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Challenging natural monopolies: Assessing market power of gas transmission system operators for cross-border capacity

Jann T. Keller [1], Gerard H. Kuper, Machiel Mulder *

Faculty of Economics and Business, University of Groningen, the Netherlands

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ABSTRACT

It is expected that several national gas markets in Europe will be merged in the near future. Such mergers provide network users transport alternatives, which may imply competition amongst transmission system operators (TSOs). TSOs are, however, regulated by default, as they are viewed to operate natural monopolies facing no effective competition. Using daily data for the German gas market over 2014–2018, this paper assesses market power for cross-border transport capacity based on the Residual Supply Index to analyse the need for regulation. To contribute to the debate on the future regulatory framework within the EU, we assess TSOs' market power for cross-border capacity in a single merged German gas market. We find 15 German TSOs operating in seven relevant markets. In 85% of the cases, we do not find any significant market power for TSOs. In 20% of these cases, the absence of significant market power was related to the utilisation of excess storage capacity. Hence, we conclude that current regulatory constraints imposed on gas TSOs, such as tariff regulation, may be relaxed for cross-border capacity, when market mergers lead to effective inter-TSO competition.

1. Introduction

Gas transmission system networks are the backbone of European gas markets, and are operated by Transmission System Operators (hereafter: TSOs), which are regulated by default as they are viewed to operate natural monopolies (Mulder, 2021). At the same time, mergers of so-called *gas market areas* are observed within the European Union (hereafter: EU), which are promoted by policy makers (ACER and CEER, 2015, 2020). The primary objective of such mergers is to enhance the development of gas wholesale markets. For example, Dukhanina et al. (2019) confirm this positive effect resulting from a market merger within France.

Market mergers do not only impact wholesale markets, but they also affect TSOs. In each market area, so-called *network users*, being traders, producers, or suppliers, are free to flow gas between any two network points that belong to the same market area. This also holds in a merged market area, in which more than one TSO offers its transmission capacity. In merged markets, network users, however, obtain the possibility to choose between different TSOs offering substitute capacities. This may allow for inter-TSO competition for cross-border capacity, which would challenge the need for regulating those TSOs.

Keller et al. (2019, 2020) empirically analyse the behaviour of the demand for and supply of transport capacities in merged gas markets. Their empirical analysis focuses on the German gas markets, which have experienced the most market mergers in the EU so far. They show that network users, if they have a choice, book capacities associated with the lowest transport costs. Hence, network users appear to be sensitive to differences in transport costs. As for the supply side, they find that TSOs have an incentive to consider the existence of transport alternatives, through other TSOs, in setting their tariffs. Such incentives even exist if the regulatory regime applied does not entail any volume risk to the TSOs.

In practice, the regulation of TSOs, thereby regulating gas markets, does not consider such potential infrastructure competition for cross-border transport capacity. On the contrary, there is evidence that policy makers rather aim at uniformity, which implies that infrastructure competition in gas transmission networks is not deemed possible (European Commission, 2017a, 2017b). As opposed to gas markets, however, infrastructure competition is considered in defining the regulatory framework in telecommunications, in which, in contrast to energy, there

* Corresponding author.
E-mail address: machiel.mulder@rug.nl (M. Mulder).

[1] EWE AG (EWE), Germany, and previously Gastransport Nord GmbH (GTG), Germany. The views expressed in this paper are those of the authors, do not necessarily reflect those of EWE or GTG, and do not constitute any obligation on EWE and GTG.

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is no regulation by default. In telecommunications, it is considered whether a firm has so-called *significant market power*, i.e., a dominant position, which allows the firm to behave independently of other market participants (Motta, 2004). Firms having significant market power are exposed to intense regulatory provisions, whereas those having not face less or even no regulation (Briglauer et al., 2017).[2] This follows the microeconomic theory, which only calls for regulation in case of ineffective competition or other market failures (Mulder, 2021).

This paper aims at challenging the general belief that gas TSOs, even if operating in merged markets, do not face any competition, and hence, always must be fully regulated. Thereby, we contribute to the literature of (de-)regulation of natural monopolies by transferring regulatory principles applied in the telecommunication's sector to gas markets. As there are several gas market mergers discussed, inter alia between Spain and Portugal, Croatia and Hungary, Italy and Austria, amongst the Baltic States, and within Germany, this paper deals with a timely and topical subject (ACER and CEER, 2020).

The need for regulation, and the possibility for competition are determined by the level of market power. For this reason, we develop a two-step approach as in competition policy, which is also applied in telecommunication (Motta, 2004; European Commission, 2018). First, the so-called *relevant markets* are defined, secondly, market power is assessed for each firm in each relevant market. Both steps make use of the so-called *Residual Supply Index*, which has widely been used in assessing competition in energy markets (e.g., Sheffrin, 2002; Swinand et al., 2010; Mulder and Schoonbeek, 2013). As to the best of our knowledge, we are the first to assess market power of gas TSOs by combining the two-step approach of competition policy, as used in the telecommunication's sector, with the Residual Supply Index, as more commonly used in the electricity sector.

As Germany has experienced more gas market mergers than any other Union's Member State, our empirical analysis focusses on assessing market power of German gas TSOs for cross-border capacity during the period 2014–2018. As we intend to contribute to the debate on the future regulatory framework of gas markets within the EU, our analysis already anticipates the merger of the remaining two German gas markets envisaged for 2021.

As a result, we find seven relevant markets for cross-border capacities offered by German TSOs. In 15% of cases, we find TSOs had significant market power; in which it was structural in two-third of cases, and in one-third of the cases it appeared to be seasonal. In 85% of the cases, TSOs are found to had no significant market power. Out of these, TSOs in 20% of cases had no significant market power due to excess storage capacity.

Based on these results, we conclude that inter-TSO competition in merged gas markets seems to be possible. Furthermore, current regulatory constraints imposed on gas TSOs, such as tariff regulation, may be relaxed when market mergers lead to effective inter-TSO competition for cross-border capacity. Such a more light-handed regulation could result in a more efficient behaviour of TSOs while, at the same time, transaction costs of regulation would be reduced. Hence, for gas TSOs, the need for the regulatory provisions of cross-border capacity should be re-evaluated by assessing market power.

Following this introduction, Section 2 provides a background of the EU's gas markets and their mergers, focussing on potential inter-TSO competition. Section 3 covers market power and its assessment in general, which in Section 4 is translated into a methodology to assess market power of gas TSOs for cross-border transport capacity in the EU. Section 5 describes the data we use when applying this methodology to German TSOs. Section 6 presents and discusses the results. Section 7, finally, provides our conclusion and policy recommendations.

[2] Note that *significant market power* is a legal term, whereby *significant* refers to the size of market power, and does not refer to any statistical significance.

2. Regulation and infrastructure competition in the EU

2.1. Gas markets and transmission networks

Being a grid-bound energy source, the traditional supply chain of gas is determined by its technical infrastructure (Ströbele et al., 2012).[3]After being produced, i.e., extracted from an underground deposit, gas is usually transported either by transmission pipelines or by vessels (see Fig. 1). Vessels play an important role in oversea transports, and require the gas to be transformed into liquified natural gas (hereafter: LNG). After onshore regasification, gas is injected into high-pressure transmission networks. Transmission networks are connected to storage facilities that are, for example, used to balance seasonal fluctuations in demand against a stable production. Additionally, energy intensive consumers may be directly connected to a transmission network. Smaller consumers, like households, are not directly connected to a transmission network, but to a distribution network, which is characterised by lower pressure, and which in turn is connected to a transmission network.

Being the backbone of gas markets, TSOs' networks are considered as an essential facility.[4] TSOs are said to be natural monopolies not facing effective competition, which creates the need for regulation (Sherman, 2001; Mulder, 2021).

As TSOs connect all major market participants, a wholesale market based on the transmission infrastructure is possible; see Fig. 2. For example, at so-called *virtual trading points* (hereafter: VTP) producers may sell their gas to retailers, or trading companies may buy and sell gas on spot and forward markets. These commercial deals can be executed without the need for market parties to consider available network capacity. Once a gas molecule is injected into the network, it can be traded on the VTP (Alonso et al., 2010).

To be able to inject or withdraw gas from the network, market players need to have access to the network. This network access is offered by TSOs in terms of transport capacities. Transports capacities refer to the right to inject or withdraw a certain amount of gas in a certain period at a specific network point. Such capacities are acquired by network users. Points at which gas may be injected, like a production facility, are referred to as entry points, those where gas may be withdrawn from the network are referred to as exit points. Originally, all entry and exit points that are connected by the same transmission network belong to the same entry-exit zone, also referred to as the market area.[5]

In general, entry and exit capacities are independent from each other, i.e., there are no predefined routes so that any entry point may be linked to every exit point (Vazquez et al., 2012). Also, gas from any entry can be used in trades at the VTP (Lohmann, 2009). In addition, network users inject and withdraw gas at specific network points without considering physical flows (Hallack and Vazquez, 2013). Ensuring gas flows according to the network users request is at the sole responsibility of the TSOs.

So-called *interconnection points* (hereafter: IPs) are of particular importance. These entry and exit points connect adjacent transmission networks located in different market areas. Hence, the IPs are vital for

[3] If not explicitly stated otherwise, we refer to the commodity, supply chain, and markets for conventional natural gas.

[4] The term essential facility refers to a bottleneck, which cannot be easily duplicated, and which cannot be bypassed supplying products or services to customers. This, for example, includes gas pipelines, railway tracks, or the local loop in telecommunication (Laffont and Tirole, 2000; Motta, 2004).

[5] The term *originally* here refers to the fact that this definition used to be applied in the past, and may not be appropriate anymore, which is particularly the case if a market merger has been performed; see Section 2.2.

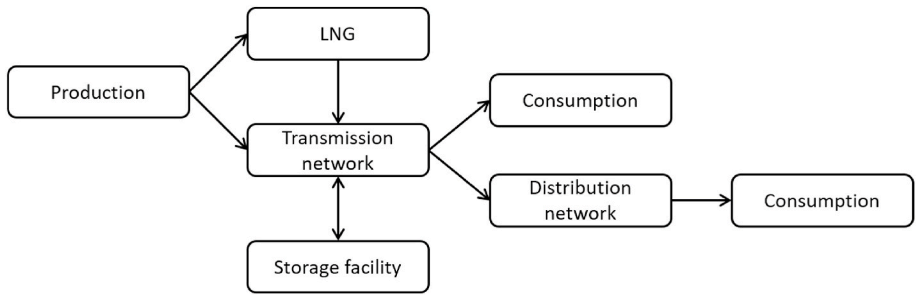

Fig. 1. Stylised technical supply chain for gas.

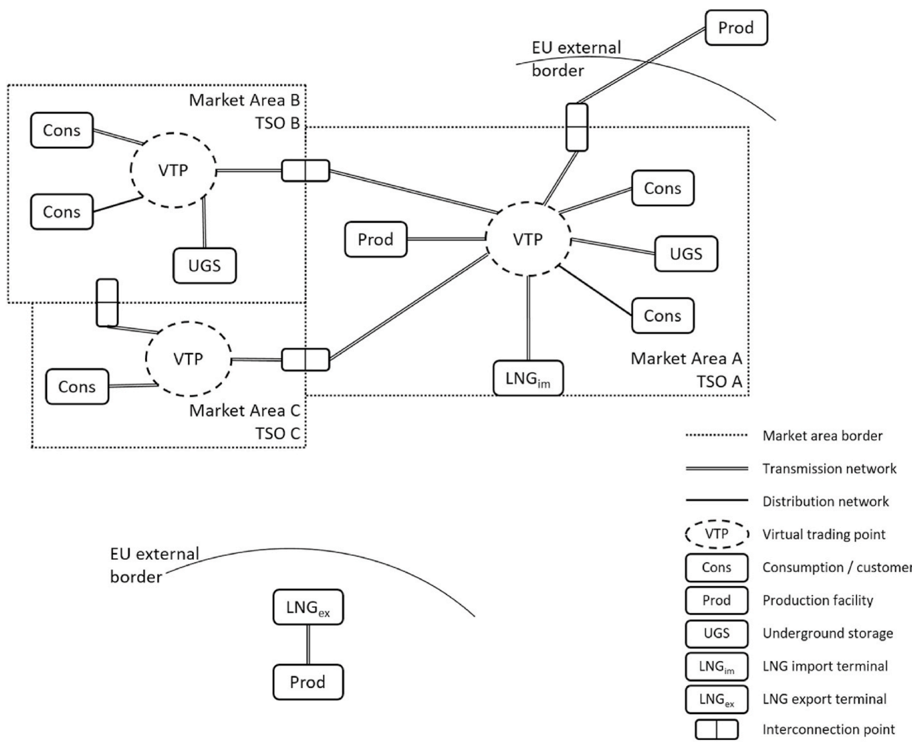

Fig. 2. Stylised representation of EU gas markets.

the EU's internal gas market, allowing for cross-border flows and trade of gas, and imports from outside the EU (European Commission, 2017a).[6]

2.2. Gas market mergers in the EU

The number of buyers and sellers together with the traded volumes determine the size of a market, and influences its liquidity. The larger the number of market parties and the more they trade, the higher the liquidity of a market. Therefore, the development of the liquidity of gas markets within the EU is promoted by market integration, particularly by market mergers (ACER and CEER, 2015).

In the past, gas market areas were usually determined by the boundaries of a TSO's network. In most EU Member States, these boundaries coincide with the Member State's geographical borders. Gas market merges have taken place within the same Member State, for example in Germany or in France, but also cross-border, for example between Belgium and Luxembourg.

As described in the previous section, network users are free to sell gas at the VTP using capacity of any entry point, supply gas from the VTP to any exit point, and directly supply gas from any entry to every exit point if this takes place within the same market area. This also holds for merged market areas. Due to the nature of the entry-exit principle, network users may not only benefit from markets with higher liquidity, but they may also obtain transport alternatives. Referring again to Fig. 2, assume market areas B and C merge, and so do their VTPs. If a network user intends to import gas from market area A to the new merged market of TSOs B and C, the network user must make a choice whether to flow gas via the IPs between TSOs A and B, or via IPs between TSOs A and C. Hence, the borders are substitutes. Analysing the booking behaviour of networks users in merged markets in Germany, Keller et al. (2019) find network users are sensitive to differences in tariffs between substitute TSOs. This is a necessary condition for inter-TSO competition in such cases.

To further improve gas wholesale markets in the EU, regulatory authorities aim at further market mergers, even cross-border mergers, and call for changes to the regulation to facilitate such mergers. Further mergers are, inter alia, discussed between Spain and Portugal, Croatia and Hungary, Italy and Austria, and amongst the Baltic States (ACER and CEER, 2020).

[6] If not stated otherwise, we always refer to the group of the 27 Member States and the United Kingdom.

So far, market mergers have particularly been observed at Germany's borders with its adjacent markets. Historically, Germany has always had a high number of network operators operating their own markets. This number has gradually been reduced by market mergers to two market areas, which we have today, and which are going to merge in 2021.[7]

3. Assessing market power in network industries

3.1. Market power and the need for regulation

In economics, the term *market power* describes the degree of a firm's ability to charge prices above its marginal costs, which is the price expected under perfect competition (Motta, 2004). If a firm has *significant market power*, it has a dominant position, which allows the firm to behave to an appreciable extent independently of other market participants. The highest level of significant market power is related to the case of a monopoly. Such a high market power allows the firm to maximise profits by charging monopoly prices, causing a deadweight loss based on allocative inefficiencies. Additionally, firms with high market power tend to show productive inefficiencies and dynamic inefficiencies due to a lack of competitive pressure.

Economic theory calls for regulation in case of ineffective competition, i.e., a situation in which a firm has significant market power. This kind of market failure is expected in case of a non-contestable natural monopoly (Baumol, 1982). As this is assumed to apply to energy networks, including TSOs' gas transmission systems, TSOs are regulated by default (European Parliament and Council of the European Union, 2009a, 2009b). This regulation refers to, inter alia, the tariffs the TSOs are allowed to charge, and the services they provide.

The regulatory approach regarding the EU's telecommunication's sector, however, is different, although this sector shows similarities to the energy sector. The entire market is based on infrastructure characterised as an essential facility. Since the beginning of liberalisation, regulation and regulatory oversight has been an integral part of the industrial organisation of the telecommunication's sector (European Parliament and Council of the European Union, 1998; 2018). In contrast to energy, however, there is no regulation by default; regulation in telecommunication is asymmetric (Briglauer et al., 2017), which means that the application of certain regulatory provisions is limited to those firms having significant market power. Therefore, regulation in telecommunication requires a market power assessment (European Commission, 2018). A firm that is shown to have significant market power is exposed to regulation, or at least to stricter, more heavy-handed, provisions, as compared to firms found to have no significant market power (see e.g. Mulder, 2021). If a regulated firm is found to have no significant market power anymore, regulatory provisions, at least to a certain extent, are economically not justified anymore. In such a case, regulatory authorities are called upon to revise the regulatory provisions imposed on to this firm and making the regulation more light-handed. All of this aims at allowing for competition where this is considered possible.

The approach applied in telecommunication could also be relevant for gas TSOs. After all, from an economic point of view, without significant market power, there is no need and even no valid economic justification for strict TSO regulation. In this paper, we are going to apply the market power assessment methodology used in the telecommunication's sector to the gas market.

3.2. Assessing market power

Assessing market power in practice, as, for example, performed by EU regulatory authorities and competition authorities in charge of telecommunication's sector, follows a two-step approach (Motta, 2004; European Commission, 2018):

As the degree of market power and competition always depends on the characteristics of a specific market, firstly, the so-called *relevant market* needs to be determined. In general, the relevant market has two dimensions being the product market and the geographic market, and aims at covering all products and areas, which can exercise competitive constraints on each other, i.e., being substitutes with an impact on prices and volumes.

Relevant markets can be determined by applying a *SSNIP test*.[8] The test asks whether it would be profitable for a hypothetical monopolist to non-transitory increase current prices by 5–10%.[9] If prices increase, consumers are expected to look for substitutes. In case substitutes exist, consumers are supposed to acquire these, so that the non-transitory price increase would not be profitable for the hypothetical monopolist. Therefore, the demarcation of the relevant market is widened, until the 5–10% non-transitory increase in prices by the hypothetical monopolist is expected to become profitable. The SSNIP test may also be applied to define the relevant geographic market. In contrast to the relevant product market, the focus is not on substitute products but on the same product available in a different area, e.g., a different city or country. If a hypothetical monopolist raises prices, the product may be imported from a different geographic location. This is particularly influenced by the transport costs of imports in relation to the price of the product.

Secondly, after having determined the relevant market, the market power of the firms operating in this relevant market is assessed, noting that this may change over time.[10] Market power is often indirectly assessed through market shares, based on the idea that a firm having high market power may have a high market share as well. In case of a monopoly, the firm has a market share of 100%. However, a measure of concentration of firms in a market may give a first indication of market power of individual firms, but it is not sufficient to determine market power of individual firms.[11] As an example, suppose two firms operate under Bertrand competition and which have a market share of 50% each. Although this represents a very high market concentration, competition may nevertheless be very intense leading to prices set equal to marginal costs, and, as a result, the duopoly may be the efficient result of a market characterised by high economies of scale and/or economies of scope (Mulder, 2021).

Defining market power as a firm's ability to charge prices above marginal costs, relates to an indicator of market power, the so-called *Lerner Index*. This index measures the mark-up defined as the difference between the market price and the marginal costs of a firm in relation to the market price. In case of perfect competition, the Lerner Index would be 0, and increases if the market power increases.

Although the Lerner Index directly measures the allocative efficiency of market outcomes, its application in practice is limited. On the one hand, the application requires data on marginal costs of firms, which is usually not available. On the other hand, even if such data would be available, they are assumed to be biased. The higher the market power, the higher the risk for productive inefficiencies meaning a lower mark-up, which results in a lower Lerner Index implying a low degree of

[7] See http://www.marktgebietszusammenlegung.de/en.

[8] The SSNIP test (small but significant non-transitory increase in prices) is also referred to as the hypothetical monopolist test.

[9] Note that the 5–10% represents a rule of thumb and is not directly derived from economic theory.

[10] For example, if a market is easily contestable, new market entrants can be expected, which will increase competitive pressure. Even without new entrants, there may be changes due to changes in demand and (excess) production capacity. As market power is not static but dynamic, it is necessary to anticipate future developments in the market already known at the time market power is assessed.

[11] A common measure, for example, is the Herfindahl-Hirschman Index (HHI) defined as the sum of squared market shares of all firms.

market power (Motta, 2004). In addition, the Lerner index may be positive due to other factors, such as temporary scarcity in a market resulting in so-called scarcity prices.

The Lerner Index, however, can be seen as a linear function of another measure related to market power, the so-called *Residual Supply Index* (hereafter: RSI) (Swinand et al., 2010). The RSI determines the extent to which a firm is needed to supply total demand (see Eq. (1)). The RSI of firm i is determined as the ratio of the sum of production capacity (q_j) of all producers $j = 1 \dots n$ minus the supply of firm i, which is compared to the total demand D. Since this measure makes use of both production capacities on firm level and total demand, it is more effective in determining market power than, for example, concentration ratios. Even in a duopoly with equal market shares, the RSI is able to reveal potential market power taking into account the individual characteristics of the firms. Furthermore, the RSI is able to determine the presence of market power more precisely than the Lerner Index, and in an unbiased manner as it precisely measures to what extent individual firms are pivotal to meet demand. Moreover, data required, particularly for infrastructure firms, is easier accessible as compared to data required to determine the Lerner Index.

$$RSI_i = \frac{\sum_{j=1}^{n} q_j - q_i}{D} \quad (1)$$

If $RSI_i > 1$, the production capacity of firm i is dispensable. This means that even if the firm's capacity was not available, the remaining producers are jointly able to serve total demand. The same holds in case the firm tries to significantly raise prices. The customers can consider switching to other producers that can supply the entire demand. Hence, firm i is supposed to have no significant market power since it is dispensable. On the other hand, if $RSI_i < 1$, firm i is indispensable. Based on this, the firm is supposed to have significant market power, which would allow the firm to profitably raise prices by a significant level. Since the RSI measures substitutability, it can be used to both assess market power and to determine relevant markets.

The latter can be shown by referring to spatial price arbitrage opportunities, where the Law-of-One-Price applies (Barrett, 2001). Assume a market A can be supplied by either imports from market B or from market C, while there is assumed to be no transport between B and C. Let p^A, p^B, and p^C denote the wholesale price of a homogenous product in each market, and let $Q^{B,A}$ and $Q^{C,A}$ stand for the maximum transport capacity possible from market B to A and from market C to A, respectively, while $q^{B,A}$ and $q^{C,A}$ indicate the actual transports. Transportation costs are given by $t^{B,A}$ and $t^{C,A}$. Assume an increase in $t^{B,A}$. In this case, the impact on wholesale prices depends on the capacity constraints. Since imports to market A from market B become more expensive, imports from market C are supposed to be preferred. In the first case, the capacity constraint is not binding (see Eq. (2a)). Therefore, imports to market A from market B can be fully substituted by imports from market C. Hence, the difference in wholesale prices between markets A and C is equal to the respective costs of transport. In the second case, the capacity constraint does bind (see Eq. (2b)). Therefore, it is not possible to fully substitute imports from market B by imports from market C. As a result, the difference between the wholesale prices of markets A and C exceed the costs of the transport between them since imports from market B to market A are necessarily needed. This means transport capacity from market B to market A is indispensable, which is why it forms its own relevant geographic market.

$$\begin{aligned} &(a)\; p^B + t^{B,A} > p^A = p^C + t^{C,A};\, (q^{B,A} + q^{C,A}) \leq Q^{C,A} \\ &(b)\; p^B + t^{B,A} = p^A > p^C + t^{C,A};\, (q^{B,A} + q^{C,A}) \rangle Q^{C,A} \end{aligned} \quad (2)$$

The RSI has already been used in the field of energy. For example, Swinand et al. (2010) use the RSI to model competition in the EU's electricity market. Furthermore, they highlight that the RSI is more suited to assess market power of individual firms than, for example, the commonly used Herfindahl-Hirschmann Index. Mulder and Schoonbeek (2013) make use of the RSI to assess the influence of several events on competition in the Dutch electricity wholesale market. A study for the European Commission's DG Competition about the structure and functioning of the EU's major countries' electricity markets provides a detailed analysis of six European wholesale electricity markets between 2003 and 2005 (DG COMP, 2007). This report, which is based on the same data as used by Swinand et al. (2010), applies the RSI to assess whether firms have significant market power. Doing so, the role of a threshold is discussed. Noticing that the threshold is not a steadfast rule, the study follows the suggestion by Sheffrin (2002). Assessing market power in US electricity markets, Sheffrin, suggests applying an RSI threshold of 1.1 instead of 1.0, which must hold for 95% of the time to call a firm having significant market power. This combination prevents from underestimating market power whilst allowing for market dynamics, including signals for new investments.

4. Methodology to assess market power of gas TSOs for cross-border transport capacity in the EU

4.1. Determining the relevant product markets

To determine relevant product markets for cross-border transport capacity in the EU, gas transport alternatives, as well as different characteristics of transport capacity needs to be discussed.

Gas may be transported not only by pipelines, but also by vessels as LNG, or via trucks. Compared to pipelines, trucks are not capable to transport large volumes over long distances. LNG vessels, however, are able to transport gas in large volumes of long distances.

In terms of pipelines, the utilisation of transmission networks is based on capacity products. According to Keller et al. (2019), a cross-border capacity product has different characteristics such as capacity type, time aspects, and gas quality. In terms of the type, capacity can be either firm, interruptible, or conditional firm. Firm capacity grants network users the right to inject or withdraw gas without any risk of interruption. Moreover, Interruptible capacity may be interrupted by the TSO in case the system's stability is at risk. In addition, there are conditional firm capacities, which are firm under certain conditions, e. g., based on temperature, and are otherwise treated as interruptible.

Regarding time, a capacity product, as offered by a TSO, has a predefined runtime. This runtime may be equal to a year, a quarter, a month, a day, or within-day, i.e., the remaining hours of a day. For instance, traders can book transport capacity for the entire 1st quarter of the next year.

As for the gas quality, gas is a natural product, which consists of different hydrocarbons. Depending on its composition, gas is said to be either low-calorific (L-gas) or high-calorific (H-gas). Whether this distinction applies to transmission capacity depends on a TSO's capability to convert gas qualities. For example, in the Netherlands the TSO has enough technical facilities to deliver the gas quality requested so that capacity products do not distinguish gas qualities. In contrast, German TSOs are capable to convert gas qualities only to a certain extent, which is why capacity products distinguish gas qualities. This means that traders have to book transport capacity for a particular gas quality. Here, the conversion between the gas qualities is offered at an additional conversion charge.

To define the relevant product market, it, firstly, needs to be assessed whether, a gas transport via trucks and LNG vessels are substitutes to pipeline transports. Secondly, it needs to be analysed to what extent the different characteristics of transport capacity (in terms of capacity type, time aspects, and gas quality) make them substitutes.

4.2. Determining the relevant geographic markets

4.2.1. Method to determine relevant markets within the EU

To determine geographic product markets for cross-border transport capacity in the EU, the concept of indispensability, as explained in

Section 3.2, can be applied. This indispensability can be assessed based on the RSI:

$$RSI_{i,m,d,t} = \frac{\sum_{j=1}^{n} max.capacity_{j,m,d,t} - max.capacity_{i,m,d,t}}{\sum_{j=1}^{n} TransportFlows_{j,m,d,t} + additionalStorageFlows_{m,t}} \quad (3)$$

According to Eq. (3), the RSI is calculated for the specific border between gas markets i and m in flow direction d at a point in time t. Hereby, m denotes the gas market of interest, which is the one in where the TSOs, whose market power shall be assessed, operate in. For example, if market power for cross-border capacity of German TSOs to Germany, i.e. entry capacity, shall be assessed, as we do in Section 6, m would stand for Germany. i may stand for the Netherlands, and d for entry. This means the RSI aims at assessing the (in-)dispensability of entry transport capacity towards Germany, offered by German TSOs, at the Dutch-German border. The nominator refers to the residual maximum capacity, i.e. the sum of the maximum (entry) transport capacity to Germany from all adjacent markets except the entry capacity from the Netherlands. For the opposite flow direction, d would stand for exit, and applying Eq. (3) would measure the (in-)dispensability of exit capacity from Germany to the Netherlands. The denominator consists of two terms. Firstly, the sum of gas flows from any adjacent market j, in the example including the Netherlands, to Germany at a specific point in time (t). Secondly, we consider excess storage capacity, as this changes the demand for cross-border transport capacity.

Storage facilities can be used to offer seasonal flexibility, such that they can fill the gap between seasonal fluctuations in demand and the observed average levels of gas production. However, also in the short term, there may be excess storage capacity in market m. Making use of this excess storage capacity leads to additional storage flows, which reduce the necessary transport flows via a border. For example, if a capacity constraint at a particular border becomes binding, so that additional imports are not possible, gas wholesale prices are expected to surge. Consequently, this surge gives an incentive to use further substitutes, namely storages. In case of limited import capacity, additional storage flows, here withdrawals, are expected, if possible.[12] This amount of gas withdrawn, however, is only temporarily available, and needs to be re-injected again. Otherwise, it may be also possible that there is not enough gas stored needed for the winter period. Even though there are restrictions to the use of storages, they need to be considered following the general definition of relevant markets, i.e. substitutability. Neglecting the role of storages, does not model gas markets appropriately, and as consequence, indispensability would be overestimated.

With reference to Eq. (3), we allow for additional storage flows in case the RSI would be below the threshold of 1.1, to the extent these are necessary to raise it to 1.1. The motivation is straightforward: If a certain border appears to be indispensable at a certain point in time, it means that, compared to the offer, there is a rather high demand for transport capacity, and hence, gas. This would cause gas prices to increase, which gives an incentive to storages to provide short-term flexibility to the market. However, this is only reasonable until the point at which the border becomes dispensable again; i.e. the threshold is met again. The use of short-term flexibility, however, is limited given the fact that storages are essential to balance seasonality in supply and demand. Hence, flexibility used to exploit short-term price signals, needs to be *recharged*. This means that if gas is withdrawn from a storage facility, it needs to be reinjected. Neglecting other constraint, this is supposed to be done during times the RSI exceeds the threshold. Hence, in case the RSI exceeds 1.1, we consider additional flows to *recharge* the excess storage capacity used as fast as possible whilst ensuring an RSI of at least 1.1. In addition to the technical constraints, we allow the utilisation of excess storage capacity only to the extent this measure does not jeopardise the security of supply. We consider this by ensuring the stored amount of gas meets the five years average, which is commonly used as benchmark for the normal seasonal storage levels (see, for example, Hulshof et al., 2016).

Comparing the RSI for a specific border against a threshold shows whether this border and its capacity is (in-)dispensable. If a border is found to be indispensable, the relevant geographic market only covers this particular border. On the contrary, if the RSI indicates dispensability, the definition of the relevant market needs to be wider. Following the logic of the SSNIP test, widening the scope of the geographic relevant market is an iterative process. This means that, starting from a specific market, the next closest market would need to be added in case the RSI indicates dispensability, and the analysis based on Eq. (3) would be repeated. Depending on the outcome, either the market would need to be widened again, or the relevant market has been determined. As an example, a trading company, also being a network user, may not be able to import gas from an adjacent market due to transport capacity restrictions. This firm is supposed to look for substitutes.

Traditionally, the definition of a relevant market and its measures point at physical markets subject to physical distances. However, these measures may not hold for virtual markets, for example, in case of e-commerce (Eben and Robertson, 2021). Following the logic of the SSNIP test, a relevant market for a homogeneous, physical product available at a local shop, is widened by adding the next closest city, where this product can be purchased at some higher (transport) costs. In terms of online shops, however, a customer may directly choose from multiple shops without any extra costs for travelling, although there may be some small differences in other costs. Hence, even if shipping costs of the products may not be identical in all cases, physical distance becomes irrelevant for the optimal choice of consumers.

As shown in Section 2, EU gas markets are also virtual markets based on entry-exit systems where transport costs are not related to distance. Hence, distance must not be measured by, for example, kilometres, but by the number of borders to be crossed. Assume a network user imports gas to Germany, and the firm is looking for a substitute to imports from the Netherlands. The Netherlands has a common border with Germany, just as other adjacent countries, and, hence, markets, like Poland, Austria, Belgium, etc. As of all them have a market based on an entry-exit system, they are all substitutes at the same level and network users can be supposed to have no ex-ante preference for any specific substitute. This is based on the following arguments: (i) there is an internal EU gas market with equal fundamentals in terms of regulatory measures and markets design, implying that, markets are not segmented (European Parliament and Council of the European Union, 2009a, 2009b); (ii) the product of natural gas as well as transport capacity products are homogeneous and are traded on (very) liquid and transparent market places,[13] which results in high price convergence for natural gas between countries and strong international price correlation (ACER and CEER, 2021; European Commission, 2017a); (iii) transaction costs are low, and (iv) there are no lock-in effects. Therefore, strictly following the logic of iteratively adding one market after the other to the analysis requires to make an arbitrary choice, and it neglects the fact that a network user is free to choose from any adjacent market at the same time.

As a conclusion, if, based on the RSI, a border is found to be indispensable, the relevant geographic market only covers this particular border. If the border is found dispensable, the relevant market needs to be widened, and a wider definition of a relevant market means that the respective border belongs to the same relevant market as all other borders i adjacent to market m considering flow direction d.

[12] The constraints are given by the technical limits of storages, such as injection and withdrawal capacity, as well as the current level of gas stored at t, and the maximum gas volume that can be stored.

[13] For example, European Energy Exchance (www.eex.com) for natural gas, and PRISMA (www.prisma-capacity.eu) for gas transport capacity.

4.2.2. Method to determine relevant geographical markets at EU borders

The previous section deals with cross-border capacity and flows within the EU. However, the main sources of gas lie outside the Union, noting that the EU's gas import dependency has been increasing over time, being around 77% in 2018 (EUROSTAT, 2020).[14] Russia and Norway account for about three fourths of the EU's gas imports (EUROSTAT, 2019).

In contrast to EU-internal markets, the major countries exporting gas to the EU do not have liquid wholesale markets that would allow for spatial arbitrage. In fact, import capacity from these countries is a connection to production facilities, operated by a limited number of producers, or even by a national incumbent. Hence, the behaviour of these producers exporting gas to the EU should be different as compared to companies trading gas within the EU.

Assume, for example, the Dutch TSO increases tariffs for import capacity from Norway. In this situation, Norwegian producers are supposed to consider re-routing gas flows to the EU via other pipelines connected to the EU that are at lower transportation costs. An entire re-routing of gas exports is, however, only feasible if the border that faces the tariff increase is dispensable. Hence, defining relevant geographic markets by calculating RSIs is also applicable to EU-external borders noting that it is necessary to consider all borders of any EU Member State with the producing country. This also implies that storages of all respective EU Member States need to be considered.

4.3. Assessing market power

Just as we use the RSI to determine the geographical markets, we also use this metric to determine the market power of individual TSOs in the defined markets. The difference is that, in assessing market power, we do not focus on the (in-)dispensability of a certain border, but we are interested in the (in-)dispensability of a specific TSO within a predefined relevant market. This can be achieved by some slight adjustments to the indices of Eq. (3) resulting in Eq. (4). Since the relevant markets are clearly defined, the indices *m* and *d* can be replaced by index *rm* referring to the respective relevant market.

$$RSI_{i,rm,t} = \frac{\sum_{j=1}^{n} max.capacity_{j,rm,t} - max.capacity_{i,rm,t}}{\sum_{j=1}^{n} TransportFlows_{j,rm,t} + additionalStorageFlows_{rm,t}} \quad (4)$$

For each relevant market (*rm*) defined in the first step, the market power for each TSO (*i*) operating in this relevant market can be assessed for a point in time (*t*). As we do in determining the relevant markets, we consider excess storage capacity in case the RSI would not meet the threshold of 1.1: In case a TSO is indispensable at a certain point in time in a certain relevant market, the firm can make use of its market power associated with the indispensability, and can raise transport tariffs. In terms of imports, this will cause gas prices to increase as well, which gives price signals to storage users to withdraw gas from storage facilities. This limits the market power of the respective TSO. Neglecting the role of storages is supposed to cause an overestimation of indispensability, hence, too high market power, and consequently, gas markets to be analysed are not analysed appropriately. Like in Section 4.2, the role of storages in balancing seasonality in supply and demand must not be jeopardised, and technical restrictions need to be considered. Hence, we consider storages in the same way as in Section 4.2.

5. Data for assessing market power of German TSOs for cross-border transport capacity

To assess market power of German TSOs for cross-border transport capacity, we use daily data. Applying Eqs. (3) and (4), data on gas flows, maximum capacity, and storages are required. Table 1 describes data on the first two. Based on the cross-border connections in scope, four groups of variables can be identified. These are (1) entry capacity to Germany from adjacent EU Member States (eight borders), (2) exit capacity from Germany to adjacent EU Member States (eight borders), (3) entry capacity to the EU from Norway (five borders), and (4) entry capacity to the EU from Russia, including transits via Belarus and Ukraine (eight borders).

In Table 1, the number of TSOs in scope per connection refers to the German TSOs offering capacity at that border in the first two groups. As for imports for Norwegian and Russian gas, this refers to TSOs in the entry market, which is usually one TSO in non-German markets. As we already anticipate the market merger in Germany expected for 2021 resulting in a single German gas market, there are at least two German TSOs active at any border.

Instead of using data on gas flows, we prefer to use (re-)nominations, as flows are the result of nominations.[15] Additionally, (re-)nominations are more accurate for our analysis as actual gas flows may be influenced by the TSOs' optimisation of the grid utilisation. Furthermore, this choice avoids inaccuracy in case of a so-called *pipe-in-pipe,* where one physical pipeline is virtually split into multiple ones for different TSOs. Whereas each TSO receives and reports (re-)nominations separately, physical gas flows are not metered separately per TSO and may be reported multiple times. Hence, using data on (re-)nominations prevents from considering too high flows, which would tend to show lower overall RSIs due to higher scarcity of capacity.

As an example, Fig. 3 illustrates the (re-)nominations and the maximum capacity for German gas imports from the Netherlands between 2014 and 2018. As the figure shows, both parameters are not stable over time but rather volatile. Additionally, a seasonality can be observed, particularly with higher (re-)nominations in the fourth quarter of a year and the first quarter of the following year. Compared to this, numbers appear lower in the second and third quarter.

Fig. 4 plots the aggregated data for the capacity and the utilisation of storage facilities in Germany. The graphs show that the working gas volume, i.e. the technical maximum of gas that can be stored, increased during 2014–2018. Over time, the graph on gas stored shows a seasonal profile, which underlines that storage facilities in Germany are used to balance seasonality.

6. Results of assessing market power of German TSOs for cross-border transport capacity

6.1. Determining the relevant product markets

We determine the relevant product markets for cross-border transport capacity of German TSOs following the methodology of Section 4.1.

At first, it needs to be assessed whether gas transports via truck or LNG vessels are a substitute to pipeline transports. As trucks are not capable to transport large volumes over long distances like pipelines, truck transport cannot be considered as a substitute to pipeline transport, and hence, both do not belong to the same relevant product market. LNG vessels can transport gas in large volumes over long distances. In case of the EU, LNG vessels may dock at one of 29 LNG import terminals (GIE, 2019). To further transport gas within the EU, LNG needs to be regasified and injected into a transmission network. Therefore, LNG can diversify sources of gas, but is unable to substitute transmission capacity offered by TSOs within the EU. Thus, we can already conclude there is no alternative within the EU to gas transport via pipelines.

Secondly, it needs to be analysed to what extent the different characteristics of transport capacity, i.e., capacity type, runtime, and gas quality, make them substitutes. Regardless of the capacity type, may it

[14] *Gas dependence=(imports-exports)/gross avalilable gas (*EUROSTAT, 2020).

[15] A nomination is a message send by a network user to inform the TSO about the intended injection or withdrawal of gas at a network point. A renomination means an update to a nomination.

Table 1
Aggregated descriptive statistics on (re-)nominations and maximum capacity for cross-border connections and TSOs in scope of market power assessment for German TSO in 2014–2018. Data source: ENTSOG (2020).

Exit	Entry	Number	(re-)nominations [GWh/d]				max. capacity [GWh/d]			
from	to	of TSOs in scope	min.	max.	mean	median	min.	max.	mean	median
Austria	Germany	4	0	301	123	128	350	481	398	419
Belgium /Luxembourg	Germany	4	0	294	105	98	61	372	209	202
Czech Republic	Germany	4	277	1,406	692	724	659	1,650	1,014	1,040
Denmark	Germany	2	0	192	66	64	33	192	91	93
France	Germany	2	0	194	22	0	0	194	22	0
Poland	Germany	2	0	1,064	918	932	0	1,064	941	932
Switzerland	Germany	3	0	39	0	0	0	195	14	0
The Netherlands	Germany	6	276	1,461	771	761	1,012	1,977	1,353	1,348
Germany	Austria	4	34	435	251	269	226	581	387	392
Germany	Belgium /Luxembourg	4	0	413	131	118	164	504	351	337
Germany	Czech Republic	5	166	1,339	893	896	517	2,050	1,090	1,131
Germany	Denmark	2	0	113	43	44	10	162	99	101
Germany	France	2	23	662	252	246	539	772	568	564
Germany	Poland	2	0	279	81	68	47	301	186	214
Germany	Switzerland	3	23	617	270	258	167	666	473	529
Germany	The Netherlands	6	64	631	365	380	251	669	524	526
Norway	Belgium /Luxembourg	1	0	477	420	450	281	477	435	450
Norway	France	1	0	597	505	533	569	597	575	569
Norway	Germany	3–4	77	1,324	806	836	852	1624	1,252	1,233
Norway	United Kingdom	1	0	24,873	1,609	1,438	3,075	24,873	3,232	3,075
Norway	The Netherlands	1	0	1,040	608	615	23,000	48,000	32,386	24,000
Russia	Germany	4–5	0	2,154	1,018	1,147	393	2,287	1,403	1,558
Russia	Estonia /Latvia	0–1	0	32	6	0	0	57	16	4
Belarus	Poland	1	100	1,215	1,082	1,121	176	1,572	1,194	1,212
Belarus	Lithuania	1	0	232	94	93	324	326	325	325
Ukraine	Hungary	1	0	1,600	185	213	517	2,421	624	605
Ukraine	Poland	1	31	150	118	127	94	150	137	136
Ukraine	Romania	1	0	0	0	0	0	575	434	369
Ukraine	Slovakia	1	0	2,171	1,275	1,319	2,205	2,347	2,261	2,280

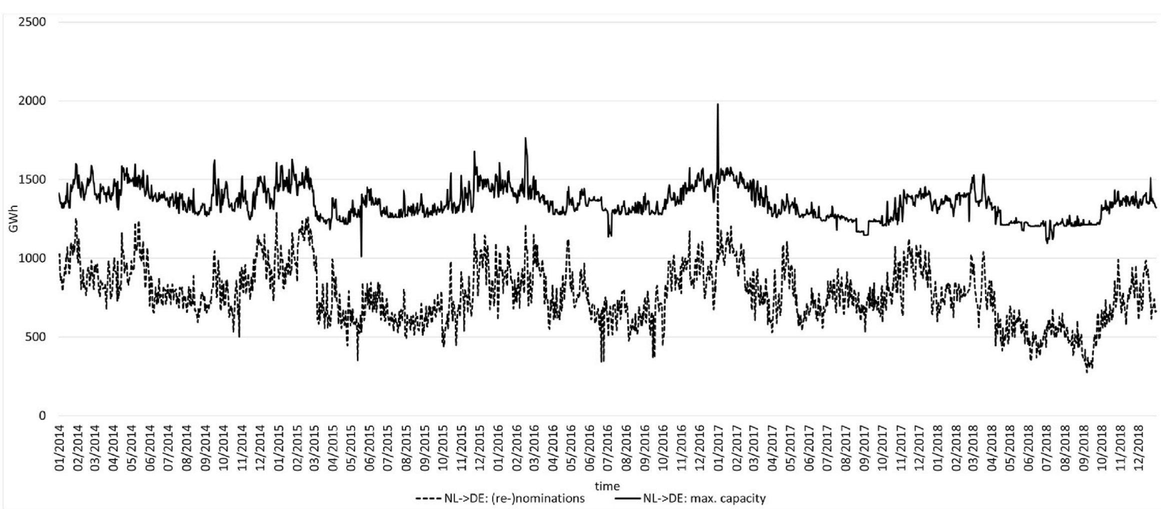

Fig. 3. (Re-)nominations and maximum capacity from the Netherlands to Germany in 2014–2018. Data source: ENTSOG (2020).

be firm, interruptive, or conditional firm, each of them allows for injecting or withdrawing gas, even if some of them carry the risk of being interrupted. Hence, every capacity product, depending on the capacity type, has a different tariff/risk-ratio. This ratio changes if a tariff changes. As a result, another capacity product, which only differs in the capacity type, may have a better ratio for network users. Therefore, in case of an increase in capacity tariffs for a particular capacity type, network users can be expected to consider other capacity types, which is why they are substitutes. Therefore, we conclude that all capacity types belong to the same relevant product market.

As for the runtime, assume a network user wants to flow the same amount of gas from market A to market B for an entire month. This can be achieved by either buying a monthly capacity product, or by acquiring daily products for all days of the month. If, for example, a capacity product of a shorter runtime becomes more expensive due to an increase in capacity tariffs, network users are supposed to consider booking capacity products of a longer runtime, and vice versa. As a result, also capacity products of different runtimes are substitutes, hence, belong to the same relevant product market.

In terms of gas quality, German TSO distinguish transport capacity for L-gas and H-gas. A conversion between the gas qualities is possible paying a conversion charge. Now, assume an industrial customer in Germany shall be supplied with H-gas being imported from an adjacent market. In case H-gas import capacities are more expensive than L-gas import capacities, rational network users are supposed to consider using L-gas capacities in case the conversion charge does not exceed the

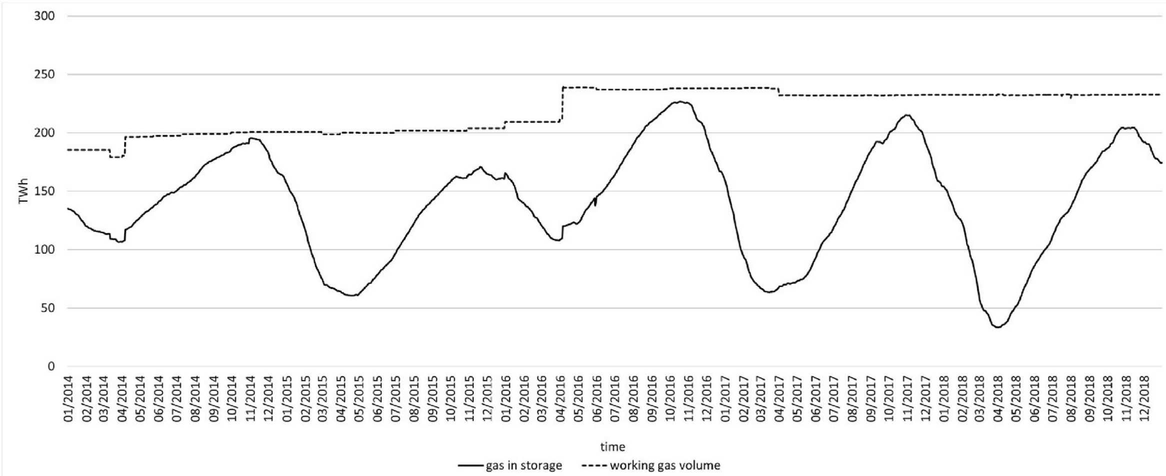

Fig. 4. Aggregated German storage data on working volume and gas stored in 2014–2018. Data source: GIE (2020).

difference in tariffs. This similarly holds in case of a tariff increase; network users are supposed to consider the conversion option. Hence, transport capacity of both qualities are substitutes, thus, belonging to the same relevant product market, in case a conversion options between these gas qualities is offered. Following a decision by Bundesnetzagentur (2012), the Germany regulatory authority, a conversion option in both quality directions has been implemented. Hence, L-gas and H-gas capacities offered by German TSOs are substitutes.

Finally, we conclude that the relevant market for assessing market power of German TSOs for cross-border transport capacity covers pipeline transports only, but it includes all capacity products offered by German TSOs.

6.2. Determining the relevant geographic markets

We determine the relevant geographical markets for cross-border transport capacity offered by German TSOs by applying Eq. (3). Daily RSIs between 2014 and 2018 are calculated for each border i per group of borders, as listed in Section 5.[16]

Table 2 summarises the results concerning the determination of relevant geographic markets. In total, we determine seven different relevant geographic markets. Next to EU imports from Russia and Norway, there is one relevant market for exit capacity from Germany to its adjacent EU Member States. Entry capacity to Germany from adjacent EU Member States is divided into four different relevant geographic markets. Since there is only one relevant product market, Table 2 provides an exhaustive list of relevant markets for our market power assessment.

Tables A1 to Table A7 in Appendix A provide detailed results on daily RSIs and the comparison against the threshold of 1.1 for 95% of days. The tables in Appendix A also show the impact of excess storage capacity. In two cases, the utilisation of excess storage capacity affects the determination of relevant markets. Initially, export capacity from Germany to the Czech Republic fails to reach the threshold. Considering the utilisation of excess storage capacity, however, changes the picture, so that the RSI can meet the threshold. The same holds for import capacity from Russia to Germany.

[16] The excess storage flows considered encompasses the German storages for the first and the second group of borders. As for the third and fourth group, storages from other EU Member States having a respective connection are additionally considered.

Table 2
Relevant geographic markets for cross-border transport to assess market power of German TSOs in 2014–2018.

Relevant market	Exit from	Entry to
1	Austria, Belgium /Luxembourg, Denmark, France, Switzerland	Germany
2	Czech Republic	Germany
3	The Netherlands	Germany
4	Poland	Germany
5	Germany	Austria, Belgium /Luxembourg, Czech Republic, Denmark, France, Poland, The Netherlands, Switzerland
6	Norway	Germany, Belgium /Luxembourg, France, The Netherlands, The United Kingdom
7	Russia, Belarus, Ukraine	Germany, Estonia/Latvia, Hungary, Lithuania, Poland, Romania, Slovakia

6.3. Assessing market power

We apply Eq. (4) to determine the daily RSIs between 2014 and 2018 for each German gas TSO i in each relevant market rm.[17] Fifteen TSOs in seven relevant markets results in 105 possible combinations, of which in 41 cases a TSO is active in the respective relevant market.

Table 3 summarises the results of the market power assessment of German gas TSOs for cross-border capacity in 2014–2018. In 41 out of 105 possible cases, at least one TSO was active in a relevant market. We find TSOs did not have significant market power in about 68%, i.e., in 28 cases. In seven cases (about 17%), a TSO in a relevant market would be said to had significant market power. However, considering excess storage capacity, these TSOs are found to had no significant market power anymore. In 15% of cases, a TSOs had significant market power, which was structural in two-third, and seasonal in one-third of cases.

Table B2 to Table B15 in Appendix B provide detailed results derived from calculating the daily RSIs, and the comparison against the threshold of 1.1 for 95% of days. Appendix C further distinguishes whether the significant market power found was structural or seasonal.

[17] The analysis makes use of TSO-IDs instead of the firms' names. Table B1 allows for a translation.

Table 3
Summary of results of market power assessment of Germany gas TSOs for cross-border capacity in 2014–2018.

relevant market	TSO-ID 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	blue	grey	green	green	grey	green	grey	green	grey	grey	grey	grey	green	green	green
2	grey	grey	grey	blue	grey	grey	grey	red	grey	grey	red	grey	red	grey	grey
3	grey	grey	purple	green	green	blue	grey	grey	grey	grey	grey	grey	purple	grey	blue
4	grey	grey	grey	red	grey	grey	grey	grey	grey	grey	blue	grey	grey	grey	grey
5	green	grey	green	blue	green	green	grey	green	grey	grey	green	blue	green	green	green
6	grey	grey	grey	grey	grey	green	grey	grey	green	grey	grey	grey	green	grey	green
7	grey	green	grey	green	grey	green	green	grey	grey	green	grey	green	grey	grey	grey

(grey) 64 cases: TSO was not active in the relevant market
(green) 28 cases: TSO had no significant market power, even without excess storage capacity
(blue) 7 cases: TSO had no significant market power utilising excess storage capacity
(red) 4 cases: TSO had structural significant market power
(purple) 2 cases: TSO had seasonal significant market power

6.4. Discussing results

Our results are based on daily data for the period 2014–2018, and assuming the German market is merged into one, as expected to happen during 2021. In 68% of cases TSOs had no significant market power. Additionally, in 17% of cases there is no significant market power found if we take into account excess storage capacity, while in 5% of cases the significant market power found was not structural but seasonal. Only in the remaining 10% of the cases, TSOs had structural significant market power.

There may be empirical evidence that supports our results. Since, on the one hand, some TSOs are found to had no significant market power, these firms may have shown a competitive behaviour. On the other hand, firms with significant market power should have shown a non-competitive or even monopolistic behaviour. Evidence that would support our results should reveal a different behaviour for the two groups of TSOs, for example, regarding third-party network access, investment, quality of service, and network tariffs.

In terms of third-party network access, we would expect that TSOs with no significant market power would grant network access to anyone requesting it, whereas a TSO having significant market power would consider excluding some networks users or delaying granting access. The latter is particularly expected in case the TSO belongs to a company that is also active in supply and trading of gas, since this TSO could provide a competitive advantage to the supply and trading affiliate.

In addition, investments of TSOs under effective competition are expected to follow market needs. TSOs with significant market power, however, are expected to invest not in accordance to market needs, but only following the firm's own interest.

Moreover, a TSO with significant market power is expected to provide a lower quality of service as those TSOs operating under competition. The higher the competitive pressure, the higher the incentive of the firm of provide higher quality of service. Therefore, more disruptions and higher outage times may be expected for those TSOs having significant market power as compared to those having no significant market power.

Finally, regarding network tariffs, a monopolist is expected to charge monopoly prices, whereas TSOs under competition are expected to set tariff equal to (long-run) marginal costs.

However, such an analysis that could be used to test our results is hindered by the fact that the firms, whose market power is assessed, have always been regulated, which impacts their behaviour. For example, third-party network access regulation is a key element of regulation, requiring the regulated network operator to grant network access to anyone requesting it. Since this is applied to any TSO, regardless of its market power, it is not possible find a difference in the TSOs' behaviour. Additionally, it is possible to observe a behaviour that may be expected under competition, however, this is a result of regulation. For example, Keller et al. (2020) find tariffs charged by German TSOs, as in this paper's analysis, appear to be lower at borders, where more than one TSO offers capacity, as compared to borders, where one TSO is the only supplier of transport capacity. The rationale behind this is that TSOs may face competitive pressure if network users are given substitutes. However, the incentive to engage in tariff competition results from the positive effect of higher network utilisation on the firm's efficiency score that results from a benchmarking. Thus, it is rather the regulation itself that creates the incentive not market power. In addition, one should keep in mind that our results are based on the assumption that the German markets have already been integrated as is going to happen in 2021, but which was not the case in the past years.

We conclude that it is not possible to find unambiguous corroborative evidence to support our results since TSO were strictly regulated during the period analysed. Incentives to engage in any kind of competition are hindered by strict regulatory provisions, and even if competitive behaviour is observed, this might be caused by the regulation itself. Furthermore, our empirical market power assessment, based on 2014–2018 data, can only be snapshot. It is possible that our results may change over time due to market dynamics. Although our analysis already anticipates the German gas market merger envisaged for 2021, there may be other developments in gas markets, such as changes in supply and demand, that could influence TSO's market power. However, we assume that the general situation has not fundamentally changed. Hence, our results are able to challenge the general belief that TSOs necessarily require regulation.

7. Conclusion and policy implications

Gas TSOs are generally viewed to operate a natural monopoly, and hence, are regulated by default. Through market mergers, however, network users are given a choice amongst capacity offered by different TSOs, which may allow for inter-TSO competition.

This paper contributes to the literature of (de-)regulation of natural monopolies by transferring regulatory principles applied in the telecommunication's sector to gas markets. Challenging the general belief that TSOs require a strict regulation due to the absence of competition, the paper recommends authorities to reconsider the regulatory framework applicable to TSOs in merged EU gas markets. As there are several gas market mergers discussed, inter alia between Spain and Portugal, Croatia and Hungary, Italy and Austria, amongst the Baltic States, and within Germany, this topic is becoming more relevant in time.

Based on our empirical results, the need for a strict, heavy-handed, regulation of German gas TSOs for cross-border capacity is economically questionable as we find no significant market power in about 85% of cases. The regulatory authority in charge should consider whether these firms should face a different regulation than the 15% that really showed a significant market power. By making this regulation less intense, the gas TSOs may get more incentives to search for the optimal tariffs, while the transaction costs of regulation may be reduced. For example, lower tariffs can be expected under Bertrand competition meaning lower transport costs for cross-border gas flows. This links adjacent gas markets more intensively, and, ultimately, leads to more intense competition and lower gas prices. In case the intensity of regulatory oversight is reduced, we expect lower costs of regulation, i.e., costs related to the tasks and efforts of the regulatory authorities, and all parties involved in regulation. For example, less efforts are needed to approve a firm's costs, or monitor its quality of service. Consequently, we advise regulatory and competition authorities to consider the impact of market mergers on inter-TSO competition and market power.

The more fundamental consequence of our findings is that regulators may need to answer the question to what extent regulation of gas TSOs can be shifted in the direction of a more light-handed regulation, in which regulated parties receive more freedom to make their own choices. In that case, however, several aspects need to be considered, particularly to avoid adverse effects. For example, inter-TSO competition occurs at borders of gas markets, however, these firms not only offer cross-border capacity, but also provide domestic capacities to industrial customers and distributions networks. This highlights the need for authorities to ensure activities of different competition levels and intensity of regulation are effectively separated, such as in telecom regulation. As the number of TSOs remains rather small, there is always a risk for joint significant market power and collusions. As the availability of excess storage capacity in some cases decides whether a TSO has significant market power, it needs to be taken account of simultaneity effects.

A more light-handed regulation reflecting actual market power implies, however, that the regulatory authorities keep monitoring the market for cross-border capacity. Hence, the threat of additional regulatory intervention remains. Even though more light-handed regulation is supposed to allow for welfare gains as compared to heavy handed regulation in theory, the actual effect depends on the effectiveness of the regulatory regime applied, which aims at simulating competition to the extent possible. Nevertheless, inter-TSO competition on cross-border transport capacity seems possible, particularly in merged gas markets, which will increasingly be introduced in Europe in the near future. Therefore, regulatory authorities are advised to assess the remaining market power of gas TSOs, and to reconsider the required intensity of the regulatory framework.

CRediT authorship contribution statement

Jann T. Keller: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft. **Gerard H. Kuper:** Conceptualization, Methodology, Supervision, Validation, Writing – review & editing. **Machiel Mulder:** Conceptualization, Methodology, Supervision, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: One of the authors used to be employed by Gastransport Nord GmbH, Germany, and is currently employed by EWE AG, Germany.

Data availability

Data will be made available on request. Data sources used are publicly accessible.

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Appendix A. Relevant market definition

Table A1
Determination of the relevant geographic market by the Residual Supply Index for cross-border entry capacity from adjacent EU Member States to Germany without utilising excess storage capacity in 2014–2018

% RSI >1.1	AT	BELUX	CH	CZ	DK	FR	NL	PL
2014–2018	100%	100%	100%	60%	100%	100%	11%	73%
2014	100%	100%	100%	70%	100%	100%	12%	87%
2015	100%	100%	100%	77%	100%	100%	18%	91%
2016	100%	100%	100%	57%	100%	100%	10%	76%
2017	100%	100%	100%	45%	100%	100%	4%	33%
2018	100%	100%	100%	50%	100%	100%	12%	78%

Table A2
Determination of the relevant geographic market by the Residual Supply Index for cross-border entry capacity from adjacent EU Member States to Germany utilising excess storage capacity in 2014–2018

% RSI >1.1	AT	BELUX	CH	CZ	DK	FR	NL	PL
2014–2018	100%	100%	100%	85%	100%	100%	24%	94%
2014	100%	100%	100%	97%	100%	100%	64%	100%
2015	100%	100%	100%	89%	100%	100%	18%	100%
2016	100%	100%	100%	96%	100%	100%	21%	100%
2017	100%	100%	100%	72%	100%	100%	4%	81%
2018	100%	100%	100%	70%	100%	100%	12%	88%

Table A3
Determination of the relevant geographic market by the Residual Supply Index for cross-border exit capacity from Germany to adjacent EU Member States without utilising excess storage capacity in 2014–2018

% RSI >1.1	AT	BELUX	NL	CH	PL	CZ	FR	DK
2014–2018	100%	100%	99%	100%	100%	60%	99%	100%
2014	100%	100%	100%	100%	100%	54%	100%	100%
2015	100%	100%	100%	100%	100%	84%	100%	100%
2016	100%	100%	100%	100%	100%	77%	100%	100%
2017	100%	100%	98%	99%	100%	58%	97%	100%
2018	100%	100%	99%	100%	100%	29%	98%	100%

Table A4
Determination of the relevant geographic market by the Residual Supply Index for cross-border exit capacity from Germany to adjacent EU Member States utilising excess storage capacity in 2014–2018

% RSI >1.1	AT	BELUX	NL	CH	PL	CZ	FR	DK
2014–2018	100%	100%	100%	100%	100%	99%	100%	100%
2014	100%	100%	100%	100%	100%	100%	100%	100%
2015	100%	100%	100%	100%	100%	100%	100%	100%
2016	100%	100%	100%	100%	100%	100%	100%	100%
2017	100%	100%	100%	100%	100%	100%	100%	100%
2018	100%	100%	100%	100%	100%	96%	100%	100%

Table A5
Determination of the relevant geographic market by the Residual Supply Index for cross-border entry capacity from Norway to EU Member States without utilising excess storage capacity in 2014–2018

% RSI >1.1	DE	FR	UK	NL	BELUX
2014–2018	100%	100%	100%	96%	100%
2014	100%	100%	100%	100%	100%
2015	100%	100%	100%	100%	100%
2016	100%	100%	100%	89%	100%
2017	100%	100%	100%	92%	100%
2018	100%	100%	100%	98%	100%

Table A6
Determination of the relevant geographic market by the Residual Supply Index for cross-border entry capacity from Norway to EU Member States utilising excess storage capacity in 2014–2018

% RSI >1.1	DE	FR	UK	NL	BELUX
2014–2018	100%	100%	100%	100%	100%
2014	100%	100%	100%	100%	100%
2015	100%	100%	100%	100%	100%
2016	100%	100%	100%	100%	100%
2017	100%	100%	100%	100%	100%
2018	100%	100%	100%	100%	100%

Table A7
Determination of the relevant geographic market by the Residual Supply Index for cross-border entry capacity from Russia and transit countries for Russian gas to EU Member States without utilising excess storage capacity in 2014–2018

% RSI >1.1	RU- > DE	BY- > LT	BY- > PL	RU- > EE/LV	UA- > HU	UA- > PL	UA- > RO	UA- > SK
2014–2018	84%	100%	98%	100%	100%	100%	100%	42%
2014	100%	100%	100%	100%	100%	100%	100%	67%
2015	100%	100%	100%	100%	100%	100%	100%	86%
2016	98%	100%	100%	100%	100%	100%	100%	25%
2017	63%	100%	92%	100%	100%	100%	100%	10%
2018	58%	100%	97%	100%	99%	100%	100%	22%

Table A8
Determination of the relevant geographic market the Residual Supply Index for cross-border entry capacity from Russia and transit countries for Russian gas to EU Member States utilising excess storage capacity in 2014–2018.

% RSI >1.1	RU- > DE	BY- > LT	BY- > PL	RU- > EE/LV	UA- > HU	UA- > PL	UA- > RO	UA- > SK
2014–2018	100%	100%	100%	100%	100%	100%	100%	100%
2014	100%	100%	100%	100%	100%	100%	100%	100%
2015	100%	100%	100%	100%	100%	100%	100%	100%
2016	100%	100%	100%	100%	100%	100%	100%	100%
2017	100%	100%	100%	100%	100%	100%	100%	100%
2018	100%	100%	100%	100%	100%	100%	100%	100%

Appendix B. Market power assessment

Table B1
Translation table for TSO-IDs and TSO names

TSO-ID	TSO name	TSO-ID	TSO name
1	bayernets	F1	GRTgaz (FR)
2	Fluxys Deutschland	F2	National Grid (UK)
3	Fluxys TENP	F3	Gasunie Transport Services (NL)
4	GASCADE Gastransport	F4	Fluxys Belgium (BE)
5	Gastransport Nord	F5	AB Amber Grid (LT)
6	Gasunie Deutschland	F6	Elering (EE)
7	Gasunie Ostseeanbindungsleitung	F7	Eustream (SK)
8	GRTgaz Deutschland	F8	FGSZ (HU)
9	jordgas Transport	F9	GAZ-SYSTEM (PL)
10	NEL Gastransport	F10	SNTGN Transgaz (RO)
11	ONTRAS Gastransport		
12	OPAL Gastransport		
13	Open Grid Europe		
14	terranets bw		
15	Thyssengas		

Table B2
Assessment of TSO's market power for cross-border capacity in relevant market 1 by the Residual Supply Index without utilising excess storage capacity in 2014–2018

% RSI >1.1	1	3	4	6	8	13	14	15
2014–2018	95%	100%	100%	100%	99%	100%	100%	100%
2014	93%	100%	100%	100%	100%	100%	100%	100%
2015	88%	100%	100%	100%	100%	100%	100%	100%
2016	99%	100%	100%	100%	100%	100%	100%	100%
2017	98%	100%	100%	100%	99%	100%	100%	100%
2018	98%	100%	100%	100%	98%	100%	100%	100%

Table B3
Assessment of TSO's market power for cross-border capacity in relevant market 1 by the Residual Supply Index utilising excess storage capacity in 2014–2018

% RSI >1.1	1	3	4	6	8	13	14	15
2014–2018	100%	100%	100%	100%	100%	100%	100%	100%
2014	100%	100%	100%	100%	100%	100%	100%	100%
2015	100%	100%	100%	100%	100%	100%	100%	100%
2016	100%	100%	100%	100%	100%	100%	100%	100%
2017	100%	100%	100%	100%	100%	100%	100%	100%
2018	100%	100%	100%	100%	100%	100%	100%	100%

Table B4
Assessment of TSO's market power for cross-border capacity in relevant market 2 by the Residual Supply Index without utilising excess storage capacity in 2014–2018

% RSI >1.1	4	8	11	13
2014–2018	97%	20%	68%	16%
2014	100%	45%	93%	23%
2015	100%	29%	100%	26%
2016	100%	16%	89%	9%
2017	100%	9%	32%	19%
2018	87%	0%	25%	0%

Table B5
Assessment of TSO's market power for cross-border capacity in relevant market 2 by the Residual Supply Index utilising excess storage capacity in 2014–2018

% RSI >1.1	4	8	11	13
2014–2018	100%	45%	86%	35%
2014	100%	98%	100%	85%
2015	100%	33%	100%	31%
2016	100%	83%	100%	40%
2017	100%	9%	79%	19%
2018	100%	0%	48%	0%

Table B6
Assessment of TSO's market power for cross-border capacity in relevant market 3 by the Residual Supply Index without utilising excess storage capacity in 2014–2018

% RSI >1.1	3	4	5	6	13	15
2014–2018	87%	100%	100%	96%	70%	97%
2014	78%	100%	100%	96%	68%	98%
2015	87%	100%	100%	92%	75%	92%
2016	89%	100%	100%	98%	69%	99%
2017	82%	100%	100%	95%	55%	98%
2018	100%	100%	100%	100%	82%	100%

Table B7
Assessment of TSO's market power for cross-border capacity in relevant market 3 by the Residual Supply Index utilising excess storage capacity in 2014–2018

% RSI >1.1	3	4	5	6	13	15
2014–2018	98%	100%	100%	100%	93%	100%
2014	98%	100%	100%	100%	97%	100%
2015	92%	100%	100%	100%	90%	100%
2016	100%	100%	100%	100%	100%	100%
2017	99%	100%	100%	100%	84%	100%
2018	100%	100%	100%	100%	94%	100%

Table B8
Assessment of TSO's market power for cross-border capacity in relevant market 4 by the Residual Supply Index without utilising excess storage capacity in 2014–2018

% RSI >1.1	4	11
2014–2018	0%	8%
2014	0%	9%
2015	0%	12%
2016	0%	5%
2017	0%	6%
2018	0%	8%

Table B9
Assessment of TSO's market power for cross-border capacity in relevant market 4 by the Residual Supply Index utilising excess storage capacity in 2014–2018

% RSI >1.1	4	11
2014–2018	5%	42%
2014	25%	95%
2015	0%	23%
2016	1%	76%
2017	0%	6%
2018	1%	9%

Table B10
Assessment of TSO's market power for cross-border capacity in relevant market 5 by the Residual Supply Index without utilising excess storage capacity in 2014–2018

% RSI >1.1	1	3	4	5	6	8	11	12	13	14	15
2014–2018	100%	100%	91%	100%	100%	99%	100%	96%	99%	100%	100%
2014	100%	100%	96%	100%	100%	100%	100%	100%	98%	100%	100%
2015	100%	100%	95%	100%	100%	100%	100%	100%	100%	100%	100%
2016	100%	100%	93%	100%	100%	100%	100%	100%	100%	100%	100%
2017	100%	99%	83%	100%	100%	98%	100%	91%	98%	100%	100%
2018	100%	100%	87%	100%	100%	98%	100%	91%	98%	100%	100%

Table B11
Assessment of TSO's market power for cross-border capacity in relevant market 5 by the Residual Supply Index utilising excess storage capacity in 2014–2018

% RSI >1.1	1	3	4	5	6	8	11	12	13	14	15
2014–2018	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2014	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2015	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2016	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2017	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2018	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table B12
Assessment of TSO's market power for cross-border capacity in relevant market 6 by the Residual Supply Index without utilising excess storage capacity in 2014–2018

% RSI >1.1	6	9	13	15	F1	F2	F3	F4
2014–2018	100%	100%	100%	100%	100%	100%	96%	100%
2014	100%	100%	100%	100%	100%	100%	100%	100%
2015	100%	100%	100%	100%	100%	100%	100%	100%
2016	100%	100%	100%	100%	100%	100%	89%	100%
2017	100%	100%	100%	100%	100%	100%	92%	100%
2018	100%	n/a	100%	100%	100%	100%	98%	100%

Table B13
Assessment of TSO's market power for cross-border capacity in relevant market 6 by the Residual Supply Index utilising excess storage capacity in 2014–2018

% RSI >1.1	6	9	13	15	F1	F2	F3	F4
2014–2018	100%	100%	100%	100%	100%	100%	100%	100%
2014	100%	100%	100%	100%	100%	100%	100%	100%
2015	100%	100%	100%	100%	100%	100%	100%	100%
2016	100%	100%	100%	100%	100%	100%	100%	100%
2017	100%	100%	100%	100%	100%	100%	100%	100%
2018	100%	n/a	100%	100%	100%	100%	100%	100%

Table B14
Assessment of TSO's market power for cross-border capacity in relevant market 7 by the Residual Supply Index without utilising excess storage capacity in 2014–2018

% RSI >1.1	2	4	6	7	10	12	F5	F6	F7	F8	F9	F10
2014–2018	100%	100%	100%	100%	100%	100%	100%	100%	42%	100%	92%	100%
2014	100%	n/a	n/a	100%	100%	100%	100%	n/a	67%	100%	100%	100%
2015	100%	n/a	100%	100%	100%	100%	100%	100%	86%	100%	100%	100%
2016	100%	n/a	100%	n/a	100%	100%	100%	100%	25%	100%	100%	100%
2017	100%	n/a	100%	n/a	100%	100%	100%	100%	10%	100%	79%	100%
2018	100%	100%	100%	n/a	100%	100%	100%	100%	22%	99%	81%	100%

Table B15
Assessment of TSO's market power for cross-border capacity in relevant market 7 by the Residual Supply Index utilising excess storage capacity in 2014–2018

% RSI >1.1	2	4	6	7	10	12	F5	F6	F7	F8	F9	F10
2014–2018	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2014	100%	n/a	n/a	100%	100%	100%	100%	n/a	100%	100%	100%	100%
2015	100%	n/a	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2016	100%	n/a	100%	n/a	100%	100%	100%	100%	100%	100%	100%	100%
2017	100%	n/a	100%	n/a	100%	100%	100%	100%	100%	100%	100%	100%
2018	100%	100%	100%	n/a	100%	100%	100%	100%	100%	100%	100%	100%

Appendix C. Distinguishing seasonal and structural significant market power

As the gas industry faces seasonality, a TSO's significant market power may rather be seasonal than structural. Therefore, we increase the granularity for these cases to analyse the daily RSIs on a monthly basis. Fig. C1 graphically presents the results. For each case, a graph shows a dummy variable for each month between 2014 and 2018 indicating whether a TSO had market power in a particular month. It is equal to 0 if the RSI threshold of 1.1 for 95% of time holds for a certain month, and 1 otherwise.

In relevant market 2, the significant market power found for TSOs 8, 11, and 13 appears to be structural. In relevant market 3, TSOs 3 and 13 usually showed no significant market power. However, in Winter /Spring 2014 /2015 significant market power existed. This is also found in Q1 2017. TSO 13 additionally shows significant market power in Q2 2017 and in the first half of 2018. Therefore, the significant market power of TSOs 3 and 13 in relevant market 3 was not structural but rather seasonal.

Relevant market 4 has only two active TSOs, it is the relevant market with lowest number of TSOs. In this, and only this, relevant market, TSO 4 had an average and mean share of maximum capacity of 99.99%. Although having a negligible share, TSO 11 appeared to have significant market power. The reason for this is that even the sum of capacity of both TSO was not sufficient to ensure a supply index being at least 1.1 for 95% of time. Hence, it is ex-ante not possible that a *Residual* Supply Index finds a TSO had no market power. Therefore, we conclude that TSO 4 had structural significant market power, whereas TSO 11 did not have any significant market power, at least if excess storage capacity is considered.

All graphs similarly show a period starting at the beginning of 2014 having different durations, where no TSO had significant market power. This is due to the utilisation of excess storage capacity, which may be needed immediately, and, depending on the actual circumstances, can be used for a longer or shorter period.

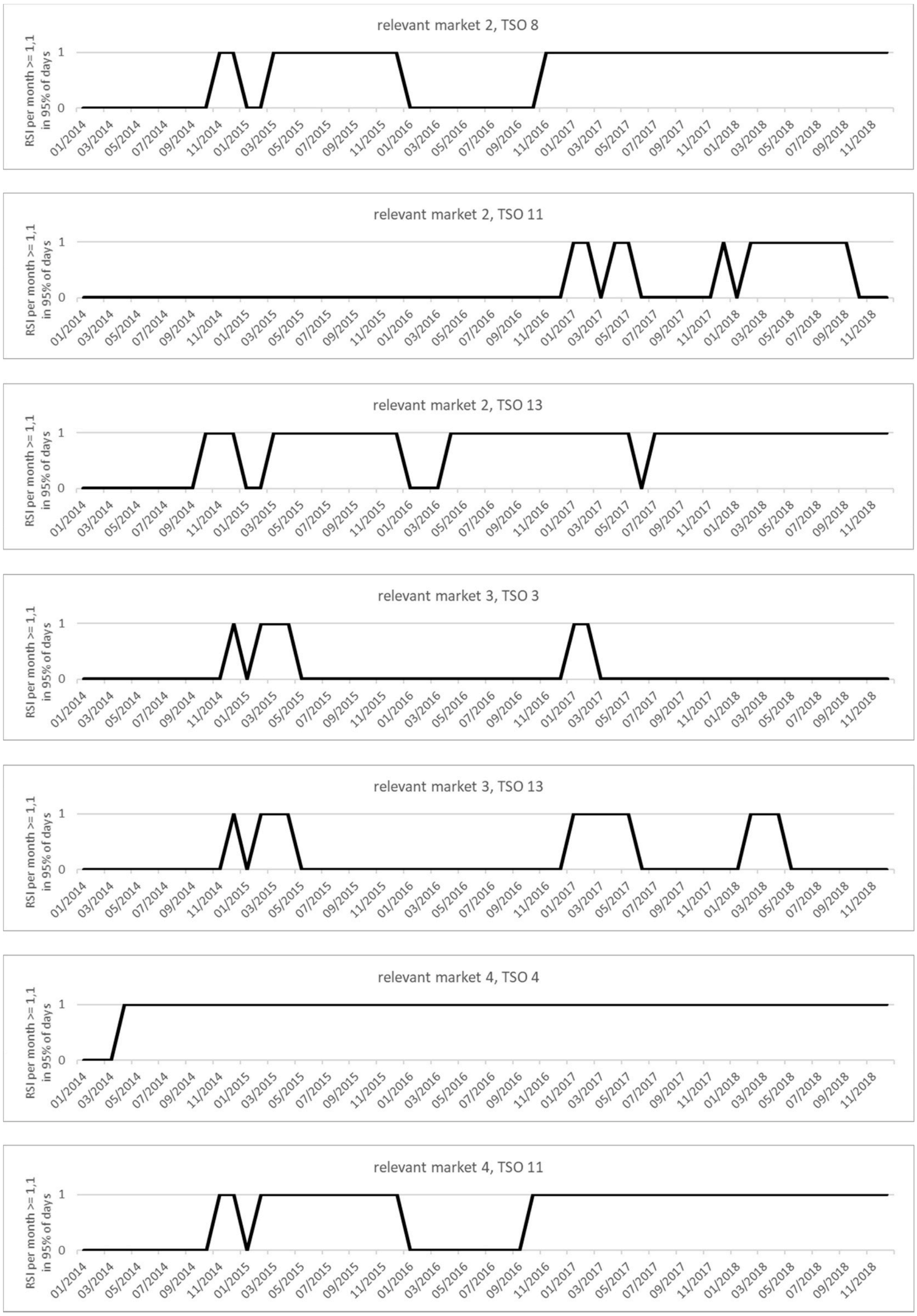

Fig. C1. Comparison of monthly RSIs against the threshold for combinations of relevant markets and TSOs found to had significant market power in 2014–2018

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