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MERGERS OF GAS MARKET AREAS AND COMPETITION AMONGST TRANSMISSION SYSTEM OPERATORS: EVIDENCE ON BOOKING BEHAVIOUR IN THE GERMAN MARKETS

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Abstract

Transmission networks are crucial for gas wholesale markets. In the past, the individual networks of transmission system operators (TSOs) determined market areas in the European Union, but driven by the prospect of higher liquidity in the wholesale market, welfare gains for society as well as completion of the internal energy market, market areas have been merged. Such market mergers, however, may also lead to competition amongst TSOs, as network users gain the possibility to book interchangeable capacity at different TSOs within one market area. A necessary condition for competition amongst TSOs is that network users book network capacity efficiently. This paper analyses whether this has been the case in the German market areas, which have experienced the highest market integration so far. We find that network users' booking behaviour is fairly efficient. We also find that it is important to control for differences in country specific capacity types. In those cases where a more expensive alternative is preferred over a cheaper alternative, this inefficient behaviour can be largely attributed to differences in capacity types. We conclude that gas TSOs may not operate as pure natural monopolists anymore.

Key Words:

Gas market, Regulation, Market mergers, Networks

JEL Codes:

Q48, L51, L95, L98, K23

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1 Introduction

As part of the European Union's (hereafter: EU) policy to establish an internal market, the EU aims to create a European internal gas market (European Union, 2012). To achieve this aim, EU policy measures directly influence national energy policies, regulatory frameworks, and the design of gas markets in Member States. In the past, this occurred especially through the three so-called *European Energy Packages* entering into force in 1998, 2003 and 2009, respectively. These implied the liberalisation of the EU gas markets and the establishment of wholesale markets. In order to allow for these developments, a regulation to ensure non-discriminatory network access and network tariffs, as well as unbundling rules has been imposed on network infrastructure companies operating the essential facilities as a natural monopoly. In particular, transmission system operators (hereafter: TSO) operate the key infrastructure the wholesale gas markets rely on. Their networks are connected to networks of adjacent TSOs as well as to storage facilities and downstream distribution system networks, and are used by producers, traders, and suppliers. Hence, regulating TSOs means regulating the entire gas market.

In the past, it was necessary for suppliers to book network capacities according to the actual transport route in order to supply a customer. This changed by introducing entry-exit systems, which decoupled the physical network and the commercial trades. As result of this change, network users were now able to inject gas at any entry point and withdraw it at any exit point of such a market area whereas the TSO was solely responsible for the management of physical gas flows. This decoupling also allowed wholesale markets to arise, as the injection and withdrawal of gas became independent of each other (CEER, 2011; Lohmann, 2009). Although the markets could evolve, the development of the wholesale markets was deemed insufficient (Frontier Economics Ltd., 2014). A measure to improve the liquidity and intensity of competition of a gas market is integration (ACER and CEER, 2017).

Market integration can be achieved by market mergers. If two markets merge to become one, the resulting single gas market is based on the infrastructure of more than one TSO. Market mergers have taken place mainly in Germany, which consisted of 41 market areas in 2006 and which were eventually merged to two today (Monopolkommission, 2009; Ströbele et al., 2012). According to regulatory authorities, most European markets are still not sufficiently developed, and there are doubts that this will happen without structural reforms (ACER and CEER, 2015). Hence, further market mergers, even cross-border, are to be expected.

The integration of gas markets is widely discussed in the literature. For example, Asche et al. (2013) found a high integration of the gas markets in the UK, the Netherlands, and Belgium. Petrovich (2013) measured the degree of market integration for different EU gas wholesale markets using the wholesale prices. Kuper and Mulder (2016) focused on the integration of the German and Dutch gas market not only based on wholesale prices but also taking into account infrastructure utilisation and regulatory changes, including mergers of markets.

Market mergers, however, do not only have an impact on wholesale markets. Networks users also obtain transport alternatives via mergers. Merging two markets areas, which are entry-exit systems, results in a new joint market area, also organised as an entry-exit system. Therefore, gas injected into the network of one TSO may be withdrawn from the network of the other TSO belonging to the same market area, and vice versa. If two market areas to be merged are both connected to a third market area, the merger creates a choice for network users between routes to import to or export gas from the merged market. Since network users obtain a choice amongst routes and TSOs, market mergers may imply competition among TSOs.

In the literature, TSOs are generally considered as natural monopolies, which need to be regulated in absence of effective competition (Sherman, 2001). In U.S. gas markets, competition between pipelines referred to vertically integrated companies, where the pipelines used to be not only an asset for transportation, but also the single suppliers of gas to local utility companies (Chermak, 1998; Makholm, 2012). As a consequence, these markets are subject to competition amongst commodity suppliers to city gates and not amongst infrastructure (Broadman, 1986). Beukenkamp (2009) assessed pipeline competition in Europe, finding that some routes across Europe have the potential to compete. However, these are long-distance routes involving several countries and TSOs, whereas this paper focuses on adjacent markets.

Von Hirschhausen et al. (2007) analysed the competition amongst German TSOs and came to the conclusion that German TSOs are not exposed to effective competition nor that there is a potential for such competition to arise. As several German TSOs asked to be granted an exemption from tariff regulation, Bundesnetzagentur (2008), as the regulatory authority in charge, also had to assess the competition between them and also concluded that the companies were not exposed to an effective existing or potential pipeline competition. However, the situation in 2007 / 2008 with Germany consisting of 16 market areas, which indicated a significant lower degree of market integration, was different from today. The regulatory regime applied has also changed in the meantime, for example, capacity products have been standardised and offered on a central booking platform. Furthermore, Bundesnetzagentur investigated whether or not the entire TSO is exposed to competition so that exemptions from the regulation may be granted. However, a TSO may be partly exposed to competition, e.g. certain network points may be competing.

In this paper, we assess whether transport alternatives resulting from market mergers could allow for competition between regulated TSOs which may allow for a change in gas market regulation. To elaborate on this, we focus on the demand for gas transport capacities to and from the two German gas markets. As Germany has been faced with such a reduction in the number of market areas via market mergers, inferences drawn from the German market areas contribute to shaping the future of the European regulatory regime and market design. This paper analyses whether the choices made by network users are efficient. We define booking behaviour efficient if network users choose the transport alternative with the lowest tariffs. We use auction data from the capacity booking platform PRISMA for the calendar year 2016 to determine the efficiency of network users' booking behaviour. Our analysis looks at all capacity alternatives to and from the German gas markets, and compares the optimal costs of booking to the costs observed. Furthermore, the paper provides explanations for inefficiencies.

For both German gas markets, the results show a fairly efficient booking behaviour of network users. We conclude that network users make efficient use of the transport alternatives obtained from market mergers. However, we also find that differences between capacity types in the European and the national German regulation need to be considered. This explains to a very large extent why in some cases apparently more expensive alternatives are preferred over cheaper ones. Although gas transport capacity is highly standardised, the quality differences, i.e. the differences in capacity types, matter to network users. Taking this into account, price signals given by different TSO tariffs steer booking behaviour. Hence, there is a certain competitive pressure for TSOs from the demand side.

Following this introduction, the paper starts with a concise description of the background and functioning of European gas markets, and the effect of market mergers. Section 3 continues with economic theory, which leads to our hypothesis. Section 4 introduces the data we use, whereas Section 5 explains how we conduct our analysis. The results are reported in Section 6. Detailed results are presented in the appendix. Section 7 provides our conclusions.

2 Regulation and integration of European gas markets

2.1 Entry-exit regulation

EU Regulations and Directives determine the regulatory framework of European gas markets. Regulation (EC) No 715/2009, being part of the so-called *Third Energy Package* and also referred to as the *Gas Regulation*, prescribes a market design to be implemented by TSOs, which is referred to as the *entry-exit system.*[1] Prior to entry-exit, network users,[2] who intended to supply customers with gas, needed to book gas transport capacities for a specific route in the network(s). Such booking of routes was not flexible and did not establish a liquid wholesale market as gas was traded at several physical network points. In contrast, the concept of entry-exit offers flexibility in gas transport, and allows for wholesale markets, so-called *virtual trading points*, in the market areas. In an entry-exit system, only two gas transport capacity contracts are necessary to supply a customer. A capacity contract at an entry point, e.g. a production facility, grants the right to inject gas into a TSO's network. Additionally, a contract for exit capacity is needed at the point where gas shall be withdrawn from the network, e.g. a customer (CEER, 2011; Lohmann, 2009). Since then, a network user only has to book and manage entry and exit capacity contracts to transport gas, and no specific routes anymore, which reduces transaction costs (Vazquez et al., 2012). A supplier also obtains increased flexibility as every entry point can supply every exit point. The management of the physical gas flows is solely the responsibility of TSOs. Hence, commercial trading, based on entry and exit, and physical gas transport became decoupled. In such a market area, a wholesale market can evolve as the entry-exit system allows to virtually withdraw gas at the virtual trading point to be sold to another party. This party may offer the same amount of gas again at the wholesale market or virtually inject it into a physical network and, for example, supply a customer or inject it to a storage facility. As TSO networks are well connected, gas may exit one market area and enter an adjacent one. Therefore, the entry-exit system allows for cross-border trade.

As defined by the Gas Regulation, capacity is generally either firm or interruptible which refers to its quality (European Parliament and Council of the European Union, 2009b). Firm capacity is without any risk to network users as it is contractually guaranteed as uninterruptible. Hence, a gas transport using firm capacity is guaranteed to take place. To guarantee the flow, the amount of firm capacity on offer is limited by physical capability of the network. In contrast, interruptible capacity may be offered unlimitedly by TSOs in addition to firm capacity. This capacity may be interrupted by a TSO, for example, to ensure security of supply in case the sum of intended gas flows would exceed the maximum flow possible.

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[1] The terms entry-exit system, entry-exit zone and market area are used interchangeably.

[2] This is a general term that encompasses different roles in the market, for example, traders, producers or suppliers.

2.2 Market integration

The introduction of entry-exit systems induced a significant change, and a major step towards completing the EU internal energy market for gas. Nevertheless, the development of European wholesale markets is viewed to be insufficient (Frontier Economics Ltd., 2014). ACER and CEER (2015) conclude that for a number of markets even the full implementation of new market provisions, as foreseen by the third energy package,[3] will not lead to a well-functioning internal gas market. Therefore, they propose to Member States to periodically review their gas markets based on so-called *metrics,* which are proposed by ACER and CEER.[4] If not meeting the criteria by 2017, ACER and CEER call for further structural reforms, i.e. more market integration.

Integrating markets can generally be referred to as abolishing barriers between single markets, such as tariffs (Belassa, 1961). If (tariff) barriers are abolished completely, the single markets become one, and the *law of one price* applies, which is widely used in the literature (Li et al., 2014). The possibility for cross-border trade and, hence, also the degree of integration, is limited by the amount of interconnection capacity between the markets (Vazquez et al., 2012). As it is widely discussed in the literature, the European gas markets are already integrated to a high extent (Asche et al., 2013; Growitsch et al., 2013; Kuper and Mulder, 2016; Petrovich, 2013). However, further integration is considered necessary in order to obtain a well-functioning internal gas market with higher liquidity and competition at the wholesale market, and higher wholesale price convergence. Therefore, the regulatory authorities refer to three potential market integration tools for EU gas markets leading to a different degree of integration (ACER and CEER, 2015). One instrument is the concept of a satellite market. This concept may be applied where a non-functioning gas market can be linked to a well-functioning adjacent market via sufficient pipeline capacity connecting both markets. However, most European markets have already reached a certain market size and level of development. The other two instruments proposed, a full and a partial market merger, seem to be more appropriate to be applied to established markets. Both the full and the partial market merger are characterised by a full merger of the wholesale markets. The difference between the two is whether or not the balancing regimes are also merged.

2.3 Virtual interconnection points

Besides market integration, the European regulatory framework foresees the concept of so-called *virtual interconnection points* (hereafter: VIP). So far, gas transport capacity has been allocated via auction procedures held for each physical interconnection point between two market areas. In order to provide a single capacity service between two connected market areas, VIPs shall be established at latest by November 2018 (European Commission, 2017a).

In case two or more physical points connect two market areas, these points shall be commercially replaced by one VIP. The capacity that was offered at the physical points shall be offered at the VIP. Thus, the available capacity of multiple points is combined and offered at one point and in one auction. Hence, it is no longer possible for network users to book capacity at one of the physical points. However, these VIPs shall only be implemented if the implementation is not detrimental to capacity on offer, and if it facilitates the economic and efficient use of the transmission systems involved (European Commission, 2017a).

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[3] See concept of network codes as stated in Article 6 of Regulation (EC) No 715/2009.

[4] For further information on the metrics see ACER and CEER (2015), Section 4.

2.4 Mergers in the German gas market

Market mergers could be observed particularly in Germany (Heather, 2015; Lohmann, 2009). Compared to other EU Member States, which usually have one or two TSOs, Germany today has 16 TSOs offering gas transport capacity.[5] In 2006, Germany consisted of 41 market areas, but due to market mergers, there are only two market areas left in Germany today, named "GASPOOL" and "Net Connect Germany (NCG)" (Monopolkommission, 2009; Ströbele et al., 2012). These two market areas shall be merged no later than 2022.[6] As Germany has been faced with such a reduction in the number of market areas via market mergers, inferences drawn from the German market areas contribute to shaping the future of the European regulatory regime and market design.

The impact of several market mergers taken place on connections to and from Germany is shown in Figure 1. The map shows the two market areas in Germany with GASPOOL mainly in the north, and NCG in the south of the country. However, in the west there is also a mixed area, where pipelines of both market areas exist. Furthermore, the map shows the number of different TSOs a network user can choose from for importing (entry) gas to and exporting (exit) gas from the German market areas. The arrows indicate the flow direction. The first number refers to the number of GASPOOL-TSOs, the second to the number of NCG-TSOs offering capacities a network user could choose from. As the figure shows, if offered, capacity between two markets is generally offered by more than one TSO. However, whether and to what extent TSOs face real competition depends, for instance, on the efficiency of network user's booking behaviour, which is the focus of this paper.

Additionally, markets mergers may also affect the quality of capacity products offered by a TSO. Within an entry-exit system, every entry point may be used to supply every exit point, which also holds if an entry-exit system consists of more than one TSO, like in Germany. However, this flexibility is limited by the capacity, which connects TSO networks. If the intended gas flows of network users induce a flow between two networks of the same market area, which exceeds the technical capacity, no transport is possible. However, if the capacity used to transport the gas is firm capacity, the TSOs do not have the right to interrupt the gas flow, although this would be necessary. Whilst market mergers resolve barriers to commodity trading, market mergers can impose restrictions in terms of firmness and free allocability of capacity; a market merger may cause a decrease in the capacity amount on offer. There are generally two possibilities to face these restrictions and avoid a reduction of capacity. Either invest into network expansions to resolve restrictions, and to guarantee the firmness and free allocability of gas flows given the new flexibility for network users and the resulting flow scenarios, or reflect the restrictions in the design of the capacity offered. The latter option may not impact the total amount of firm capacity, however, a certain amount is now firm only to certain conditions (Wagner & Elbling GmbH, 2014).

German TSOs chose the latter option, and introduced additional capacity types reflecting the restrictions implied by the merger taken place. All of them are treated as firm capacity although they are firm only conditionally. These conditions may be linked to, for example, fluctuations in demand or specific point-to-point connections (Kooperationsvereinbarung Gas (Annex 1), 2016). Hence, there is not only one firm capacity type in Germany as compared to European regulation.

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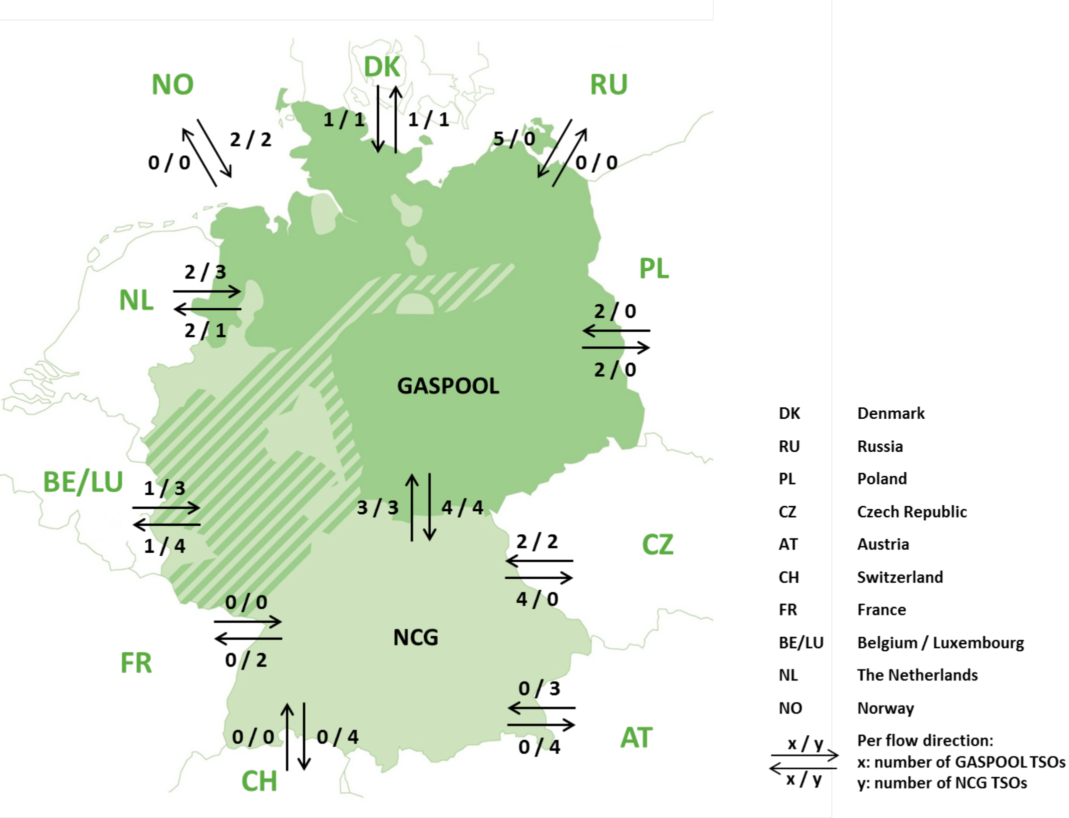
[5] See https://platform.prisma-capacity.eu.

[6] See Erste Verordnung zur Änderung der Gasnetzzugangsverordnung, 11 August 2017 (BGBl. I S. 3194).

Figure 1: Map of German and adjacent market areas, and number of German TSOs offering firm capacity products per flow direction



Note: The national markets of Belgium and Luxembourg have already merged. France has two national gas markets. However, NCG is only connected to the northern part of France (PEG Nord).

Source: www.fnb-gas.de, ENTSOG (2017b); own calculations.

3 Theoretical framework

3.1 Impact of market mergers on the choice of network users

Suppose there are three market areas A, B and C, which are operated by TSO A, TSO B and TSO C (see Figure 2). In this case, each market area is determined by the boundaries of the physical network of the TSOs. Each TSO has a number of entry and exit points. If, for example, A4 is a production facility and A2 is a customer to be supplied by gas injected at the point A4, then a supplier would need to book entry capacity at A4 and exit capacity at A2 as the market area implements an entry-exit system. If B3 is another customer to be supplied by gas from A4, then four capacity contracts are needed: entry at A4, exit at A1, entry at B1 and exit at B3. An entry-exit system allows only combining entry and exit points that belong to the same market area. In the example, the customer is located in a different market area, which is why two additional contracts at A1 and B1 are needed to allow for the cross-border flow (Lohmann, 2009; Vazquez et al., 2012). Figure 3 illustrates the effect of a merger of the market areas A and B: the commercial border, i.e. A1/B1, between the two markets disappears. Note that only the market areas merge while the TSOs A and B remain independent companies. If B3 shall be supplied by gas from A4 after the merger has taken place, only two contracts instead of four are still necessary, i.e. entry at A4 and exit at B3. This is possible as every entry point is virtually connected to every exit point of the same market area. As gas shall flow within an entry-exit system without any border restrictions, this also applies to the merger of market areas consisting of more than one TSO. The merged market area is no longer determined by one TSO network but by two.

Merging the market areas *A* and *B* creates opportunities for network users to choose between TSO *A* and TSO *B* with regards to the connection to market *C*. Assume a customer *B3* shall be supplied by gas from *C3*. Before the merger, gas would have been transported via the border *C2/B6* as it can be assumed that this route is cheaper than exporting the gas to market area *A, via C1/A6,* and exporting again to market area *B, via A1/B1*. However, after the merger, the border *A1/B1* disappeared. Hence, there are now two possibilities for suppliers to supply *B3* with gas from *C3*, either via *C1/A6* or via *C2/B6.* The border points *A6* and *B6* are competing, and so are the TSOs *A* and *B*. Thus, it can be inferred, that market mergers can lead to choices for network users.

Figure 2: Example of unmerged market areas with entry-exit system

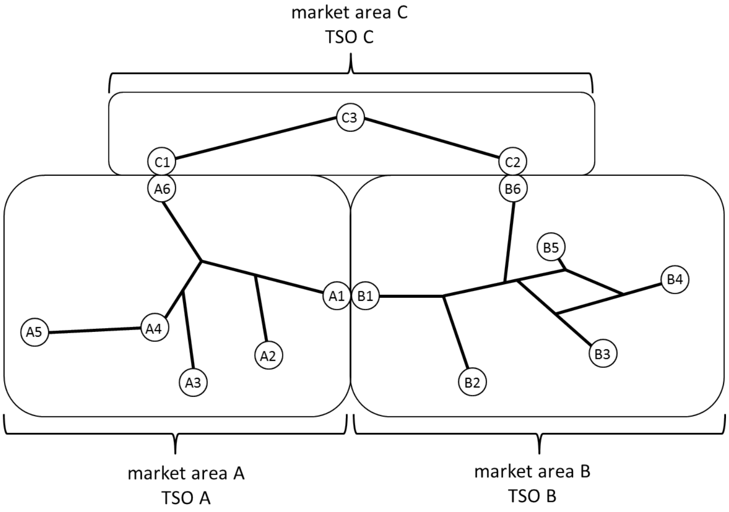
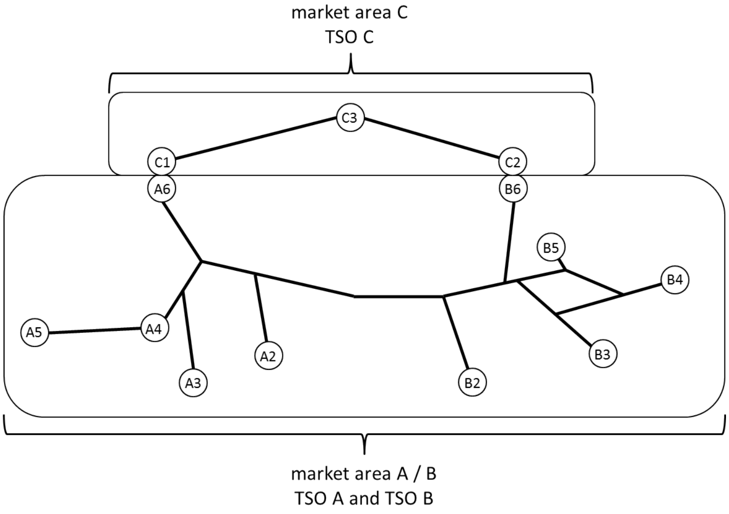


Figure 3: Example of merged market areas with entry-exit system

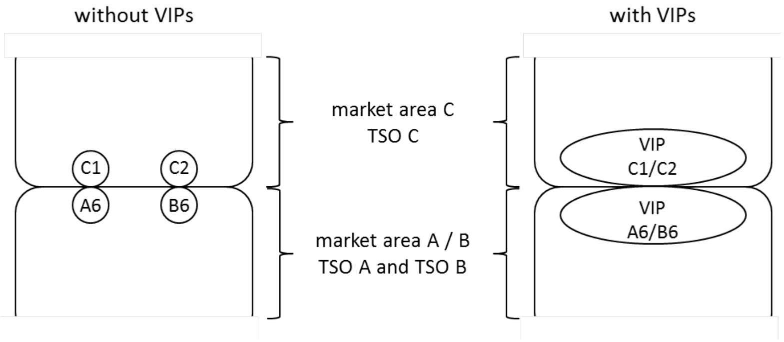


3.2 Impact of VIPs on the choice of network users in merged markets

VIPs, as referred to in Section 2.3, affect the choice of network users to book capacity at different points and TSOs, which resulted from market area mergers. If two or more physical points connect the same two market areas, these points are to be combined into one VIP. ACER (2012) highlights that this shall equally apply to market areas where capacity is marketed by more than one TSO, to the extent possible.

Referring back to the example shown in Figure 3, the market area A/B is connected to *C* via two points, i.e. *A6* and *B6* being connected to *C1* and *C2*. Implementing VIPs, points *C1* and *C2* will be integrated into a new *VIP C1/C2*. Since VIP are also to be implemented in case two or more TSOs offer capacity on one side of the same border, capacity will no longer be offered at the two points *A6* and *B6* but at the new VIP *A6/B6*. Figure 4 shows the commercial situation before and after implementing VIP in the example.

Figure 4: Example of the impact of VIPs in merged market areas with entry-exit system



Prior to merging market areas *A*, *B* and *C*, network user had no choice in terms of booking capacity between two markets (Figure 2). After the markets A and B have been merged, network users obtained a choice (Figure 3). Implementing VIPs, the possibility to choose between capacity at different points, and TSOs, offered at different tariffs is removed again (Figure 4). Once VIPs are implemented, network users can only book capacity at the new VIP.

3.3 Network users' booking behaviour

Mergers of market areas can create choices for network user booking gas transport capacity. Having a choice, network user needs to decide between different alternatives. Their decisions are supposed to be made in line with individual preferences based on utility and profit maximisation. If two (or more) capacity products differ in any of the characteristics they are made of, network users are supposed to choose the alternative in accordance with their preferences. Nevertheless, capacity booking is a means to trade gas and therefore, it should allow for the trade the network user aims at. Although capacity products are highly standardised by European regulation, a supplier, for example, still has to choose between booking a yearly capacity contract and a profiled booking using multiple capacity products of shorter runtimes (European Commission, 2017a). Additionally, capacity is firm or interruptible. Interruptible capacity is associated with the risk of interruption, which is why it is of a lower quality compared to firm, and is offered at a discounted tariff reflecting the risk of interruption (European Commission, 2017b). For this reason, a network user may have a preference to book such capacity of lower quality if this is suitable for the underlying trade, and the discount is subjectively perceived to outweigh the risk. Besides that, however, a network user may prefer to book a more expensive alternative at a certain TSO if, for example, both companies belong to the same corporate group. In order to avoid any kind of biased behaviour of vertically integrated companies, unbundling obligations have been established (Bernaerts, 2013; European Parliament and Council of the European Union, 2009a).

Besides costs for the capacity product, a network user should consider additional costs such as those related to the booking procedure. For instance, a lack of transparency regarding available capacity may cause information costs. In order to book capacity, a network user needs to be aware of what capacity products are on offer and how these can be booked. If more information about a specific capacity product is provided compared to an alternative product, it may be better understood by potential customers and thus, may be associated with less risk. Therefore, it may be preferred over a cheaper alternative. In addition, a network user may invest in additional information, which creates additional costs. However, increased transparency about the capacity on offer, for example provided by the TSO, can reduce such costs (Kury, 2015).

This paper focuses on how network users appear to be sensitive to differences in gas transport capacity offered. This sensitivity can be measured by looking at the difference between actual booking and optimal booking behaviour. The latter is defined as behaviour that results in lowest costs for booking with all other product characteristics being equal. This allocative efficiency measure is, for instance, used in the analysis of the dispatch of power plants: given a variety of power plants using different technologies, an optimal dispatch needs to be determined to supply a given demand for electricity (Müsgens, 2006). Since electricity is a homogeneous good, the optimal dispatch can be determined by a merit order of the unit costs at which the power plants offer electricity to the market. The most expensive plant necessary to provide the demand and in line with the merit order sets the market price for electricity to be obtained by all power plants. Hence, every supplier with lower costs than the one setting the market price does not only cover the costs but also receives additional revenues (Cludius et al., 2014). Allocative efficiency in this respect refers to the degree the final dispatch is in line with the merit order. In case the dispatch is fully in line with the merit order, there is full allocative efficiency. If not, additional costs constitute inefficiencies. In a well-functioning market with perfect competition, one may assume that the actual dispatch is equal to the optimal dispatch, if other factors are equal.

The concept of a merit order analysis can also be used to measure the allocative efficiency for gas transport capacities. Gas transport capacities are booked via auctions on booking platforms. Alternatives of gas transport capacities are not offered in joint auctions, hence, there is no merit order created by the booking platform. However, network users are able to compare the prices for standardised capacity products on offer, and create merit orders themselves in order to decide which capacity to book. As compared to this, production capacity for electricity has a merit order created by a market place, for example, an electricity exchange. However, the production capacity for electricity may be offered not only at one market place but also at different market places. In terms of prices, TSOs charge regulated tariffs whereas power plants are offered at marginal costs (Morales and Pinedab, 2017).

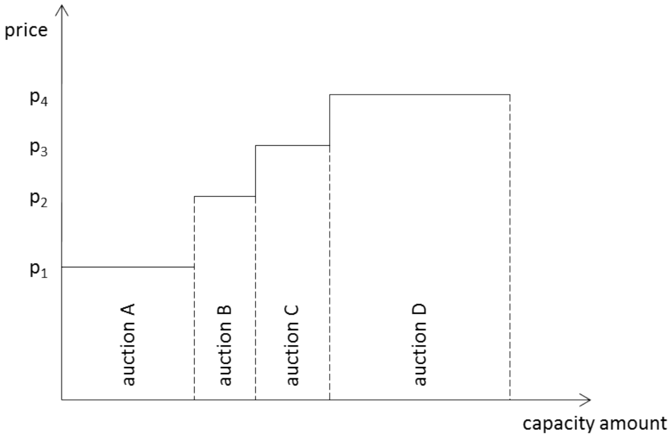
Figure 5 shows an example for gas transport capacity auctions and their merit order: since all the auctions are independent of each other, a network user is able to book capacity from each of the auctions. If, for example, capacity is booked in auction *C*, then the network user has to pay the amount of capacity booked times the tariff of that particular auction. If another network user had booked capacity in auction *A*, than the tariff of auction *A* would apply. Since the auctions are independent of each other, there is no single market price. Thus, booking capacity in auction *C* is not efficient in case capacity has been available in other auctions at lower tariffs. However, scarcity may arise if all networks users would try to book capacity in auction *A*. If in an auction the demand for capacity exceeds the amount on offer, surcharges will be added to the price of capacity. These auction surcharges may cause a capacity allocation at a price which is higher than the price at which capacity was offered in auction *B*. Hence, it would have been more efficient for a network user to directly book capacity at auction *B*. If charged, they are included in the actual costs of booking.

Like for electricity, the comparison of actual capacity allocation to the merit order determines the degree of allocative efficiency. Therefore, we can measure the allocative inefficiency by comparing the actual costs of booking observed with the optimal costs:

$$\text{inefficiency} = \frac{\text{actual costs of booking}}{\text{optimal costs of booking}} \tag{1}$$

The optimal costs are based on a merit order of all capacity products a network user could have chosen from. The actual costs observed directly refer to the booked capacity amount and the price to be paid, which include auction surcharges if occurred. Both the actual and optimal costs are based on all capacity products: both can be expressed as the average costs per unit.[7]

Figure 5: Example of a merit order for gas transport capacity products



Given a European regulatory framework with effective unbundling rules, harmonised capacity products, the entry-exit system, and an equal level of transparency and transaction costs, the price of capacity is expected to be the driving force for deciding between transport alternatives. In absence of restrictions, it is economically efficient for network users to choose the cheapest alternative available. Therefore, we hypothesise that if network users have the choice between gas transport alternatives for one and the same market area, they book those capacities that are associated with the lowest total costs. Hence, in that case the inefficiency value calculated as per Equation (1) would be 1.00, indicating no inefficiency.

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[7] To compare: in electricity markets, the inefficiency is calculated on the basis of the market price (i.e. the actual system marginal costs) and the system marginal costs in case of optimal dispatch.

4 Data

We use auction data from the capacity booking platform PRISMA for the calendar year 2016 to determine the efficiency of network users' booking behaviour. Gas transport capacities are offered by TSOs and booked by network users. Capacities are offered on booking platforms and allocated via auction procedures in line with European network access provision stated in the so-called *network code on capacity allocation mechanisms* (hereafter: NC CAM) (European Commission, 2017a). Except for capacity to and from Poland, all auctions for primary capacity at German TSOs are auctioned via the leading European booking platform for gas transport capacity named *PRISMA.*[8,9] This also includes capacity between GASPOOL and NCG. PRISMA reports detailed results of each auction held. These auction data reflect the result of network users' booking decisions, and provide a solid basis for the analysis of booking behaviour by network users. The auction results are publicly available,[10] and include, amongst others, entry and exit market area and network points, entry and exit TSO, capacity on offer and allocated as well as all tariffs and additional fees that are charged to network users (PRISMA European Capacity Platform GmbH, 2016). The NC CAM rules are applied since 1 November 2015. PRISMA even reports earlier data. However, the introduction of NC CAM implied a huge change to the regulatory framework and the allocation procedure. Furthermore, before NC CAM not all TSO offered capacity via PRISMA. To ensure data consistency, the data set used in the analysis covers the calendar year 2016 in which no major regulatory changes, in particular to capacity allocation and network tariffs, were applied.

Data extraction from PRISMA for calendar year 2016 delivers 2,089,914 single observations of auctions. However, data cleansing is necessary. Table 1 summarises the data cleansing steps.

Table 1: Summary of PRISMA auction data for 2016, and data cleansing

	Number of auctions
PRISMA auction data (1 Jan. 2016 – 1 Jan. 2017)	2,089,914
- auctions not involving German markets	1,087,388
- auctions where capacity is not bundled and not firm	472,753
+ auctions where capacity is unbundled firm and to or from non-EU country	116,138
- cancelled auctions	182
Remaining	645,729
of which auctions to or from EU countries	529,618
of which auctions to or from non-EU countries	116,111

Source: PRISMA European Capacity Platform GmbH (2016); own calculations.

As outlined in Section 2.1, capacity may be either firm or interruptible. NC CAM prescribes TSO to offer firm capacity as bundled capacity. Bundling refers a package of corresponding firm entry and exit capacity that is auctioned. Interruptible capacity is not offered bundled. Firm capacity may be offered unbundled, though. However, this is limited to the case where available capacity on one side

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[8] According to the Gas Regulation, primary capacity refers to capacity that is directly booked at the TSO. As compared to this, secondary capacity may be offered by network users, who have acquired this as primary capacity before.

[9] See https://platform.prisma-capacity.eu.

[10] The data are available on the PRISMA website: https://platform.prisma-capacity.eu/#/reporting/standard.

of the border exceeds the available firm capacity on the other side. Network users who already hold corresponding capacity at the other side, e.g. due to an existing long-term contract, may book such unbundled firm capacity. Also network users who are willing to combine one firm capacity product with interruptible capacity may be interested in such unbundled firm capacity. However, network users assess their demand for interruptible capacity differently. Although relevant data are publicly available, the assessment, for example of the probability of interruption, and the resulting consequences, differ per network user. The risk preference differs as well. As a consequence, only firm and bundled capacity can be considered for the analysis, as unbundled and interruptible capacities require additional data, which are not available. Thus, it is not possible to control for such prerequisites, which requires omitting these observations in order to avoid a distortion of the analysis' results.

The NC CAM, as an EU Regulation, only applies to TSOs within the EU. However, such TSOs may have a connection to countries outside of the Union (non-EU countries). German TSOs have connections to Norway, Russia, and Switzerland. German TSOs offer such capacity also via PRISMA in line with the same provisions that apply for connection to other EU Member States. In terms of bundling, however, the approaches differ. Firm capacity to and from non-EU countries is marketed only unbundled. The same reason why unbundled firm capacity data are omitted may apply to such auctions as well. However, it does not necessarily have to. Since the analysis can distinguish between adjacent market areas, as such information is included in the data set, unbundled firm capacity data for non-EU countries are not omitted but taken into account with special caution.

NC CAM harmonises *capacity products*. A capacity product is defined by its runtime, which may be a year, a quarter, a month, a day, or a number of hours of a day. Table 2 shows the number of auctions according to these harmonised capacity products.

Table 2: Number of PRISMA auctions, offered capacity, and booked capacity per capacity product of German TSOs in 2016

Capacity product	Number of auctions	Capacity on offer [GWh/h/runtime]	Capacity booked [GWh/h/runtime]	Booking rate [%]
Within-day	617,100	899,590	1,150	0.13
Day-ahead	27,426	40,820	617	1.51
Month	590	1,094	35	3.23
Quarter	214	392	4	1.05
Year	399	884	14	1.63

Source: PRISMA European Capacity Platform GmbH (2016); own calculations.

The longer the runtime, the fewer auctions take place. This seems obvious as, for example, within the runtime of a yearly capacity product, 365 (366) day-ahead auctions take place. However, there were on aggregate more auctions for yearly capacity held in 2016 than quarterly ones. Whereas NC CAM provisions allow TSOs to offer monthly capacity only one month ahead, a TSO is permitted to offer yearly capacity up to 15 years ahead during the annual auction for yearly capacity products. As one year is the maximum duration of a capacity contract, 15 years ahead means that 15 auctions may be on offer, each covering a runtime of one year.

Furthermore, Table 2 compares the amount of capacity offered and booked. The booking rate indicates that the demand for capacity is fairly low. However, it needs to be considered that the data cover all auctions with German TSO in 2016. A network user may hold a long-term contract concluded in the past, which is still valid. Hence, such a network user has no or at least a lower demand for new capacity. On the other hand, the capacity products are dependent on each other. For example, a capacity, which has been offered but not been booked in the auction for yearly capacity, will be offered again as quarterly products. The amount left unallocated will be reoffered in monthly product, day-ahead and maybe within-day products. Hence, one unit of capacity, which is not booked, will be counted several times. Taking this into account, the booking rate still indicates a fairly low level of demand for primary capacity.

Table 3 and Table 4 give an overview of the number of auctions held in 2016 per gas transport connection to and from Germany.

Table 3: Number of PRISMA auctions for entry capacity to the German market areas in 2016

Exit \ Entry	GASPOOL	NCG	Sum
internal borders			
GASPOOL	-	73,194	73,194
NCG	56,940	-	56,940
external borders			
Austria	-	20,712	20,712
Belgium / Luxembourg	8,679	25,799	34,478
Czech Republic	8,787	36,293	45,080
Denmark	8,711	8,457	17,168
The Netherlands	31,698	77,130	108,828
Norway	22,195	24,377	46,572
Russia	18,236	-	18,236
Sum	155,246	265,962	421,208

Source: PRISMA European Capacity Platform GmbH (2016); own calculations.

Table 4: Number of PRISMA auctions for exit capacity from the German market areas in 2016

Entry \ Exit	GASPOOL	NCG	Sum
internal borders			
GASPOOL	-	56,940	56,940
NCG	73,194	-	73,194
external borders			
Austria	-	3,842	3,842
Belgium / Luxembourg	8,519	17,610	26,129
Czech Republic	19,553	13,123	32,676
Denmark	12,159	-	12,159
France	-	19,690	19,690
The Netherlands	21,915	56,807	78,722
Switzerland	-	26,311	26,311
Norway	8,754	16,238	24,992
Sum	144,094	210,561	354,655

Source: PRISMA European Capacity Platform GmbH (2016); own calculations.

Independent from the flow direction, more auctions where held involving the NCG markets area compared to GASPOOL (approx. 63% entry, 59% exit). The number of auctions held in 2016 largely varies amongst the different connections for both entry and exit. Entry from the Dutch TTF shows by far the largest number of auctions. The same applies to exit flow direction except for the inner-German capacities from GASPOOL towards NCG that are almost the same level.

5 Methodology

5.1 Constructing homogeneous groups of auctions

Using the data mentioned above, we test the hypothesis formulated in Section 3.3 on the level of homogeneous groups of auctions. As the data set contains auctions which are single observations, we need to group these observations in such a way that any group of observations represents an exhaustive list of all alternatives a network user with a specific need for gas transport capacity could have chosen from. This will be called a *homogeneous group of auctions*. For every homogeneous group of auctions, we determine the efficiency of the network users' booking behaviour.

The following attributes are considered to guarantee that all auctions having equal characteristics of these attributes belong to the same homogeneous group of auctions and thus, are alternatives for network users. All these attributes are contained in the PRISMA auction data set.

- *Market area entry and market area exit:*
  To be an alternative for network users, capacity needs to connect the same two market areas. If the origin and destination are not equal for capacity being offered in two (or more) auctions, the auctions cannot be alternatives. Since capacity is a means to fulfil a commodity trade, the commodity trade prescribes the capacity needed. Every auction offering capacity that allows for the trade to be physically fulfilled needs to connect the same market area in entry as well as in exit direction. Treating entry and exit as two different attributes, ensures that all auction of a homogeneous group of auctions have the same flow direction, which is a necessary condition.
- *Capacity product (runtime):*
  A network user may place a bid in an auction offering, for example, a monthly capacity product. However, he may also book day-ahead capacity on every day of the month. By placing a bid in an auction for monthly capacity, the network user reveals a preference for the monthly product over a month of day-ahead products. The revealed preference indicates that the network user is interested in buying a monthly product at that point in time. Hence, other capacity products may be an alternative but are not preferred or were not auctioned at the time the network users wanted to obtain capacity. Thus, only capacities with the same runtime are considered alternatives. This implies that the analysis does not measure cross-product inefficiency.
- *Start of auction:*
  As stated, one capacity product may not be auctioned at the same time as capacity of another runtime. The timing of capacity auctioning follows the so-called *auction calendar* (ENTSOG, 2017a; European Commission, 2017a). In general, deciding between alternatives has a time dimension. If a network user wants to book capacity at a certain point in time, he can only chose from those auctions that are open at that point in time. In accordance with the auction calendar and the auction algorithms applied, the start of an auction is

harmonised. Only if the start of auctions is equal, the auctions can be alternatives. If the start of auctions is not equal, they can never be alternatives as the network users do not have the ability to choose amongst those.

- *Runtime start:*
  The capacity product and the start of the auction are not sufficient to cover the time dimension. According to the auction calendar, there are two different within-day auctions taking place at 7:00 p.m. each day: Firstly, within-day capacity is offered for the next gas day.[11] It has the same runtime as a day-ahead product, i.e. one gas day of 24 hours. As within-day capacity is sold after day-ahead capacity, the amount offered is the non-allocated amount of firm day-ahead capacity. The runtime of this capacity starts at the next gas day, i.e. 6:00 a.m. Secondly, within-day capacity for the rest of the current gas day is also auctioned at 7:00 p.m. The runtime of this capacity starts four hours after the start of the respective auctions and ends at the end of the same gas day (European Commission, 2017a). This underlines that within-day capacity is in fact a “rest-of-the-day” capacity. Since these two within-day auctions are no alternatives of gas transport capacity, the runtime start of the capacity products on offer is needed defining homogeneous groups of auctions.
- *Gas quality:*
  Natural gas is a natural product. Thus, the chemical composition may vary within a certain range. A capacity product in Germany may be either H-gas (high) or L-gas (low) capacity. Since a H-gas (L-gas) capacity refers only to transport high (low) calorific gas, H- and L-gas capacity are no substitutes and, hence, they are no alternatives for network users.

If auctions have equal characteristics defined by these attributes, they can be considered as alternatives for network users – they belong to the same homogeneous group of auctions. It is worth to mention that, according to this definition, a homogeneous group can contain auctions of several TSOs. As stated in Section 2, this is the result of market mergers that have taken place and a reason why network user have a choice between alternatives in gas transport. It is a necessary condition to allow for infrastructure competition.

In order to determine the efficiency of the homogeneous groups, two conditions need to be applied:

(1) The efficiency of a booking behaviour may only be assessed if network users have a choice. In case a homogeneous group of auctions consists of only one auction, networks users do not have choice between alternatives. Thus, as a condition, a homogeneous group needs to contain multiple auctions.
(2) Since we intend to measure allocative efficiency, capacity needs to be allocated. Therefore, as a condition, the sum of capacity allocated in all the auctions of that group must be greater than zero.

Only those homogeneous groups of auctions fulfilling the conditions are considered in determining the efficiency.

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[11] A gas day is defined as the period of 24 hours starting at 5.00 UTC in wintertime and starting at 4.00 UTC in daylight saving time (European Commission, 2017a). Hence, in central Europe a gas day is from 6.00 a.m. till 6.00 a.m. the next day. If not stated differently, the time refers to Central European (Summer) Time, CE(S)T.

5.2 Inefficiency measure

In order to test the hypothesis, the efficiency of every homogeneous group of auctions is determined. For this purpose, an indicator IER is calculated. By this inefficiency ratio, we compare for each homogeneous group the actual costs of booking observed with the optimal costs of booking. Hence, IER will have a minimum value of 1.00. In case there are no inefficiencies; efficiency is 100%.

$$\text{IER} = \frac{\text{actual costs of booking}}{\text{optimal costs of booking}} \tag{2}$$

IER is calculated for each homogeneous group of auctions. To interpret and compare the results, and draw conclusions from the results, a weighted IER for a cluster of homogeneous groups can be used. Such a cluster may consist of, for example, all homogeneous groups connecting two specific market areas, and its IER may be compared with those of another connection. For this purpose, a weighted IER may be used. This is calculated as a weighted average of all the individual IER of the relevant homogeneous groups. As a weight, we use the runtime of the capacity product normalised to days [d] as well as the capacity allocated in kWh/h/runtime of each homogeneous group [i] as expressed by Equation 3.

$$\text{IER}_{\text{weighted}} = \frac{\sum_{i=1}^{n} (\text{IER}_i \times \text{runtime}_i \times \text{allocated capacity}_i)}{\sum_{i=1}^{n} (\text{runtime}_i \times \text{allocated capacity}_i)} \tag{3}$$

In order to compare the actual and optimal costs, we calculate for every auction the price of a single unit of capacity, which a network user would have paid in case capacity was booked. This price is based on regulated network tariffs. In case of contractual congestions, an auction premium is added. Furthermore, additional charges or fees are considered if applied by the respective TSO. These may be charged, for example, for metering services, billing services, or gas quality conversion. All the costs may be charged in different units. In order to compare, all components are harmonised to *cent/kWh/h/runtime*. In case charges are not provided in Euros, daily exchange rates of the European Central Bank are used to convert to Euros. After calculating the total price per unit of capacity for all auctions, we create a merit order for every homogeneous group by ranking all contained auctions by the total price per unit of capacity. The optimal costs of booking are determined for every homogeneous group of auctions pricing the total capacity allocation of all auctions of a homogeneous group according to the merit order. The actual costs of booking are determined for every homogeneous group by sum of the price of a single unit of capacity multiplied by the amount of capacity allocated of all auctions belonging to the same homogeneous group. An IER is calculated for every homogeneous group of auctions by dividing the actual costs of booking observed by the optimal costs of booking.

6 Results

6.1 Efficiency of booking

The conditions of a mandatory capacity allocation and the minimum size appear to have a large impact on the number of homogenous groups of auctions. According to Table 5, 645,729 observations are allocated to 262,881 groups following the definition of homogeneous groups. Approximately 36% (93,546) of all homogeneous groups need to be omitted as they consist of only a single auction. Hence, these groups do not offer a choice to network users. The second condition has an even larger impact. Only 1.5% of all groups contain at least one auction where at least one unit of capacity was allocated. This means that in vast majority of all auctions, capacity was offered but not booked.[12] Therefore, 3,003 out of 262,881 homogeneous groups remain for our analysis as these meet the two necessary conditions.

Table 5: Number of homogeneous groups of auctions based on PRISMA auction data for Germany TSOs in 2016 under conditions

	Number of auctions and homogeneous groups
Single auctions after data cleansing	645,729
Homogeneous groups of auctions	262,881
of which containing one auction	93,546
of which containing multiple auctions	169,335
of which no capacity allocated	258,957
of which capacity allocated	3,924
of which unconditional	259,878
of which conditional	3,003

Note: The number of conditional homogeneous groups of auctions refers to those that contain multiple auctions as well as allocated capacity as stated in Section 5.1. Unconditional refers to those auctions and homogenous groups on which the two conditions are not imposed.

Source: PRISMA European Capacity Platform GmbH (2016); own calculations.

Table 6 shows the impact of the conditions applied to homogenous groups of auctions per capacity product. Less than one per cent of all within-day auction and groups of within-day auctions meet the conditions. However, within-day capacity, auctions as well as homogeneous groups amounts to approximately 96% of all data in the data set.

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[12] See also Table 2.

Table 6: Number of homogeneous groups of auctions based on PRISMA auction data for Germany TSOs in 2016 under conditions per capacity product

Capacity product	Unconditional		Conditional		Conditional / Unconditional	
	Auctions	Homogeneous groups	Auctions	Homogeneous groups	Auctions [%]	Homogeneous groups [%]
Within-day	617,100	251,293	5,260	1,528	0.85	0.61
Day-ahead	27,426	10,955	1,374	1,374	5.01	12.54
Month	590	287	216	70	36.61	24.39
Quarter	214	100	32	14	14.95	14.00
Year	399	246	47	17	11.78	6.91
Sum	645,729	262,881	6,929	3,003	1.07	1.14

Note: The number of conditional homogeneous groups of auctions refers to those that contain multiple auctions as well as allocated capacity as stated in Section 5.1. Unconditional refers to those auctions and homogenous groups on which the two conditions are not imposed.

Source: PRISMA European Capacity Platform GmbH (2016); own calculations.

The size of homogeneous groups varies between one and eight auctions, as shown by Table 7. The number of auctions is obtained by multiplying the size of groups with the number of homogeneous groups. As already stated, groups consisting of only one auction are to be omitted as they do not offer a choice to network users. If omitted, about 74% of all homogeneous groups consist of two (approximately 40%) or three (approximately 33%) single auctions. Omitting groups consisting of one auction, and applying the condition of a successful capacity allocation, about 30% off all remaining homogeneous groups contain two single auctions, and about 55% contain three single auctions.

Table 7: Number and size of homogeneous groups of auctions based on PRISMA auction data of Germany TSOs in 2016, and allocation of capacity

Number of auctions per homogeneous group	Number of homogeneous groups	of which	
		no capacity was allocated	capacity was allocated
1	93,546	92,625	921
2	68,272	67,374	898
3	56,367	54,790	1,577
4	13,268	13,228	40
5	7,963	7,797	166
6	11,591	11,381	210
7	10,887	10,783	104
8	987	979	8
Sum	262,881	258,957	3,924

Source: PRISMA European Capacity Platform GmbH (2016); own calculations.

In order to assess efficiency of network users' booking behaviour, the ratio IER is used. To show results for different cluster of connections or capacity products, we cluster the individual inefficiency ratios calculated and derive the weighted IER using the runtimes and capacity allocated as the weights.[13] Table 8 summarises the results of the efficiency calculation; more detailed results are provided in the appendix. According to these, GASPOOL capacity is booked less efficiently compared to NCG capacity. However, about three quarters of the loss in consumer welfare is caused by NCG capacity. Although there may be restrictions regarding booking capacity to and from non-EU countries,[14] those capacities are booked more efficiently (1.05) compared to connection to and from EU countries (1.07). The overall inefficiency is at about 6%. For 2016, the total loss in consumer welfare amounts to about four million Euros.

Table 8: Inefficiency ratios and loss in consumer welfare based on PRISMA auction data of German TSOs in 2016

Cluster of connections	Weighted IER	Loss in consumer welfare [thousand Euros]
GASPOOL entry	1.22	731
GASPOOL exit	1.02	48
Total GASPOOL	**1.16**	**780**
NCG entry	1.03	2,389
NCG exit	1.31	894
Total NCG	**1.05**	**3,283**
EU	1.07	3,002
Non-EU	1.05	1,028
Overall	**1.06**	**4,030**

Source: PRISMA European Capacity Platform GmbH (2016); own calculations.

6.2 Explaining observed inefficiencies by national regulation

After having calculated the inefficiencies of network users' booking behaviour, we examine these inefficiencies. As elaborated in Section 4, the analysis takes into account only firm capacity. With reference to the European regulatory framework, it has been assumed that gas transport capacity offered by the TSOs is harmonised such that the quality of capacity is always either firm or interruptible. Besides the European regulation, however, there is also national regulation, which may need to be considered.

The European definition of firm capacity is not exactly the same as German firm. German firm also includes conditional firm capacities foreseen by national regulation, and introduced by German TSO in the course of market mergers.[15] These conditions imply a risk, which is reflected in the networks tariffs by granting a discount (Bundesnetzagentur, 2015). Multiple firm capacity types offered by German TSO may have an impact on the network users' booking behaviour. Although there might be a cheaper conditional firm capacity on offer, the capacity may not be suitable for a network user. This may be either because of the conditions or because of the discount that may not

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[13] See Equation (3) in Section 5.2.

[14] See Section 4.

[15] See Section 2.4.

adequately reflect the risk as assessed by the network user. As an explanation of the inefficiencies measured initially, we hypothesise that the quality of a capacity product, i.e. the capacity type, matters to network users, and has an impact on their booking behaviour. This hypothesis refers to the fact that, for example, a capacity that is always firm, having no conditionality, and a capacity that is firm only in accordance with a certain demand are of a different quality, and, therefore, are no complete substitutes. Hence, a network user who might be completely risk averse may never book conditional firm capacity even in case it is offered at a lower price compared to non-conditional firm. This has an impact on the definition of a homogeneous group of auctions. If the capacity type matters, then the analysis needs to control not only for firm and interruptible capacity but also for different firm capacity types. Thus, the definition of homogeneous groups will be extended by the type of firm for both entry and exit capacity of a firm bundled capacity product.

Since the definition of a homogeneous group has become stricter, the number of groups increases. Table 9 is based on Table 5, and compares the number of homogeneous groups for the two different definitions of firm capacity. The stricter definition leads to an increase from 262,881 to 448,822 groups, as a stricter definition requires auctions to have more equal characteristics in order to belong to the same group. However, the number of groups with at least two single auctions decreases by approximately 16%. On the other hand, the condition that capacity needs to be allocated in at least one auction of a group is also very restrictive. The number of group meeting this condition rises by about 19%, which is less than the increase in all homogeneous groups (+71%). The number of groups meeting both conditions declines by about 42%.

Table 9: Comparison of the number of homogeneous groups of auctions based on PRISMA auction data of Germany TSOs in 2016 under conditions and according to the EU and German definition of firm capacity

	Number of auctions and homogeneous groups	
	according to EU firm capacity	according to German firm capacity
Single auctions after data cleansing	645,729	645,729
Homogeneous groups of auctions	262,881	448,822
of which containing one auction	93,546	305,764
of which containing multiple auctions	169,335	143,058
of which no capacity was allocated	258,957	444,162
of which capacity was allocated	3,924	4,660
of which unconditional	259,878	447,095
of which conditional	3,003	1,727

Note: The number of conditional homogeneous groups of auctions refers to those that contain multiple auctions as well as capacity was allocated as stated in Section 5.1. Unconditional refers to those auctions and homogenous groups on which the two conditions are not imposed.

Source: PRISMA European Capacity Platform GmbH (2016); own calculations.

Figure 6 summarises the results of the adjusted efficiency calculation considering the German definition of firm capacity, and compares it to the initial calculation using the EU definition of firm capacity.[16]

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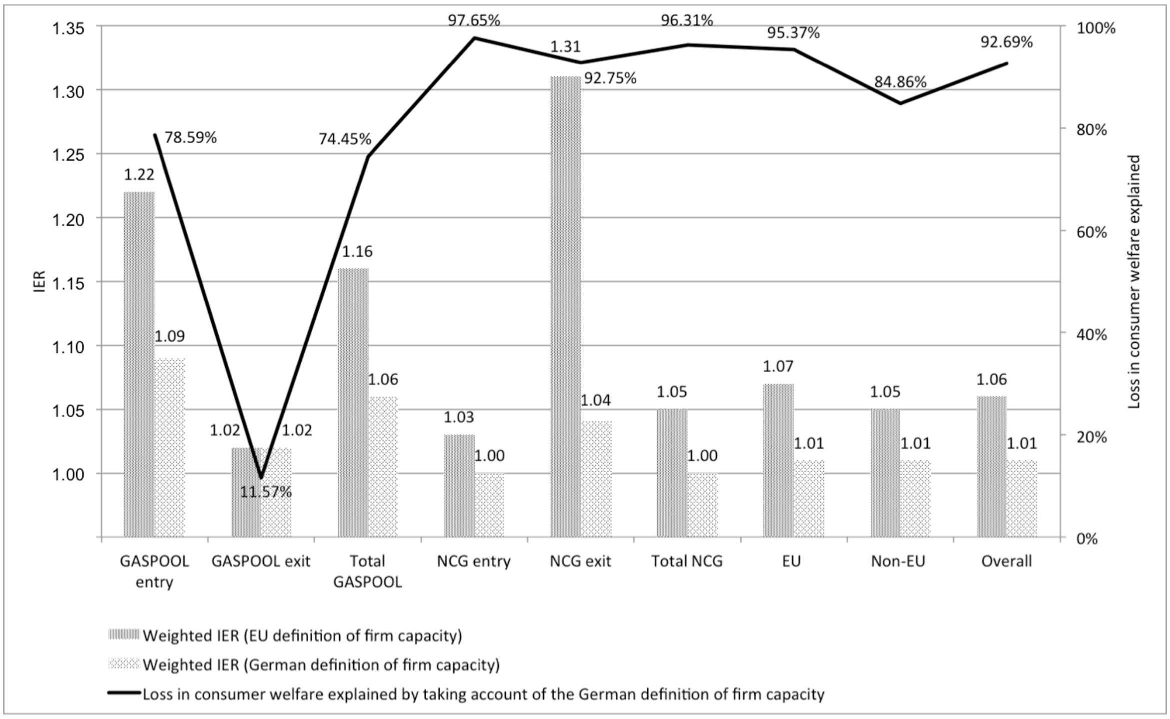
[16] The detailed results of the efficiency calculation using a weighted IER are shown in Table A1 to Table A12 of the appendix.

Initially, the weighted IER for GASPOOL entry and NCG exit show relatively high inefficiencies. Taking account of the different firm capacity types that exist in Germany resulted in large decrease of these inefficiencies. Overall, GASPOOL has a weighted IER of 1.06 and NCG even of 1.00 compared to 1.16 and 1.05 initially calculated applying the EU definition of firm capacity. EU connections are at 1.01, falling from 1.05. Even though there may be additional restrictions influencing the booking behaviour at the border with non-EU countries, also these connections show a weighted IER of 1.01. Overall, the inefficiency measured is at about 1%. In monetary terms, approximately 93% of all inefficiencies can be explained by controlling for different firm capacity types as used in Germany. However, the loss in consumer welfare explained by the different definition of firm capacity for GASPOOL exit is, compared to the other clusters of connections, relatively low (about 11.6%). Comparing the inefficiency initially calculated in absolute monetary terms of GASPOOL exit with, for example, NCG exit, NCG exit shows a loss in consumer welfare of about 19 times the loss of GASPOOL exit. Applying the German definition of firm capacity, the loss in consumer welfare of GASPOOL exit is only about 0.76 times the loss of NCG exit. Hence, looking at the absolute numbers reveal that the inefficiency initially determined has already been relatively low for GASPOOL exit, and therefore, applying the different definition of firm capacity to explain inefficiencies only has a relatively small impact.

Figure 6: Inefficiency ratios (IER) and loss in consumer welfare explained by taking account of the German definition of firm capacity based on PRISMA auction data of German TSOs in 2016



Source: PRISMA European Capacity Platform GmbH (2016); own calculations.

7 Conclusions

European regulators aim at higher integration of gas markets (ACER and CEER, 2015). Mergers of gas markets may lead to competition between transmission system operators within the merged markets. One condition for competition to emerge is that network users make efficient choices, i.e. that they choose those network connections with the lowest network tariffs. To analyse the efficiency of booking behaviour of cross-border gas capacity, one needs to control for differences in the European and national regulations in terms of capacity types.

Analysing the booking behaviour of network users in the German gas markets over 2016, we find an inefficiency of approximately 6% when we only include one type of firm capacity as defined by European regulation. Most of these inefficiencies, however, can be explained by taking into account different types of firm capacity, which actually exist in Germany. The remaining inefficiency is about 1%. Thus, we conclude that network users are sensitive to differences in gas transport capacity offered by TSOs, and that their booking behaviour is to a very large extent efficient. Our analysis underlines that network users are not only sensitive to differences in network tariffs, but that differences in terms of the quality of capacity products also matter to network users making their booking decisions.

Our analysis differs from previous studies on market integration (e.g. Asche et al., 2013; Kuper and Mulder, 2016; Petrovich, 2013) as it does not focus on the degree of wholesale market integration, but on the impact of gas market mergers on the competition among infrastructure operators. As we find that network users make efficient use of the booking alternatives that are created by merging markets, we conclude there is an indication that market mergers have the potential to create an infrastructure competition amongst TSOs.

To what extent market mergers create effective competition amongst TSOs, however, does not only depend on the network users' behaviour, but also on the behaviour of TSOs themselves. In this paper we did not analyse how TSOs set the tariffs for access to their networks. This behaviour of TSOs depends on the regulatory framework they are operating in. Therefore, before any conclusion on the potential of competition among TSOs within merged market areas can be drawn, it is necessary to study such a behaviour taking into account constraints given by the regulatory framework.

The results of this analysis may be relevant for the debate on the European regulatory framework, which is, amongst others, directed at harmonisation within the EU (European Parliament and Council of the European Union, 2009b). One of these topics, for example, is the provision regarding virtual interconnection points, which require TSOs to combine their network points that connect the same entry-exit systems into one virtual point for the sake of joint capacity marketing (European Commission, 2017a). Our paper reveals that network users are able to choose between different capacity alternatives, and to make efficient booking decisions. However, the introduction of virtual interconnection points takes away the possibility to choose between such alternatives.

Appendix A: Detailed results of inefficiency determination

Table A1 to Table A6 show detailed results of the analysis for different clusters of connections. Table A1 to Table A4 deal with connections to and from the German market areas; Table A1 (entry) and Table A2 (exit) with GASPOOL, Table A3 (entry) and Table A4 (exit) with NCG. The results are also shown separately for the borders of the German market areas with EU Member States (Table A5) and with non-EU countries (Table A6). In terms of the inefficiency ratio IER, the tables report the minimum, maximum, average ($\bar{x}$), standard deviation (σ) and coefficient of variation ($\sigma/\bar{x}$), and a capacity and runtime weighted average for each cluster of connection. All the calculations are based on auction data from PRISMA European Capacity Platform GmbH (2016).

Table A1: Inefficiency results for entry connections to GASPOOL based on PRISMA auction data for 2016

Exit	Gas quality	Unconditional		Conditional		Efficiency ratio IER						Actual costs [€]	Auction surcharge [€]	Optimal costs [€]	Inefficiency [€]
		Homogeneous groups	Auctions	Homogeneous groups	Auctions	Min.	Max.	$\bar{x}$	σ	$\frac{\sigma}{\bar{x}}$	Weighted				
NCG	H	9,079	54,086	88	493	1.00	1.63	1.38	0.22	0,16	1.16	42,330	-	37,455	4,875
Norway	H	8,855	22,195	177	473	1.00	1.10	1.05	0.05	0.05	1.09	2,090,395	-	1,934,782	155,612
Russia	H	9,057	18,236	3	6	1.00	2.65	2.10	0.78	0.37	2.10	799,579	-	325,040	474,539
The Netherlands	L	9,016	22,895	368	1,025	1.00	1.92	1.07	0.16	0.15	1.02	3,409,200	10,843	3,323,662	96,381
Sum		36,007	117,412	636	1,997						1.22	6,341,504	10,843	5,620,939	731,407

Table A2: Inefficiency results for exit connections from GASPOOL based on PRISMA auction data for 2016

Entry	Gas quality	Unconditional		Conditional		Efficiency ratio IER						Actual costs [€]	Auction Surcharge [€]	Optimal costs [€]	Inefficiency [€]
		Homogeneous groups	Auctions	Homogeneous groups	Auctions	Min.	Max.	$\bar{x}$	σ	$\frac{\sigma}{\bar{x}}$	Weighted				
Czech Republic	H	8,459	19,553	26	70	1.00	1.55	1.11	0.19	0.17	1.02	870,378	-	853,588	16,790
Denmark	H	8,642	12,159	65	130	1.00	1.03	1.00	0.01	0.01	1.00	10,548	-	10,507	41
NCG	H	9,082	56,724	117	723	1.00	1.61	1.06	0.15	0.14	1.01	1,418,425	-	1,397,795	20,630
The Netherlands	H	8,790	14,477	40	80	1.00	1.48	1.06	0.13	0.12	1.04	93,478	-	90,156	3,322
NCG	L	8,736	16,470	231	462	1.00	1.22	1.21	0.05	0.04	1.05	150,177	-	142,825	7,352
Sum		43,709	119,383	479	1,465						1.02	2,543,006	-	2,494,871	48,135

Table A3: Inefficiency results for entry connections to NCG based on PRISMA auction data for 2016

		Unconditional		Conditional		Efficiency ratio IER									
Exit	Gas quality	Homogeneous groups	Auctions	Homogeneous groups	Auctions	Min.	Max.	$\bar{x}$	σ	$\frac{\sigma}{\bar{x}}$	Weighted	Actual costs [€]	Auction surcharge [€]	Optimal costs [€]	Inefficiency [€]
Czech Republic	H	8,945	36,293	2	7	1.08	1.10	1.09	0.01	0.01	1.09	49	-	44	4
GASPOOL	H	9,082	56,724	117	723	1.00	1.61	1.06	0.15	0.14	1.01	1,418,425	-	1,397,795	20,630
Austria	H	5,479	20,712	10	35	1.38	2.01	1.60	0.23	0.14	1.49	6,449	-	4,372	2,077
Norway	H	8,985	24,377	201	581	1.00	1.31	1.16	0.08	0.07	1.02	21,785,433	-	21,387,847	397,586
The Netherlands	H	9,084	52,550	139	753	1.00	1.92	1.09	0.13	0.12	1.06	1,196,677	17,029	1,143,066	70,640
Belgium / Luxembourg	H	8,915	25,799	10	23	1.00	1.18	1.03	0.06	0.06	1.01	2,194	22	2,193	22
GASPOOL	L	8,736	16,470	231	462	1.00	1.22	1.21	0.05	0.04	1.05	150,177	-	142,825	7,352
The Netherlands	L	8,856	24,580	949	2,720	1.00	1.21	1.04	0.06	0.06	1.04	52,360,236	96,325	50,565,743	1,890,818
Sum		68,082	257,505	1,659	5,304						1.03	76,919,640	113,376	74,643,885	2,389,129

Table A4: Inefficiency results for exit connections from NCG based on PRISMA auction data for 2016

		Unconditional		Conditional		Efficiency ratio IER									
Entry	Gas quality	Homogeneous groups	Auctions	Homogeneous groups	Auctions	Min.	Max.	$\bar{x}$	σ	$\frac{\sigma}{\bar{x}}$	Weighted	Actual costs [€]	Auction surcharge [€]	Optimal costs [€]	Inefficiency [€]
Switzerland	H	9,019	26,311	35	87	1.00	1.00	1.00	-	-	1.00	1,149,916	-	1,149,916	-
Czech Republic	H	8,433	13,123	3	6	1.04	1.08	1.06	0.02	0.02	1.06	8,663	-	8,247	416
GASPOOL	H	9,079	54,086	88	493	1.00	1.63	1.38	0.22	0.16	1.16	42,330	-	37,455	4,875
France	H	6,855	19,690	55	153	1.00	1.16	1.03	0.03	0.03	1.04	631,453	-	611,244	20,209
Austria	H	2,990	3,842	196	402	1.00	10.05	3.01	2.24	0.74	1.51	2,356,379	284,590	1,961,632	679,338
The Netherlands	H	9,000	39,510	230	1,191	1.00	11.77	1.13	0.72	0.64	1.18	1,016,633	153,009	983,087	186,555
Belgium / Luxembourg	H	8,904	17,610	7	14	1.00	1.00	1.00	-	-	1.00	62,216	35	62,121	130
The Netherlands	L	8,183	17,297	51	135	1.00	1.21	1.03	0.07	0.07	1.02	176,781	16	174,162	2,635
Sum		62,463	191,469	665	2,481						1.31	5,444,371	437,650	4,987,864	894,158

Table A5: Inefficiency results for entry and exit connections to and from Germany and adjacent EU countries based on PRISMA auction data for 2016

Capacity product	Gas quality	Unconditional		Conditional		Efficiency ratio IER						Actual costs [€]	Auction surcharge [€]	Optimal costs [€]	Inefficiency [€]
		Homogeneous groups	Auctions	Homogeneous groups	Auctions	Min.	Max.	$\bar{x}$	σ	$\frac{\sigma}{\bar{x}}$	Weighted				
Within-day	H	157,261	418,522	473	2,314	1.00	11.77	1.11	0.52	0.47	1.13	2,649,957	164,698	2,541,032	273,623
Within-day	L	43,104	87,401	894	2,499	1.00	1.92	1.05	0.11	0.10	1.03	15,944,187	101,351	15,542,562	502,977
Day-ahead	H	6,883	18,671	469	1,606	1.00	10.05	1.92	1.72	0.90	1.98	1,776,639	289,987	1,359,291	707,334
Day-ahead	L	1,904	3,984	682	1,787	1.00	1.75	1.09	0.10	0.09	1.06	5,540,668	5,832	5,279,987	266,513
Month	H	204	420	34	127	1.00	1.61	1.23	0.22	0.18	1.01	1,696,906	-	1,678,617	18,289
Month	L	35	75	19	47	1.00	1.11	1.03	0.04	0.04	1.04	10,480,214	-	10,105,814	374,400
Quarter	H	72	156	5	12	1.00	1.00	1.00	-	-	1.00	1,300,800	-	1,300,800	-
Quarter	L	12	28	1	2	1.58	1.58	1.58	-	-	1.58	23,316	-	14,735	8,580
Year	H	193	315	7	21	1.00	1.58	1.18	0.21	0.18	1.02	291,569	-	285,767	5,802
Year	L	28	46	3	7	1.00	1.11	1.05	0.05	0.05	1.04	24,108,008	-	23,263,293	844,716
Sum		209,696	529,618	2,587	8,422						1.07	63,812,264	561,868	61,371,898	3,002,234

Table A6: Inefficiency results for entry and exit connections to and from Germany and adjacent non-EU countries based on PRISMA auction data for 2016

Capacity product	Gas quality	Unconditional		Conditional		Efficiency ratio IER						Actual costs [€]	Auction surcharge [€]	Optimal costs [€]	Inefficiency [€]
		Homogeneous groups	Auctions	Homogeneous groups	Auctions	Min.	Max.	$\bar{x}$	σ	$\frac{\sigma}{\bar{x}}$	Weighted				
Within-day	H	50,928	111,177	161	447	1.00	1.21	1.10	0.09	0.08	1.08	654,879	-	605,604	49,275
Day-ahead	H	2,168	4,771	223	621	1.00	1.31	1.10	0.09	0.08	1.09	851,493	-	784,673	66,820
Month	H	48	95	17	42	1.00	1.21	1.10	0.05	0.05	1.10	1,275,151	-	1,159,726	115,425
Quarter	H	16	30	8	18	1.00	2.65	1.50	0.67	0.45	1.57	1,672,401	-	1,107,524	564,878
Year	H	25	38	7	19	1.00	1.10	1.02	0.03	0.03	1.01	21,371,399	-	21,140,059	231,340
Sum		53,185	116,111	416	1,147						1.05	25,825,323	-	24,797,586	1,027,738

Table A7 to Table A12 show detailed results of the analysis for different cluster of connections taking into account the German definition of firm capacity. Table A7 to Table A10 deal with connections to and from the German market areas; Table A7 (entry) and Table A8 (exit) with GASPOOL, Table A9 (entry) and Table A10 (exit) with NCG. The results are also shown separately for the borders of the German market areas with EU Member States (Table A11) and with non-EU countries (Table A12). In terms of the inefficiency ratio IER, the tables report the minimum, maximum, average ($\bar{x}$), standard deviation (σ) and coefficient of variation ($\sigma/\bar{x}$), and a capacity and runtime weighted average for each cluster of connection. All the calculations are based on auction data from PRISMA European Capacity Platform GmbH (2016).

Table A7: Inefficiency results for entry connections to GASPOOL based on PRISMA auction data for 2016 considering German definition of firm capacity

Exit	Gas quality	Unconditional		Conditional		Efficiency ratio IER						Actual costs [€]	Auction surcharge [€]	Optimal costs [€]	Inefficiency [€]
		Homogeneous groups	Auctions	Homogeneous groups	Auctions	Min.	Max.	$\bar{x}$	σ	$\frac{\sigma}{\bar{x}}$	Weighted				
NCG	H	32,722	54,086	76	252	1.00	1.31	1.18	0.10	0.08	1.06	16,232	-	15,272	961
Norway	H	8,855	22,195	177	473	1.00	1.10	1.05	0.05	0.05	1.09	2,090,395	-	1,934,782	155,612
Russia	H	17,389	18,236	0	0	-	-	-	-	-	-	-	-	-	-
The Netherlands	L	22,895	22,895	0	0	-	-	-	-	-	-	-	-	-	-
Sum		81,861	117,412	253	725						1.09	2,106,627	-	1,950,054	156,573

Table A8: Inefficiency results for exit connections from GASPOOL based on PRISMA auction data for 2016 considering German definition of firm capacity

Entry	Gas quality	Unconditional		Conditional		Efficiency ratio IER						Actual costs [€]	Auction surcharge [€]	Optimal costs [€]	Inefficiency [€]
		Homogeneous groups	Auctions	Homogeneous groups	Auctions	Min.	Max.	$\bar{x}$	σ	$\frac{\sigma}{\bar{x}}$	Weighted				
Czech Republic	H	12,898	19,553	20	42	1.00	1.69	1.14	0.22	0.19	1.02	857,390	-	842,814	14,576
Denmark	H	12,159	12,159	0	0	-	-	-	-	-	-	-	-	-	-
NCG	H	25,119	56,724	118	452	1.00	1.61	1.06	0.14	0.13	1.01	1,411,302	-	1,393,986	17,315
The Netherlands	H	8,790	14,477	40	80	1.00	1.48	1.06	0.13	0.12	1.04	93,478	-	90,156	3,322
NCG	L	8,736	16,470	231	462	1.00	1.22	1.21	0.05	0.04	1.05	150,177	-	142,825	7,352
Sum		67,702	119,383	409	1,036						1.02	2,512,347	-	2,469,781	42,565

Table A9: Inefficiency results for entry connections to NCG based on PRISMA auction data for 2016 considering German definition of firm capacity

Exit	Gas quality	Unconditional		Conditional		Efficiency ratio IER						Actual costs [€]	Auction surcharge [€]	Optimal costs [€]	Inefficiency [€]
		Homogeneous groups	Auctions	Homogeneous groups	Auctions	Min.	Max.	$\bar{x}$	σ	$\frac{\sigma}{\bar{x}}$	Weighted				
Czech Republic	H	27,586	36,293	2	4	1.07	1.08	1.08	0.01	0.01	1.08	49	-	45	4
GASPOOL	H	25,119	56,724	118	452	1.00	1.61	1.06	0.14	0.13	1.01	1,411,302	-	1,393,986	17,315
Austria	H	12,370	20,712	10	24	1.00	1.23	1.06	0.08	0.08	1.02	6,449	-	6,350	99
Norway	H	16,746	24,377	161	322	1.00	1.00	1.00	-	-	1.00	14,993,504	-	14,993,504	0
The Netherlands	H	26,226	52,550	137	373	1.00	1.45	1.03	0.08	0.08	1.01	1,054,807	7,981	1,050,544	12,243
Belgium / Luxembourg	H	19,343	25,799	2	4	1.00	1.12	1.06	0.06	0.06	1.11	-	-	-	-
GASPOOL	L	8,736	16,470	231	462	1.00	1.22	1.21	0.05	0.04	1.05	150,177	-	142,825	7,352
The Netherlands	L	17,141	24,580	496	992	1.00	1.16	1.00	0.01	0.01	1.00	17,797,001	19,218	17,797,001	19,218
Sum		153,267	257,505	1,157	2,633						1.00	35,413,289	27,199	35,384,255	56,231

Table A10: Inefficiency results for exit connections from NCG based on PRISMA auction data for 2016 considering German definition of firm capacity

Entry	Gas quality	Unconditional		Conditional		Efficiency ratio IER						Actual costs [€]	Auction surcharge [€]	Optimal costs [€]	Inefficiency [€]
		Homogeneous groups	Auctions	Homogeneous groups	Auctions	Min.	Max.	$\bar{x}$	σ	$\frac{\sigma}{\bar{x}}$	Weighted				
Switzerland	H	9,019	26,311	35	87	1.00	1.00	1.00	-	-	1.00	1,149,916	-	1,149,916	-
Czech Republic	H	13,123	13,123	0	0	-	-	-	-	-	-	-	-	-	-
GASPOOL	H	32,722	54,086	76	252	1.00	1.31	1.18	0.10	0.08	1.06	16,232	-	15,272	961
France	H	13,595	19,690	42	84	1.00	1.13	1.01	0.03	0.03	1.02	459,213	-	455,023	4,190
Austria	H	3,718	3,842	8	16	1.00	1.42	1.06	0.14	0.13	1.13	71,271	9,332	71,159	9,443
The Netherlands	H	35,082	39,510	121	242	1.00	13.23	1.16	1.12	0.97	1.21	206,377	47,345	206,133	47,589
Belgium / Luxembourg	H	17,610	17,610	0	0	-	-	-	-	-	-	-	-	-	-
The Netherlands	L	8,183	17,297	51	135	1.00	1.21	1.03	0.07	0.07	1.02	176,781	16	174,162	2,635
Sum		133,052	191,469	333	816						1.04	2,079,790	56,693	2,071,665	64,818

Table A11: Inefficiency results for entry and exit connections to and from Germany and adjacent EU countries based on PRISMA auction data for 2016 considering German definition of firm capacity

Capacity product	Gas quality	Unconditional		Conditional		Efficiency ratio IER						Actual costs [€]	Auction surcharge [€]	Optimal costs [€]	Inefficiency [€]
		Homogeneous groups	Auctions	Homogeneous groups	Auctions	Min.	Max.	$\bar{x}$	σ	$\frac{\sigma}{\bar{x}}$	Weighted				
Within-day	H	298,392	418,522	327	830	1.00	13.23	1.08	0.69	0.64	1.06	1,540,315	49,998	1,523,800	66,514
Within-day	L	64,205	87,401	431	893	1.00	1.22	1.01	0.04	0.04	1.01	4,467,039	19,235	4,458,426	27,847
Day-ahead	H	13,256	18,671	206	625	1.00	1.42	1.08	0.12	0.11	1.04	652,867	14,659	644,352	23,173
Day-ahead	L	2,923	3,984	335	672	1.00	1.22	1.14	0.11	0.10	1.00	2,126,153	-	2,124,797	1,356
Month	H	285	420	35	100	1.00	1.69	1.16	0.21	0.18	1.01	1,688,423	-	1,673,491	14,932
Month	L	57	75	10	20	1.00	1.00	1.00	-	-	1.00	3,993,695	-	3,993,695	-
Quarter	H	106	156	1	2	1.00	1.00	1.00	-	-	1.00	3,405	-	3,405	-
Quarter	L	20	28	-	-	-	-	-	-	-	-	-	-	-	-
Year	H	258	315	7	16	1.00	1.58	1.19	0.20	0.17	1.02	291,557	-	286,435	5,122
Year	L	42	46	2	4	1.00	1.11	1.06	0.06	0.06	1.00	7,537,072	-	7,537,070	3
Sum		379,544	529,618	1,354	3,162						1.01	22,300,526	83,892	22,245,471	138,947

Table A12: Inefficiency results for entry and exit connections to and from Germany and adjacent non-EU countries based on PRISMA auction data for 2016 considering German definition of firm capacity

Capacity product	Gas quality	Unconditional		Conditional		Efficiency ratio IER						Actual costs [€]	Auction surcharge [€]	Optimal costs [€]	Inefficiency [€]
		Homogeneous groups	Auctions	Homogeneous groups	Auctions	Min.	Max.	$\bar{x}$	σ	$\frac{\sigma}{\bar{x}}$	Weighted				
Within-day	H	66,315	111,177	158	376	1.00	1.10	1.02	0.04	0.04	1.02	642,121	-	631,058	11,063
Day-ahead	H	2,847	4,771	187	442	1.00	1.10	1.03	0.04	0.04	1.04	593,511	-	574,018	19,493
Month	H	67	95	16	36	1.00	1.10	1.06	0.05	0.05	1.00	884,382	-	884,382	-
Quarter	H	23	30	5	10	1.00	1.10	1.06	0.05	0.05	1.09	872,822	-	805,254	67,568
Year	H	26	38	7	18	1.00	1.10	1.01	0.03	0.03	1.00	15,240,979	-	15,183,491	57,488
Sum		69,278	116,111	373	882						1.01	18,233,815	-	18,078,203	155,612

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