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Natural Gas Markets in the European Union: Testing Resilience

HENRY BARTELET^a and MACHIEL MULDER^b

ABSTRACT

The liberalization and integration of natural gas markets in Europe have resulted in gas-to-gas competition on a European scale with closely related natural gas prices in the various markets. More recently, the European Union aims to become a resilient energy union which may call for additional policy measures. In this paper we discuss the need for such additional measures on top of the existing measures to liberalize and integrate markets. We test the hypothesis that the European natural gas market is resilient to adequately deal with external shocks by analyzing the five most dramatic supply disturbances in the European natural gas markets over the past decade. We find that the natural gas markets were able to trigger responses by market parties which prevented forced supply of gas to consumers in almost all cases. In one case, infrastructure bottlenecks prevented market players to adequately respond to a shock. Hence, we conclude that the best policy to create a resilient energy union is to further integrate European markets and to further remove barriers for market participants.

Keywords: gas market, security of supply, resilience, EU energy policy

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1. INTRODUCTION

The policies of governments regarding energy systems generally refer to different objectives which may be conflicting with each other. In the European Union, the energy policy is built upon five closely related pillars: supply security, a fully integrated internal energy market, energy efficiency, emission reduction and research and innovation (European Commission 2015b). In accordance with its ambition that Europe needs to have a secure, affordable and climate-friendly energy system, the European Commission wants to develop the European natural gas infrastructure in such a way that gas can flow without any technical or regulatory barriers between the regional gas markets. This policy is part of the ‘Energy Union Package’, which is meant to increase the so-called ‘resilience’ of the European natural gas market. This package contains “a framework strategy for a resilient energy union with a forward-looking climate change policy” (European Commission 2015c). The package is addressing the whole energy mix. In the context of natural gas, the Commission points to security of supply which should be enhanced through diversification of import routes and increasing the role of storages.

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Direct interventions by the European Commission aimed at increasing the diversification of energy supply, such as building alternative routes, through pipeline or LNG, to suppliers outside of the European Union, however, runs the risk to be at odds with the idea behind a liberalized market¹. In a well-connected European market, investments in such infrastructure would be made by network operators operating in a regulatory framework or commercial market players for which the investment decision is a function of expected market sizes and expected regional price differences. In theory, an integrated European market should be able to attract such investments in infrastructure, where and when they are needed.² In addition, national solutions to deal with security of supply risk may be more efficient than measures at regional level such as regional infrastructure projects (Noël et al., 2013). However, it seems that resilience, as proposed in the Energy Union Package, seems to be strongly related to market interventions directed at stimulating regional infrastructure investments.

The proposal within the Commission's Energy Union package for 'voluntary demand aggregation mechanisms for collective purchasing of gas during a crisis' (European Commission 2015c) strengthens the idea that the European Commission wants to give a more important role to coordinated decision making. With the aim of increasing buyer power, it seems to switch back to (large) central market players. As a country decides to join the collective buying of gas it will undermine gas trading on the liberalized gas hubs. As a result, liquidity on the gas hubs may be expected to slow down and reverse. Developing such mechanisms can be seen as a counter-policy towards the market liberalization which has been rolled-out over the last fifteen years.

In this paper we analyze the resilience of the European natural gas markets over the past years. This paper contributes to the literature by providing a better explanation of the term resilience in relation to gas markets. This term, used by the European Commission regarding its energy policy, comes from ecological economics (Folke 2006; Plummer & Armitage 2007; Walker et al. 2004) and has not been assessed yet in the literature dealing with energy markets. Unlike most papers, assessing only price responses to shocks,³ this paper analyzes the market mechanism of adjustment and how the physical balance is restored. This represents a novel point of view and provides a useful analysis for assessment of the European security of supply policy.

This paper analyzes the five most extreme disturbances since the liberalization of the European gas market in order to assess whether the market proved to be resilient. Our analysis focuses on the role of the market's price mechanism to restore the supply/demand balance. We find no reason to reject the hypothesis that the liberalized gas market model is resilient. Therefore, we conclude that European policy making for gas markets should focus on strengthening interconnections within the European market and leave the security and diversity of supply issue primarily to the market.

1. If governments would directly invest in infrastructure, this may crowd out commercial investments. This does, however, not imply that any government intervention directed at supporting commercial investments would not fit in a liberalized market model.

2. As is the case in the USA where even the within-border infrastructural projects are privately-owned and driven by commercial interests. In the European market, the incentives for network operators to invest in new capacity strongly depend on the regulatory environment and the organization of entry-exit zones (Vazquez et al., 2012).

3. For instance, Huntington (2018) finds that the oil price increases by about 40% in response to a 10% negative shock in world oil production. Kaufmann (2016) estimates the price premium buyers have to pay for oil from countries with a higher risk of supply disruption. Jadidzadeh et al. (2017) find that 45% of the fluctuations in the natural gas price in the US market can be attributed to shocks in the oil market.

The remaining of this paper is organized as follows. Section 2 discusses the liberalization of the gas market and how the concept of resilience can be applied to these markets. Section 3 discusses the hypotheses which will be tested, and it also describes the past disturbances in more detail. Section 4 presents and discusses the results. The conclusions and policy recommendations are given in Section 5.

2. GAS MARKETS AND RESILIENCE

2.1 Liberalization of European natural gas markets

Historically in Northwestern Europe, and still in most parts of East- and Southern Europe, the coordination mechanism to allocate supply over demand was based on a monopolistic or oligopolistic structure. This meant that customers had to buy their gas from one or a few gas-supplying firm(s). Within this market structure, long-term contracts were often negotiated in which the pricing terms were related to the price of oil-products, with periodic price reviews, an annual off-take quantity and minimum take-or-pay levels. On such ‘centralized’ markets, the buyers take the ‘price risk’ and the sellers take the ‘volume risk’ (Stern and Rogers 2014). Thus, the monopolistic player is responsible for supplying sufficient volumes of gas to the market, and in the case of a disruption in its supply, it will need to have access to alternative volumes of gas, for example through storages or other gas fields.

With the first energy package in 1998, the European Union (EU) started a process of gas market liberalization aimed at breaking the monopolistic structures. A competitive and open

FIGURE 1
Gas hubs and exchanges in Europe.

Source: <http://www.etrmsystems.com/markets-EUgas.htm>.

gas market would help the EU to reach its goals of secure, affordable and climate-friendly energy for both citizens and businesses (European Commission 2015a). By a gas market model as was introduced in the United States of America (US) and by strengthening the gas infrastructure within Europe, gas should be able to flow freely between different regional markets based on both physical requirements and price signals (Heather 2012).

In the US, gas markets are based on physical hubs located at nodes in the gas network, but in the EU most of the hubs are virtual, which means that all gas within the network can be traded.⁴ The hubs serve as a virtual entry point in the portfolio of a trader who buys gas on the hub or as a virtual exit point in the portfolio of a trader who sells gas (Heather 2012). The network operator registers the transfer of ownership rights for which traders have to submit nominations (i.e. electronic messages stating volume, period, purchasing and selling parties). Trade on gas hubs can be done on different types of market places: exchanges, bilateral or Over-the-Counter (OTC). Major hubs in Europe are NBP (Net Balancing Point) in the UK, TTF (Title Transfer Facility) in the Netherlands, NCG (Net Connect Germany) and GPL (GasPool Balancing Services) in Germany and PSV (Punto di Scambio Virtuale) in Italy (Figure 1). Especially the trading hubs in north-western Europe are viewed to have reached a high level of maturity given the wide number and variety of participants, high churn ratios and prices that are not influenced by individual market players.

2.2 The concept of resilience

Resilience thinking has its origin in the field of ecology (Walker et al. 1969) but has also become widely applied in the field of environmental science (Pimm 1984; Tilman and Downing 1994), though with a different, engineering-based angle. Holling (1996) explains the fundamental difference between the definitions of resilience coming from the two branches of study. The concept of resilience from an engineering background is mostly quantitative and it focuses on measuring the speed of return to equilibrium as a measure of the system's ability to deal with disturbances. The ecologists focus on the existence of two or more equilibrium states and define resilience as the ability of the system to remain within the desired equilibrium state as it experiences disturbance. The commonality in both approaches is that the resilience of a system depends on its ability to "prepare for disruptions, recover from shocks and stresses, and to adapt and grow from a disruptive experience" (Rodin 2015). Based on the study of a variety of social-ecological systems, the three most important factors that increase the resilience of a system are (Walker and Salt 2012):

1. Diversity; a variety in the number of species, people, and institutions that exist in the system and that are responsible for creating both functional and response diversity;
2. Modularity; systems with subgroups of components that are strongly linked internally, but only loosely connected to each other, have a modular structure;
3. Tightness of feedback; refers to how quickly and strongly the consequences of a change in part of the system are felt and responded to in other parts; institutions play key roles in determining tightness of feedback.

4. On a virtual hub, the gas price is a representation of the gas situation in a certain country or region, without geographic differentials due to transport costs, while on physical hubs prices reflect the supply/demand balance at physical entry/exit points. The Baumgarten gas hub in Austria is the most important physical gas hub in the EU.

As this paper is the first to examine the resilience of natural gas markets, it proposes to assess the market using a definition of resilience which encompasses both an engineering and ecological perspective. From the field of engineering, the degree of resilience of the market is related to the time of return to and the level of equilibrium after the shock. From an ecological point of view, a second (unstable) state is identified in which the market mechanism is unable to meet security of supply to its end-consumers. If this unstable state is reached, the transmission system operator has to step in and cut off supply to some of the end-consumers, until the market is again able to meet supply requirements (the desired equilibrium state).⁵ A resilient gas market is thus defined as a market which has the capacity to absorb different kinds of shocks and to restore price equilibrium swiftly, without jeopardizing security of supply to its end-consumers. It is important to realize that this definition of a resilient gas market excludes the potential help of network operators to deal with disturbances. If operators are needed to restore the balance of gas networks by shutting off some groups of customers, the market is apparently not able to do this itself. In a broader definition of resilience, interruptible contracts by TSOs could be argued to be part of the resilience of the market by having the option of shutting off interruptible customers when there is a danger for net stability.

The general resilience of the gas market refers to its capacity to absorb disturbances of all kinds, including novel, unforeseen ones. The resilience of a system (here the gas market) can be assessed based on three kinds of stresses: characteristic disturbances, large infrequent disturbances, and unknown shocks (Walker and Salt 2012).

Characteristic disturbances are related to a specific resilience, which includes its ability to cope with known and regular changes in market circumstances. Such characteristic disturbances include notable changes in weather conditions and planned maintenance of the physical gas infrastructure. Since characteristic disturbances have a high level of predictability to market players, they will be able to deal with them in advance. Market players can use, for instance, the swing within their gas contracts, buy gas on the forward market, attract storage capacity and buy gas on the spot market. On a highly-resilient gas market, characteristic disturbances are not likely to have a strong effect on prices on the spot market, since market players are able to anticipate those disturbances beforehand and use several portfolio and trading options to restore the supply balance.

Large infrequent disturbances and unknown shocks are related to the general resilience of the system. A large infrequent disturbance could be an (unexpected) outage at one of the major gas suppliers or a problem at one of the main gas pipelines. Unknown shocks could include changes outside of the gas market itself, for example an accident at a nuclear power plant that leads to a strong increase in gas demand by power generation companies. Large infrequent disturbances and unknown shocks have less predictability and are therefore related to the general resilience of the system. Whereas characteristic disturbances are not expected to produce price signals on a resilient market, such signals can be expected when a market experiences a large and infrequent disturbance or an unknown shock. Such an event will have a quick and strong impact on the market prices, which will trigger market players to respond on the short, medium and long-term, bringing the price back down to its equilibrium value quickly (Figure 2). In a non-resilient market, the price response is slow and long lasting.

Reaching a high level of resilience can be accomplished as an iterative process, in which the market players will improve their response mechanisms as they learn from prior market

5. Note that interruptible contracts can be deemed cost-efficient since it offers certain customers a discount on their gas contract because the TSO has the flexibility to curtail their off-take of gas during situations of high stress.

FIGURE 2

Impact of disturbance on price in resilient and non-resilient market.

Source: Own illustration.

disturbances. From studying nature, we learn that ‘a forest in which fire is always prevented eventually loses the species capable of withstanding fire; so the only way for a forest to remain resilient to fire is for it to be burned every now and then’ (Kupers 2014). In the same way, the gas market can increase its resilience by experiencing disturbances every now and then.

✎ 3 METHOD AND DATA ✎

3.1 Testing hypotheses

In order to assess to what extent European gas markets are resilient, we analyze how the market has responded in a number of unexpected disturbances to the gas system over the past decade. During each of these events, the supply of gas to the market was heavily interrupted. For each event, we test the following hypotheses:

1. Following an extreme disturbance, the market price provides an immediate signal (price peak) to reflect the new supply and demand balance.
2. Following the price peak, market players respond accordingly by sourcing sufficient additional sources of gas to the market and/or by decreasing demand.
3. Following the adequate response of the market players, no involuntary supply cuts to end-users (households and industry) have to be enacted by the transmission system operator (TSO).
4. Following the adequate response of the market players, the market price is restored back to its equilibrium level.

Our analysis focuses on the aggregate behavior of the gas market during and after the period of disruption, using daily data from Bloomberg.⁶ First, we consider the price response mechanism to the disruption by analyzing the development of hub prices immediately after a period of disruption. We discuss the speed and duration of price changes and compare the price movements to the average movements of prices on the same days over a number of years.⁷ Secondly, the response of market players to the disruption is assessed by analyzing the international flows between markets as well as the usage of storages. Thirdly, we assess whether the markets were able to prevent forced terminations of gas supply, enacted by the TSO, to end-consumers during the disturbances. Finally, we quantitatively examine how fast the gas price is restored back to equilibrium by comparing the duration of the increased price levels to the duration of the disturbance.

3.2 Recent disruptions in the European gas market

We analyze the response of the market to the major disruptions over the past decade. Research from the Oxford Institute for Energy studies concluded that the main disruptions on the European gas market have been the Russian/Ukraine crisis of January 2009, the combination of cold weather and Russia/Ukraine problems of February 2012 and the March/April 2013 cold spell (Stern and Rogers 2013). Several other studies have confirmed that the main recent disruptions on the European gas market occurred in February 2012 and March 2013, caused by a combination of cold weather and a disruption in the supply of gas (E.ON 2013; European Commission 2013; Henderson and Heather 2012; IEA 2012b; IEA 2014). Since the publications of these reports, there was one other serious disruption in the European gas market, which was the explosion at the Baumgarten gas plant in Austria in December 2017, which led to an interruption in gas flows from one of Europe's most connected gas hubs. This explosion took place during a period of increasing cold weather. Thus, in this research the cases of January 2009, February 2012, March 2013 and December 2017 will be explored further (Table 1).

January 2009 is the first period since the liberalization of the European gas market, which classifies as a large infrequent disturbance. In this period, Russian gas deliveries to the European market were disrupted because of a gas dispute between Russia and the transiting country Ukraine (Aune, et al. 2017). Because of this dispute, Russian gas exports to the EU were significantly reduced by January 6 and completely cut off by January 7. It took until January 20 before gas deliveries were restarted (Pirani et al. 2009; IEA 2009). The impact of this disruption was the strongest in the Balkan and Eastern European gas markets, which were almost completely dependent on this transit route for gas deliveries. In our analysis we will focus on the impact of this disturbance in the south of Germany, where there was a reduction of gas supplies of 60% compared to normal import levels (Pirani et al. 2009). The disturbance coincided with surging gas demand caused by the extremely cold weather in large parts of Western and Central Europe (IEA, 2009).

In February 2012, there was a period which qualifies as a large infrequent disturbance in which extreme cold temperatures and transit problems in Ukraine led to a supply shortage of

6. The movements of aggregate market data is, of course, related to the individual behaviour of market players, such as contractual delivery commitments, portfolio options and trading strategies.

7. The actual number of years considered differs across the different markets, depending on the availability of this data in Bloomberg. For the prices at the NBP, TTF, NCG and GPL prices this period is 1 January 2010 until 31 December 2017, but for other variables, such as prices at PSV, the period may be a bit shorter.

TABLE 1
Major disruptions in the European gas market since 2009.

Period	Disturbance	Market	Size of disturbance	Weather (actual temperature below normal temperature)	Start date	End date
January 2009	Disruption gas transits Ukraine	NCG (GER)	60% compared to normal import levels	-10 degrees Celsius	January 6	January 20
February 2012	Disruption gas transits Ukraine	NCG (GER)	30% compared to normal import levels	-11 degrees Celsius	February 2	February 7
March 2013	Nyhamna plant outage (Norway)	NBP (UK)	10% compared to normal import levels	-8 degrees Celsius	March 3	Lasted a few days ^{c)}
March 2013	Interconnector outage	NBP (UK)	25% of recent UK demand levels ^{a)}	-4 degrees Celsius	March 22 (0700 GMT)	March 22 (1500 GMT)
December 2017	Baumgarten explosion	PSV (IT)	40% compared to normal import levels ^{b)}	+2 degrees Celsius	December 12	December 13

Note: The weather variable is an average of the daily average temperatures during the disruption period. For German shocks in Munich, for UK in Southend-On-Sea and for Italy in Barona, Milan (Source: <https://www.wunderground.com/weather>).

Sources: a) <https://www.platts.com/latest-news/natural-gas/london/wrap-uk-gas-market-spikes-on-interconnector-outage-6282481>; b) <https://www.rt.com/business/413375-russia-gas-europe-lng-dependence/>; c) http://www.mondovisione.com/_assets/files/Platts-International-Gas-Report-April-8-Edition.pdf.

Russian gas to, among others, the German market (Henderson and Heather 2012). The impact was the strongest in the south of Germany, where gas imports from Russia, at the Waidhaus entry point, were down 30% below normal while at the same time natural gas demand soared due to extremely cold temperatures (IEA 2012a). Average recorded temperatures in Munich on the 2nd of February reached -9 degrees Celsius and it reached a low of -15 degrees Celsius on the 6th of February.

In the beginning of March 2013, the gas market in the United Kingdom (UK) faced a large infrequent disturbance when an outage at the Nyhamna gas processing plant caused an interruption in gas supply from Norway to the UK of 53 million cubic meters of gas per day (Platts 2013a). The Nyhamna plants processes gas from the Ormen Lange field in Norway before transporting it to the United Kingdom, through the Langed pipeline. The supply through this route averaged around 10% of the UK's daily gas supply in 2013 (Parliamentary Group on Energy Costs 2015). Besides the interruption of gas supply from the Langed pipeline, large parts of Europe faced an extreme cold spell with 5 to 10 °C below normal temperatures (KNMI 2013). The Nyhamna outage and cold spell coincided with the UK's storage facilities, mainly the largest seasonal storage facility in Rough, being almost empty at the end of the winter period.

Furthermore, on the 22th of March 2013, a failure at the Bacton receiving terminal in the UK led to an interruption in gas supply coming through the Interconnector which connects the UK's market the Zeebrugge market in Belgium (Platts 2013b).⁸

In the middle of December 2017, the gas market in Italy faced a large infrequent disturbance when a gas explosion at a natural gas switching station in Baumgarten, Austria, led to

8. The interruption was caused by a failure in the hot water system and lasted for eight hours before the pipeline was back to full capacity again at 3pm on the same day (Platts 2013c)

a disruption at one of the major regional gas transfer nodes in Europe. This led to a strong reduction in gas deliveries destined for the Italian market, which is the largest recipient of gas flows from the gas hub in Austria. During this period, northern Italy also faced a period of extreme cold weather which led to soaring gas demand.

4. RESULTS

4.1 Disruption transit Ukraine in January 2009

The disruption in the transit route to Western Europe resulted in a significant loss of import volumes destined for the southern German gas market (NCG). The decline in supply to this market in a period of very low temperatures immediately raised the day-ahead price from 23 to 27 euro/MWh (Figure 3). The reduced supply was replaced by a combination of storage withdrawals, increased flows from Russia through the Yamal-Pipeline transiting Belarus and Poland, and higher cross-border flows from the Netherlands.⁹ These extra flows from the Netherlands were for a large part sourced from the United Kingdom through the interconnector, driven by increased price differentials between the NBP and the continental gas hubs. The increased export from the UK resulted in a relatively strong decline of the British storage levels. This increase demand for gas in the UK raised the spot price at NBP.

FIGURE 3

Daily average temperature in Germany, gas price on NBP and NCG, and UK storage level, January 2009.

Note: Vertical dotted lines refer to start and end of disturbance. Normal is average since 2010.

Source: Own illustration based on Bloomberg.

9. Because of limited data availability of gas flows for this period, we depend on the International Energy Agency's (2009) detailed assessment of the European gas market's response to the disruption in Russian transits through Ukraine.

Although the reduction of gas volumes to the Southern German gas market was severe and long-lasting, the market was able to restore balance without the TSO having to interrupt either industrial or domestic end-consumers. The IEA concludes that the high level of resilience of the German gas market to this particular disturbance was related to the presence of its own and neighboring countries' gas hubs, on which price signals were the driver to rapidly move gas volumes to the places where they were needed most. The resilience was also high due to high levels of storage at the time of the disturbance and the presence of a second import route with spare capacity through which Russian exports could be re-directed and replaced. However, it has also been argued that the economic crisis in Europe was a contributing factor for the market's ability to deal with the disturbance as industrial and commercial energy demand were significantly lower than normal (IEA 2009).

Other countries were more severely affected by the disruption in the transit through Ukraine in January 2009. Serbia, being fully dependent on Ukraine transits to receive gas from its only supplier, Gazprom, faced an extreme disturbance when transit flows stopped at the time when it was also faced with extremely low temperatures. As Serbia does not have a gas trading hub and its only supplier could not reach the market because of a problem with the transit route, there was no price signal to reflect the new supply/demand balance after the disturbance. Furthermore, given the fact that the country has almost no storage of natural gas or access to alternative supply routes, there was no possibility to source additional volumes of gas to the market. As a result, the Serbian TSO had to cut gas supplies to almost all end-users, including households. This crisis forced Serbian households to switch to alternative means of heating including electrical and firewood heaters at high social and economic costs. From this we can conclude that the countries without a well-functioning gas market, like Serbia at that time, were not resilient to cope with the sudden and extensive shock in the supply of gas.

4.2 Disruption in transit through Ukraine in February 2012

In response to the second disruption in gas supplies through Ukraine in February 2012, in which period temperatures were again very low, gas prices at European hubs like the NCG increased strongly (Figure 4). The spike in the spot price (from €27 to €38) in the period 2-7 February 2012 provided a strong signal to source additional volumes of gas to the market.

The withdrawal of extra gas from gas storage facilities, which were around 67.5% at the time in Germany, proved to be an important market-based measure in response to the hub's price signal (Henderson and Heather 2012; IEA 2012a; Westphal 2012). Furthermore, additional gas supplies were sourced to the German market through its diverse import routes with neighboring countries (Figure 5). Those additional supplies were sourced mainly from Norway, the Netherlands, and the United Kingdom and through European LNG terminals. Those import volumes have been sold as spot volumes on the German gas hubs (IEA 2012a; Henderson and Heather 2012).

Importers of the additional gas mainly balanced their portfolio by entering their physical volumes of gas in the North of Germany (IEA 2012a). Transporting the large volumes of gas from the North to the South of Germany led to congestion within the German gas network, where gas supply to parts of South-Western Germany was reduced because of a bottleneck south of the MEGAL pipeline (Westphal 2012; IEA 2012a). As a result, the risk of forced termination of gas supply strongly increased and the German transmission system operators (TSOs) had to respond by restricting supplies to customers with interruptible contracts (IEA

FIGURE 4

Daily gas prices and average temperature in Germany, February 2012.

Note: Vertical dotted lines refer to start and end of disturbance.

Source: Own illustration based on Bloomberg.

2012a; Westphal 2012; Henderson and Heather 2012). Under the German Energy Industry Act, this measure can be used in case of risks for maintaining network stability.

As can be concluded from the analysis above, the German gas market proved to be resilient, in terms of hypothesis 1 and 2, during the disruption period, as the price signals triggered additional and 'sufficient' sources of gas to be supplied to the market. However, since the European hubs are 'virtual hubs', the market players are only responsible for nominating their gas through the entry/exit system. The physical transportation of the gas within the market belongs to the responsibility of the TSO. This raises an additional question regarding the flows of gas after it has been sourced through the gas hubs, namely 'whether gas will be available as required, in sufficient quality at cost-efficient prices and exactly where it is needed' (Westphal 2012, 5). In this case, a problem arose due to the congestion in the German north-to-south gas transportation network. As extra sources of gas were mostly sourced through Northern Germany (Gaspool), the congestion led to a problem of transporting this gas to Southern Germany (NCG). This transport problem was solved by transporting from the North of Germany through the Netherlands to the South of Germany.

As can be inferred from the hub prices in Figure 4, the market provided a clear price signal for market players: higher prices on the NCG led to increased supplies of (lower-priced) gas from neighboring gas hubs, which in turn was replaced by gas from other entry points. However, the flows of gas from the Dutch to the South-German market had to be facilitated by means of gas swaps between the TSOs (IEA 2012a). The inability of the market to provide these flows was possibly caused by a lack of accessibility and transparency of the German transport capacity. This could have been caused by the fact that the German gas transport system consisted of 14 TSOs, which made it more difficult for the gas to flow freely between different regions because market players have to book entry and exit capacity through differ-

FIGURE 5

Daily flows from Dutch to German market and German storage levels, February 2012.

Note: Vertical dotted lines refer to start and end of disturbance.

Source: Own illustration based on Bloomberg.

ent operator networks.¹⁰ In response to this and similar situations, in which the flow of gas between neighboring countries was hindered due to capacity access problems, the European Union proceeded with its regulations focused on increasing the commercial functioning of the capacity allocation market. With its new Capacity Allocation Mechanism network code, which was implemented in 2015, unused transport capacity can be auctioned in bundles on online booking platforms, accessible for all commercial gas hub players (ACER and EntsoG 2015).¹¹

Thus, for the disturbance of February 2012, we have to reject the hypothesis that the market was resilient, as the TSO had to intervene in the market and enforce interruptible contracts to deal with the shortage of gas.

4.3 Outage of Nyhamna plant and Interconnector in March 2013

In response to the Nyhamna outage in combination with the cold spell, the NBP's price level (day-ahead) increased strongly (Figure 5). The price increased immediately after the outage occurred and kept rising after the outage was solved. Although storage levels in the UK were already very low in the beginning of March, compared to the average levels over a number of years, storages continued supplying gas as a response to the Norwegian supply interruption, low temperatures and an increasing NBP price. As can be seen from Figure 6, storage inventories were almost completely depleted at the end of March, certainly compared to the average

10. The recent merger of German TSOs has improved the accessibility of the German gas networks.

11. However, this may not fully solve the problem as the infrastructural capacity between north and southern Germany is constrained. In that case, more investments are also needed.

FIGURE 6

Daily average temperature, day-ahead prices and storage levels, UK March 2013.

Note: Vertical dotted lines refer to start and end of disturbance.

Source: Own illustration based on Bloomberg.

values for these days over a number of years. Research by the Oxford Institute for Energy Studies also concluded that on the NBP hub, storage is used as a responsive short-term commercial tool (Henderson and Heather 2012).

The physical reduction in supply from Norway has mainly been replaced by imports from the continent, through the Interconnector (Belgium) and BBL (the Netherlands) (Figure 7). The market mechanism played a dominant role in attracting these supplies, because of the increasing price differential between the NBP and the continental hubs (CREG, ACM, and OFGEM 2013). The fact that in the previous year the interconnector flows were actually in the reverse direction shows the role of the market mechanism in directing the flows of gas. This response by the neighboring markets can also be seen by the reduction in the exports from the Dutch to the German market. Apparently, gas flows going outside The Netherlands were shifted from Germany to the UK.

During the interruption of the Interconnector on the 22th of March, within-day prices gas prices on the NBP spiked, and flows were restored by increasing supplies from storage facilities at Rough and Holford and an increase in LNG flows from the Island of Grain and Milford Haven (Department of Energy & Climate Change 2014). A few days after the disturbance in the Interconnector, the LNG import increased again.

The import of LNG is important for the security of supply in the UK, but this case shows that the LNG import is not able to quickly respond to a sudden shock in supply elsewhere (Figure 8). During the days of reduced supply from Norway, the import of LNG increased to a small extent, but very quickly afterwards the LNG imports declined strongly. During the disturbances in March 2013, high prices were needed to attract LNG deliveries mainly destined for the highly priced Asian market. Therefore, the prices peaked to the levels that made

FIGURE 7

Daily flows from Belgium (Interconnector) and Netherlands (BBL) to the UK, March 2013.

Note: Vertical dotted lines refer to start and end of disturbance.

Source: Own illustration based on Bloomberg.

the NBP attractive to import supplies which are positioned higher within the merit-order¹². The LNG cargoes from Qatar reached the UK around the 24th of March but these volumes were ordered in response to the Nyhamna outage around the 12th of March¹³. In response to the interconnector outage, additional volumes of LNG cargoes have also been attracted, but these cargoes arrived much later than the 22th of March. Hence, the merit-order of the market responses is not always respected due to delays of LNG deliveries and their further impact on the market when they need to be unloaded. This could potentially bring the gas prices down to a lower level than in equilibrium (e.g. negative price peaks).

Although the short Interconnector outage on the 22th of March coincided with the large disturbance of gas supplies from Norway, the market mechanism was able to restore balance. As such, National Grid, the UK's TSO, did not have to declare a gas supply emergency which would have given it the option to interrupt gas supplies to parts of the market (National Grid 2018). Furthermore, at the end of the month (around the 24th of March), LNG deliveries from Qatar reached the UK's gas market, thereby further rebalancing both supply and reducing the price on the NBP back to normal levels again (Figure 6).

This analysis has shown that the NBP market proved to be resilient in the first shock, but less resilient in the case of the disruption in the Interconnector. Price signals triggered the most cost-efficient responses to become active at each point in time. While storage levels were relatively empty in the UK, they still seemed to respond in a commercial way to the price peak. The storages also served as a buffer to provide immediate gas supplies to the market in response

12. Due to oversupply on the LNG market, the current spot price of LNG is relatively low, that makes LNG attractive for the European gas market allowing a diversification of its supply sources

13. It takes around 2 weeks for LNG cargoes from Qatar to reach the UK's gas market

FIGURE 8

Daily flows from Dutch to German market, and UK import of LNG, March 2013.

Source: Own illustration.

to the disruption in gas flows, while they were later replenished by LNG cargoes that naturally take time to reach the market. Furthermore, gas from the European continent (with a strong role for gas from German storage) was attracted through the interconnector capacity which was utilized by market players who were trading based on hub prices differentials. Finally, when the interconnector with Belgium had an outage and UK's storage levels were almost empty, the NBP's hub price spiked to reflect the necessary price level to attract international LNG cargoes. Thus, a combination of storage, interconnector capacity, demand-side response and finally LNG imports eventually led to a restored supply/demand balance on the UK's gas market.

4.4 Baumgarten explosion in December 2017

In response to the Baumgarten explosion, the gas flows from Austria to Italy decreased strongly. This volatility in import was, however, not exceptional, as the level of total imports fluctuated also in the previous period, but the decline in December 2017 was due to a sudden, unexpected shock in supply (Figure 10). As a result, the day-ahead price at the Italian gas hub PSV spiked immediately (Figure 9). The storages were immediately used to deliver a shortage in supply from Austria, as can also be seen from Figure 10.

The Italian Ministry of Economic Development declared a state of emergency in response to the disruption in gas supplies from Baumgarten. In the case of a prolonged disruption, this declaration would give her the option to increase gas imports through other routes (most notably Algeria) and to increase power production from coal and nuclear power plants. Because the disruption lasted only for a day, the market was able to restore balance. Increased withdrawals from Italian storages together with increased imports through the interconnection pipeline

FIGURE 9

Daily gas price at PSV and flows from Austria to Italy, December 2017.

Note: Vertical dotted lines refer to start and end of disturbance.

Source: Own illustration based on Bloomberg (data on flows only for 2017 available).

FIGURE 10

Daily total imports and level of storages in Italy, December 2017.

Note: Vertical dotted lines refer to start and end of disturbance.

Source: Own illustration based on Bloomberg (data on flows only for 2017 available).

with Switzerland were sufficient to provide the market with additional gas volumes. Gas imports via Switzerland increased from 29mcm before the disturbance to 41mcm after (ICIS 2018). Given the lesser degree of responsiveness of imports through the north-African pipelines, the increased imports through Switzerland are most likely responsible for the increase in Italy's total imports before the end of the disturbance, as can be inferred from Figure 10. The imports through the interconnection with Switzerland could have been sourced by Gazprom to replace its export volumes which were supposed to reach the Italian market through Baumgarten or from German storage facilities in response to increasing price differentials between the NCG and PSV.

✎ 5. DISCUSSION AND CONCLUSIONS ✎

Over the past decade, the European gas markets have been able to quickly return to a stable situation after the occurrence of a disturbance without intervention by TSOs except in southern Germany in February 2012. In most cases, the functional and response diversity within the market was responsible for adjusting the supply and demand balance after a major disturbance. The tightness of feedback, in the form of rapid price peaks and increasing regional price differentials after the disturbance, helped to quickly incentivize the market players to source additional volumes either from storage or neighboring countries. In all cases the day-ahead gas price increased quickly and strongly (see Table 2). The disturbance at Baumgarten took only one day, which was also the duration of the price shock at the Italian gas market. In two cases, the duration of the increased gas price was significantly longer than the duration of the shock. In February 2012, this can be attributed to the restrictions in the German gas network which hindered market players to respond more quickly. In March 2013, the relatively long duration of the increased prices is related to the fact that also the demand for gas was high over a number of weeks because of the cold spell while the storages were almost empty and supply routes of LNG needed some time to arrive in the United Kingdom.

From these crises in the European gas market, we conclude that the modularity in interconnection capacity proved valuable in terms of diverting gas flows through other import routes after the outage of a major transport node. This helped Germany to replace its Russian gas imports through Ukraine by increasing its imports through Poland, it helped the UK to replace its direct Norwegian gas imports by increasing its imports through the Netherlands and Belgium and it helped Italy to replace its Russian gas imports through Austria by increasing its imports through Switzerland. In southern Germany in February 2012, due to a bottleneck in transport capacity from northern Germany to the south, the market seemed to be able to divert these flows through sourcing them through the Netherlands to the south of Germany. However, due to a lack of accessibility to German transport capacity, the TSO had to intervene to balance flows between the markets. This lack of resilience could be explained as a failure of tightness of feedback, as the market was hindered from responding quickly to the congestion problem by re-sourcing the gas through alternative routes.

Looking at the extreme disturbances in the European gas market since 2009, we cannot falsify the hypothesis that the liberalized European gas market is resilient. Even during the extreme disturbances in the recent past, the market has been able to provide an adequate response to restore the supply and demand balance. As such, the four sub-hypotheses have not been falsified since:

TABLE 2
Overview gas market resilience of case studies.

Period	Price increase ^{a)}	Market response	Forced terminations	Duration of increased price level ^{b)}	Ratio duration price increase/duration disturbance
January 2009	28% (NCG)	storage, yamal pipeline, imports NL	no	13 days	0.9
February 2012	52% (NCG)	storage, imports NO and NL	yes	12 days	2.0
March 2013	46% (NBP)	imports NL and BE, LNG import, storage	no	38 days	1.9
December 2017	215% (PSV)	storage, imports SW	no	1 day	1.0

^{a)} highest price level in percentage of initial level a day before the disturbance occurred;

^{b)} measured from the first day of the disturbance until the day the price was back at the initial level

Source: Own illustration.

1. Following the extreme disturbance, the gas market price provided a price signal (price peak) to reflect the new supply and demand situation (shortage of gas).
2. Following the price signal, market players responded accordingly by sourcing additional sources of gas to the market and by decreasing demand.
3. Following the adequate response of the market players, no forced terminations of gas were needed to restore the supply/demand balance. This only happened in one case, Germany February 2012, but this was due to constraints in the gas networks which hindered market participants to react to new market circumstances.
4. And, finally, the gas price returns to its previous equilibrium level.

Besides the strengthening of the main hypotheses about the resilience of the European gas market, we may postulate that the market-based responses, employed on a merit order based on their relative cost of supply, provided the responses to disturbances. Furthermore, it appeared that reactions by market players and regulators which were triggered by the disturbances in the gas market can be seen as rational responses which further increase the resilience against future shocks.

One caveat, however, should be mentioned regarding these findings. Market parties may have had some prior information on a supply shock which was going to occur. In particular the two Ukrainian gas transit disruptions could have been partly foreseen by market players. For the January 2009 crisis, the start date of the large interruption of flows to the NCG was January 6th, but already on January 3, a news article was posted by Bloomberg (2009) about the Russia-Ukraine gas conflict, and so there was an indication that this interruption could at least partly be foreseen by the market players.¹⁴ On the February 2012 disturbance, a report by the Oxford Institute for Energy studies (Henderson and Heather, 2012) mentions that by late January, there were signs of a potential issue with gas supply from Russia because of very low temperatures all over Russia. Nevertheless, we state that the high amount of uncertainty regarding the start date, duration and size of the disturbance would still define these disturbances as ‘large and infrequent’ rather than ‘characteristic’.

The results of this paper are relevant because of their implications for the proposed policies within the Energy Union package. The past evidence shows that the gas market seems to be

14. Although it must be noted here that the referenced news article is a rectified one, as the text talks historically about events that happened on January 5th, e.g. “By Jan. 5, Bulgaria, Croatia, the Czech Republic, Greece, Hungary, Poland, Romania, and Turkey already had registered dips in supply” (Bloomberg, 2009)

able, even in extreme situations, to supply both security and diversity of supply by means of its price mechanism. It must be noted, however, that there must be sufficient infrastructure in place to be able to rely on the market to cope with supply and demand shocks. Furthermore, the market is able to do so based on a cost-efficient merit order, which was also shown by IEA (2014). Especially due to the opportunity costs involved in the LNG market, this merit order is of dynamic nature. Any interventions, such as the proposed collective gas purchasing mechanism, by non-market players can be expected to influence or even distort, the functioning of the price mechanism on the gas hubs. As such, they can have the opposite effect which is limiting its resilience.

Policies which are intended to strengthen the European internal gas market may be expected to have a beneficial effect on gas hub trading within the European Union. As the regional markets start to become more connected, gas hubs in different locations will get more liquid and thereby more attractive for new market players to enter. For example, new gas sources from the Mediterranean (Cyprus, Egypt and Israel), Romania, Turkey, Poland and the Caspian region will now become available for the entire European gas market. And oppositely, gas from northwestern Europe and different LNG terminals (such as Spain, Portugal and the Baltic States) might be sold on multiple hubs in Europe based on the attractiveness of spot and forward prices. In the long term, improved interconnectivity may lead to a fully competitive internal European gas market in which gas can be attracted from outside of the region when needed and flow freely within the European markets based on price differentials between the hubs.

Investments in cross-border infrastructure and measures to reduce trade barriers are not necessarily provided by market players. As such, it is recommended for European policy makers to remain focused on the completion of the full European internal gas market, by improving interconnectivity to other regions within the European Union. The recent monitoring report of the European energy regulator already shows that the functioning of the European gas market has improved in recent years, but that a number of bottlenecks still exists resulting in suboptimal integration of markets indicated by regional price differences (ACER, 2015). Furthermore, implementation of existing legislation (e.g. Third Energy Package) should remain a high priority. As barriers of entry between markets are removed and interconnectivity is increased, increasing liquidity on the gas hubs will help to provide transparent price signals. As such they will have a positive effect on the resilience of the European gas market.

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