Utilities Policy 25 (2013) 23–32

Contents lists available at SciVerse ScienceDirect

Utilities Policy

journal homepage: www.elsevier.com/locate/jup

European Union regulation of gas transmission services: Challenges in the allocation of network resources through entry/exit schemes

Michelle Hallack*, Miguel Vazquez[1]

Loyola de Palacio Chair, RSCAS, European University Institute, Via delle Fontanelle, 10, Florence, Italy

ARTICLE INFO

Article history:
Received 17 May 2012
Received in revised form
29 January 2013
Accepted 30 January 2013

Keywords:
Natural gas
Market design
Transmission capacity
Entry–exit
Network balancing

ABSTRACT

The current definition of "commercial" gas networks in the European Union (EU) is based on entry/exit schemes and balancing mechanisms. This regulation of grid services aims to enhance the liquidity of wholesale markets. In order to facilitate the gas commodity trade among players with different network usage profiles and different network connection points, some network services are socialized across the market zone. That socialization of network services in the EU leaves the task to reconcile physical gas flows and commercial gas flows to a regulated system operator. We show that in practice, it leads, on the one hand, to offer less "commercial" transmission capacity than the physical capacity of the network, and on the other, to the cross-subsidization of line-pack services between high profile and low profile users. The guidelines proposed by the Agency for the Cooperation of Energy Regulators (ACER) for the gas balancing network code do not explicitly address all the drawbacks of existing entry/exit schemes, but they leave room to design mechanisms that increase the efficiency of short-term network allocation. Contributing to this open debate, we point out that improved allocation comes with market mechanisms to allocate short-term network services, instead of relying solely on Transmission System Operators' management of network resources.

1. Introduction

The liberalization process of the gas sector has been significantly different among continents. The United States (US) gas industry was one of the pioneers. Its liberalization was markedly characterized by strong reliance on market forces to drive decisions along the whole production chain. Broadly, the US gas sector is organized around private companies that decide on production, transportation, and storage of gas. In this context, operation and investment in the gas transmission network are mainly decided on by non-regulated agents, even if closely monitored by the federal regulator (FERC).[2] To coordinate these activities, transmission rights are usually purchased through long-term contracts. Market players and network operators enter into contracts offering the right to use the network to transport gas from one point to another, whose counterparts are the owners of the infrastructure involved in the path between their connection points. In that view, shippers decide by themselves on the physical path that the gas will follow and pay for the use of the associated infrastructure. In the short run, shippers face frequent flow imbalances due to unexpected injections and withdrawals, which must be dealt with by complex combinations of gas trades and special arrangements associated with the corresponding transmission rights (ERA, 2005; Costello, 2006). Consequently, US wholesale markets are typically associated with a precise definition of the place where the physical delivery of the commodity takes place. That "physical hub" is intended to facilitate short-term balancing transactions by offering widely open network and commodity services. As in the case of long-term contracting, the US gas sector leaves these transactions to bilateral arrangements, so the coordination of the short-term usage and operation of the gas network is done by bilateral agreements between gas arbitrageurs and network operators.

The European Union (EU) liberalization of gas industries came after the US liberalization, so one might think that the US market was somehow a model for the European liberalization. However,

* Corresponding author. Tel.: +39 (0)554685758.
E-mail addresses: michelle.hallack@eui.eu, michellehallack@gmail.com (M. Hallack).

[1] We thank Yannick Perez and Jean-Michel Glachant for many comments and insightful discussions. Comments by referees were very helpful.

[2] The US regulation guarantees fair service pricing, but allows players to negotiate the services characteristics.

0957-1787/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jup.2013.01.003

European and US industries have few common points.[3] In fact, the design of EU gas markets seem to be closer to the design of the EU electricity markets than to the US gas markets. The EU gas markets have followed the design of the UK gas market, which developed after 1996, with gas transactions been organized around a “virtual hub”[4] covering all the market area (Heather, 2010). The virtual hub approach implies that gas market players use, for most of their commodity transactions, a “commercial” network that is different from the physical network. In particular, the standard definition of the commercial network in the EU is the entry/exit regulation (Hunt, 2008). Under that definition, market players have the right to inject gas in the system at any entry point, and to withdraw gas from any exit point. In order to manage such rights, the market design provides a set of additional elements that bridge the gap between the commercial and the physical networks. These “market to network” bridges are usually grouped under the header of balancing mechanisms. In that view, the rules governing the network use are supposed to allow using it efficiently. The design of those rules, however, is not straightforward in an entry/exit scheme.

In practice, in the existing regulatory frame, some of the rules applied to European gas markets lead to inefficiencies in the offer of transmission services. This is particularly the case with regard to two main issues. On the one hand, one finds inefficiencies associated with the *ex-ante* calculation of transmission capacity in entry/exit allocations. By definition, entry/exit implies a Transmission System Operator’s[5] (TSO) estimation of the future use of the network by shippers, so that the capacity sold will actually be available whatever the shippers will actually do. This process necessarily results in selling less “commercial” capacity than the network physical capacity can bear. Put it differently, entry/exit allocation provides shippers with a free provision of spatial flexibility, which subtracts transmission capacity that could have a value for several market players in the commodity market. On the other hand, many balancing arrangements provide line-pack storage (storage of gas inside the gas pipe) for free. Line-pack storage is rarely sold to market participants, but instead it is a tool for TSOs’ balancing mechanisms. This implies disregarding market preferences in the allocation of line-pack storage (“socialization”), which in turn represents an inefficient allocation. EU gas systems typically face a dilemma between socializing the line-pack storage (e.g. daily balancing mechanisms) or closing the use of line-pack storage (e.g. hourly balancing mechanisms).

Our paper will argue that inefficiencies would be substantially reduced by the design of a short-term market aimed at separating shippers’ short-term adjustments from TSO’s balancing actions. Such a market would give some locational signals to network users, to avoid the need for calculating transmission capacity only *ex-ante*. Furthermore, that market would trade line-pack products, so that line-pack would become a service allocated at a price by market players’ decisions. The guidelines from the Agency for the Cooperation of Energy Regulators[6] (ACER) (ACER, 2011a,b), while not pushing that far in this direction, opened the door for an implementation of such mechanisms.

Our paper is organized as follows. In Section 2, we describe the logic for current EU gas regulation, pointing out the relevance of certain regulatory decisions for market outcomes. In Section 3, we identify the limitations of entry/exit schemes in achieving an efficient allocation of network services. We also describe European regulations designed to deal with the drawbacks of entry/exit schemes. We show that the main drawbacks are based on passing through the network allocation problems to the balancing mechanism, so that the Transmission System Operator has to be the ultimate resort for the feasibility of former trades. Section 4 shows such regulatory frames with the analysis of three cases of balancing regimes. Section 5 looks for remedies that are compatible with the existing process of achievement of the European Internal Market. We show that most of the current inefficiencies are going to continue in the coming EU-wide market if no new market tool to allocate network resources is implemented. Section 6 concludes, and offers general principles that could guide the design of an efficient procedure to allocate network services.

2. Design of markets based on virtual hubs

2.1. The motivation for gas markets based on virtual hubs

The choice of the European Union (EC, 2009),[7] is to design gas markets that build on trades made through a virtual hub. The motivation for that may be traced to the concern of European systems with the creation of liquid wholesale gas markets. The organization of markets around virtual hubs is considered as a means to enhance the liquidity of wholesale trade. We will then analyze the rationale behind these virtual hubs, with the aim to point out the logic for certain EU regulatory choices required by markets based on virtual hubs.

2.1.1. Entry barriers in point-to-point regulation

One of the most popular arguments to support virtual hubs is the difficulty for small players to trade in a system where the market for gas commodity builds on the real physics of the transportation network, see for instance (EC, 2007). Large players often have diversified gas and consumers portfolios, whose deviations from expected plans can be largely managed internally, whereas small wholesalers will have to buy all their network and commodity flexibility needs from the market. Such flexibility needs, thus, would represent an entry barrier. On the contrary, in a commodity market based on a virtual hub, where network flexibility is given for free and its costs socialized, the advantage associated with the incumbent’s diversified portfolios would disappear.

However, although large players need not buy as much flexibility from the markets, they have similar costs when adjusting their portfolios internally. Hence, in our view, the only situation where those entry barriers exist is associated with the illiquidity of flexibility offers in the markets. Except when incumbents’ strategic behavior aims at draining liquidity from those markets (Vazquez

[3] The explanation of why the EU and US models have followed different, and even opposite paths has different dimensions. Abhishek et al. (2012) point at the historical importance of property rights in the US, in contrast to the EU common-carriage system. Cramton (2007) underlines the role of players with different interests (at the national and regional levels) in both sectors. As the parties involved in the development of institutions in the EU and US had different interests, the resulting institutions were different as well. Gordon and Weber (1984) point out positive and negative economic aspects of both models, which explain the economic logic for their adoption. In Section 2, we will describe in detail the economic logic for the EU model, which in turn helps to explain the motivation for those institutional differences.

[4] The virtual hub is not a physical junction of pipelines, but instead a standard set of delivery points with a simplified representation of the physical characteristics of the network.

[5] The Transmission System Operator is an entity (public or private) entrusted with transporting natural gas in a specific region.

[6] ACER is a EU body aimed to assist National Regulatory Authorities (NRAs) in exercising, at Community level, the regulatory tasks that they perform in the Member States and, where necessary, to coordinate their action. ACER sets up guidelines in order to harmonize rules for the flow of gas across EU. In practice it gives the boundaries within which the NRAs should act.

[7] We will use the term “EU entry/exit regulation” to refer to the network rules based on entry/exit capacity and balancing mechanisms. That combination is specified in the Third Package for Electricity and Gas markets (EC, 2009).

and Barquin, 2007 analyzed this strategy in the Spanish gas system), it seems to be no reason for having such illiquidity.[8]

2.1.2. Strategic use of capacity contracting

An alternative argument builds on considering the strategic use of network congestion. It gives a rationale for a market design taking into account *ex-ante* further potential strategic behavior. A key is the strategic use of network congestions: the incumbent may have an incentive to over-contract network capacity to foreclose short-term markets for small competitors, and hence to induce effective entry barriers. On the contrary, when the market design implicitly allocates the rights to use the network from the commodity trade merit order, the gas is traded without any need for *ex-ante* contracting of network services, and thus the incentive for incumbents to foreclose contracting of network capacity disappear (see for instance Joskow and Tirole, 2000 or Gilbert et al., 2004) for the argument applied to power networks).

In this regard, the advantage of a market design with virtual hub is that, as it does not consider the physical representation of the network, the "network congestion" strategy described above cannot be pursued. As transportation capacity within the limits of the virtual hub is socialized among all market participants, it can be thought of as loose kind of implicit allocation.

2.1.3. Asset specificity in point-to-point regulation

In our view, the strongest case for virtual hubs comes from the possibly overly complex system of bilateral contracts required to implement transmission rights in physical "point to point" networks (Ruff, 2011). Gas networks are actually characterized by numerous tight technical constraints, and thus the contracting architecture required to trade and to deliver the commodity at different network points and horizons must be necessarily complex. This fact has been seen as an important source of transaction costs. The argument can be supported from the economics of transaction costs developed in Williamson (1975, 1983, 1985). Glachant (2002) used the framework to analyze the institutions of network industries. In the context of the electricity industry, Joskow and Schmalensee (1983) and Joskow (1985) applied this framework to the analysis of USA electricity industry, and Glachant and Finon (2000) applied it to the EU electricity systems.

In the gas industry, the argument starts with defining transmission services as produced by assets with strong site specificity.[9] Purely decentralized market may not obtain the efficient outcome whether the assets are highly specific (as gas transmission network). In order to decrease the costs of transacting it may be better to market only some of the services provided by the assets, and to allocate the rest of them through socialization among network users. This is the idea behind a virtual hub. It is possible to enhance market liquidity by defining a commercial platform, not considering in detail demanding network constraints. Simplifying the characteristics of the physical flows seen by the commodity market also means reducing the amount or the scope of transmission services left to market choices. With a virtual hub, instead of centralizing the whole industry, the market design chooses a halfway. It consists in socializing only the costs of some of transmission services with strong "asset specificity". Nonetheless, it leaves to market participants the task of allocating the rest of network services, whose asset specificity is sufficiently low to be easily traded in a decentralized market.

We may now start reasoning the other way around. We may face already a gas system with a virtual hub. Then the market design may consider the possibility of carefully reintroducing additional transmission services in a decentralized market mechanism. A practical difficulty thus is the so-called measurement problem (Barzel, 1982). The market design must consider whether reducing the inefficiencies associated with the socialization of certain network services compensate for the cost of including a new service in the market. In any market, both sellers and buyers need to measure with enough accuracy the characteristics of the good that they trade. Hence the measurement cost. That cost is sometimes too high for one or the two trading parties and the market fails to deliver efficiency (e.g. "second hand" good trade; or meat in a period of "mad cow disease"). In this view, the rationale based on measurement is close to the reasoning used above to motivate service costs socialization, which aimed at reducing the transaction costs associated with asset specificity. To end, we should recall that the discussion on externalities (Coase, 1960), when applied to network industries,[10] is frequently about disentangling measurable and non-measurable services. That is, the externalities that cannot be internalized by market arrangements would be either the externalities that cannot be measured by trading parties (e.g. the loop flows of power networks) or the externalities that have significantly large measurement costs (e.g. inter-TSO compensation mechanisms).

2.2. Additional design elements in markets based on virtual hubs

The main consequence of using virtual hubs is the fact that they do not consider the physical network that will be ultimately used by the flows resulting from wholesale commodity transactions. As the physical network is not seen by market players, commodity markets based on virtual hubs must address two necessarily demanding issues. First, the way in which transmission capacity is allocated to market players. Second, the way in which gas network technical characteristics will finally be fulfilled by the flows resulting from "blind" commodity trading. Our next two sections describe the solutions proposed to cope with those questions.

2.2.1. Entry/exit capacity allocation

Virtual hubs are designed to reduce asset specificity by disregarding several physical characteristics of the actual network. Nonetheless, the usual situation in European systems is that an important part of the gas to be consumed in the system is purchased outside it by means of long-term contracts. Therefore, the long-term allocation of the transmission rights is a central tool for shippers to manage their risk, as long-term network allocation allows shippers to hedge their importing positions. For instance, if gas producers (typically outside the system) need long-term contracts to ensure the minimum level of production that they require, but the transmission capacity can only be purchased in the short-term, the shipper would have a markedly open position.

Allowing shippers to purchase capacity in the long-term can be done through some level of explicit allocation of the network. But as virtual hubs disregard the physical representation of the network, the way to explicitly allocate the network is not straightforward. Put it another way, the spirit of virtual hubs is allowing every shipper in the market to trade with any other shipper, without considering the physical network. But if the capacity is allocated explicitly, shippers must take it into account to trade in the market.

[8] Assuming that the industry has not excessive horizontal concentration. The assumption is not critical, as the potential for market organizations of the gas industry is drastically limited in such cases.

[9] Masten et al. (1991) and Glachant and Finon (2000) proposed that temporal specificity might be a separate type of specificity. We follow, however, Williamson (1996) and Joskow (2005) in considering it as a particular case of site specificity.

[10] See for instance Hunt and Shuttleworth (1996) for the case of electricity.

The solution adopted by EU gas markets is to define the capacity to enter and exit the system. In this situation, shippers need only to define their needs for entry and exit capacity, so that they first purchase the right to enter (or exit) the market, and then they are allowed to trade without capacity constraints. Note that, according to the above reasoning, entry and exit capacity would be allocated separately (to avoid specificity), i.e. shippers do not need to purchase entry and exit capacity at the same time. In that situation, the principle of "keeping assets as non-specific as possible" is fulfilled and the transmission capacity is explicitly allocated.[11] Hence, the implicit assumption of this scheme is that the cost of entering the system is significantly higher than the cost differences among the possible trades inside the system. This is the situation in most EU systems, where the relevant network cost is the one associated with carrying gas from long-distance production fields to national systems.

Nonetheless, in markets with entry/exit capacity allocation, the TSO must define in advance the transmission capacity available for shippers to be allowed to buy and sell in the wholesale market, see for instance Lapuerta and Moselle (2002). In Section 3.1, we will show that this allocation procedure leads in general to inefficient uses of transmission networks. As entry and exit capacity is allocated before the trades take place, the capacity calculation is made with an estimation of the future gas flows, and thus the network cannot be allocated efficiently.

2.2.2. The rules of balancing mechanisms in virtual-hub regulations

The balancing mechanism is the part of the virtual-hub regulation where the trade-off between reducing asset specificity and increasing network use inefficiency becomes more apparent. Consequently, the choice of rules governing the balancing mechanism must depend on the particular characteristics of each gas system, as some of the costs related to the simplifications aimed at reducing transaction costs might become prohibitively large if gas flow patterns change.

In fact, the central idea behind simplifying the network to reduce transaction costs is socializing some of the transmission services in order to reduce asset specificity. The underpinning for this regulatory strategy may be the fact that some services have approximately the same value for all network users. Thus, removing those services from the market and socializing them implies little inefficiency, but it actually reduces the specificity of transmission services. However, a central condition to pursue this strategy is the condition that services have approximately the same value for all users. Whether this condition is fulfilled markedly depends on the particular characteristics of each system.

Section 3.2 will show that the choice of a daily gas balancing mechanism of most EU gas markets (KEMA, 2009), which were conceived to provide shippers with enough flexibility in a context of homogeneous flow patterns, may be not approximate enough in a context of severely heterogeneous patterns. And these heterogeneous patterns are currently found in most gas markets in Europe, because of the high penetration of consumption from gas-fired power plants and of supply from liquefied natural gas sources, see for instance (Honore, 2011; Hallack, 2011). Consequently, with the current characteristics of EU gas flows, the inefficiency associated with the socialization of line-pack services[12] is likely outweighing the benefits of the specificity reduction of such socialization.

3. Inefficient offers of network services in entry/exit regulations

The combination of the physical characteristics of the gas network, and the rules defining its use, results in a commercial transmission network with a particular offer of network services. Therefore, in the entry/exit scheme, the largest part of the gas transactions are determined using the commercial network, up to the point when market players are incentivized to balance their portfolios (often, by means of imbalance penalties). Then, the process of network service allocation begins under the responsibility of the system operators.

This section will show that, although the motivation of entry/exit regulations is enhancing gas trading, if the rules of using the network are not carefully designed, the resulting system may actually harm gas trading.

3.1. Inefficient transmission capacity allocation

In an entry/exit system, in order to calculate the available capacity of commercial network, TSOs must take account of the fact that market participants own the right to carry gas from one entry point to any exit point. Hence, they must reserve not only the network required to carry gas from an entry to a certain exit, but also the network required to carry gas to all other exit points of the system. Therefore, congestion in the network from an entry point and one exit point might cause congestion in the network to other exit points. This might result in a situation where the network is not physically congested, but the system operator cannot sell more firm capacity.[13] The direct consequence is that the network is not efficiently used. In addition, shippers cannot express their preferences on the exit point that they intend to serve.

Let us put forward a simple example to illustrate the problem. Consider three pipelines connecting a certain consumption point A to two different supply points, B and C; each pipeline has a maximum capacity of 100 MW, so that the real capacity faced by point A is 200 MW. However, in an entry/exit scheme, consumers at point A have the right to buy either from B or from C. That is, when consumption at A enters into a supply contract, they have the right of using both pipelines at the same time. Therefore, the firm capacity faced by point A is only 100 MW. This is the idea behind contractual congestions. Spatial flexibility, in this case, is a substitute of gas trading, as trades involving the remaining 100 MW are never done.

In current entry/exit schemes, the TSOs' allocation of the commercial network does not give enough information about the use of network facilities. Thus, the firm commercial capacity, which TSOs must guarantee to shippers, does not allocate the entire physical infrastructure. Therefore, it results in the under use of network resources, unless some other tools are added.

3.1.1. Palliative measures for contractual congestions

There are three tools often applied to decrease the inefficiency of network allocation: over-booking firm capacity, selling interruptible capacity and selling within-day (or day-ahead) implicit capacity.

[11] Note that under this scheme, firms have the opportunity to behave strategically (Section 2.1.2), buying entry capacity to foreclose the market.

[12] Line-pack services are the different kinds of services (economic functions) that the use of line-pack storage may provide (line-pack storage is the capacity to store gas inside the pipeline). For instance, line-pack services include balancing the flows injected and withdrawn at different points in time.

[13] At least, the TSO cannot sell more firm capacity without the risk of not honoring the contract, i.e., without the risk to have to deal with a physical congestion.

Over-booking firm capacity (used for instance by UK) builds on the idea that the TSO calculates the probability that shippers use different paths of the network. Thus, the TSO uses shippers' historical flows to define the amount of firm network capacity that will be really used, and offers some extra capacity accordingly. In this approach, on the one hand, the TSO faces the need for matching the network capacity sold to shippers and the physical capacity available in the system. To do so, the only tool available to the TSO is the balancing mechanism. On the other hand, the offer of network capacity is based on TSO's forecasting, and hence the needs for balancing crucially depend on the accuracy of such forecasting.

Offering interruptible capacity is based on the idea that, if the network is not fully used in the short run, a certain shipper is allowed to use it. However, interruptible capacity has a lower value for shippers, so risk-averse shippers tend not to purchase this kind of capacity, even if offered with lower tariffs. Put it differently, it is not a substitute of the firm transport service. Moreover, the TSO faces the additional role of determining when it should interrupt the service, and when it should act to balance the flows. The limit is not always clear, as it is not clear whether the definition of a physical congestion is before or after the intervention of the TSO in the management of gas flows.

The third mechanism is the short-term implicit auction. The motivation for the mechanism can be viewed as a consequence of the fact that, once the entry/exit scheme is chosen, the TSO is the only informed player about the network characteristics. Thus, the TSO may define a short-term offer of transportation services when congestion or under use of capacity occurs. That is, the TSO defines a short-term auction based on gas prices, taking into account the capacity with a finer representation of the network. To do so, when there is congestion in a certain zone, the TSO participates in the market by buying and selling gas. The mechanism is the more efficient one of the three proposed solutions to manage congestions, as the capacity in this market is allocated to shippers according to their gas prices. However, it interacts with entry/exit rights (nomination and re-nomination), because the TSO face uncertainty about what will be the physical flow finally allocated through commercial contracts. Therefore, even in within-day horizons, the physical capacity that may be allocated through implicit auctions is not known with certainty.[14]

In that view, although all previous measures are designed to solve the allocation problems found in entry/exit regulation, such problems are just added to the decisions taken by the TSO at the balancing stage. Actually, the idea behind the measures is the consideration of entry/exit misallocation as a gap between commercial and physical networks. That is, the TSO modifies the offer of network to the market participants, anticipating the needs that it will face in the system balancing. Therefore, the measures proposed to mitigate the network allocation inefficiency are in fact TSO's forecasts of the final use of the network, instead of an allocation based on players' preferences. The tools to do so, consequently, are the tools available to the TSO in the balancing mechanism.

3.2. Inefficient offer of line-pack services

The design of the rules for possible network services may have deep consequences on the possibilities for market players to express their preferences. A paradigmatic instance of the problem is the allocation of line-pack storage.

The network allocation described so far has consisted in the allocation of transmission capacity. Actually, the network allocation was done by allocating the capacity to enter the system and the capacity to exit the system. In addition, the imbalances caused by differences between both capacities are solved by short-term balancing mechanisms. The first and frequently the main tool used by TSOs to balance the system is the network line-pack buffer (Keyaerts et al., 2011).

This fact points out that line-pack storage is not considered as a service to be allocated among market participants. In fact, line-pack is used, in European rules for network use, as a tool for gas balancing.[15]

3.2.1. The line-pack dilemma

The transportation capacity of a certain pipeline (in the sense of its capacity to transport gas molecules from one point to another) depends on the pressure differential between inlet and outlet points. At the same time, the line-pack storage increases when this differential of pressure decreases, by increasing the pressure in the entire system. Hence, there is a trade-off in the use of the same infrastructure. Loosely, assuming the same pipeline characteristics, the trade-off can be stated as follows: the higher the pressure differential, the higher the capacity to offer transport services; the lower the pressure differential, the higher the capacity to store gas inside the pipeline.

The line-pack storage capacity of a pipeline is thus a substitute of its transportation capacity, and the combination of both services offered by a certain pipeline should depend on market players' preferences. However, as the market uses a commercial network without representation of physical pipelines, it cannot reveal preferences regarding the combination of line-pack and transportation. The ultimate decision on such combination is taken by system operators, and that may have a significant impact on market outcomes.

In fact, the balancing mechanisms associated with entry/exit schemes typically face the problem of choosing between mechanisms defined on hourly and daily bases. The choice, in turn, affects the trade-off between line-pack and transportation services. For instance, if the hourly balancing is the option chosen, the system is implicitly forcing the pipelines to transport as much as they can, and thus the line-pack is not offered to market participants. If the balancing design chooses a daily balancing mechanism, the line-pack will be socialized among all network users.

In the latter option, if all market participants have the same needs for line-pack services, the socialization allocates them efficiently. But if they have heterogeneous needs, the allocation is inefficient. Hence, the need for line-pack will be closely related to the needs for flexibility of shippers, which in turn is closely related to the time-variability of their gas flow patterns (in Section 3.2.2, we will show that flow patterns in current European gas system are significantly heterogeneous with respect to time-variability, and that they will be likely more variable in the future).

To illustrate the problems associated with the socialization of line-pack services, let us use the following case: we consider a gas network with three entry/exit points, A, B and C. A certain shipper is looking for a trade consisting in buying gas in point A at time t, and selling it in point C at time $t + T$. In this context, the shipper can choose among the following options:

[14] It may be possible to define a gate-closure on gas systems, in order to allow more efficient role of within-day or day-ahead implicit allocation. It will be discussed in the end of this paper.

[15] We describe in Section 4 the balancing mechanism in 3 different EU countries and how line-pack storage is used in them.

Option 1 (no storage possibilities):

- At time t: she buys gas in point A and sells it in point B. To do so, she must pay for transport from A to B.
- At time $t+T$: she buys the gas in point B and sells it in point C. She must pay for the transport from B to C.

Option 2 (costless line-pack):

- At time t: she only buys gas in point A. To do so, she pays for the transport from A to C, obtaining line-pack freely.
- At time $t+T$: she sells the gas in point C. The associated transport price is already paid for.

Option 3 (costly line-pack):

- At time t: she only buys gas in point A. To do so, she pays for the transport from A to C, and she pays for the line-pack corresponding to storage from t until $t+T$.
- At time $t+T$: she sells the gas in point C.

Option 2 involves lower risks, because it is not necessary to trade at point B. Therefore, the risk premium associated with the open position from time t to $t+T$ does not exist. In such situation, the shipper will always prefer the second option. When choosing between option 1 and option 3, the decision will depend on the comparison of the risk premium associated with the open position and the cost of line-pack. In a well-behaved market (perfectly-informed, arbitrage-free market), the cost of line-pack will be defined by the equilibrium market price of risk. This is the theoretical valuation of any storage facility. Therefore, from the analysis above, options 1 and 3 are equivalent in terms of market efficiency (with regard to inter-temporal allocation).

We can identify the situation described in option 2 with the one in a daily balancing. Line-pack services are used to balance the system, and hence socialized among the market players. On the one hand, the amount of services is administratively determined by the TSO, regardless the preferences of market participants. On the other hand, the value of line-pack plays no role in its allocation among shippers, who has potentially different values for the service. These line-pack values, as shown above, will be associated to their needs to allocate inter-temporal preferences and hence, the more variable flow patterns, the highest value for line-pack.

Option 1 may be identified with the choice of an hourly balancing mechanism, where no line-pack is offered to the market. Finally, option 3 is related to the introduction of network tariffs that reflect the actual use of line-pack, as the one proposed in Keyaerts et al. (2011). Although this option solves the problem of the allocation among players, it leaves to the TSO the decision on the trade-off between line-pack and transportation.

In summary, the offer of line-pack implied in the rules for network use has an impact in market outcomes. Moreover, if such line-pack offer is costless but line-pack services have a market value, it is in fact a substitute for gas trading, as the economic signals associated with the inter-temporal allocation of network rights are weakened.

3.2.2. Relative impact of inefficient line-pack allocation

From the analysis above, it is possible to conclude that the impact of the inefficient allocation of line-pack services is related to the heterogeneity of shippers' gas flows. The motivation for the temporal aggregation of network services is to make the gas traded over some period (e.g. over the day) the same product, and thus to decrease its specificity. In this situation, the TSO reduces the gas specificity by managing the differences within the day with line-pack services. It is sensible, thus, to investigate whether this is the case in the current situation of European gas systems.

From a historical point of view, until the 1990's network services demanders were basically composed by household and industrial consumers. Thus, the demand of network services was essentially a flat pattern, and so the active constraint on network services was the transport capacity. Besides the liberalization, after 1990 the gas industry also experienced structural changes on gas demand and supply. Between 1990 and 2010, gas demand has dramatically changed. This change has been largely motivated by the massive introduction of gas-fired power plants as gas consumers. Consequently, power plants became an important demander of gas transport services, increasing the heterogeneity among network service demanders. In that view, flexibility services have become a substitute of transportation, and thus the traditional aggregation of the network, where all pipelines are modeled as a group represented by its transmission capacity, may be not approximate enough anymore.

Hence, the heterogeneity is significant in current EU systems, and it will be likely larger in the future, as more intermittent power generation is included in European power systems. The inclusion of gas-fired power plants changed the gas demand profile, increasing hourly peaks and flow uncertainty in the last 20 years. Recently, the increase of wind generation has increased the role of gas-fired power plants as back-up generation. This in turn increases the role of natural gas as a flexibility provider for power systems. In addition, wind generation is expected to increase in the future. According to EREC (2011), the EU 27 power generation from wind should reach 14% in 2020. Comparing to the 4.6% in 2010, it will be a massive increase of wind production. That increase of intermittences (and hence of needs for back-up), is expected to be provided largely by gas-fired power plants.[16]

In EU, the offer of network services has been the result of installed infrastructure and a set of network usage rules. In this context, we should logically conclude that the new demand of network services required by power plants, especially due to the massive inclusion of intermittent wind power plants, needs an adaptation of the network rules.

4. The relationship among rules and tools: three balancing cases

Each of the three palliative measures described above to deal with the allocation of network services in entry/exit schemes implies some additional role for the TSO. In that view, the original role of the balancing mechanism is enlarged with the role of solving contracting inefficiencies. To do so, the TSO may use a range of possibilities, under significant uncertainty regarding the real flow that will finally take place.

When the adjustment required is low, the TSO may do it using only line-pack storage. When the need for adjustment increases, the TSO needs to use other infrastructures, such as underground storage, Liquefied Natural Gas (LNG) regasification,[17] or gas field variations (or pipeline imports). The tools applied by European TSOs are quite different, as shown in the table below.

[16] For more detailed discussions see Boccard (2010), Hiroux and Saguan (2010), Hallack (2011) and IEA (2011).

[17] LNG is an alternative method to transport natural gas. LNG regasification facilities receive LNG ships, store the LNG until required, and send out gaseous methane into the local pipeline grid. The peak send out capacity is the key variable to determine how much flexibility LNG can deliver to the system. It depends on LNG storage tankers size, vaporization size and technology, etc. For more details see Tusiani and Shearer (2007).

Country	TSO balancing tools				
	Line-pack	Production	Storage	LNG	Pipeline
Austria	×		×		×
Belgium	×		×	×	×
France	×		×	×	
Germany	×	×	×		×
UK	×	×	×	×	×
Italy	×		×		
Spain	×		×	×	

Source: Authors elaboration, data (KEMA, 2009).

All previous tools share the feature that they are time-flexibility mechanisms that the TSO needs in order to deal with the uncertainty in the use of the network. Put it another way, as the market leaves part of the network allocation to TSO's decisions, it has to be able to decide on the tools that allow balancing the results obtained through commercial arrangements and the physical characteristics of the network. This necessarily implies the loss of the corresponding market signals. Thus, the TSO is forced to use several flexibility tools of the network, regardless the market value that such tools may have. We will use three representative examples, UK, Italy and Spain, to illustrate the additional roles of the TSO.

4.1. UK balancing mechanism

The UK gas system operates a daily balancing regime in one zone. Any residual intra-day imbalances are contractually cleared by TSO's balancing actions. In the UK, the TSO may use different tools to balance the network system, as explained by Heather (2010). Among the main tools available to National Grid, the regulated tools used for balancing are line-pack and LNG peak-shaving. Line-pack is the tool used in the first place, leaving LNG as a tool for extreme conditions. That is, there is a strong use of line-pack storage as a tool to manage the gas balancing (National Grid, 2010).The gas imported through pipelines is the second source of daily flexibility.

If shippers are imbalanced at the end of the day, they should pay for the imbalance a price based on the System Marginal Price. This price depends on market prices, as it is either the highest (or lowest) balancing trade or the System Average Price, which represents the average cost of balancing actions in the market in order to adjust upwards or downwards (depending on the individual imbalances).

4.2. Italy balancing mechanism

In Italy, physical and contractual balancing are largely based on line-pack storage and underground storage. The imbalance charges are different for shippers with and without storage portfolio. Along the same lines of the UK balancing, shippers are charged for imbalances on a daily basis, but only if they violate a certain threshold (tolerance).

The TSO has the priority right to use an important part of the storage, as well as the withdrawal and the injection rates. In intraday horizons, the first tool applied by the TSO is line-pack storage. Only if it is not enough to balance the system, the storage tools come into play. If the shipper has storage rights in her portfolio, the imbalance is calculated as if the TSO would have used her storage capacity. That is, they pay for gas withdrawal (or injection) and for the storage capacity. If the shipper has no storage rights in her portfolio, the charge follows a rule detailed in the Network Code.[18]

4.3. Spain balancing mechanism

In Spain, as well as in the two other country cases, there is a daily balancing period and just one balancing zone. The gas commodity is traded in a virtual point, as in the UK, although its relative volume with respect to total gas transactions is considerably smaller. The shippers can trade gas at the Spanish balancing point within the day to adjust their balance. The main balancing tools are line-pack and LNG storage/regasification facilities. In that view, the transportation capacity that shippers pay for already has a price involving the line-pack. In addition, the system operator organizes a daily auction mechanism to restore any deviations to an acceptable level.

Similarly to the Italian system, Spanish balancing system has tolerances, allowing shippers to use the line-pack included in transportation services. Thus, the shipper can store up to 50% of its daily capacity in order to use in the following day. And this tolerance increase up to five days of contracted capacity in case of LNG facilities. From this point of view, there is a close relationship between the balancing approach and the available LNG regasification capacity.

The Spanish case includes different fees depending on whether there is over- or under-capacity (KEMA, 2009). The fees change if the shipper has LNG storage in the gas portfolio. In this regard, it is close to the Italian scheme where the balancing depends on the storage portfolio of the shippers. In Spain, as LNG is one of the main sources of flexibility, LNG storage is seen as a valuable back-up to the deficit of gas in the network. The excess and deficit in the LNG storage level are also penalized. The penalty associated with the first one is a regulated penalty, whereas the penalty associated with the second one is negotiated and depends on the LNG terminal (CNE, 2008).[19]

4.4. General criteria behind the country cases

The three case studies chosen in this section represent different set of tools to balance the system. Nonetheless, it has been shown that, even if the tools are different, the criteria to define the TSO participation follow the same idea.

The line-pack is the first tool utilized by all the TSOs to balance their systems. It may be explained because it is seen as a free tool, even when it has a cost associated with the use of the infrastructure. But such cost of the line-pack is socialized among all shippers in their network tariffs. As the imbalance increases its relative size, TSOs are allowed intervening additional network services, such as storage or LNG facilities. Although they are addressed as more costly options, the logic for their use is the same: the TSO needs flexibility tools to correct the allocation obtained from the market.

Therefore, the general problems addressed in this paper are illustrated by the country cases. The balancing mechanism is not only responsible to take account of the technical characteristics of the network, but also to decide on the resource allocation. The latter task, however, should be based on market players' preferences.

5. The future of the EU entry/exit regulation

5.1. ACER guidelines

According to the Third Package for Electricity and Gas markets (EC, 2009), the development of a coherent set of technical and

[18] The value lower than 8% of the capacity has no penalty, it is free tolerance. If the value is higher than 8% but still lower than 15%, the penalty is equivalent to 0.1€/GJ, if the unbalanced value is higher than 15% the penalty is higher, 0.3€/GJ.

[19] In Spain there are five types of possible imbalances: excess/deficit of stock level in LNG tanks; excess/deficit stock level in storage for commercial operation and deficit stock level operational reserves (line-pack). Network users are entitled to a tolerance band between 0 and 50% of the daily contracted capacity in the grid and up to five days of the contracted capacity in case of LNG facilities (KEMA, 2009).

market codes is needed for the integration of the EU national gas markets. In this process, the Agency for the Cooperation of Energy Regulators (ACER) is responsible to define guidelines to design a set of common capacity allocation and balancing rules, before the commitology process takes place. On the one hand, the proposals presented in the two ACER guidelines (ACER, 2011a,b), increase the simplification of the commercial network. But on the other, they allow the design of a better mechanism to adjust commercial and physical flows.

First, we may observe that the simplification associated with an entry/exit scheme will increase, through the development of bundled capacity among the cross-borders of national networks. “The Network Code shall set out that Transmission System Operators jointly offer bundled firm capacity services” (ACER, 2011a, page 9). And also by the creation of a virtual interconnection point, where two or more adjacent entry/exit systems are integrated by means of a single capacity service, representing one virtual connection point.

Second, there is also an increased use of palliative measures to improve the allocation of network resources, as day-ahead (or within-day) implicit auctions, over-booking capacity and interruptible capacity. The short-term implicit auctions, however, continue facing the constraint of continuous re-nomination. As the shippers may re-nominate their capacity rights, TSOs are not able to define the amount of available capacity to re-allocate implicitly even in the short run. As explained in the Congestion Management Procedures, the TSO should calculate network capacity and technical constraints based on its forecasts, market trends, historical flow data and results of allocation processes. Moreover, it underlines that the calculation of oversubscription and interruptible capacity should take into account also scenarios about probable amount of unused capacity, and thus they must make available an extra amount of capacity exceeding the firm capacity calculated. Therefore, there is strong uncertainty regarding what would be the gas flow. And it is the TSO who has the duty to guarantee the capacity that is made available to market participants.

Furthermore, the ACER guidelines may have some implementation challenges. On the one hand, the adjustment needed between commercial and physical flow increases the role of TSOs in the balancing mechanism. But the framework guidelines on gas balancing have indicated the need to increase the participation of shippers in the system balancing. “The principle is to provide, as much as possible, for network users to balance their individual portfolios which is likely to minimize the need for TSOs’ balancing actions” (ACER, 2011b, page 10). However, they do not propose clear mechanisms to minimize TSOs’ balancing actions.

We may point out two key aspects of the balancing guidelines aimed to reduce TSOs’ actions, and thus to increase the efficiency of the short-term network allocation: the line-pack allocation and the within-day obligations. First, the framework guidelines on gas balancing recognize the possibility for TSOs to sell line-pack services. They also underline the need to sell this service using a market based approach (although the guidelines do not propose a mechanism to market it). In addition, the balancing guidelines indicate that TSOs should cover the possibility to establish within-day obligations.

Together, these proposals from ACER (within-day obligations and commercial line-pack services) do not solve the problem of adjusting commercial and physical flows, but they open the possibility to separate the markets.

5.2. TSO balancing obligations and commercial needs for flexibility

Gas network flexibility has become a critical issue for gas market players and policy makers. Moreover, it also affects security of power systems operation and it is a central piece to achieve the EU renewable policy (IEA, 2012). Consequently, the need of providing flexibility services is difficult to dispute and has been supported by industry stakeholders.[20]

We do not dispute it either. We question the adequacy of allocating such flexibility through socialization in the balancing mechanism instead of through a mechanism representing players’ preferences. In this paper, we have shown that gas balancing as a mechanism to provide flexibility implies an inefficient allocation of the network resources. And we have shown that such inefficiencies are related to mixing two different tasks: ensuring system security and providing commercial flexibility. In that view, the source of the inefficiencies is not the flexibility provision itself, but the use of a unique mechanism to allocate two services with considerably different economic properties.

System security is a public good,[21] so its allocation through socialization is an efficient way to provide the service. On the other hand, flexibility to allow commercial arbitrage (between gas prices or between gas and electricity prices) is a private good.[22] Thus, the definition of property rights can lead to a better allocation of the available resources. The separation of those services is critical to improve the allocation of the network resources. Privatizing a public good (system security) can lead to a system crash. But making public those services with characteristics of private goods (as arbitrage services) may result in inefficiency.

A possible solution to implement the separation between security and commercial services has been proposed in Vazquez and Hallack (2012). On the one hand, one needs flexibility available to shippers. On the other, a relevant part of the flexibility needs to be priced. This task requires the tight coordination between a regulated player (the TSO) and market participants. This is a typical task of auctions. Vazquez and Hallack (2012) proposed two different auctions mechanism for improving the allocation of both line-pack storage (for arbitrage purposes) and transport capacity. This kind of mechanism would delimit the balancing services provided by the TSO as provider of system security, and at the same time, it would provide a fair price for flexibility. In addition, it would avoid potential entry barriers and would give signals to other facilities with potential as flexibility provider. Moreover, pricing flexibility is essential to give economic signals to the electricity sector. Nonetheless, this kind of mechanism has potential drawbacks that need to be better evaluated by policy makers. For instance, the costs of metering or the potential decrease of balancing market liquidity have been pointed out as drawback of the schemes restricting balancing just to system security services.[23] The trade-off between the costs and benefits of each option should be better assessed in further studies.

[20] Many of these opinions have been raised in the process of developing the EU Balancing Network Code, see the ENTSO-G Balancing Working Group material that can be accessed at http://www.entsog.eu/publications/balancing. A relevant future study would consist in the analysis of different players’ reactions to different proposals in the discussion of the guidelines and the network code.

[21] In terms of Ostrom et al. (1994), it is non-excludable and non-subtractible. If the system is secure, one cannot exclude a certain player from having security without excluding all other players (non-excludable). The security for a certain player does not decrease the security for the rest of players (non-subtractible).

[22] In terms of Ostrom et al. (1994), it is excludable and subtractible. The arbitrage ability can be privately appropriated, and the arbitrage ability of a certain player decreases the rest of players’ arbitrage ability (because it decreases the amount of network services available to the rest).

[23] See the ENTSOG Balancing working group material that can be accessed at http://www.entsog.eu/publications/balancing. These costs should be better assessed in further studies.

6. Conclusion

We have shown in this paper that current EU entry/exit regulation has driven an inefficient allocation of network resources. One of the first conclusions that can be drawn from the analysis developed in the paper is that the implementation of entry/exit regulations is not straightforward, as all the problems analyzed herein are associated with the simplification implied in the definition of the commercial network. We have taken for granted that transaction costs are prohibitively high in a market built on a pipeline-by-pipeline representation. However, it is worth to note that the US experience shows that, in an extremely complex network, the importance of transaction costs can be reduced by a variety of contractual solutions, and it is actually one of the most liquid markets in the world.

In any case, the entry/exit regulation is the choice of EU gas industry. In that case, several problems must be addressed to avoid the inefficiency in the operation of gas networks. In that view, we have shown that the role played by the TSO as a substitute of the secondary market for long-term gas transactions, is at the core of the problem.

Current EU entry/exit regulations are relying on the intervention of the TSOs to correct inefficient market outcomes. First, the inefficient capacity allocation associated with entry/exit schemes, and especially those resulting in contractual congestions, must be solved by TSO actions. However, the problem may be traced back to the impossibility of market participants to express their preferences on short-term capacity. The direct solution, thus, is to implement a short-term mechanism that allows market players to manage their short-term needs. This is a typical aim of a secondary market.

Moreover, transmission capacity is not the only service that can be offered by pipelines. Besides, they may serve as a storage facility using their line-pack capacity. However, line-pack depends on the pipeline pressure, so that it is in fact a substitute of transmission capacity. Currently, such trade-off is determined by the TSO but, even if some line-pack is used to ensure the security, line-pack has economic value, and cross subsidies implicit in its allocation may distort significantly the behavior of gas markets. The relative importance of these effects depends markedly on the nature of the gas transactions that are present in the corresponding wholesale market. Actually, the rules to useline-pack services in current EU entry/exit regulations are somehow designed for relatively homogeneous patterns of gas flows. But if the heterogeneity of network use increases, the rules for using line-pack results imply its inefficient use. This is the situation in current European systems. Again, the allocation of line-pack is a typical task of a secondary market.

We have finally analyzed the ACER proposal, showing that none of these effects have been addressed, but they allow the possibility of using more efficient mechanisms to allocate network services. In this regard, this paper shows that some solutions to cope with the information problems need to be better developed. In particular, EU regulations, based on the combination of entry/exit allocation and a balancing mechanism seem not to be sufficient to obtain the efficient allocation of the network. In addition, a short-term, market based mechanism is required, in order to allow shippers reveal their preferences on the operation of the gas network.

The general principle guiding the design of such mechanism must be the minimization of TSO participation in the market. To do so, auctions may be used in order to include both commercial services that networks may offer: transport and storage services. In this view, the short-term mechanism should not be based in homogeneous offers of network services. In particular, as the time-variability of shippers' gas patterns is not homogeneous, their needs for line-pack and transmission services will not be homogeneous either. Therefore, the short-term mechanism should allow shippers to reveal their preferences on the trade-off between transmission and line-pack services.

References

Abhishek, Vineet, Hajek, Bruce, Williams, Steven R., 2012. Auctions with a Profit Sharing Contract. University of Illinois, USA.

ACER, 2011a. Framework Guidelines on Capacity Allocation Mechanisms for the European Transmission Network. Agency for the Cooperation of Energy Regulators. Draft for Consultation, DFGC-2011-G-001.

ACER, 2011b. Framework Guidelines on Gas Balancing in Transmission Systems. Agency for the Cooperation of Energy Regulators. Draft for Consultation, DFGC-2011-G-002.

Barzel, Yoram, 1982. Measurement costs and the organization of markets. Journal of Law and Economics 25 (1), 27–48.

Boccard, N., 2010. Economic properties of wind power: a european assessment. Energy Policy 38 (7), 3232–3244.

CNE, 2008. Informe 8/2008 De La Cne Sobre La Propuesta De Resolución Por La Que Se Modifican Las Normas De De Gestión Técnica Del Sistema Ngts-06 'Repartos' Y Ngts – 07 'Balance' Y El Protocolo De Detalle Pd 02 'Repartos En Redes De Distribución'. Comisión Nacional de la Energía (in Spanish).

Coase, Ronald, 1960. The problem of social cost. Journal of Law and Economics 3, 1–44.

Costello, K., 2006. Efforts to harmonize gas pipeline operations with the demands of electricity sector. The Electricity Journal 19 (10).

Cramton, Peter, 2007. How best to auction oil rights. In: Humphreys, M., Sachs, J.D., Stiglitz, J.E. (Eds.), Escaping the Resource Curse. Columbia University Press, USA.

EC, 2007. Commission Staff Working Document on Capacity Allocation and Congestion Management for Access to the Natural Gas Transmission Networks Regulated under Article 5 of Regulation (Ec) No 1775/2005 on Conditions for Access to the Natural Gas Transmission Networks, European Commission.

EC, 2009. Regulation (Ec) No 715/2009 of the European Parliament and of the Council of 13 July 2009 on Conditions for Access to the Natural Gas Transmission Networks and Repealing Regulation (Ec) No 1775/2005.

ERA, 2005. Energy Resource Associates Report on Behalf of the Ontario Energy Board.

EREC, 2011. Eu Member States Collectively Forecast to Exceed the Biding 20% Rer Target, Press Release. European Renewable Energy Council. 5th January.

Gilbert, Richard, Neuhoff, Karsten, Newbery, David, 2004. Allocating transmission to mitigate market power in electricity markets. RAND Journal of Economics 35 (4), 691–709.

Glachant, Jean-Michel, 2002. L'approche Néo-Institutionnelle De La Réforme Des Industries De Réseaux. Revue économique 53, 425–435 (in French).

Glachant, Jean-Michel, Finon, Dominique, 2000. Why do the European Union's electricity industries continue to differ? A new institutional analysis. In: Menard, C. (Ed.), Institutions, Contracts and Organizations. Edward Elgar, Cheltenham.

Gordon, Walker, Weber, David, 1984. A transaction cost approach to make-or-buy decisions. Administrative Science Quarterly 29 (3), 373–391.

Hallack, Michelle, 2011. Economic regulation of offer and demand of flexibility in gas networks. Universite Paris-Sud 11.

Heather, P., 2010. The evolution and functioning of the traded gas market in Britain. Working Paper NG44. Oxford Institute of Energy Studies.

Hiroux, C., Saguan, Marcelo, 2010. Large-scale wind power in European electricity markets: time for revisiting support schemes and market designs? Energy Policy 38 (7), 3135–3145.

Honore, A., 2011. Economic recession and natural gas demand in Europe: what happened in 2008–2010? Oxford Institute for Energy Studies. NG 47.

Hunt, Paul, 2008. Entry–exit transmission pricing with notional hubs: can it deliver a pan-European wholesale market in gas? Oxford Institute for Energy Studies. NG 23.

Hunt, S., Shuttleworth, G., 1996. Competition and Choice in Electricity. J. Wiley, New York.

IEA, 2011. The Impact of Wind Power on European Natural Gas Markets. International Energy Agency, Paris.

IEA, 2012. The Impact of Wind Power on European Natural Gas Markets. International Energy Agency, Paris.

Joskow, Paul, 2005. Vertical integration. In: Menard, C., Shirley, M. (Eds.), Handbook of New Institutional Economics.

Joskow, Paul, 1985. Vertical integration and long-term contracts: the case of coal-burning electric generation plants. Journal of Law, Economics and Organization 1 (1), 33–80.

Joskow, Paul, Schmalensee, Richard, 1983. Markets for Power. MIT Press.

Joskow, Paul, Tirole, Jean, 2000. Transmission rights and market power on electric power networks. RAND Journal of Economics 31 (3), 450–487.

KEMA, 2009. Study on methodology for gas transmission network tariffs and gas balancing fees in Europe, Report ordered by European Commission DG TREN.

Keyaerts, N., Hallack, M., Glachant, J.M., D'haeseleer, W., 2011. Gas market effects of imbalanced gas balancing rules: inefficient regulation of pipeline flexibility. Energy Policy 39 (2), 865–876.

Lapuerta, C., Moselle, B., 2002. Convergence of non-discriminatory tariff and congestion management systems in the European Gas Sector, The Brattle Group. Report to European Commission.
Masten, Scott, Meehan, James, Snyder, Edward, 1991. The costs of organization. Journal of Law, Economics and Organization 7, 1–25.
National Grid, 2010. Published Bmra Initial Demand Outrun.
Ostrom, E., Gardner, R., Walker, J., 1994. Rules, Games and Common-Pool Resources. The University of Michigan Press.
Ruff, Larry E., 2011. Gas markets reform: a global perspective. Gas Industry Company Conference. Optimizing the Contribution of Gas to New Zealand, Market Reform.
Tusiani, M.D., Shearer, G., 2007. Lng: A Nontechnical Guide. Penn Well Books, Oklahoma, USA.
Vazquez, Miguel, Julian, Barquin, 2007. Gas Logistics Costs: Simulation of the Proposed Endesa/Gas Natural Merger. IAEE European Energy Conference, Florence, Italy.
Vazquez, Miguel, Michelle, Hallack, 2012. Design of auctions for short-term allocation in gas markets based on virtual hub, EUI Working Paper RSCAS 2012/43.
Williamson, Oliver, 1983. Credible commitments: using hostages to support exchange. American Economic Review 73, 519–540.
Williamson, Oliver, 1985. The Economics of Institutions of Capitalism. Free Press, New York.
Williamson, Oliver, 1975. Markets and Hierarchies: Analysis and Antitrust Implications. Free Press, New York.
Williamson, Oliver, 1996. The Mechanisms of Governance. Free Press, New York.