



# A fundamental analysis on the implementation and development of virtual natural gas hubs



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## ABSTRACT

The ongoing gas market liberalization in Europe has brought up a new competitive environment in which shippers (i.e., companies that are responsible for conveying gas from producers to consumers) must adapt their behavior to the changing conditions. The development of gas virtual hubs increases market interactions among shippers, but the oligopolistic market structure may give room for strategic behavior. The market is in addition segmented by type of customer. Each shipper maximizes its profit by supplying gas to households, businesses and industries (conventional customers), participating in the electricity market, trading in the global LNG spot market and interacting with the rest of shippers in a virtual hub. During the hub implementation and development, the following questions arise: How do shippers behave at the different levels of hub maturity? And, to what extent does the implementation of virtual hubs in entry-exit systems diminish the barriers to entry of new market players, provides more flexibility and fosters competition?

With this aim, the decision-making process of the different shippers is simulated under different market structures, representing four stages of the market liberalization process at different levels of hub maturity. First, the proto-liberalization case includes the global LNG spot market which is represented as a perfectly competitive market, the electricity market which is represented as an oligopoly, and the conventional demand which is assumed to be captive (i.e., monopolized). Second, a hub is implemented, which provides transparency and reduces information costs by revealing the gas price. Third, switching rates are expected to grow as consumers have access to a transparent gas price; hence, the conventional demand is no longer considered as captive. Fourth, wholesale (procurement) and retail activities are unbundled, and a wholesale market is established where the retailers presumably buy gas from the shippers; thereby wholesale and retail activities acquire importance and market transactions (i.e., liquidity) increase. From the simulation and the analysis of the different market equilibria, the following conclusions emerge. First, with the introduction of the virtual hub, the marginal cost of all shippers reaches a unique value, i.e., the transparent gas hub price. Second, the aggregated profit of the shippers is increasing even when anticompetitive behavior is not explicitly represented, due to the flexibility gained by shippers with the hub. Accordingly, and third, the hub is a necessary, but not sufficient, condition to increase competition. The entry of new players is critical and discouraging market regulations or the anticompetitive behavior of a highly concentrated market may not facilitate it.

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## 1. Introduction

The EU is leading the way towards the gas market liberalization through the implementation of virtual hubs. The 3rd EU Gas Directive (2009/73/EC) proposes the unbundling of activities (i.e., separation of networks from activities of production and supply), the implementation of entry-exit access systems and the constitution of national or supra-national virtual hubs in order to enlarge the market, reduce the entry

barriers and improve the degree of competition. An entry-exit system is a third-party network access system, which allows network users to book capacity rights at specific entry and exit points of the so-called balancing zones. Every day, the users nominate the amount of gas that they expect to inject to and withdraw from the entry and exit points, respectively. The nomination process determines the gas transport through the pipelines embedded within the balancing zone. Since the entry and exit nominations may not coincide with the real inflows and outflows, virtual trading points (i.e., virtual hubs) have been created where gas balancing and wholesale trading is facilitated. Therefore, the virtual hubs are balancing electronic platforms that are associated with a set of delivery points for which the same specific balancing regime is

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**Notation**

*Sub-indexes*

<i>a</i>	index of shippers
<i>w</i>	index of wholesalers
<i>r</i>	index of retailers
<i>p</i>	index of periods

*Parameters*

$P_{ap}^{c_0}$	intercept of shippers' cost function per period (€/MWh)
$\alpha_{ap}^c$	slope of shippers' cost function per period (€/MWh <sup>2</sup> )
$P_{ap}^{l_0}$	intercept of the conventional demand function per period (€/MWh)
$\alpha_{ap}^l$	slope of the conventional demand function per period (€/MWh <sup>2</sup> )
$P_{ap}^{e_0}$	intercept of the electricity demand function per period (€/MWh)
$\alpha_{ap}^e$	slope of shippers' electricity demand per period (€/MWh <sup>2</sup> )
$P_p^x$	price of global LNG market per period (€/MWh)
$\bar{Q}_{ap}^c$	maximum gas volume contracted per shipper per period (MWh)
$\underline{Q}_{ap}^c$	minimum gas volume contracted per shipper per period (MWh)
$\bar{Q}_a^c$	maximum gas volume contracted per shipper for all periods (MWh)
$\underline{Q}_{ap}^c$	minimum gas volume contracted per shipper for all periods (MWh)
$\bar{Q}_p^x$	maximum liquidity of global LNG markets for all shippers (MWh)

*Variables*

$p_{ap}^i$	shippers' price for conventional demand (captive demand) (€/MWh)
$p_p^i$	shippers'/retailers' price for conventional demand (€/MWh)
$p_p^e$	electricity demand price (€/MWh)
$q_{ap}^i$	gas demanded by shipper for supplying conventional demand (MWh)
$d_{rp}^i$	gas demanded by retailers for supplying conventional demand (MWh)
$q_{ap}^e$	gas demanded by shipper for its electricity demand (MWh)
$q_{ap}^x$	gas demanded by shipper for the global LNG market (MWh)
$q_{ap}^c$	gas contracted by shipper from long term contracts (MWh)
$c_{ap}$	procurement cost function (€/MWh)
$\Delta q_{ap}$	shippers' gas purchase in the hub per period (MWh)
$\nabla q_{ap}$	shippers' gas sales in the hub per period (MWh)
$\lambda_p$	price in the hub (€/MWh)
$\varepsilon_{ap}^1$	dual variable of the upper bound on gas demanded by a shipper per period
$\varepsilon_{ap}^2$	dual variable of the lower bound on gas demanded by a shipper per period
$\varepsilon_a^3$	dual variable of the upper bound on gas demanded by a shipper for all periods
$\varepsilon_a^4$	dual variable of the upper bound on gas demanded by a shipper for all periods
$\mu_{ap}^l$	dual variable of the lower bound on gas demanded by a shipper for its captive demand

$\mu_{ap}^e$	dual variable of the lower bound on gas demanded by a shipper for its electricity demand
$\mu_{ap}^{\Delta q}$	dual variable of the lower bound on gas purchases by a shipper in the hub
$\mu_{ap}^{\nabla q}$	dual variable of the lower bound on gas sales by a shipper in the hub
$\chi_{ap}^1$	dual variable of purchases on gas delivered to the global LNG spot market by a shipper
$\chi_{ap}^2$	dual variable of sales on gas delivered to the global LNG spot market by a shipper

applicable, including the rules that apply to TSO balancing and the procurement of balancing services. Hence, the virtual hubs are not linked to a specific gas facility or any physical junction of pipelines, but to the gas facilities embedded in the balancing zone.

The liberalization process has changed the legal and economic framework of the gas industry, from monopolies to oligopolies, as in most of the EU countries (e.g., Spain and Portugal, Germany, or the UK). The introduction of competition in the gas market due to the ongoing liberalization in Europe increases the interaction among shippers (i.e., companies that are responsible for conveying the gas from producers to consumers) in downstream gas systems. As the entries and exits from the balancing zones may be uncertain, shippers buy and sell gas to balance their position. Shippers have usually performed OTC bilateral operations in the search of daily balancing their entries, exits and inventory variations. The creation of European gas hubs is based on the shippers' necessity to cope with their imbalances and on regulators' interests regarding transparent and public price formation. Despite the similarities between the 3rd Gas Directive and the Electricity Directive 2003/54, the organization and development of wholesales trading platforms in the electricity market and in the gas markets have been entirely different (Polo and Scarpa, 2013).

Gas markets have traditionally been based on long-term supply bilateral contracts for covering gas demand. These contracts normally entail restrictive clauses (e.g., Take-or-Pay (ToP) clauses) that reduce flexibility and slow down the market liberalization process. However, this liberalization is gaining importance as it is being reflected on gas-to-gas competition and a general trend toward more flexible long-term supply contracts, although rigid contracts are still signed. Conversely, gas demand is expected to be even more volatile (e.g., gas-fired power plants) in the future and yet current pricing and market structures are not amenable to that outcome.

The introduction of virtual hubs is expected to reduce transactions costs, achieve additional flexibility, increase liquidity, and favor forward and future markets. Once the market gains liquidity, the hub might turn out to be an alternative to long-term contracts and become another procurement source. The development of the European gas hubs, with different volumes and liquidities has brought up the two following questions: How do shippers behave at the different levels of hub maturity? And, to what extent does the implementation of virtual hubs in entry-exit systems diminish the barriers for the entrance of new market players, provide more flexibility and foster competition? In order to answer to these questions we present a novel representation of the strategic behavior of profit-maximizing shippers within the different stages of the evolution of virtual gas hubs.

The gas sector liberalization process has received wide attention during the last years and several models and analyses have been developed. Mathiesen (2001) analyzes the market power in the EU gas sector concluding that it can be described as a Cournot oligopoly. Golombek et al. (1994, 1998) analyze the effects of liberalizing the gas market in Western Europe by distinguishing between upstream and downstream agents and allowing agents to arbitrage. The GASTALE model, Boots et al. (2003, 2004) focuses mainly on the role of the downstream trading companies in the European gas market. Their interaction with

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