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The development of gas hubs in Europe

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HIGHLIGHTS

- The paper illustrates development paths for natural gas hubs in Europe.
- Wholesale trade increases with competition.
- The regulatory settings of UK, Netherlands, Germany and Italy are reviewed.
- Each country is located into the evolutionary path highlighted in the analytical framework.

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ABSTRACT

This paper investigates the development of wholesale markets for natural gas at the different stages of market liberalization. We identify three steps in the process: wholesale trade initially develops to cope with balancing needs when the shippers and suppliers segments become more fragmented; once the market becomes more liquid, it turns out to be a second source of gas procurement in alternative to long term contracts; finally, to manage price risk financial instruments are traded. We review in detail the different regulatory measures that must be introduced to create an efficient and functioning wholesale gas market. Finally, we analyze the evolution of gas hubs in the UK, the Netherlands, Germany and Italy in terms of market rules and market liquidity. We argue that each of these country cases can be easily located into the evolutionary path we have highlighted at the beginning, with the UK and the Netherlands leading the process, Germany and Italy constrained by limited supply; Italy is also showing an interesting counterfactual.

1. Introduction

In the last decade, wholesale gas markets have developed in several European countries, with very different volumes and liquidity. This diversified landscape suggests interesting research questions: what determines the emergence of gas hubs? Is there a predictable pattern of development that helps interpreting the different situations as part of a common process?

In the European liberalization design the successful development of a liquid wholesale gas market has required the definition of a set of rules and mechanisms addressing the choice of a transmission system model, the design of the balancing rules and the set-up of transparency requirements. Within these market rules, a growing demand for wholesale gas, pushed by industry fragmentation, has been in our view the driving force in the process.

We argue that balancing needs to clear individual portfolios in a liberalized and fragmented market have been the initial motivation to trade. As wholesale transactions developed, operators had the opportunity to purchase gas at the hubs as an alternative to long-term contracts. Moreover, domestic producers, when significant, could sell at the hub in parallel with their long-term provision contracts, giving a push to liquidity. We argue this process has characterized the development of national gas hubs in each European country, with a more dynamic process in the gas systems where domestic production plays a significant role. The need to hedge price risk has led to introduce financial instruments, that may be traded even in market venues distant from the

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location of physical trades. We expect them to concentrate in a few number of market venues.

We apply this analytical framework to the evolution of the wholesale natural gas markets in Germany, Italy, the Netherlands and UK[1], analyzing their balancing systems and tools for physical and commercial flexibility, and the development of market liquidity. We focus on these countries as, in our view, each of them represents a different evolutionary stage in the process depicted above.

Although the dynamics of gas markets is receiving increasing attention, a comprehensive analysis of the development of wholesale gas markets in Europe and the related regulatory issues is in our view still missing in the literature. NERA and TPA (2005) review and evaluate balancing rules in some EU countries, but the report is by now outdated. Migliavacca (2009) surveys some aspects of the Italian balancing system, highlighting the contacts with the electricity sector, while KEMA (2009) offers an interesting report that deals nonetheless only briefly with balancing and flexibility, being concerned with transmission tariffs. Lapuerta (2010) examines some balancing mechanisms and analyzes the balancing system in the UK and Germany and Keyaerts et al. (2011) deal with flexibility issues focusing on line-pack. Many studies deal with the impact of European integration on gas market: recently, Neumann and Cullmann (2012) measured the degree of integration of gas markets based on the prices of eight European hubs, finding a significant level of convergence. Asche et al. (2013) analyzed the degree of market integration between the British NPB, the Dutch TTF and the Belgian Zeebrugge, also finding a high integration. Petrovich (2013) studies hubs integration verifying the reliability of hub prices as reference price signals. A large literature deals with the implications of the entry-exit model and, more in general, with the European Gas Target Model (also GTM). Among others, it is worth recalling the works by Hunt (2008) that explores the implications of having an entry-exit model on integration and wholesale markets and by Vazquez and Hallack (2013), that identify the central significance that balancing markets assume within the entry-exit framework. Glachant et al. (2013) further discuss the GTM with a special focus on the regulation of network capacity. Finally, KEMA/COWI (2013) analyze the different role of long and short term contracts on EU competition and security of supply. Heather (2012) accurately describes and categorizes the main European gas hubs and their liquidity. We move alongside this line of study, but focusing rather on balancing mechanisms and rules, and viewing liquidity as a result of growing demand and of the rules set by each country's regulator.

The contribution of this paper is threefold. First, we build an analytical framework to study the balancing issue and the related development of wholesale demand; second, we review the EU regulation on wholesale gas markets and the balancing regimes adopted by four countries; third, we provide supporting data and indicators to confirm our line of reasoning.

The paper is organized as follows. Section 2 offers an analytical framework of the increase in liquidity stemming from market liberalization and the role of balancing. Section 3 reviews the EU regulation on balancing and transmission, reviewing the balancing mechanisms and flexibility tools available for UK, the Netherlands, Germany and Italy. Section 4 follows the evolution of the hubs of the four selected countries as trading platforms and evaluates their performance according to their liquidity and physical endowment. Section 5 discusses the main results and concludes.

[1] A more detailed study that includes also France, Spain, Belgium and Austria is Dickx et al. (2014).

2. Methods

In this section we show through a simple analytical framework how the liberalization process creates a demand for wholesale gas to balance individual positions of the operators.

2.1. Liberalization and the development of wholesale transactions

With the progresses of gas market liberalization in Europe, gas systems moved from a monopolistic to a more fragmented environment. In the former, a single vertically integrated company managed most of the injections and withdrawals, balancing the ex-post shocks in supply or demand by adjusting flows within its portfolio of contracts. In the latter, instead, different agents each cover a smaller share of the aggregate traded gas volumes, increasing the fraction of shocks that cannot be compensated within individual portfolios and the number of associated imbalances. Wholesale trade, then, offers a way to clear individual positions, easing the need to balance physical injections and withdrawals. In turn, as wholesale trade and liquidity develop, price signals become more reliable and a wholesale market offers a second source of gas provision in alternative to the traditional long-term contracts. Price variability still remains, due to aggregate shocks, and requires financial instruments to hedge the price risk. We argue that this process, with balancing, second sourcing and financial instruments as the three steps, characterize the development of wholesale trade in the liberalized European markets.

2.2. The balancing issue

Flows in the gas transmission system (GTS) occur from one point to another in the network by virtue of the differential in pressure existing between those two points. Pressure fluctuations stemming from market parties' injections and off-takes to and from the network can threaten the system integrity.[2] It is therefore crucial to design a balancing system that ensures that pressure in the system remains within safe operational limits.[3] Demand and supply shocks make this task challenging.

Inflow and outflow decisions are taken by a set of economic agents or institutional bodies within contractual frameworks that usually define ex-ante a certain flow and adjust ex-post to the realized volumes. Outflows, for example, depend on the decisions of final users, who contract their gas provisions according to their predictable needs, and can further withdraw gas adjusting and paying ex-post their off-takes. These latter are mirrored by a corresponding decision of inflow (e.g. import) by upstream agents as shippers. Hence, the flows in the GTS depend on a large set of demand and supply decisions by different agents, and reflect their underlying choices. Supply and demand shocks may create imbalances between planned and realized inflows and outflows, with a variation in the pressure into the system. Balancing ex-post inflows and outflows is therefore a crucial activity in the management of a GTS.

[2] From Keyaerts et al. (2008 p. 2) "system integrity" is defined as "*each situation of a transport system where the pressure [and the quality of the natural gas] remain within the lower and upper limits set by the system operator such that the transport of natural Gas is guaranteed*".

[3] The sources of inflows in the GTS are imports (by pipeline or LNG terminals), domestic production and withdrawals from the storage facilities (depleted gas fields, aquifers, salt caverns, facilities at LNG terminals), each characterized by some capacity constraint. Outflows correspond to withdrawals from the GTS. They can take different forms: final demand by end users directly connected to the GTS or to the distribution networks, exports to foreign GTS's by pipelines or LNG, and injections into storage facilities.

2.3. Balancing: A simple analytical framework

To illustrate in a very simple manner the balancing issue, let us consider this oversimplified example, corresponding to a market with four final identical clients, supplied through contracts that commit them in the short run to remain with their shipper.[4]

Demand. We assume that final users' demand is perfectly inelastic[5] and has a predicted component d and a random shock ε_i, according to the expression

$$D_i = d + \varepsilon_i \tag{1}$$

If the price p is not above the reservation value v, and 0 otherwise, where $i=1,...,4$. The shocks are iid and may be positive or negative with equal probability, i.e.

$$\varepsilon_i \in \{-\varepsilon/4, \varepsilon/4\}$$

Hence, demand shocks have zero mean and standard error $\sigma_\varepsilon = \varepsilon/4$.

To cover the downstream contract a shipper j signs a corresponding upstream contract for an amount equal to the level of expected demand d, and injects into the system this flow of gas.[6] Therefore, the system is *ex-ante* balanced both commercially (supply and demand d for each contract are equal) and physically (total injections and *ex-ante* withdrawals are equal to $4d$). Although the system is *ex-ante* balanced, *ex-post* shocks create imbalances at the level of the single trade and, potentially, at the system level. With 4 clients we have 16 possible combinations of realized shocks that can be grouped into 5 different cases:

States of the worlds: individual shocks and aggregate system position

(1) *Four negative demand shocks*: one combination only, with aggregate imbalance: $-\varepsilon$.
(2) *Three negative and one positive demand shocks*: four different combinations, with an aggregate imbalance of $-\varepsilon/2$.
(3) *Two negative and two positive demand shocks*: six different combinations, with the system balanced at the aggregate level.
(4) *One negative and three positive shocks*: four combinations, with an aggregate positive imbalance of $\varepsilon/2$.
(5) *All four customers hit by a positive demand shock*: one combination with an aggregate imbalance ε.

Supply. For simplicity, we assume that all the shippers pay the same upstream wholesale price w to their providers (e.g. producers). This way, the only dimension where the shippers may be heterogeneous, and the upstream market structure can vary, is through the number of shippers and the size of their portfolios.

Since the aggregate imbalance of the system depends on the sum of the shocks, whereas each shock creates an imbalance at the level of the single contract, it may happen that the system is balanced, as in case (iii), but individual contracts are not. In this latter case, the shipper can balance his position commercially in different ways. If, for instance, he is short on one contract, he can compensate it with the long position (if any) of another contract in his portfolio, or he can buy gas from another shipper with a long position. Alternatively, the shipper can withdraw the gas from a storage facility, or procure it from the producer. Although these alternative balancing actions may be equivalent for the shipper, they are not at the system level. The former two actions, indeed, do not vary the total amount of gas in the system, whereas the latter two solutions increase the amount of gas, and the pressure, in the system.

The extent of compensations among contracts, in turn, depends on the size of individual portfolios, e.g. on the supply side of the industry. We consider the following market configurations according to the number of shippers and the size of their portfolios of contracts, where the capital letters identify a shipper and the numbers correspond to the contracted customers.

Shippers' market structures

(1) **A(1,2,3,4)**: (pre-liberalization) monopoly.
(2) **A(1,2), B(3,4)**: two symmetric large shippers
(3) **A(1,2,3), B(4)**: two asymmetric shippers
(4) **A(1,2), B(3), C(4)**: one large and two small shippers
(5) **A(1), B(2), C(3), D(4)**: a symmetric fragmented supply side.

What changes according to the different cases is the ability of a shipper to adjust the individual shocks within his overall portfolio of contracts, and therefore his net residual imbalance once he realizes these adjustments. When individual customers are hit by shocks, with different aggregate effects described in the (i)–(v) cases above, some of these shocks of opposite sign can be adjusted either within each portfolio, or relying on trade between shippers with opposite net positions. This way, shocks can be netted out up to the aggregate imbalance at the system level, which requires dealing with other tools and agents. We define this solution as *efficient balancing*.[7]

In this perspective, the adjustments allowed by wholesale trade may play a crucial role to reach efficient balancing. Absent this balancing tool, each supplier should clear its imbalances by trading with agents outside the system, as additional imports, or net variations in their storage positions, which would exacerbate the physical imbalances of the system.

3. Results

Table 1 reports, averaging across the 16 realizations of shocks, the amount of expected internal compensations within the portfolios and the volume of expected wholesale trading between shippers in the different market structures. It also shows the expected amount of external adjustment needed to cope with the net aggregate imbalance at the system level in the different states of the world.[8]

We can split the aggregate shock that hits the system, equal to ε, in three parts. A first component, corresponding to the average aggregate imbalance ($6\varepsilon/16$) requires changing the level of injections or withdrawals at the system level, for instance by using a variation in the net storage positions. The residual part of the shocks ($10\varepsilon/16$), however, can be adjusted within the system with no net variation in total injections or withdrawals, since they hit with opposite imbalances individual contracts (implying therefore an expected net transfer of volumes across contracts equal to $5\varepsilon/16$). The way they are cleared, through internal adjustment within each portfolio or by trading with other shippers, depends on the

[4] The analysis can be easily generalized to M suppliers and N customers, with M and N large. See footnote 9 for details. The case with 4 customers is sufficient to illustrate the main features.

[5] The assumption of perfectly inelastic demand, although empirically relevant in the short run, can be relaxed assuming an elastic demand $d(p)$, as long as total demand can be decomposed into a deterministic and a random component.

[6] We assume that transmission capacity is contracted to deliver the gas into the GTS. See Glachant et al. (2013) for a detailed analysis of the issue.

[7] Efficient balancing, therefore, limits the physical adjustment of the system to the level corresponding to the aggregate imbalance, using commercial wholesale transactions to compensate individual positions of opposite sign without further affecting the overall level of injections or withdrawals. For instance, in case (iii)

[8] See Appendix A for the computations of the within portfolio adjustments and wholesale trade.

Table 1
Wholesale trade, portfolio adjustment and external adjustment, different market structures.

Market structure	Wholesale trade	Portfolio adjustment	External adjustment
(a) Monopoly	0	$5\varepsilon/16$	$6\varepsilon/16$
(b) Symmetric duopoly	$\varepsilon/16$	$4\varepsilon/16$	$6\varepsilon/16$
(c) Asymmetric duopoly	$2\varepsilon/16$	$3\varepsilon/16$	$6\varepsilon/16$
(d) Asymmetric oligopoly	$3\varepsilon/16$	$2\varepsilon/16$	$6\varepsilon/16$
(f) Symmetric oligopoly	$5\varepsilon/16$	0	$6\varepsilon/16$

perimeter of the shippers' portfolios, that is on the market structure. The larger the size of the portfolios, the higher the percentage of shocks that are adjusted within, and the lower the scope for clearing positions through trading between shippers.

Table 1 shows also how wholesale trading between shippers develops as we move across different market structures. Two features positively affect the volumes traded: the number of shippers, and the number of agents with the smaller portfolio size. These two elements, indeed, negatively affect the ability to compensate internally the shocks within each portfolio, enhancing the residual scope for wholesale trading. Hence, we can argue that as long as liberalization drives the market toward more fragmented and symmetric supply configurations, the volumes of gas traded for commercial balancing increase.[9]

The following proposition summarizes the results so far.

Proposition 1. *When random shocks hit gas customers' demand and supply contracts are set according to the expected demand, individual shippers may face ex-post individual imbalances, while the system as a whole may be unbalanced as well. These latter imbalances can be cleared only dealing with agents, and using tools, outside the network of pipelines (e.g. imports, storage). Shocks hitting individual customers' demand can be cleared through compensations within each operator's portfolio of contracts and through wholesale trade between shippers with opposite net positions . This latter tool involves larger volumes of trade the larger the number of shippers and the larger the number of shippers with small portfolios.*

We move now from volumes to prices, in order to see whether the different market structures affect the way prices are formed in the wholesale market, and if price manipulation is more likely in certain environments than in others. The issue is relevant because the total volumes of gas traded in the market ($4d$ in expected terms, in our example) are much larger than the gas traded on the wholesale market for balancing purposes. Then, we want to understand if the price that is set on the wholesale market reflects

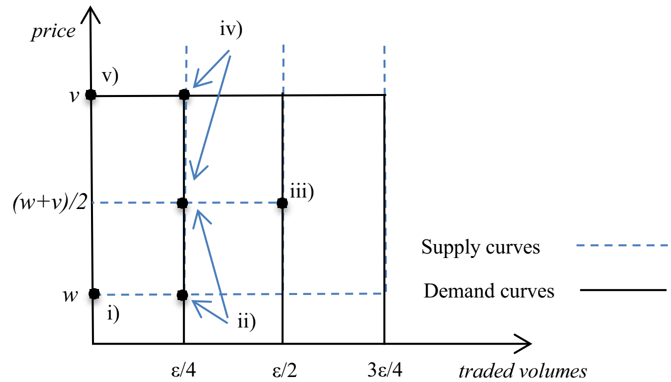

Fig. 1. Equilibria for all states of the world.

the actual conditions of the overall gas market, or if it delivers biased signals instead. In the first case, the wholesale market produces a public price signal that helps operators taking their decision based on the evolution of market fundamentals. Since gas trading inherited from the pre-liberalization world is based on long term contracts, where prices are private information and are often set according to formulas that do not reflect the actual scarcity of the resource[10], a reliable price signal in the wholesale market can introduce an important innovation in the market.

In our analytical framework the customers are homogeneous with a willingness to pay v, and the shippers have a reservation price w, differing only in terms of the size of their portfolio of contracts. Then, when demand and supply of gas in the wholesale market are equal, the equilibrium price is[11] $p=(v+w)/2$. When, instead, there are more shippers with a long than a short net position (excess supply), the market price is $p=w$. Finally, when short positions prevail (excess demand), the equilibrium price is $p=v$.

Fig. 1 shows the equilibrium prices in the five cases (i)–(v) previously described when we have a symmetric oligopoly with each shipper serving one customer. A negative demand shock, then, determines a supply of gas in the wholesale market and vice versa.[12] In a fragmented market the price reflects the overall state of the gas system. A high wholesale price v when the overall market is in excess demand (cases v) and (iv)), a low wholesale price w twined with an overall gas market in excess supply, and an intermediate price when the overall and the wholesale markets are balanced. In other words, the wholesale market, where a small fraction of the total gas is traded, conveys the correct signal on the state of the overall gas market when the supply side is fragmented.

Market manipulation, however might distort the wholesale price away from the level consistent with market fundamentals when there are dominant shippers. Consider, for instance, case (c) of asymmetric duopolies, in which one shipper has three contracts and the other just one. In this case, it may happen (state (iv) above) that all the three clients of shipper A have a positive shock and shipper B's sole client a negative shock. Shipper A, then, demands $3\varepsilon/4$ on the wholesale market while shipper B supplies

[9] We can easily generalize this example. Suppose there are N clients of equal size, each one with a demand corresponding to (1) and iid shocks $\varepsilon_i \in \{-\varepsilon/N, \varepsilon/N\}$ with equal probability. Then, there are 2N different sequences of N shocks. If K and $N-K$ are, respectively, the number of negative and positive shocks, each sequence composed by these shocks, that we define as $(K,N-K)$, occurs $N!/(K!(N-K))!$ times. In any such sequence, if there is a single operator, $min\{K,N-K\}$ shocks can be internally adjusted within the portfolio with the same number of shocks of opposite sign, while $N-(2\varepsilon/N)min\{K,N-K\}$ remain unbalanced and require to change the net injections/withdrawals in the system. If there are $M>1$ operators, each one managing a portfolio of $n=N/M$ clients, then, the sequence $(K,N-K)$ of shocks can be relabeled, according to the portfolios of the M operators, as $((k_1,n-k_1),(k_2,n-k_2),\ldots,(k_{M-1},n-k_{M-1}),(K-\sum_{j\neq M}k_j,n-K+\sum_{j\neq M}kj))$ with $k_j\le min\{n,K\}$ and $\sum kj=K$. Each individual vector of shocks $(k_j,n-k_j)$ for operator $j=1,\ldots,M$ occurs $n!/(k_j!(n-k_j))!$ times. Each operator $j=1,\ldots,M$, then, will be able to adjust $min(k_j,n-k_j)$ shocks within its portfolio of n contracts, with a net unbalance of $n-(2\varepsilon/N)\ min(k_j,n-k_j)$ to be cleared through transactions with other operators, if feasible. Then, when the size of the individual portfolios, n, becomes smaller, the number of internal adjustments falls as well, and each operator has to rely more on market transactions to adjust its overall net imbalances.

[10] See Stern (2012).

[11] Although any price between w and v clears the market, we focus on this solution, which can be thought as the outcome of a balanced bargaining process.

[12] Hence, for instance, in case (i) with four negative shocks all shippers offer gas while there is no net demand on the whole market, and the price is $p=w$ with no trade. In case (ii) with one positive shock and three negative shocks one shipper demand $\epsilon/4$ of gas while the other three offer, overall, $3\epsilon/4$ of gas: the excess supply entails a price $p=w$ and a volume $\epsilon/4$ of gas traded. In case (iii) there is a net supply of gas of $\epsilon/2$ matched with an equal amount of demand, and the price clears the market at $p=(w+v)/2$. Finally, in case (iv) there is a demand for gas of $3\epsilon/4$ and a supply of gas of $\epsilon/4$, leading to a price $p=v$.

only $\varepsilon/4$. Excess demand, then, makes the wholesale price raising to $p=v$, inducing other operators to sell in the market to match the excess demand. However, by withdrawing part of its demand, shipper A can apparently balance the wholesale market and pay a price $p=(w+v)/2<v$. A similar argument applies to the state of the world (ii) with shocks $(-\varepsilon/4, -\varepsilon/4, -\varepsilon/4, \varepsilon/4)$. In this case shipper A is in excess supply but, by withdrawing part of its supply, can make the price raising to $p=(w+v)/2>w$ obtaining an extra profit.[13]

We summarize our findings on wholesale pricing in the following proposition.

Proposition 2. *When the market structure of the shippers is not excessively asymmetric, the price that is set on the wholesale market is an unbiased signal of the state of the aggregate market for gas. When one shipper dominates the market, managing a large portfolio of contracts, it can manipulate the market by withdrawing part of its demand or supply and pushing the price up when in a long position and down when being in a short position. In these cases, the wholesale price does not reflect the market fundamentals.*

3.1. From balancing to second sourcing and price risk management

As long as liberalization proceeds, the gas hub becomes the central balancing tool and liquidity increases (Proposition 1). Moreover, a more fragmented market structure makes the prices an increasingly reliable signal of the demand and supply variations in the system (Proposition 2). As such, the wholesale market may gain a further important role by providing a reference to the selling or buying decisions of individual traders. Thereby, a liquid wholesale market may offer additional opportunities of trade to the upstream and downstream operators, as long as the prices that prevail in the hub correctly reflect the evolution of gas demand and supply.

When sufficiently liquid, then, the wholesale market can represent a second source of gas for suppliers, as opposed to long or medium term contracts with the shippers for the bulk of their needs (the d component in our model). Moreover, the wholesale market can be an alternative place where shippers can realize a share of the sales that their long-term contracts with the producers require to conclude according to take-or-pay obligations. A liquid wholesale gas market can also give domestic producers additional opportunities to sell, exploiting differences in prices with respect to those of long-term contracts.[14] In this sense, the proximity of gas fields within a national gas system may allow gas producers to exploit opportunities in the wholesale market, by increasing production when prices are favorable. A similar choice instead is less easily managed by foreign, often very distant producers.[15] From this perspective, therefore, we expect that a significant domestic production of gas may favor the increase in market liquidity.

Even in a liquid wholesale market, still, some price variability remains, reflecting the underlying aggregate shocks of the system (see Fig. 1). Hence, relying on the gas hub to procure gas, for balancing or final usage purposes, leaves the operator exposed to some price risk. The creation of a portfolio of products and contracts, with different maturity and structures, then, can offer new tools for price risk management, satisfying an underlying demand for hedging. The third phase in the development of wholesale gas markets, therefore, can be associated with the supply of a full range of financial products to manage price risk, as futures and forward contracts.

Concerning the location of market venues, the first two phases, related to balancing and second sourcing, are strictly connected to the physical provision of gas, and therefore are naturally committed to take place within the gas system they serve. Then, balancing and second sourcing needs will favor the development of gas hubs in all the European countries, with obstacles and incentives related to the structural features of the system, the availability of physical flexibility tools and the kind of regulation adopted.

However, the emergence of market venues to trade financial products may not necessarily follow the same pattern. The development of financial instruments to manage the price risk, indeed, is mostly unrelated to the physical delivery of gas, and therefore can take place in market venues different from those where the physical deliveries occur.

The financial literature on security markets has highlighted the economies of scale and scope emerging from a concentration of trade in few large venues (Clayton et al., 1999, Foucault et al., 2013). It seems reasonable to extend these predictions to the trade of financial instruments related to the gas markets. Hence, the evolution of the gas wholesale markets in Europe may be characterized by the consolidation of national hubs focused on balancing and second sourcing and the prevalence of few focal market venues where the instruments for covering the price risk of gas contracts will be traded.

Before moving to the analysis of the regulation and emergence of wholesale gas hubs in 4 European countries, we briefly summarize some predictions and educated guesses stemming from our analysis.

1. *The first phase in the development of a wholesale gas market entails balancing as the primary objective of traders, while a more mature phase entails gas provision as a second sourcing in the wholesale market. These phases tend to develop in each liberalized national gas system.*
2. *A combination of entry–exit model, market-based balancing regime and rules for fundamental transparency is a favorable market design for the development of a wholesale gas market.*
3. *The wider the virtual trading area within a national gas system, the more rapid and effective the development of wholesale gas markets*
4. *Market liquidity increases more rapidly in countries endowed with significant domestic gas production, and less so when long term import contracts dominate the provision of gas.*
5. *Transactions of financial instruments to hedge gas price risk concentrate in a small number of market venues.*

4. Discussion

This section compares the predictions and educated guesses drawn from our analysis with the regulation and some performance indicators in four European gas hubs, each representing a different stage of development of wholesale gas market. The aim is

[13] This distortion would not occur in a less asymmetric market structure. If A has two contracts and B and C just one (case d), then no manipulation could arise. In this case, both A and B are willing to sell their gas to C, and A faces a competitor on its side of the market, and has no incentive to restrict output leaving room to another shipper.

[14] If producers sell to shippers under take or pay obligations, their revenues are guaranteed. Then, they may sell to suppliers, in competition with the shippers, when the demand is tight and the price high. This is an instance of the commitment problem in vertical relations. See, for instance, Rey and Tirole (2007). For an analysis of the competitive effects of take or pay contracts v. wholesale market provision see Polo and Scarpa (2013).

[15] One additional obstacle that distant producers may face in the attempt to provide additional gas into European hubs may arise due to the constraints in long distance transmission capacity that prevent large swings in deliveries. To avoid this bottleneck, storage facilities may help distant producers to keep reserve gas for short term deliveries. However, this solution seems costly if justified only as a short term trading solution. Nonetheless, it has been recently observed that Gazprom has started to trade on European gas hubs with significant volumes.

Table 2
Indicators description.[a]

Prediction	Characteristic	Indicator	Formulation
Prediction 1	Trading development, Liquidity	Number of operators	
		Churn Ratio	Volumes traded/ Physical deliveries
		Gross Churn Ratio	Demand/Physical deliveries
		AI – availability index	Physical deliveries/ Demand
Prediction 2	Market design	Balancing rules	
		Entry–Exit	
		Transparency	
Prediction 3	Market integration	Widening of market areas	
Prediction 4	Resource availability	SSI – self-sufficiency indicator	Production/Demand
		IDI – import dependence index	Import/Demand
Prediction 5	Financial instruments	Volumes of forward trades	

[a] Note that: Gross Churn Ratio = Net Churn Ratio. *Availability Index.

to verify whether the sequence of phases identified-balancing, second sourcing and financial instruments-replicates the actual pattern of evolution of national gas markets. For each country, we analyze the balancing regime in place and build a set of indexes that are able to capture some key dimensions of gas markets, comparing them within our predictions (see Table 2 for a synthesis of the indicators).

4.1. EU framework for balancing

Although economic forces may push towards the development of wholesale trade, without a proper regulatory framework and market rules it is hard that such developments may take place. In the last few years, the European Commission has promoted a framework of rules and procedures, under the framework of the Gas Target Model,[16] to guide the different member states in developing gas hubs and to promote the integration of a EU-wide gas market. The most important areas refer to transmission, transparency and balancing. To ease the convergence of balancing arrangements and balancing zones, the European Commission has included in the Gas Regulation specific provisions for the harmonization of balancing systems across Member States (ACER, 2011).[17]

Concerning the *transmission system model*, under Regulation 715/2009 (EU, 2009) the European Commission has favored and required by September 2011 the adoption of an entry–exit capacity model[18]. The entry–exit model twins a specific entry (exit) point with all the exit (entry) points in the national transmission system (NTS), a feature that gives the operators the possibility to redirect the gas transactions in a simplified contractual framework when imbalances force to sell or buy additional gas out of the original purposes. Furthermore, the entry–exit model favors the emergence of a virtual balancing point by automatically creating a single entry–exit zone where gas can be traded, corresponding to a proper virtual trading point.

Regulators at the European level have also included a set of provisions in the Gas Regulation concerning *fundamental transparency* requirements and related record keeping obligations.[19] Fundamental data transparency refers to the availability on an equal basis to all market participants of information regarding physical gas flows in the grid, storage and LNG facilities, and other relevant physical information mainly before trading[20]. The information that is potentially useful to the market participants to organize efficiently their activities is quite large. It involves both information on programmed and realized flows through the different facilities and on available capacities, which are essential to undertake ex-post balancing actions.

Balancing rules are the third pillar in the regulatory design of gas hubs. The Network Code submitted by ENTSOG to the European Commission in October 2012 outlines the "Balancing Target Model", which can be summarized as follows. First, the Network Code requires Member States to implement a market-based daily balancing regime with shared responsibilities of the shippers and the transmission system operator (TSO). The TSO, burdened with residual obligations, adopts balancing actions by buying or selling short-term standardized products on the wholesale gas market, giving priority to Title Market Products, i.e. non-physical products traded at a virtual trading point, or recurring to other types of standardized short-term products defined in the Network Code (ENTSOG, 2012). When these interventions on the wholesale gas market cannot guarantee the system integrity (for example due to the lack of liquidity on the wholesale market or when the response time of balancing services is faster as compared to the lead time of short-term products), the TSO may recur to balancing services trading with third parties.

The design of balancing rules aims at reaching two goals. First, creating the proper incentives for the operators to clear their individual imbalances by reciprocal trading in the wholesale market, in order to reduce the residual gap to the aggregate imbalance at the system level. Secondly, to efficiently deal with this aggregate imbalance using all the physical flexibility tools available. A role for the TSO is crucial under this respect, and many different solutions can be envisaged. The TSO may play as a coordinator, leaving the balancing actions to private operators, or it can take a

[16] According to the Agency for Cooperation of Energy Regulators (ACER)'s definition, the European GTM is a structural framework that sets out how a European market for gas should emerge. In particular, the market envisaged within this framework will consist of interconnected entry–exit zones with virtual hubs. The process to obtain such results entails the creation of market rules that enable gas markets to become more integrated, competitive, sustainable and secure.

[17] Specifically, the Gas Regulation requires the European Network of Transmission System Operators for Gas (ENTSOG) to submit to the European Commission the Network Code on balancing based on the ACER Framework Guidelines on Gas Balancing in Transmission Systems, published in October 2011.

[18] "*To enhance competition through liquid wholesale markets for gas, it is vital that gas can be traded independently of its location in the system. The only way to do this is to give network users the freedom to book entry and exit capacity independently, thereby creating gas transport through zones instead of along contractual paths. The preference for entry–exit systems to facilitate the development of competition was already expressed by most stakeholders at the 6th Madrid Forum on 30 and 31 October 2002*" European Union (2009), Recital 19.

[19] Article 18 of the Gas Regulation requires the TSO to make public detailed information regarding the services they offer according to the network code. All appropriate information on capacities at all relevant entry and exit points on the grid and on supply and demand of natural gas based on the nominations received by market participants both ex-ante and ex-post; actual and estimated future flows of natural gas in and out of the system. Second, within the same Regulation, Article 19 imposes similar transparency requirements on storage and LNG facilities operators and the obligation to publish information regarding the volumes of gas in each single or group of storage facilities, the volumes within LNG facilities, the available storage and LNG capacities and the relative inflows and outflows of natural gas (European Union, 2009).

[20] Sometimes it is referred also to as "*pre-trade transparency*" since it is often delivered prior trading occurs. Nonetheless, fundamental data transparency within this paper refers to all "physical data" related to the natural gas market and which can be distinguished from pure financial data and information.

more active role into the trades.

Since any individual imbalance that is not cleared by the operators requires the TSO to intervene, purchasing or selling gas from other agents, either on the wholesale market or relying on external subjects and sources as the storage facilities, production swings or line-pack deals, these interventions are costly to the system. The incentives provided to the operators to induce them to clear their individual imbalances, therefore, should be based on these avoided costs, i.e. they have to be market based. Moreover, the responsibility for balancing the transmission system has to be shared between shippers and the TSO, with the network users taking primary responsibility for balancing their inputs against their off-takes from the relevant *balancing zone* and within a given *balancing period* through the use of the *short-term wholesale gas market.*

In a daily balancing setting, for instance, at the end of each day (so called *Gas Day*), for any residual deviation between gas injections and withdrawals, shippers incur *imbalance charges* for the imbalanced volumes accumulated throughout the day in a given balancing zone, and not timely compensated. These charges are designed to incentivize shippers to keep their positions balanced (to minimize their residual deviations) and have to be cost-reflective (i.e. reflect the actual costs incurred by the TSO to balance the system). The TSO has only a residual role in balancing, to assure that from a physical point of view the system is kept within safe operational limits. The TSO can engage in trading on the wholesale market (what are called usually *balancing actions*), or recurring to contracts with third parties to supply natural gas (the so called *balancing services*).

4.1.1. Balancing regimes: country experiences

United Kingdom. Following the wave of liberalizations in the 80s and 90s, and the subsequent entry of many firms in a once monopolistic market, controlling gas flow and balance into the *British* gas pipelines became challenging. The solution identified by the energy regulators and policymakers was to introduce a mechanism coherent with market liberalization, in which every economic agent would be responsible for its own balancing. Shippers were entitled to participate in an auction, offering on a daily basis for balancing purposes all of the gas not previously allocated. This system, called *Flexibility mechanism* heavily relied on the physical balancing tools available in the country. In the space of only few years, the NBP worked so well that shippers began to exchange gas for trading purposes and not only for balancing (second sourcing phase). In 1999, the *New Gas Trading Arrangements* NGTA has replaced the flexibility mechanism. The new regime is characterized by more reliance on market-based tools for balancing, in order to improve prices as signals of demand/supply conditions and to reduce the cost of balancing[21]. Operators have incentives to clear their positions, with the TSO (National Grid) balancing only residually the system at a price related to the System Average Price (SAP), which results from transactions on the On-the-day Commodity Market (OCM) managed by ICE-Endex. Nowadays, all the gas consumed in the UK passes through NBP. Players in NBP are primarily gas shippers, but there are also producers, power generators and financial institutions. The British system has somehow served as a paradigm for the EU balancing markets reform. In short, the reasons for its success are based on the following reasons: flexibility offered by the daily balancing regime and balancing prices that discourage individual unbalances.[22]

The Netherlands: The Dutch TSO, Gas Transport Services B.V. (GTS) introduced an entry-exit capacity system and a virtual trading point in 2004. However trades were limited until 2011, when a “new market model” (in Dutch, *Nieuw marktmodel*) has been introduced. Since April 2011 the Title Transfer Facility (TTF), the Dutch virtual trading point, has become the central trading point for all natural gas in the Dutch transmission system and a new balancing regime has been put in place. With the new balancing regime every market party is responsible for keeping its own portfolio balanced through buying and selling gas on the TTF, according to daily system with hourly adjustments. Balancing prices use a system of penalty and reward for, respectively, operators which cause imbalances and operators which help overcoming them.

Germany: Germany started wholesale gas trading in 2002, with the creation of the Bunde-Oude hub on the Dutch/German border, but difficulties in obtaining third-party access to pipelines and the complex network ownership situation caused trading activity at Bunde to have little impact on the whole volumes of transactions. In July 2005 the new German Energy Law, Energiewirtschaftsgesetz (EnWG), came into force to comply with EU legislation and market rules in Germany changed towards a non-discriminatory network access based on an entry-exit system. Germany was initially divided into 19 entry-exit zones, called “Marktgebiete”, i.e. “market areas”; at the end of 2008 the areas were reduced to 12 and now they are three, two for H-gas, NetConnect Germany (NCG) and Gaspool, and one for L-gas. The German regulator BNetzA strongly encouraged this process, requiring the TSOs to reduce the market areas for L-gas to one and for H-gas to two by April 1, 2011 (BnetzA, 2011). NCG now covers the South and West of Germany while Gaspool is located in the northern part of Germany, being responsible for balancing within their market area. In contrast with the rest of the EU countries, Germany has 14 Transmission System Operators[23], divided in two large groups corresponding to the NCG or Gaspool areas. They all chose the form of the independent transmission operator (ITO)[24], and most of them are subsidiaries of gas suppliers or large energy groups. The basic system currently in place for balancing is based on the “GABi Gas“ model[25]. However, this system is experiencing a series of profound changes. EEX reference prices are the new basis for calculating compensation energy, instead of the method originally entailed in GABi (Germany Energy Blog, 2011). In the first half of 2014 BNetzA has started the consultations to reform the system according to the EU network code within 2015.

Italy: Starting from December 1st 2011 Italy implemented a new balancing system with the aim of gradually introducing market-based balancing rules. The new balancing system entailed the creation of a balancing platform (PB-Gas), organized and operated by the GME (*Gestore Mercati Energetici*) on behalf of Snam Rete Gas, which is the sole counterpart of the transactions of the PB-Gas and is ultimately responsible for the overall physical balancing of the Italian gas system, guaranteeing the system integrity and security of supply. The PB-Gas is organized as a daily auction (*Comparto G+1*), in which authorized players have to submit daily

[21] For an accurate description of the evolution of the British gas wholesale market see Heather (2010).

[22] A discussion of the different possible balancing regimes goes beyond the scope of this paper. A brief description of the main differences in the balancing regimes of the countries we analyzed is offered in the Appendix B. A synthesis of their main characteristics is summarized in the last column of Table 3.

[23] As reported in the ENTSO-G member list.

[24] Following EU's Third Energy Package (2009) requirement of the separation of production from transmission (unbundling), every TSO had to choose among three models with different degrees of separation: ISO (Independent System Operator); ITO (Independent Transmission Operator) and OU (Ownership Unbundling).The strongest form of unbundling is ownership unbundling (e.g. Snam Rete Gas in Italy).

[25] Grundmodell der Ausgleichsleistungs- und Bilanzierungsregeln im Gassektor, implemented in May 2008.

Table 3
Propositions, indicators and main results.[a]

Prediction	Characteristic	Indicator	Formulation	Results
Prediction 1	Trading development, Liquidity	Number of operators		Increasing number of operators for all countries.[b]
		CR – Churn Ratio	Volumes traded/Physical deliveries	For all countries, improving CR after market reforms for balancing and entry-exit.
		GCR – Gross Churn Ratio	Demand/Physical deliveries	For all countries, improving GCR after market reforms for balancing and entry-exit.
		AI – availability index	Physical deliveries/Demand	Except for the UK, which can be considered a mature market, increasing AI for all countries after market reforms.
Prediction 2	Market design	Balancing rules		– *UK*: daily balancing, fully market-based. Balancing prices are structured in order to discourage unbalances. – *Netherlands*: daily balancing with hourly adjustments. Balancing prices use a system of penalty and reward for, respectively, operators which cause unbalances and operators which help overcoming unbalances. – *Germany*: daily balancing, not completely market-based, linked to the physical procurement of gas by the system operator. Prices are computed in order to discourage unbalances. – *Italy*: daily auction of storage capacities, in order to allow physical procurement of gas by the system operator. There is no price incentive for operators.
		Entry–Exit		All countries implemented the system.
		Transparency		All countries provide open information for all parties, but there is room for improvement.
Prediction 3	Market integration	Widening of market areas		Germany is still divided in two market areas.
Prediction 4	Resource availability	SSI – self-sufficiency indicator	Production/Demand	Countries with a higher SSI tend to develop more liquid markets.
		IDI – import dependence index	Import/Demand	Countries with a lower IDI tend to develop more liquid markets
Prediction 5	Financial instruments	Volumes of forward trades		Only the UK has a fully developed forward market.

[a] Data for the number of operators have been derived from National Grid, Gas Transport Services, NCG, Gaspool and AEEGSI websites.
[b] To avoid too many figures only data for Italy are displayed (see Fig. 7).

demand bids and supply offers for the storage resources available to balance the system. Indeed, in Italy, as in Germany, storage facilities are the main physical flexibility tool available to balance the system. Likewise, Snam Rete Gas-as balancing operator-submits demand bids and supply offers for a volume of gas corresponding to the overall imbalance of the system, to procure the resources offered by participants and needed to keep the gas system balanced. Another section of the PB-Gas (*Comparto G-1*) has been introduced in order to widen the flexibility tools available for the balancing of the system. This new, day ahead market has been scarcely used so far and storage still represents the major flexibility tool available to Snam Rete Gas to physically balance the system along with the availability of line-pack in the national pipeline grid[26].

4.1.2. Rules for transparency

Regarding market transparency, all the countries that we study provide sufficient information and support to market operators, in order to help them taking part in the balancing and trading on the gas markets platforms. In Germany, where there are two market areas, operators (especially foreigners) have to bear the additional cost of learning two mechanisms, and of bearing some (small) degree of uncertainty regarding the cost of the services. With the perspective of an integrated European market, harmonizing the measurement units used across all the different hubs could improve market transparency and comparability of the figures across hubs. Furthermore, there is sometimes lack of information on the conversion factors and on the exact content of the figures reported (e.g. there is sometimes no clear distinction between physical and nominated volumes).

4.2. Liquidity and the development of trading

Table 2 describes the liquidity indicators shown in this section. Although widely considered the most liquid European gas market, over the years the British *NBP* is increasingly facing competition by the Dutch TTF, which is rapidly taking the lead in gas market transactions, at least in the OTC segment (Fig. 2). Fig. 3 shows liquidity indicators related to NBP.

TTF development has been initially sluggish due to lack of import infrastructure and storage facilities, and due to a poor utilization of the transport infrastructure, problems with quality conversion, low transparency and an outdated balancing regime (NMA, 2007). The elimination of the two types of gas quality traded at the TTF (H-gas and L-gas) in 2009 represented a positive change and the new rules for balancing have completed the restructuring of the market[27]. Nowadays, after NBP, TTF is the most developed hub in Europe, and it serves as a reference market for Continental Europe. As can be noted from Fig. 4, the churn ratio and traded volumes show an increasing tendency.

The positive evolution of the German market can be appreciated in the performance of volume-based liquidity indicators of its two hubs, *NCG* and *Gaspool*, particularly the traded volumes (Fig. 5)[28]. Germany is updating its regulation and trying to improve its balancing mechanism. The significant reforms, with the reduction in the number of market areas and the new rules for

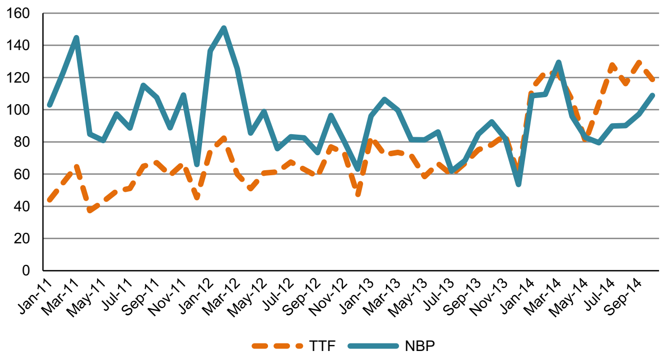

Fig. 2. Traded volumes (spot market only) comparison for NBP and TTF. Figures in bcm (*billion cubic meters*). Data sources: Gasunie, National Grid and LEBA.

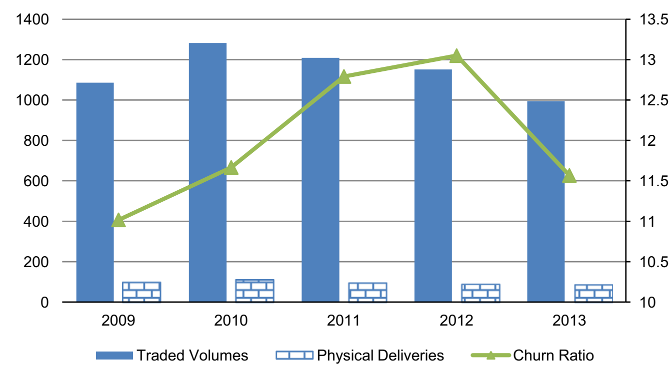

Fig. 3. Liquidity indicators for NBP. Data source: authors' elaboration on National Grid and LEBA data. Figures on the 1st *y*-axis are expressed in bcm. Numbers on the 2nd *y*-axis refer to the churn ratio.

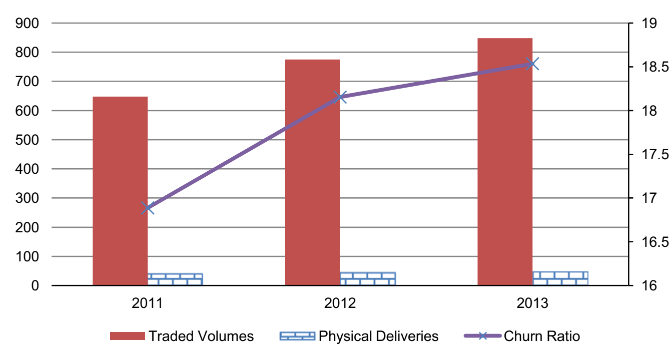

Fig. 4. Liquidity indicators for TTF. Data source: authors' elaboration on Gasunie and LEBA data. Figures on the 1st *y*-axis are expressed in bcm. Numbers on the 2nd *y*-axis refer to the churn ratio.

market-based balancing, are bringing good results. At first the NCG hub seemed the most promising one, but trading volumes and other liquidity indicators of the two German hubs are now converging.

The Italian virtual hub is PSV (*Punto di Scambio Virtuale*). Natural gas is traded on the PSV principally over-the-counter, while the gas exchange is not yet fully developed, in spite of being in function since October 2010. PSV is managed by the system operator Snam Rete Gas, while the energy exchange operator GME organizes and manages the gas exchanges[29]. The implementation of the balancing platform PB-Gas has been extremely beneficial both for liquidity and for the number of market operators

[26] For further details on the balancing systems in the mentioned countries, refer to Dickx et al. (2014).

[27] Before 2009, shippers had to reserve quality conversion capacity with GTS to convert H-gas to L-gas for supplying end-consumers, and this created a barrier to entry to other shippers and was detrimental to the development of the TTF. Following the amendment to the Gas Act, quality conversion is now part of GTS's system services with cost being socialized over all entry and exit points on the grid.

[28] We added up data for NCG and Gaspool in order to get an estimate of the total volumes traded and delivered within the German area.

[29] There are three main exchange platforms: M-Gas, P-Gas and PB-Gas, each with a different function. For a more detailed explanation see Dickx et al. (2014).

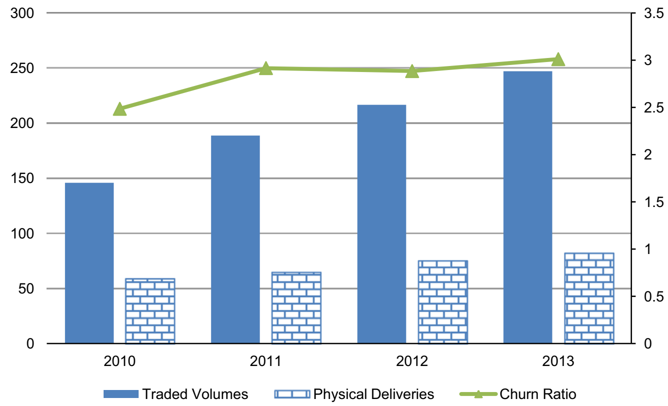

Fig. 5. Liquidity indicators for Germany hubs. Data source: authors' elaboration on NetConnect Germany and Gaspool data. Figures on the 1st *y*-axis are expressed in bcm. Numbers on the 2nd *y*-axis refer to the churn ratio.

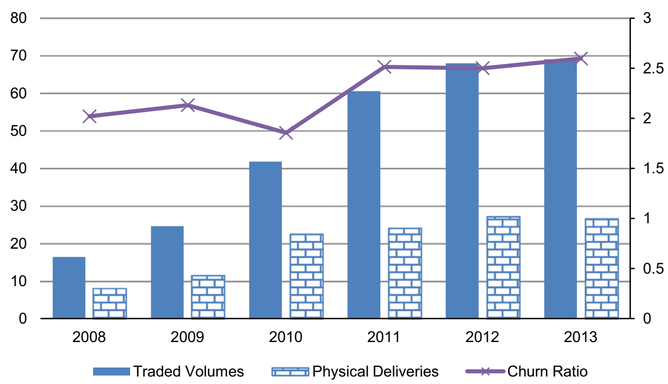

Fig. 6. Liquidity indicators for PSV. Data source: authors' elaboration on Snam Rete Gas data. Figures on the 1st *y*-axis are expressed in bcm. Numbers on the 2nd *y*-axis refer to the churn ratio.

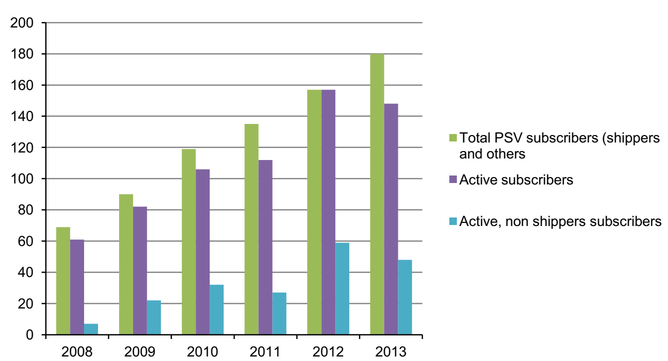

Fig. 7. Number of operators at PSV. Data source: AEEGSI (Autorità per l'Energia Elettrica, il Gas e il Sistema Idrico).

(see Figs. 6 and 7). PSV has considerably grown its volumes traded with respect to previous years.

Although we observe an increase in liquidity indicators in all four countries, the British and Dutch hubs display much larger volumes than the German and the Italian ones, despite the large amount of gas consumption in these latter countries.

4.3. *The importance of countries' endowment*

As already remarked, resource availability is a matter of chance: a country either has or does not have gas, and its geographical position is also crucial to build adequate infrastructures. Resource availability has important implications for the development of gas trading, as with internal production supply is more flexible: production swings can modulate variations in demand and the proximity to wholesale markets allows domestic producer to exploit more easily trade opportunities.

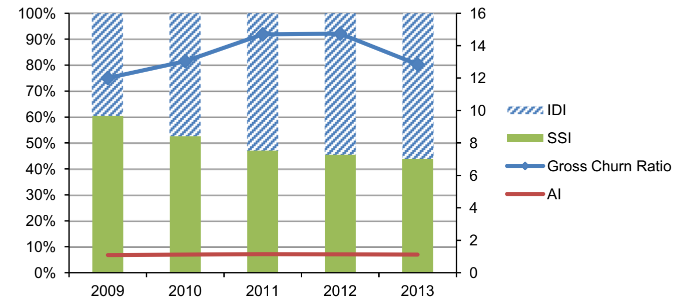

Fig. 8. UK resource availability indicators. Data sources: authors' elaboration on IEA and National Grid data. Left *y*-axis refers to bars, while right *y*-axis refers to lines.

The self-sufficiency indicator (SSI) interpretation is straightforward: it is a measure of the ability of a country to produce enough gas for internal consumption and for export. A complementary measure, very often used in gas markets analyses, is the import dependence index (IDI). From Prediction 4, we expect that countries with a higher SSI-and a lower IDI-will higher traded volumes in the wholesale market.

To measure the relevance of gas hubs in a national gas system we use the availability index (AI). It is the ratio between the volume of gas physically delivered within the hub and total consumption in the area. The AI is a measure of the importance of wholesale trade with respect to total consumption, and allows appreciating the role of the hub within the national gas system. We can consider a gas hub as a relevant market venue when a high liquidity is twined with a substantial part of the gas consumed being traded in the hub. The indexes computed for each countries are reported in figures from Figs 8–11.

The SSI show that the UK and the Netherlands have an initial endowment advantage with respect to Germany and Italy, although the British advantage is declining. Domestic production, indeed, peaked in the year 2000 and the UK became a net importer of gas at the end of 2004. The Netherlands is a main producer and exporter of natural gas in Europe. Production coming from the Groningen field, although decreasing, is sufficient to cover internal gas demand and to export to neighboring countries. Conversely, Germany is the largest gas user in Europe and relies on imports. Italy is the fourth importer of gas worldwide and it can rely on a well-developed transmission network to receive gas from abroad. Domestic production of natural gas has been constantly declining since the 90s. As a consequence, imports have steadily acquired importance and amount nowadays to approximately 90% of gas consumption.

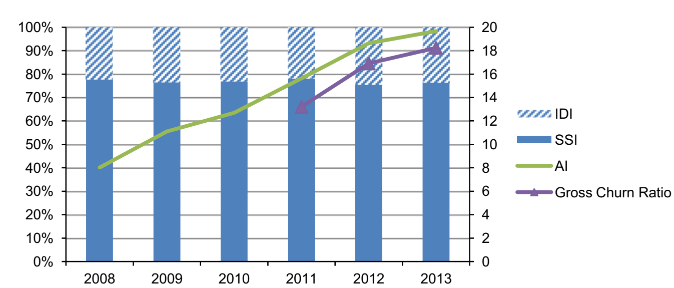

Fig. 9. Netherlands resource availability indicators. Data sources: authors' elaboration on IEA, Gasunie and LEBA data. Left *y*-axis refers to bars, while right *y*-axis refers to lines.

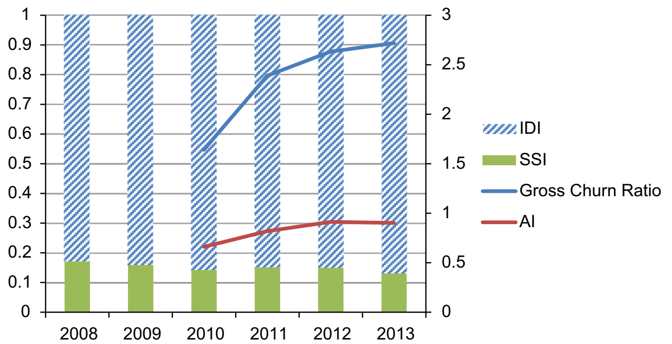

Fig. 10. Germany resource availability indicators. Data sources: authors' elaboration on IEA, NetConnect Germany and Gaspool data. Left *y*-axis refers to bars, while right *y*-axis refers to lines.

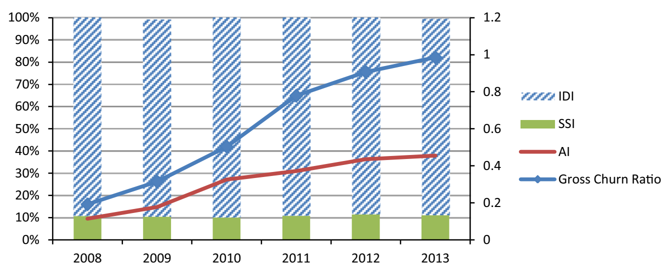

Fig. 11. Italy resource availability indicators. Data sources: authors' elaboration on IEA and Snam Rete Gas data. Left *y*-axis refers to bars, while right *y*-axis refers to lines.

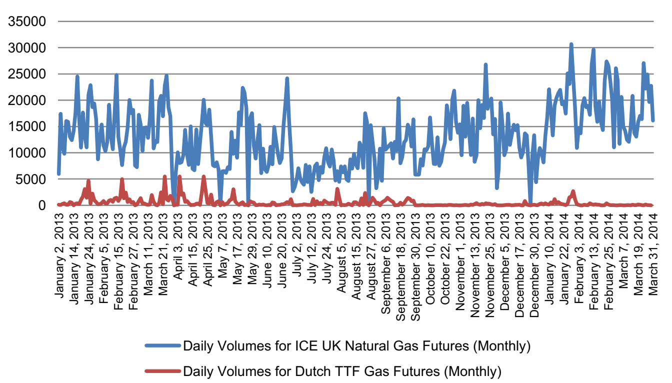

Fig. 12. Futures contract comparison (NBP vs TTF) on the ICE platform. Number of contracts, 1 month. Data source: ICE market data.

5. Conclusion and policy implications

Wholesale gas trading has been a consequence of market liberalization. Not by chance, the first country introducing a wholesale market has been the UK, which is also the first European country that liberalized its energy markets. In this paper we identified a pattern of development, that is well-suited to describe the evolution of European markets. The UK gas system and the NBP offer clear evidence of these three steps in the evolution and maturity of a wholesale gas market. NBP started as a balancing platform, then becoming a second source of gas provision in parallel with long term contracts, and finally developing a market for financial instruments to hedge price risk (Predictions 1, 2, 3 and 5).

In a progressively fragmented market, operators needed to balance their positions through trade rather than internal adjustment within their portfolios of contracts, giving impulse to the creation of the NBP and the adoption of the Flexibility Mechanism.

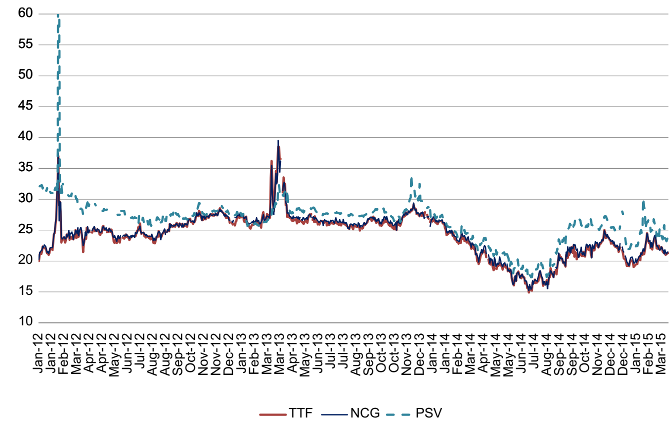

Fig. 13. Reference prices at selected Continental hubs (in €/MWh). Data source: Bloomberg.

In a few years, NBP has transformed from a simple balancing platform to a gas trading point, where shippers can purchase and sell gas for sourcing purposes, and not merely for balancing. The UK has further developed a wide range of financial instruments for hedging the price risk (Alterman, 2012), traded on different platforms but mainly on the ICE (International Commodity Exchange).

Following EU requirements and guidelines, all the countries considered in this study introduced an entry-exit system for natural gas transmission and accessible data to market operators, although some work needs to be done in harmonizing the contents, measurement units and conversion factors. The rules for balancing and the design of the market are still slightly different across countries. Although the differences appear to be small, they may have a big impact on market development. Table 3 offers a synthesis of the main results stemmed from the framework we built.

TTF has begun only recently its race to become the reference hub for Continental Europe, but thanks to gas availability in the Netherlands, an appropriate market regulation and a strong push from the Government, it is nowadays closing the gap with NBP, at least in terms of spot traded volumes. In particular, as discussed above and in line with prediction 2, what has favored TTF development has been the provision of a balancing system that works and encourages trade. Nonetheless, TTF does not yet compete with NBP in terms of financial trading. Instruments available for hedging at TTF are not as wide as for NBP, even though TTF titles are listed on all the main European energy exchanges, and the volumes of financial instruments exchanged, although increasing, are still far below those of NBP. This evidence – see Fig. 12-seems consistent with our prediction 5, that concentration in financial instruments in a few, or a single, security exchanges may replicate an analogous tendency to concentration that we observe in security markets.

Looking at Germany, the initial fragmentation into 19 market areas has likely slowed down the development of liquidity. The reduction in the number of market areas and the convergence to a two-areas system has favored the increase in liquidity, as predicted. Furthermore, the German system is still under revision, and it might be difficult to predict if new rules will be implemented to complete the passage to a sourcing platform. Germany's gas trading mainly occurs on the EEX (European Energy Exchange), where some futures contracts are available for operators.

Italy, rather than creating a balancing platform, has initially tried to create an OTC market on the PSV and an exchange to encourage trading and second sourcing. The performance in terms of volumes traded, however, has been not encouraging in this first implementation. Volumes and market liquidity seem to have

Table A1
Demand shocks, within portfolio adjustments and wholesale trade.

Mkt structures	A(1,2,3,4)		A(1,2) B(3,4)		A(1,2,3) B(4)		A(1,2) B(3) C(4)		A(1) B(2) C(3) D(4)		
Shocks	P.A.	W.T.	P.A.	W.T.	P.A	W.T.	P.A	W.T.	P.A	W.T.	E.A.
$(-\varepsilon/4, -\varepsilon/4, -\varepsilon/4, -\varepsilon/4)$	0	0	0	0	0	0	0	0	0	0	$-\varepsilon$
$(-\varepsilon/4, -\varepsilon/4, -\varepsilon/4, \varepsilon/4)$	$\varepsilon/4$	0	$\varepsilon/4$	0	0	$\varepsilon/4$	0	$\varepsilon/4$	0	$\varepsilon/4$	$-\varepsilon/2$
$(-\varepsilon/4, -\varepsilon/4, \varepsilon/4, -\varepsilon/4)$	$\varepsilon/4$	0	$\varepsilon/4$	0	$\varepsilon/4$	0	0	$\varepsilon/4$	0	$\varepsilon/4$	$-\varepsilon/2$
$(-\varepsilon/4, \varepsilon/4, -\varepsilon/4, -\varepsilon/4)$	$\varepsilon/4$	0	$\varepsilon/4$	0	$\varepsilon/4$	0	$\varepsilon/4$	0	0	$\varepsilon/4$	$-\varepsilon/2$
$(\varepsilon/4, -\varepsilon/4, -\varepsilon/4, -\varepsilon/4)$	$\varepsilon/4$	0	$\varepsilon/4$	0	$\varepsilon/4$	0	$\varepsilon/4$	0	0	$\varepsilon/4$	$-\varepsilon/2$
$(-\varepsilon/4, -\varepsilon/4, \varepsilon/4, \varepsilon/4)$	$\varepsilon/2$	0	0	$\varepsilon/2$	$\varepsilon/4$	$\varepsilon/4$	0	$\varepsilon/2$	0	$\varepsilon/2$	0
$(-\varepsilon/4, \varepsilon/4, -\varepsilon/4, \varepsilon/4)$	$\varepsilon/2$	0	$\varepsilon/2$	0	$\varepsilon/4$	$\varepsilon/4$	$\varepsilon/4$	$\varepsilon/4$	0	$\varepsilon/2$	0
$(\varepsilon/4, -\varepsilon/4, \varepsilon/4, -\varepsilon/4)$	$\varepsilon/2$	0	$\varepsilon/2$	0	$\varepsilon/4$	$\varepsilon/4$	$\varepsilon/4$	$\varepsilon/4$	0	$\varepsilon/2$	0
$(\varepsilon/4, \varepsilon/4, -\varepsilon/4, -\varepsilon/4)$	$\varepsilon/2$	0	0	$\varepsilon/2$	$\varepsilon/4$	$\varepsilon/4$	0	$\varepsilon/2$	0	$\varepsilon/2$	0
$(-\varepsilon/4, \varepsilon/4, \varepsilon/4, -\varepsilon/4)$	$\varepsilon/2$	0	$\varepsilon/2$	0	$\varepsilon/4$	$\varepsilon/4$	$\varepsilon/4$	$\varepsilon/4$	0	$\varepsilon/2$	0
$(\varepsilon/4, -\varepsilon/4, -\varepsilon/4, \varepsilon/4)$	$\varepsilon/2$	0	$\varepsilon/2$	0	$\varepsilon/4$	$\varepsilon/4$	$\varepsilon/4$	$\varepsilon/4$	0	$\varepsilon/2$	0
$(\varepsilon/4, \varepsilon/4, \varepsilon/4, \varepsilon/4)$	$\varepsilon/4$	0	$\varepsilon/4$	0	0	$\varepsilon/4$	0	$\varepsilon/4$	0	$\varepsilon/4$	$\varepsilon/2$
$(\varepsilon/4, \varepsilon/4, -\varepsilon/4, \varepsilon/4)$	$\varepsilon/4$	0	$\varepsilon/4$	0	$\varepsilon/4$	0	0	$\varepsilon/4$	0	$\varepsilon/4$	$\varepsilon/2$
$(\varepsilon/4, -\varepsilon/4, \varepsilon/4, \varepsilon/4)$	$\varepsilon/4$	0	$\varepsilon/4$	0	$\varepsilon/4$	0	$\varepsilon/4$	0	0	$\varepsilon/4$	$\varepsilon/2$
$(-\varepsilon/4, \varepsilon/4, \varepsilon/4, \varepsilon/4)$	$\varepsilon/4$	0	$\varepsilon/4$	0	$\varepsilon/4$	0	$\varepsilon/4$	0	0	$\varepsilon/4$	$\varepsilon/2$
$(\varepsilon/4, \varepsilon/4, \varepsilon/4, \varepsilon/4)$	0	0	0	0	0	0	0	0	0	0	ε
Average	$5\varepsilon/16$	0	$4\varepsilon/16$	$\varepsilon/16$	$3\varepsilon/16$	$2\varepsilon/16$	$2\varepsilon/16$	$3\varepsilon/16$	0	$5\varepsilon/16$	$5\varepsilon/16$

P.A.: Portfolio adjustment
W.T.: Wholesale trade
E.A.; External adjustment.

received a decisive boost once the rules for balancing through the PB-gas have been set, restoring the rational sequence of steps that we identified. Interestingly, the volumes traded at the old exchanges have fallen to zero after the PB-gas has started, suggesting that operators are more willing to trade on the balancing platform[30], in order to exploit the opportunities associated with a large number of operators while adjusting their portfolio of transactions. The country has limited instruments for hedging; a physical forward market has been implemented on the GME platform, but it is not yet fully functioning.

Finally, our results show that the importance of wholesale gas markets does not depend on the absolute size of a country's gas consumption, whereas it seems more related to the structure of supply, highlighting the importance of domestic production with respect to a supply more constrained by imports through long-term contracts. In the UK and the Netherlands the spot wholesale gas markets plays a central role in the overall transactions of gas. Germany and Italy, on the other hand, although recording the largest gas consumptions in our sample, are trading in their hubs a small fraction of the overall gas, that for the most part is bought through long term contracts.

The positive performances in liquidity of the European gas hubs considered suggest that the policy and regulatory measures of the Gas Target Model and their implementation in the member countries have proven effective. A better interconnection among National Gas Systems, in turn, has pushed gas prices towards a significant convergence, as Fig. 13 and several studies show. Italy, for example, has benefitted from effective rules for cross border transmission capacity allocation. The PSV price, which has been for years divergent with respect to the level of the other European hubs, started converging in the last part of 2012 to the trend of the other Continental countries, although it is still slightly higher.

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Appendix A.

See Table A1

Appendix B. Balancing systems

UK: The New Gas Trading Arrangements (NGTA) has been introduced also to reduce the cost of balancing and to create incentives on the operators to clear their positions, by making the TSO (National Grid) balancing residually the system at a price related to the System Average Price (SAP). Rules on balancing are established via a Uniform Network Code which is published and managed by the Joint Office of Gas Transporters. The main market instrument to acquire the resources for balancing is the On-the-day Commodity Market (OCM). OCM is a platform of continuous and anonymous exchange managed 24/7 by ICE-Endex. Exchanges can either refer to the virtual point (NBP), or be physical exchanges related to precise locations in the network. The price set on the OCM is used as a reference for the SAP; afterwards, the System Marginal Buy Price (SMBP) and the System Marginal Sell Price (SMSP) are computed. The SMBP is the price paid for gas in case of a negative imbalance, and the SMSP is the price paid in case of a positive imbalance. In the former case, the Code states that the price paid by the shipper to the System Operator (SMBP) must be the highest between the System Average Price plus 0.0287 pence/kWh and the highest balancing action offer price in relation to a market balancing action taken for that day. Otherwise, if the imbalance is positive, i.e. the TSO has to buy gas from the shipper, the SMSP is the lowest between the System Average Price less 0.0324 pence/kWh and the lowest balancing action offer price in relation to a market balancing action taken for that day.

Netherlands: With the new market model introduced from April 1st, 2011 the TTF has become the central trading point for all natural gas in the Dutch transmission system and a new balancing regime has been introduced. Every market party is responsible for keeping its own portfolio balanced through buying and selling gas on the TTF. Every day all shippers send in their entry, exits and

[30] It is worth recalling that the participation to the balancing platform is mandatory for all the operators with available storage capacity.

trading plans for the day ahead by using a so-called *damping formula*. Based upon almost real time information about the single portfolio positions of shippers GTS publishes the Program Imbalance Signal (POS) which is the accumulated balancing position of every participant. Thereafter by summing up the individual POSs, GTS calculates and publishes the System Balance Signal (SBS). A system imbalance occurs when the SBS deviates from zero, scoring either a shortfall in gas supply (negative imbalance) or an excess of gas (positive imbalance). Given the figures of the SBS, GTS publishes also the POSs of the helpers (operators with POS of the opposite sign of the SBS) and the causers (operators with POSs with the same sign of the SBS) of the SBS. When the SBS deviates from a certain threshold, a market based correction mechanism called the Bid Price Ladder (BPL), comes into action: GTS will buy or sell gas on the BPL if respectively the system is short or long.

The damping formula to be computed by the shippers constitutes an ex-ante, short-term and individual device that contributes to system balancing. Through this formula provided by GTS, shippers reduce and delay their hourly entry flows. On a daily basis the sum of all hourly entries and sum of all exits must be equal, but on an hourly basis entry and exit may not balance exactly. The damping formula is used to adjust shippers' short term individual position according to the daily congestion of network capacity. The formula has two parameters, alpha and beta, which are adjusted every day. The alpha parameter is used to maximize the amount of line-pack available every day. By changing the beta parameter, the intention is to make entry flatter and smoothly distributed during the day. In case of system imbalances shippers can support the TSO in balancing the system by making offers or bids for gas to GTS on the Bid Price Ladder and GTS will buy/sell at the marginal price (buy or sell). The accumulated volume of the helpers is bought or sold at the marginal price and their balances are restored (i.e. POS restored to zero) whereas a pro-rata of the involved volumes of gas will be allocated to the POS of the causers.

Germany: GASPOOL and NCG are the responsible for balancing within their market area. Operators may be part of so-called balancing groups, within one of the two market areas. The basic balancing system in Germany operates on a daily basis. The relevant volumes for balancing are the nominated hourly volumes at the entry and exit points of market areas, border points, connection points to storage and virtual trading points. Trading partners who have a balancing group at their disposal in the GASPOOL or NCG market area can conduct trading transactions at one of the two hubs. Sellers and buyers nominate the volume of gas from their balancing group for a determined period; the balancing operators facilitate matching of offers, and in the event of a mismatch, the lower of the two values in a transaction is allocated.

The responsible for balancing carries on two sets of operations: the physical procurement of gas for balancing purposes (so called "control energy"), and the allocation of all or part of such energy to balance the system differences between in-takes and off-takes of each balancing group account. There are two types of control energy products: commodity and flexibility products. Commodity products consist in the purchase and selling of gas quantities for medium-long term balancing actions in the market area. The two commodity products available are "Day-Ahead", which can be used for one gas day only, and "Long-Term", which can be offered for one or more gas days. For each gas day, all of the control energy contracts are stacked in a merit order list according to the price offered, which determines their call-off by the balancing operator, prepared for each gas quality (H-Gas or L-Gas). Flexibility products refer instead to short-term balancing services, and consist in delivery ("parking") or acceptance ("borrowing") of quantities of gas in the market area, kept in a gas account. The positive/negative account balances can be equalized at any time, and must be equalized at the latest by the end of the contract period. The prices for balancing gas are computed based on the day-ahead reference price published on EEX and ICE-Endex (Gabigas). Group network operator shall pay a charge amounting to the second lowest selling price among the reference prices Gaspool's One Day-Ahead Settlement Price, NCG'S One Day-Ahead Settlement Price, TTF or Zeebrugge, multiplied by 0.9 to the balancing group manager, in case of negative balancing energy. In case of positive balancing energy, the balancing group manager shall pay a charge amounting to the second highest purchasing price of the reference prices abovementioned, multiplied by 1.2 to the balancing group network.

Italy: The Italian balancing platform is the PB-Gas (Piattaforma del Bilanciamento). The PB-Gas is organized as a daily auction, in which authorized players have to submit daily demand bids and supply offers for the storage resources that they have available. Likewise, Snam Rete Gas may-as balancing operator-submit demand bids and supply offers for a volume of gas corresponding to the overall imbalance of the system, with a view to procuring the resources offered by participants and needed to keep the gas system balanced.

From an operational point of view, starting from the fourth gas-day preceding the gas-day to which bids/offer refer (D-4), market parties have the obligation to make offers on the PB-GAS to increase (or decrease) the injected or withdrawn quantities of gas from the storage facilities connected to the Italian grid with the aim of keeping their own portfolio balanced and to contribute to the system's overall balance. Snam Rete Gas on the day following the gas day to which bids and offers refer (D+1) makes an offer corresponding to the total system imbalance (SBS, Sbilanciamento Complessivo del Sistema) which is calculated as the difference between the shippers' programs and the actual gas withdrawn or injected at the storage facilities. Bids and offers on the PB-GAS are selected on a daily basis through an auction mechanism; bids are stacked on a merit order up to the point where the SBS is covered. Finally imbalances are cashed out at a balancing market price, where the price is cost reflective of the price paid by Snam Rete Gas to procure balancing resources and corresponds to the price of the last accepted offer.

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