewable energy into the market context and their need to react quickly to the external event. However, auctions are still fundamental to maintain the liquidity of the market and to contain the price volatility that could be registered during the continuous trading. In fact, the match prices of continuous trading follow the prices that come out from the day-ahead market auction as well as the intraday auctions. So, combining successfully auctions and continuous trading, the new design of Italian ID market enhanced its efficiency and allow a stronger penetration of renewable power plants into the system thanks to the possibility to adjust the position closer to the delivery time, providing a good liquidity and reducing the price volatility.

4. Conclusions

The paper investigates the main features of the Italian intraday market taking into account the transaction between a system based on seven internal implicit auctions to a hybrid model composed by three cross regional implicit auctions and continuous training. The first part of this paper is focused on the description

of the two market structures while the second part compares the behaviour of players and highlights considerations about the general efficiency of the two systems. In particular, statistical analyses of prices and volumes of transactions occurs in 2020, 2021 and 2022 has been carried out to explore which sessions of the market are the most exploited by players, how agents adapt their strategy trading in the hybrid model and how continuous trading impacts on the volatility of prices.

Results show that players prefer to trade energy during the first auction in the past ID market model as well as in the current one, conferring it the successful session in terms of liquidity. However, the trend is moving towards a utilization of the sessions closer to the real time to exchange energy and in particular the continuous trading. This happen because a predominance of wind and solar power plants are approaching the energy market and they need to trade closer to the delivery time to avoid imbalances and because agents are more capable to trade in continuous after one year of transactions. A similar behaviour has been registered in the Iberian ID market (historically based on auctions as the Italian one) immediately after the introduction of the SIDC project. But the big number of auctions (6) decrease the liquidity of the continuous trading and players find hard to find a profitable match. Another consideration is that the strategy adopted to trade in the ID market is to submit offers following the prices of the day-ahead market. Indeed, analyses show that results of DAM give the price signals to submit successful offers and bids in the following market sessions. This consideration not exactly focusing on the initial period of the SIDC market where agents were still not expert on trading in the hybrid model and not so clever strategy were adopted. The price volatility inevitably increased during the new ID model overall for the continuous trading mechanism. In fact, the pay as bid system and the first come-first served rule allow agents to submit offers and bids with high and low prices with respect to the auctions scheme in order to hopefully gain higher revenues. As result, most of the transactions take place around the price signal that comes out from the day-ahead market but, in many cases, there are outliners values that remark the trading ability of some players and the difficulties of others in front of unexpected imbalances. The same trend has been registered in the German ID market after the introduction of an auction besides continuous trading, but the volatility of prices is higher compared to the Iberian market.

To conclude, analyses demonstrate that auctions are still a very important mechanism to maintain the correct liquidity and to limit the price volatility. On the other hand, continuous trading is necessary to give the possibility to agents to react quickly to event such as the forecast variations overall for the intermittence resources that are emerging in the energy market. The hybrid model seems to be the best options to facilitate the trading of renewable energy power plants for all European bidding zones and the model adopted by the Italian market is the best compromise regarding the number of auctions that have to be introduced beside continuous trading. As the Italian market increased its efficiency allowing renewable players to enter in the market, the future of the SIDC market coupled among all European countries can successfully follow the Italian design.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Andrea Alberizzi conducted the research. Andrea Alberizzi and Alessandro Zani analyzed the data. Andrea Alberizzi wrote the paper and all authors had approved the final version.

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