The Development of Gas Hubs in Europe[1]

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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.

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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?

The successful development of a liquid wholesale gas market requires designing a proper set of rules and mechanisms addressing several issues, including the definition of a transmission

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system model, the design of the balancing rules and the set-up of transparency requirements. The specific solutions, however, may depend also on the different physical flexibility tools available in the national gas systems.

We argue that gas transactions are originally motivated by balancing needs to clear individual portfolios in a liberalized and fragmented market. As wholesale trade develops, gas hubs may represent a second source of gas provision in parallel with long-term contracts. Moreover, the availability of gas supply not constrained by long-term contract obligations is larger where domestic gas production plays an important role in the overall supply to the system. Hence, we expect that national gas hubs develop in each country, with a more dynamic process in the gas systems where local production is significant compared with long-term import contracts. Conversely, financial instruments may be traded even in market venues that are far away from the location of physical trades, and 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, Netherlands and the UK[2], 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 are receiving increasing attention, a comprehensive analysis of the development of wholesale gas markets in Europe and of the regulatory issues involved 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 analyses the balancing system in the UK and Germany and Kayaerts 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 integration. 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. 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. 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 the rules set by each country's regulator.

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

The contribution of this paper is threefold. First, we review synthetically the EU regulation on wholesale gas markets and the balancing regimes adopted by four countries; second, we build an analytical framework to study the balancing issue and the related development of European hubs; 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 section 6 concludes.

2. Balancing and the development of wholesale transactions

With the progresses of gas market liberalization, gas systems move from a monopolistic to a more fragmented environment. In the former, the same 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 small fraction of the aggregate traded gas volumes, increasing the fraction of shocks that cannot be cleared within individual portfolios and the number of associated imbalances. Wholesale trade, then, offers a way to clear individual positions, easing the need to keep the gas system physically balanced between aggregate 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, tends to develop naturally, as long as market rules are set to help developing wholesale trade.

2.1 The balancing issue

Natural gas flows in the transmission system 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*.[3] It is therefore crucial to design a balancing system that ensures that pressure in the system remains within safe operational limits.[4]

[3] From Keyaerts et al. (p.2, 2008) "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*".

[4] The sources of inflows in the system 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 gas transmission

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 gas transmission system (GTS) depend on a large set of demand and supply decisions by different agents, and reflect their underlying choices and unexpected shocks: inflows to meet demand requirements may experience unforeseen stops, and demand by final users typically displays random ex-post adjustments. Supply and demand shocks, therefore, may create imbalances between realized inflows and outflows as compared to the planned and contracted flows based on the ex-ante decisions of the agents involved.

In order to keep the GTS balanced, i.e. with the pressure into the system within given safety boundaries, the difference of inflows and outflows, i.e. imbalances, is to remain within certain thresholds. Balancing inflows and outflows is therefore a crucial activity in the management of a GTS.

2.2 A simple model

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. The number and size of shippers, corresponding to the number of contracts in their portfolio, describes the supply side of the market.

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

$$Di = d + \varepsilon\mathrm{i} \tag{1}$$

if $p \leq v$ 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. 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 $4d$). 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.

system (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.

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. The 16 possible states of the world, corresponding to the different combinations of realized shocks in the demand of the four final customers are grouped here below in 5 different cases:

States of the worlds: individual shocks and aggregate system position

i) Four negative demand shocks: one state only, with aggregate imbalance: $-\varepsilon$.
ii) Three negative and one positive demand shocks: four different states, with an aggregate imbalance of $-\varepsilon/2$.
iii) Two negative and two positive demand shocks,: six different realizations, with the system balanced at the aggregate level.
iv) One negative and three positive shocks, four states with an aggregate positive imbalance of $\varepsilon/2$.
v) All four customers hit by a positive demand shock, just one state with an aggregate imbalance ε.

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 state 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 way individual shocks are managed depends on the private actions of the shippers, and therefore on how the supply side is shaped. 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

a) **A(1,2,3,4)**: (pre-liberalization) monopoly.
b) **A(1,2), B(3,4)**: two symmetric large shippers
c) **A(1,2,3), B(4)**: two asymmetric shippers
d) **A(1,2), B(3), C(4)**: one large and two small shippers
e) **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) states of the world, 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*.

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.

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

Market structure	Wholesale trade	Portfolio adjustment	External adjustment
a) monopoly	0	5ε/16	6ε/16
b) symmetric duopoly	ε/16	4ε/16	6ε/16
c) asymmetric duopoly	2ε/16	3ε/16	6ε/16
d) asymmetric oligopoly	3ε/16	2ε/16	6ε/16
f) symmetric oligopoly	5ε/16	0	6ε/16

Table 1 reports, averaging across the 16 states of the world, 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.[5]

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 (6ε/16) requires to change 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 (10ε/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 5ε/16). The way they are cleared, through internal adjustment within each portfolio or by trading with other shippers, depends on the 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, and

[5] The values are obtained starting from the sixteen different shock configurations, identifying in each of them the internal adjustment and wholesale trade in the different market structures and then computing the overall expected volume of internal adjustment and wholesale trade.

therefore 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.[6]
The following proposition summarizes the results so far.

Proposition 1: *When random shocks hit gas customers' demand while 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 (*4d* in expected terms, in our example) in the market 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 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[7], a reliable price signal in the wholesale market can introduce an important innovation in the market.

In our model the customers are homogeneous with a willingness to pay v, and the shippers have a reservation price w while 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[8] $p = (v + w)/2$. When, instead, there are more shippers with a long than a short net position

[6] 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 2^N different sequences of N shocks. If K and $N\text{-}K$ are, respectively, the number of negative and positive shocks, each sequence composed by these shocks, that we define as $(K,N\text{-}K)$, occurs $N!/(K!(N\text{-}K)!$ times. In any such sequence, if there is a single operator, $min\{K,N\text{-}K\}$ shocks can be internally adjusted within the portfolio with the same number of shocks of opposite sign, while $N\text{-}(2\varepsilon/N)min\{K,N\text{-}K\}$ 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 $(K,N\text{-}K)$ of shocks can be relabelled, according to the portfolios of the M operators, as

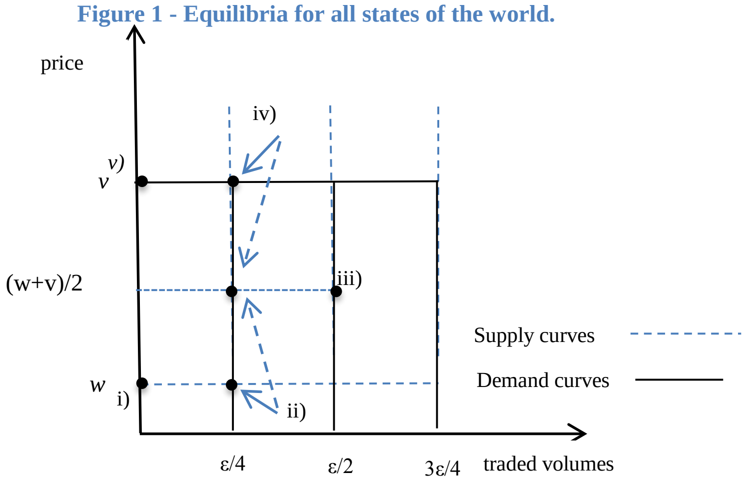
$$((k_1,n\text{-}k_1), (k_2,n\text{-}k_2),\ldots, (k_{M-1},n\text{-}k_{M-1}), (K\text{-} \Sigma_{j\neq M}\, k_j,n\text{-} K+\Sigma_{j\neq M}\, kj))$$

with $k_j \leq min\{n,K\}$ and $\Sigma\, kj=K$.
Each individual vector of shocks $(k_j,n\text{-}k_j)$ for operator $j=1,..,M$ occurs $n!/(k_j!(n\text{-} k_j)!$ times. Each operator $j=1,\ldots,M$, then, will be able to adjust $min(k_j,n\text{-}k_j)$ shocks within its portfolio of n contracts, with a net unbalance of $n\text{-}(2\varepsilon/N)\, min(k_j,n\text{-}k_j)$ 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.
[7] See Stern J. (ed.) (2012), *The Pricing of Internationally Traded Gas,* Oxford U.P.
[8] 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.

(excess supply), the market price is $p = w$. Finally, when short positions prevail (excess demand), the equilibrium price is $p = v$.

Figure 1 shows the equilibrium prices in the five states of the world i)-v) previously described. Price equilibria are obtained in the five cases i)-v) by summing up the individual imbalances net of the internal adjustments within each portfolio. At a first glance, 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 $(v+w)/2$ 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.

Figure 1 - Equilibria for all states of the world.



Market manipulation, however might distort the wholesale price away from the level consistent with market fundamentals when there are dominant shippers. Consider, in particular, case c) of asymmetric duopolies, in which one shipper has three contracts and the other just one. In this case, it may happen (state *ii)* above) that all the three clients of shipper A have a negative shock and shipper B's sole client a positive shock. A, then has a net supply of $3\varepsilon/4$ on the wholesale market while shipper B has a net demand of $\varepsilon/4$ to clear its imbalance. If the large shipper offers all its gas surplus on the wholesale market, the equilibrium price would be $p = w$. However, in this case, shipper A, that monopolizes the supply of gas in this realization of the shocks, can withdraw part of its supply, selling only $\varepsilon/4$ on the wholesale market, with a price $p = (w + v)/2 > w$. This is convenient since the level of trade remains the same, depending on the demand for gas from the shipper in a short position, but the price obtained by shipper A is higher.

A similar argument applies to the state of the world *iv)* when $(-\varepsilon/4,-\varepsilon/4,-\varepsilon/4, \varepsilon/4)$. Shipper A, in this case, has an excess demand of $3\varepsilon/4$ facing a net supply of gas of $\varepsilon/4$ on the wholesale market by shipper B, leading to a price $p = v$. However, by withdrawing part of its demand, shipper A can apparently balance the wholesale market and pay a price $p = (w + v)/2 < v$.

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.

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 price pushing it 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.*

2.3 From balancing to second sourcing and price risk management

As long as liberalization proceeds, the gas hub becomes the central place where balancing trades are performed and liquidity increases (Proposition 1), and a more fragmented market structure makes the prices a more and more 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 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 toy 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 local producers additional opportunities to sell, exploiting differences in prices with respect to those of long-term contracts. 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 when the main source of injection is through pipelines and long term contracts with far away producers. From this perspective, therefore, we expect that a significant domestic production of gas may favor the increase in market liquidity.

In conclusion, the second phase in the evolution of the wholesale markets can be associated with the development of larger volumes of gas traded and with the use of the wholesale markets as a parallel source of gas, together with the long and medium term contracts with the upstream operators.[9]

Even in a liquid wholesale market, still, some price variability remains, reflecting the underlying aggregate shocks of the system (see figure 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 products to manage price risk, as futures and forward contracts.

[9] For an analysis of the competitive effects of take or pay contracts v. wholesale market provision see Polo and Scarpa (2013)

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. The development of financial instruments to manage the price risk, instead, 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.

Then, it follows that 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 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) and 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 national gas system.*

2*: An entry-exit model, a market based balancing regimes and rules for fundamental transparency are the more favorable market design for the development of a wholesale market for balancing needs.*

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.*

3. EU framework for balancing regulation

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 to guide the different member states in developing gas hubs within their gas systems 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).[10]

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[11]. 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 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.[12] 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[13]. 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 (ENTSOG 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 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.

[10] 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 Agency for the Cooperation of Energy Regulators' (ACER) Framework Guidelines on Gas Balancing in Transmission Systems, published in October 2011.

[11] "*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.

[12] Article 18 of the Gas Regulation (European Union, 2009) 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).

[13] 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.

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 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.* A Network Code usually states the rules of the balancing regimes.

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 imbalance 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*).

3.1 Balancing regimes: country experiences

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[14]. 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 Dutch TSO, Gas Transport Services B.V. (GTS) introduced an entry-exit capacity system and a virtual trading point in 2004. In 2011 a "new market model" (in Dutch, *Nieuw marktmodel*) has been introduced in order to facilitate and strengthen the functioning of the gas market and increase security of supply. 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. The amendments to the Gas Act further introduced a new balancing regime in the Netherlands in line with the guidelines outlined by ACER. With the new balancing regime every market party is responsible for keeping its own portfolio balanced through buying and selling gas on the TTF, implying that the TTF has become the central balancing platform for all natural gas in the Dutch transmission system. GTS acts only as a residual responsible for balancing the system.

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 (EWG), 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. BNAfrom Spetember 2010 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 (BNA, 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[15], divided in two large groups, according to their belonging to the NCG or Gaspool area. They all chose the form of the ITO, 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[16]. 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 BNA has started the consultations to reform the system according to the EU network code within 2015.

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 on behalf of

[14] For an accurate description of the evolution of the British gas wholesale market see Heather (2010).
[15] As reported in the ENTSO-G member list.
[16] Grundmodell der Ausgleichsleistungs- und Bilanzierungsregeln im Gassektor, implemented in May 2008.

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 demand bids and supply offers for the storage resources 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. Recently, a new 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[17].

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. A problem that should be solved is given by the differences in the measurement units used across all the different hubs, which makes it very hard to compare the figures among countries. It would be advisable to adopt a uniform standard for the quantification of the volumes and prices, to clearly state the conversion factors and to specify in detail the type of figures reported, e.g. explain and define which kind of volumes are reported in a dataset.

4. Descriptive analysis

This section compares the predictions and educated guesses drawn from our analysis with some performance indicators for four European countries' gas hubs, each representing a different stage of development of wholesale gas market. The aim is to verify whether the sequence of phases identified -balancing, second sourcing and financial instruments- tends to replicate the actual pattern of evolution of national gas markets.

For each country, we build a set of indexes[18]. that are able to capture some key dimensions of gas markets and analyze the balancing regime in place. As explained in the predictions, in our view, the key elements that make a gas market work are a combination of resource availability, good rules for balancing and trading and transparency.

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

[18] For a thorough explanation of the criteria used in the choice of the data used to compute the indicators, see the Appendix.

Table 2 – Indicators' description*.

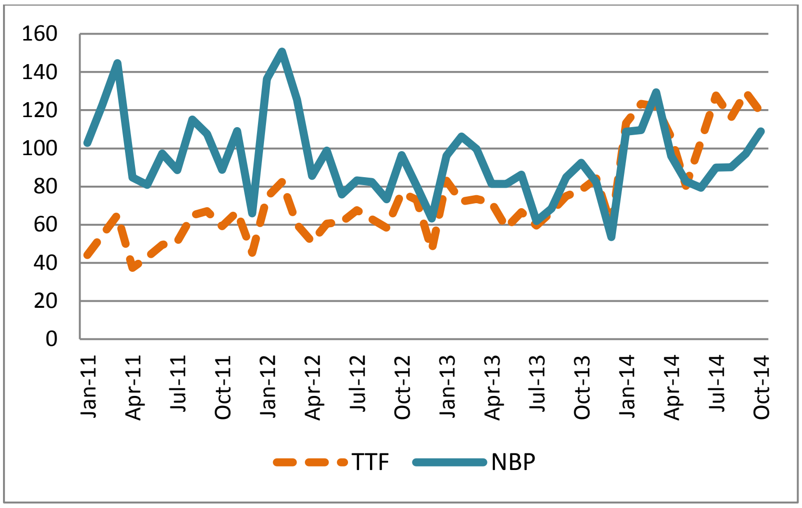
Predictions	Characteristic	Indicator	Formulation
Prediction 1	Trading development, Liquidity	Number of operators	
		Churn Ratio	Volumes traded/Physical deliveries
		Gross Churn Ratio	Demand/Physical deliveries
		AI - availability index	Physical deliveries/Demand*
Prediction 2	Market design	Balancing 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	

*Note that (Gross Churn Ratio = Net Churn Ratio * Availability Index)

4.1 The development of trading

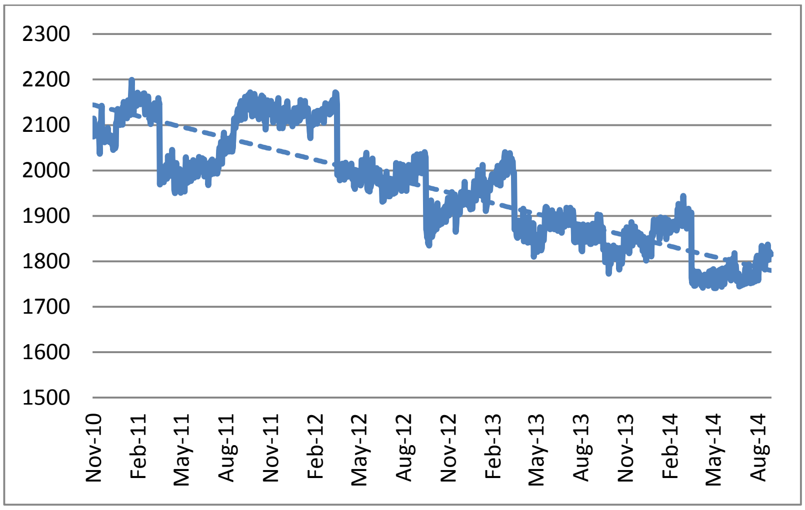
Although widely considered the most liquid European gas market, over the years the NBP is increasingly facing competition by the Dutch TTF, which is rapidly taking the lead in gas market transactions, at least in the OTC segment (figure 2). As can be seen from figure 3, the number of trades is also decreasing. Figure 4 shows some liquidity indicators related to NBP.

Figure 2 - Traded volumes (spot market only) comparison at NBP and TTF.



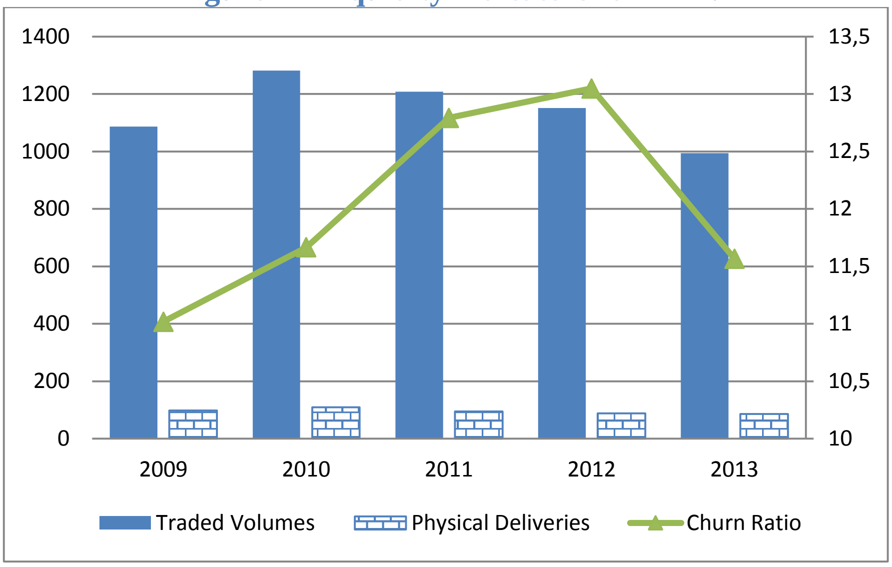
Data sources: Gasunie, National Grid and LEBA.

Figure 3 - Daily number of trades at NBP..



Data source: National Grid

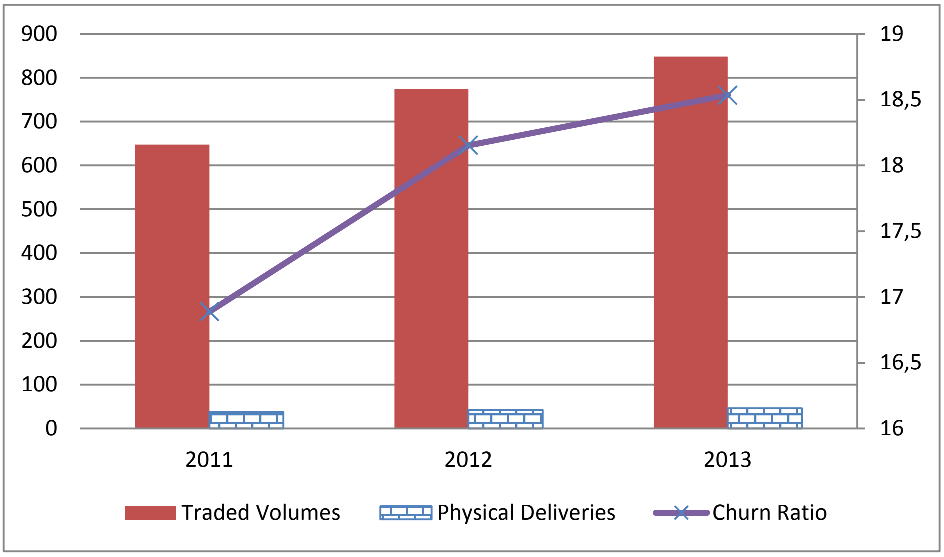
Figure 4 - Liquidity indicators for NBP.



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.

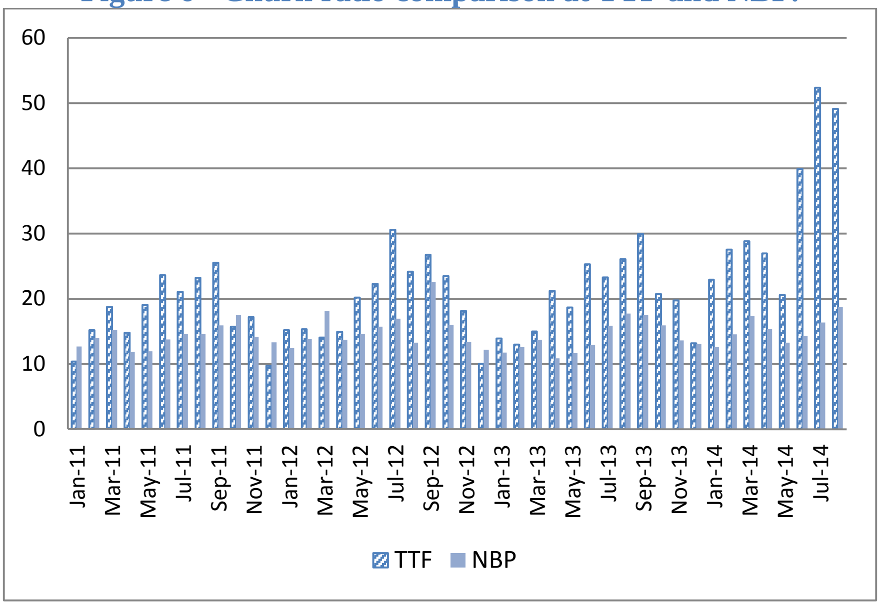
TTF development has been initially sluggish due to lack of import infrastructure and storage facilities, and due to a poor utilization of the transport infrastructure, problems with quality conversion, low transparency and an outdated balancing regime (NMa, 2007). The elimination of the two types of 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[19]. 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 figure 5, the churn ratio and traded volumes show an increasing tendency. Moreover, a comparison of the churn ratios at TTF and the British NBP shows that the gap between the two hubs is constantly reducing (figure 6).

Figure 5 - Liquidity indicators for TTF.



Data source: authors' elaboration on Gasunie data. Figures on the 1st y axis are expressed in bcm. Numbers on the 2nd y axis refer to the churn ratio.

Figure 6 - Churn ratio comparison at TTF and NBP.

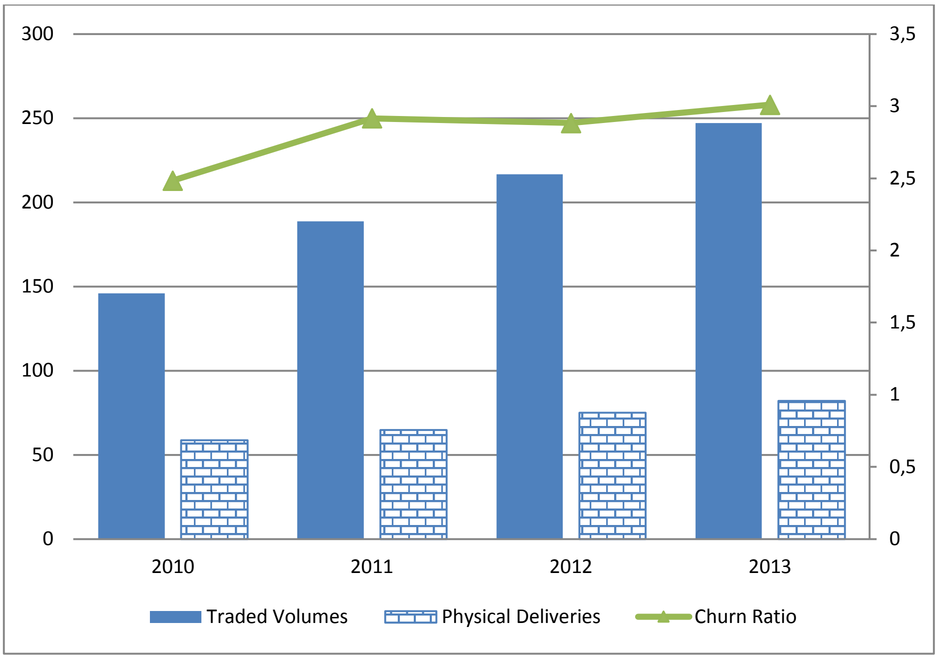


Data source: authors elaboration on National Grid and Gasunie data.

[19] 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.

The positive evolution of the German market can be appreciated in the performance of volume-based liquidity indicators of its two hubs, particularly the traded volumes (figure 7). Germany is updating its regulation and trying to improve its balancing mechanism. Starting from the reduction of market areas to the new rules for market-based balancing, it appears that Germany's effort is 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.

Figure 7 - Liquidity indicators for Germany hubs.

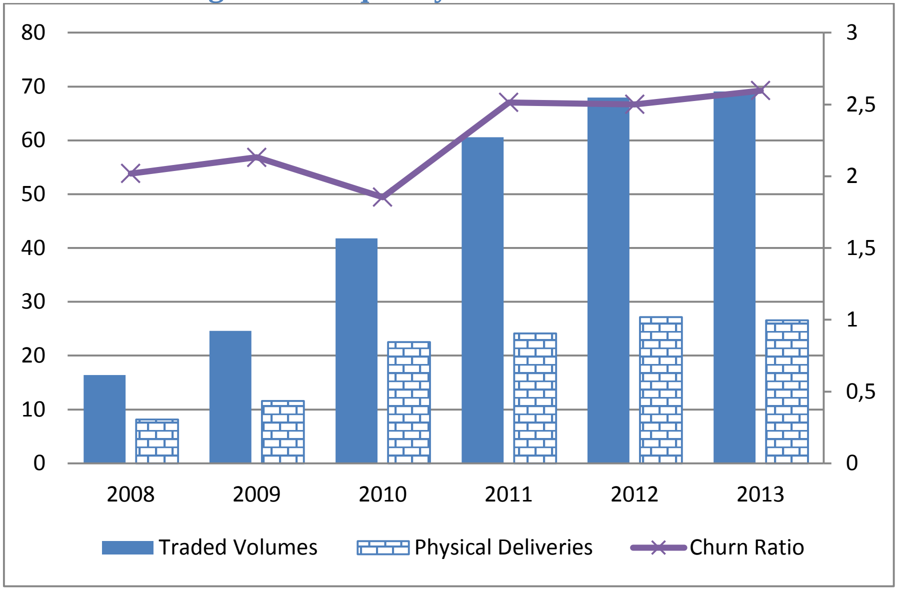


Data source: authors' elaboration on NetConnect Germany and Gaspool data. Figures on the 1st y axis are expressed in bcm. Numbers on the 2nd y axis refer to the churn ratio.

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 (*Gestore Mercati Energetici*) organizes and manages the articulations of the gas exchanges[20]. The implementation of PB-Gas has been extremely beneficial both for liquidity and for the number of market operators (see figures 8 and 9). PSV has considerably grown its volumes traded with respect to previous years.

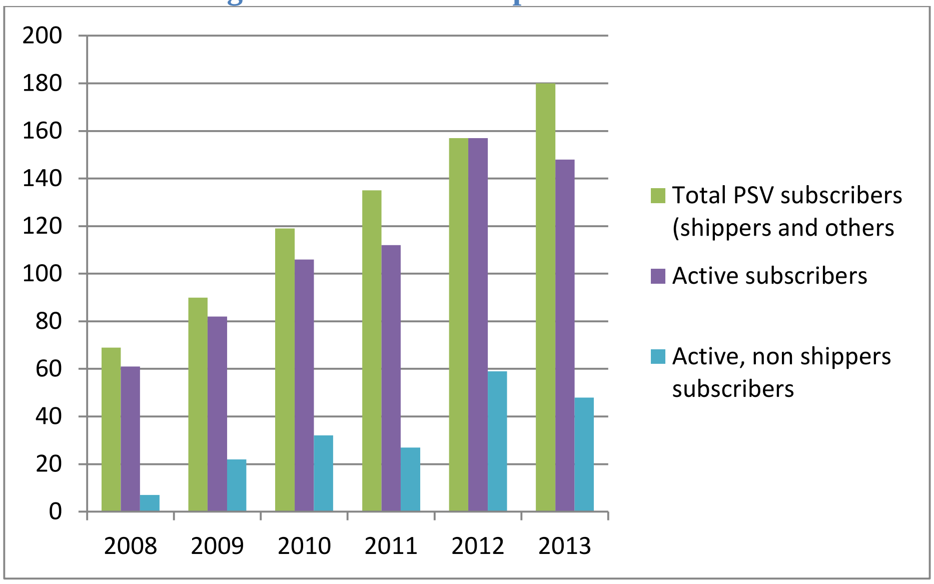
[20] There are three main exchange platforms: M-Gas, P-Gas and PB-Gas, each with a different function. For a more detailed explanation see the Dickx et al., 2014.

Figure 8 - 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.

Figure 9 - Number of operators at PSV.



Data source. AEEGSI.

4.2 The importance of countries' endowment

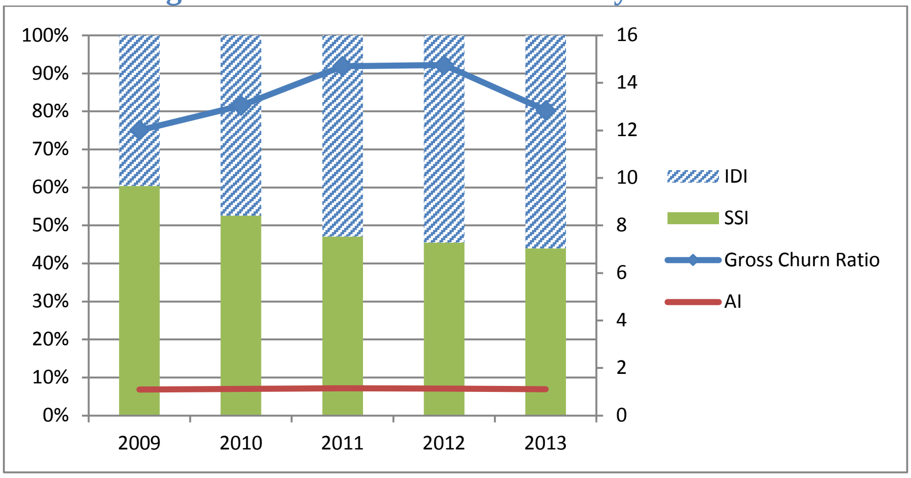
As already remarked, resource availability is a matter of chance: a country either has or does not have gas, and its geographical position is also crucial to build adequate infrastructures.

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 analyses of gas markets, is the import dependence index (IDI). From Prediction 4, we expect that countries with a higher SSI - and a lower IDI - will yield higher traded volumes in the wholesale market. The availability index (AI) is the ratio between the volume of gas physically delivered within the hub area and total consumption, to express the amount of gas traded relative to the total amount of gas consumed in the country.

The AI is thought as a measure of the degree of reliance on market prices as well: if the volumes traded are sufficiently high with respect to internal consumption (i.e. the index is close to 1), then we can assume that there is enough trade going on in the hub to reflect actual resource scarcity. If this index is low, then the amount of gas traded at the hub is not representative of market conditions, and therefore hub reference prices may not be reliable signals.

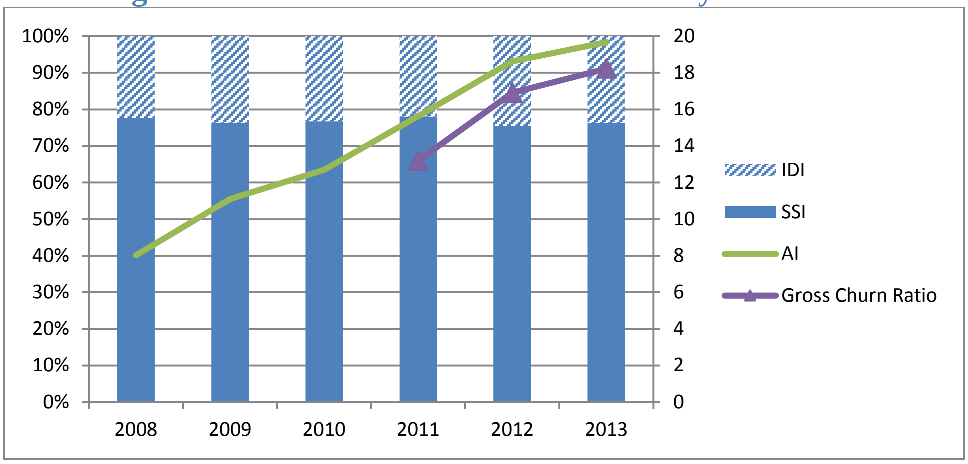
The resource availability indicators show that the UK and the Netherlands have an initial endowment advantage with respect to Germany and Italy, although the British advantage is declining.

Figure 10 - 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.

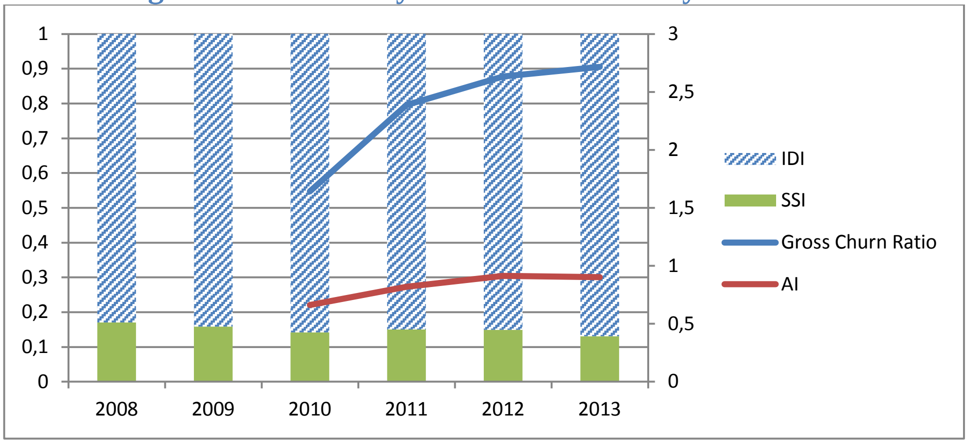
Figure 11 - Netherlands resource availability indicators.



Data sources: authors' elaboration on IEA, Gasunie and LEBA data. Left y-axis refers to bars, while right y-axis refers to lines.

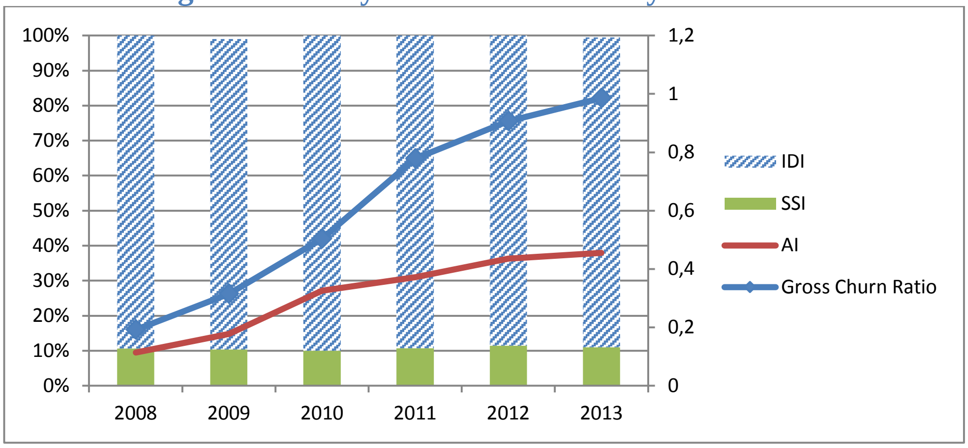
Domestic production peaked in the year 2000 and the UK became a net importer of gas at the end of 2004. The Netherlands is a main producer and exporter of natural gas in Europe. Production coming from the Groningen field, although decreasing, is sufficient to cover internal gas demand and to export to neighboring countries. Germany is the largest gas user in Europe and relies on imports. The medium terms perspective in its demand for gas are hard to forecast. On the positive side we can mention the dismantling of nuclear power plants and the possibility of a more balanced ETS price, presently favoring coal fired plants. The large deployment of RES, on the other hand, may pose doubts on the amount of gas demand coming from the energy sector in the medium term (WEO, 2011). 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[21]; as a consequence, imports have steadily acquired importance and amount nowadays to approximately 90% of gas consumption.

Figure 12 – 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.

Figure 13 – Italy resource availability indicators..

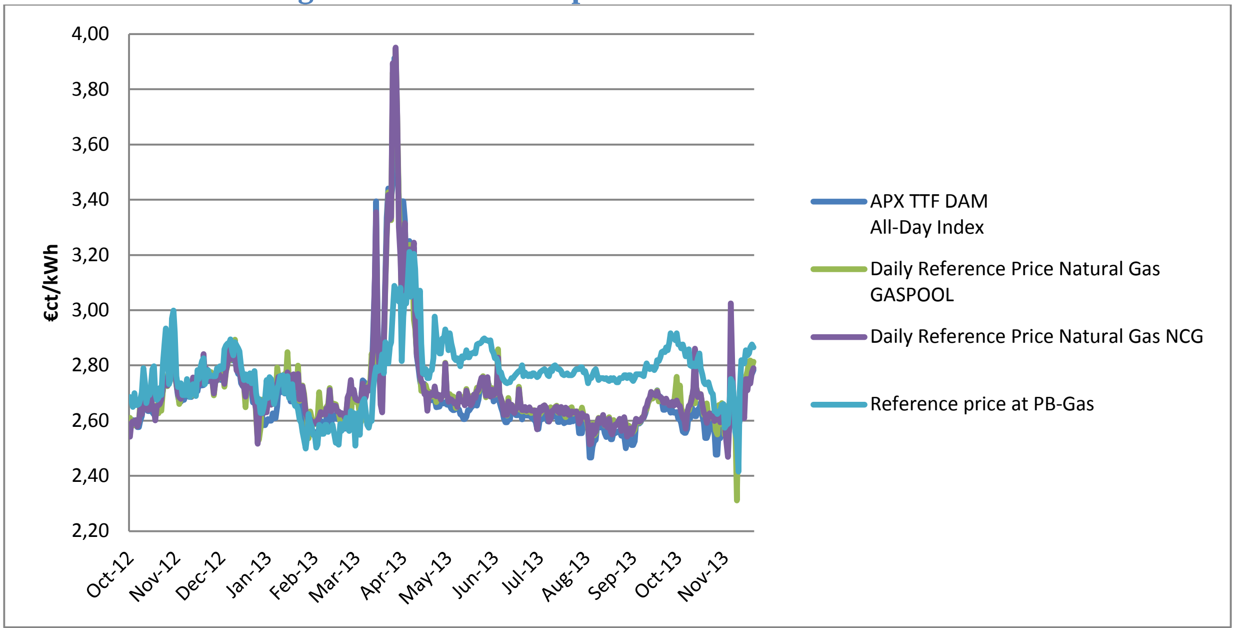


Data sources: authors' elaboration on IEA and Snam Rete Gas data. Left y-axis refers to bars, while right y-axis refers to lines

[21] AEEG (2013) reports a slight increase in domestic production in the years 2011 and 2012, but it has not been sufficiently high to alter the country's external dependence.

If markets are sufficiently liquid, price differential among countries should merely reflect different transportation and ancillary costs. It can be seen from figure 14 that Continental hubs show a remarkable degree of price alignment, as several recent studies have confirmed. In Italy prices tended to be higher, but are now showing signs of convergence.

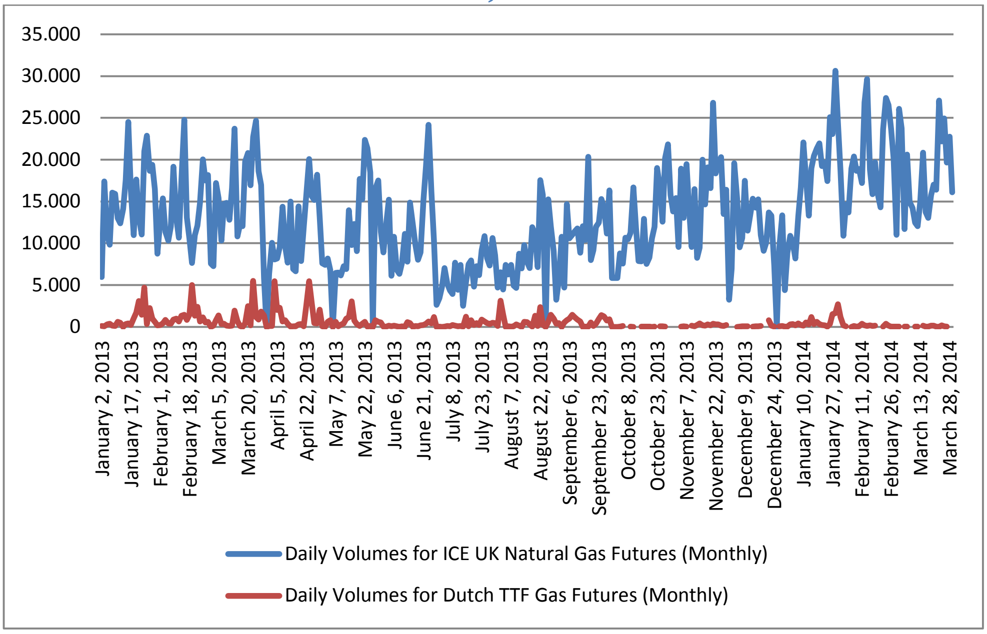
Figure 14 - Reference prices at Continental hubs..



Data source: Huberator

Finally, to test the last prediction, figure 15 show the volumes traded on the forward markets on the ICE exchange. It can be noted that although TTF OTC volumes are increasing for spot transactions, NBP still leads for the forward market.

Figure 15 - Futures contract comparison (NBP vs TTF) on the ICE platform. Number of contracts, 1 month.



5. Discussion and conclusions

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. The UK gas system and the NBP offer along their evolution clear evidence of these three steps in the evolution and maturity of a wholesale gas market, starting as a balancing tool, 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.

The emergence of many fragmented market operators which needed to balance their positions has given impulse to the creation of the NBP and the creation of the Flexibility Mechanism. 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 only for balancing. The UK (Alterman, 2012) has further developed a wide range of financial instruments for hedging the price risk, traded on different platforms but mainly on the ICE (International Commodity Exchange).

Following EU requirements and guidelines, all the countries object 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.

TTF has begun only recently its race to become the reference hub for Continental Europe, but thanks to natural advantages like 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 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 market division in two areas reduces the total liquidity and may create barriers to entry. 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 offers an interesting counterfactual of the model we depicted: it has only recently implemented a balancing platform, and has done so only after the creation of an OTC market at PSV and an exchange, to encourage trading, reverting through regulation the path of a gas hub from balancing to second sourcing. The initial performance, however, has been very poor. The increase in volumes and market liquidity seems to have 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, suggesting that operators prefer to trade on the balancing platform[22], 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 just 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 importance of domestic production with respect to the imports through long-term contracts. In the UK and the Netherlands the spot wholesale gas markets plays a central role in the overall transaction of gas. Germany and Italy, in turn, recording the largest gas consumptions in our sample, are still trading in their hubs a small fraction of the overall gas, that for the most part is still operated through long term contracts.

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

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