Network Access and Market Power

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Abstract

We study the impact of the liberalization of EU natural gas markets on the balance of power between 'local champions', customers, and outside producers, such as Russian Gazprom. We distinguish between two steps of the reform: 1. opening access to transit pipes and 2. opening access to distribution systems, hence customers. Using the Shapley value as a power index, we find a modest and rather heterogeneous impact from the first step. The impact of the second step is much larger and yields a clear pattern: all local champions lose, while all customers and all outside players gain. As one third of the losses of champions within EU leaks to players abroad, current reforms might enhance the dominance of already powerful outside producers. When network power is assessed with the nucleolus, in contrast, full liberalization of access to customers does not benefit outside producers at all.

Keywords: Network Access, Natural Gas, Countervailing Power, Shapley Value, Nucleolus
JEL class.: L1, L95

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1 Introduction

In the early nineties the European gas industry looked like a patchwork of regional monopolies. Typically, a state owned or tightly regulated domestic champion controlled (i) local gas production, (ii) the high pressure transmission grid, hence, gas transit, and (iii) the distribution networks, hence, access to local customers.[1] When taking up the challenge to develop this fragmented industry into an integrated and competitive common market, the European Commission (EC) identified the liberalization of access to gas pipelines as the key element for success. Competition can only flourish when transparent and fair access to the bottleneck facility creates a level playing field. To prevent the incumbents from obstructing competition, the EC pushed for Third Party Access based on regulated cost-based tariffs and unbundling of the different activities (production and import, transport, distribution).

Consumers are likely to benefit from reduced transport fees and a diversified choice of suppliers, but according to the EC not only customers are supposed to gain from opening pipeline access: “An integrated market also provides a more powerful bargaining position for European energy companies when sourcing energy in global markets since there is a larger range of options available as regards supply routes and better access to customers” (Commission (2007a), p. 5.).

Sceptics, however, pointed out that two thirds of the EU’s gas consumption is imported from a small number of producers beyond jurisdiction of the EU. Russian Gazprom, Algerian Sonatrach and Norwegian Statoil which alone account for more than three quarters of imports, have only negligible stakes in the intra-European pipeline network. They derive market power from controlling the source, gas fields outside the EU, not from owning pipelines within. In their opposition to the EC’s policy, national champions, and often their respective governments, argued that a limited number of strong European market players is needed to counter the power of these outside producers (Commission (2007b)). Or in the words of former French President Nicolas Sarkozy, quoted in Mortished (2007): “Without Gaz de France, who would stand up to Gazprom?”

The notion that it takes strong buyers to create ‘countervailing power’ against powerful sellers has been controversial among academic economists ever since it was

[1] Obviously, this is an idealized description, fitting nicely to France/GdF, Austria/OMV, Italy/Eni. In Germany, however, E.ON-Ruhrgas faces a smaller rival Wintershall and both have only limited stakes in the distribution networks. When gas pipelines were privatized in Slovakia and Czech Republic they were bought by foreign companies. Nevertheless, it is possible to identify a dominant player for most regions in Europe.

coined by Galbraith (1952). The economic literature on deregulation and liberalization tends to emphasize potential efficiency gains. In the gas industry, however, sunk investments in gas fields, pipelines and appliances create large quasi rents, so that a loss of bargaining power can have a substantial impact on the distribution of welfare between customers, regional champions and outside producers.

In this paper we analyze the impact of access rights on market power from a cooperative game theory perspective, using the Shapley value and the nucleolus as indicators for market power. We are not concerned with the institutional details of liberalization, e.g. whether it is achieved by ownership unbundling or by regulated third party access. However, the distinction between access to high pressure trunk pipes, needed for *gas transit* across Europe and access to low pressure distribution networks, allowing for *access to customers* in a region, will be essential. Conceptually, the EC does not draw such a distinction, though in practice, the liberalization of transmission networks is advancing at a faster pace.[2]

To obtain a differentiated picture we start from a *fragmented market* in which regional champions control local production, transmission, and access to local customers. This scenario captures the stylized features before the onset of reforms. In a first step, we consider the liberalization of access to the transmission networks. With cost-based access to transit pipelines, we obtain a regime which we call an *integrated market*. Local champions, as well as external producers, can ship their gas within the EU upon paying a cost-based transport fee. The champions, however, remain the gatekeepers of access to local customers. In a second step, we also allow for open access to distribution networks, a scenario to which we refer as *liberalized market*. Here, the champions are reduced to local producers, competing for customers against each other and against the outside producers. We take this scenario to reflect the final aim of the EC's liberalization policy.

Opening access to trunk pipes is likely to have very different effects on the power structure than opening access to distribution pipes. Consider the example of Russian Gazprom planning to supply gas from the German/Polish border to a customer in France. In a fragmented market, it needs the cooperation of the French champion Gaz de France to access the customer, and the German champion E.ON-Ruhrgas to transport the gas to France. Both partners will use their leverage to extract some of the surplus of the deal between the external producer and the local customer. In an integrated market, access to transmission networks is open and Gazprom can

[2] In the year 2003 the Directive 2003/55/EC (EU (2003)) specified deadlines for legal unbundling of July 2004 and July 2007 for transmission and distribution networks, respectively.

do away with the German champion, but it still needs the cooperation of Gaz de France to access the customer. Cutting out the German 'middleman' will benefit Gazprom, Gaz de France, and the French customer. In this sense, Gaz de France and its customers may gain from improved access to other producers outside and inside the EU. However, the overall impact of market integration is more complex because Gaz de France, as other regional champions, also loses its transit power. A gas poor region with privileged location for Russian gas, such as Poland, will be exposed to tougher competition from customers in other regions as gas is more easily shipped away from its borders. On the other hand, it will also benefit from easier access to alternative suppliers.

Now consider the case, when, in addition to transit pipelines, access to the distribution networks is liberalized. In such a fully liberalized market, Russian Gazprom and the French customer can cut out both, the German and the French champion. Regional champions lose the ability to extract rents from controlling transit and access to customers and are reduced to their function as local producers. Customers and outside producers will gain through improved access to suppliers and markets, respectively.

The results from our quantitative model of the European gas network support this intuition if market power is assessed with the Shapley value. Overall, we find modest and heterogeneous effects for the opening of access to transit pipelines. Customers in the EU tend to gain. The exception are customers in the Netherlands which enjoyed a privileged position with respect to ample local supplies in a fragmented market. Local champions in the central regions providing transit for Russian and Norwegian gas lose bargaining power, while those which are located more at the receiving end, e.g. Italy and France/Spain, gain from improved access to suppliers. All these effects, however, are fairly small and the aggregate impact on the balance of power between customers and champions within the EU on one side, and outside producers and transit countries on the other side is positive for the EU but small in magnitude.

If we add the liberalization of access to distribution networks, thus moving on to a completely *liberalized market*, the effects are amplified by an order of magnitude and a simple pattern emerges. Compared to the initial situation of a fragmented market, the power of customers is substantially enhanced in all regions of the EU, while the power of the old champions, now reduced to local producers, is dramatically diminished. However, up to one third of what is taken from the champions ends up not with European customers, but with external suppliers and transit countries. We do not find support for Galbraith's controversial hypothesis that customers would ultimately benefit from countervailing power. Quite to the contrary, European customers do gain a lot from dismantling the power of local champions, but there is also a very substantial 'leakage' of surplus to outside producers. This side effect might justify protective measures, such as the strategic diversification of gas supplies (Hubert and Cobanli (2016)) or the use of trade quotas (Ikonnikova and Zwart (2014)).

When the nucleolus is used to determine the power structure, we again obtain a very substantial redistribution through the full liberalization. Surprisingly however, for this metric outside producers do not benefit from 'cutting out the middlemen'. The losses of the local champions correspond exactly to the gains of the customer in the very same region.

The remainder of the paper is organized as follows. In the next section we use a a simple example to illustrate in more detail the reasoning behind the cooperative approach and contrast it to previous non-cooperative literature. In section 3, we describe the network model, briefly explain the solutions and explain the principles of the calibration. Section 4 presents the results and robustness checks. Section 5 summarizes and concludes. The appendix provides additional information on the calibration of the model.

2 The Approach and Related Literature

In order to contrast the cooperative approach with previous non-cooperative studies we consider a very simple network example. There are three players, one producer, one consumer and the owner of the pipeline connecting the two. Initially, the owner of the pipeline has unrestricted control over transport through the pipeline. The economic surplus depends on the amount of gas q delivered to the customer and is given as $S(q) = U(q) - T(q) - P(q)$, where U denotes utility from consumption, T and P stand for cost of transport and production cost, respectively. By modelling the interaction as a cooperative game, we *assume* that the players are able to coordinate efficiently. Hence, they will produce the welfare maximizing quantity q^*, ship it to the customer and generate maximal surplus of S^*.

How do the players share the benefits from cooperation? The answer to this question reflects the power of the players in the network and is usually referred to as the solution of the corresponding cooperative game. Cooperative game theory has proposed various solutions to determine the power structure: the Shapley Value, the core, the nucleolus etc. For the simple model at hand, all unique solutions predict that the surplus will be shared equally. Hence, each player will obtain a fraction of $1/3$ of S^*, formally $x^o_U = x^o_T = x^o_P = 1/3$, where the subscripts U, P, and T refer to consumer, producer, and pipeline owner respectively. This result follows from the fact that it takes all three players to generate a benefit. Smaller coalitions as well as single players lack either the gas, the means of transport, or the ability to utilize gas.

The efficient solution with equal surplus sharing can be implemented through several commercial arrangements. Using price-quantity contracts which are common in the gas industry, the pipeline owner may buy q^* from the producer making a total payment of $\frac{1}{3}S^* + P(q^*)$ and sell it to the consumer receiving $\frac{2}{3}S^* + P(q^*) + T(q^*)$. Netting out payments and cost yields the same welfare of $\frac{1}{3}S^*$ for every player. It is also possible that the customer buys directly from the producer paying $\frac{2}{3}S^* + P(q^*) + T(q^*)$ and the producer reimburses the pipeline owner for transport services $\frac{1}{3}S^* + T(q^*)$. The model is agnostic about such details.[3]

Now assume that a regulatory authority liberalizes pipeline access by obliging the pipeline owner to ship gas for anybody, provided he is reimbursed his cost $T(q)$. With cost-based pipeline access, the owner is no longer entitled to withhold his service and has no leverage to extract a share of the surplus in bargaining. It requires only the cooperation of the producer and the customer and a side payment of $T(q^*)$ to generate S^*. All unique solutions in cooperative game theory predict that the new power structure is characterized by $x^1_U = x^1_P = 1/2$ and $x^1_T = 0$. Again, there are various commercial arrangements implementing this solution.

Since the efficiency of the market is not affected, gains and losses exactly net out so that the overall relevance of the reform can be measured by the fraction of the surplus which is redistributed, in our case $1/3$. The impact of the reform on a player i is given by the difference of his shares before and after $x^\Delta_i = x^o_i - x^1_i$. In our case we obtain: $x^\Delta_U = -1/3$ and $x^\Delta_U = x^\Delta_P = +1/6$. As the pipeline owner is the only player who suffers, he bears 100 percent of the loss from redistribution while producer and gas user each reap 50 percent of the gains. If the gas user and the pipeline owner are from the same country while the producer is an outsider, the reform would result in a welfare loss for this country.

[3]Price-quantity contracts, also called ‘take–or–pay’ contracts, stipulate a quantity and a total payment to be made (see Energy Charter Secretariat (2007) for details). The quantity is set to ensure the efficient usage of the capacity and the transfer is used independently to share the surplus. Obviously, the total payment can be expressed as an average price per unit. However, since there is no trade at the ”average price” at the margin, this figure is of little economic relevance.

How does the cooperative approach contrasts to the non-cooperative approach? The non-cooperative approach starts from assumptions on how players coordinate their activity in the market, in game theoretic jargon, by defining their strategy space. Large scale, non-cooperative models of the European gas market such as Golombek et al. (1995), Boots et al. (2004), Egging and Gabriel (2006), and Holz et al. (2008) Chyong and Hobbs (2011) and Xu et al. (2017) analyze the value chain as a succession of oligopolies, with players setting prices or quantities (for a review of the early contributions see Smeers (2008)).[4] For example, the seller might be restricted to set a linear price, i.e. one price per unit at which he is willing to sell any amount of gas to the buyer. Confronted with such a price and no option for a counter offer, the buyer can only choose the quantity of gas to buy. In such a tightly constrained setting, the seller will charge a mark-up on marginal cost reducing the quantity traded below the efficient amount. This will happen with every trade along the value chain. The equilibrium strategies yield quantities and prices from which the surplus and its distribution can be obtained.

As the equilibrium is sensitive with respect to functional forms and parameters, we need to be more specific to solve our simple model. Assume that marginal utility is given as $U'(q) = 2 - 2q$, cost of production and transport are zero. Thus, we obtain a simple textbook example of "double marginalization" for which welfare is maximized with $q^* = 1$ yielding $S^* = 1$. In the non-cooperative Nash-equilibrium the producer charges $p_P^o = 1$. At that price, the intermediary buys $q_T^o = 1/4$ and charges the consumer $p_T^o = 3/2$ who in turn buys $q_C^o = 1/4$. From these equilibrium strategies we compute the resulting shares of the surplus as $x_U^o = 1/16$, $x_T^o = 2/16$, and $x_P^o = 4/16$.

Compared to the cooperative solution, two features stand out. Due to inefficient cooperation resulting in "double marginalization", only one quarter of the efficient quantity is produced and more than half $(9/16)$ of the potential welfare is lost. At the same time "market power" as measured by the distribution of the remaining surplus is highly asymmetric. The producer reaps twice as much as the pipeline owner and

[4]An alternative approach within the non-cooperative framework is to allow the players contractual flexibility, while specifying their strategies in a well defined negotiation process. The theoretical literature has proposed several models of bargaining in vertical structures, but it did not develop a canonical setting for the analysis (see among others Horn and Wolinsky (1988), Von Ungern-Sternberg (1996), Snyder (1998), Chae and Heidhues (2004), Inderst and Wey (2003)). So far this approach has not been applied to the gas industry and it is difficult to imagine sensible restrictions on the bargaining process, as we observe bilateral as well as multilateral negotiations which may be carried out simultaneously as well as sequentially.

four times as much as the consumer. Both features are a result of the particular constraints on the process of economic coordination.[5]

If we introduce cost-based pipeline access in this framework, the producer can sell directly to the customer, cutting out one layer of inefficiency. The equilibrium quantity will increase to $q_C^1 = 1/2$ and the resulting payoffs become: $x_U^1 = 4/16$, $x_T^1 = 0$, and $x_P^1 = 8/16$. As in the cooperative case, the pipeline owner loses his market power, $x_T^\Delta = -2/16$, but this effect is small compared to the efficiency gain of $S^\Delta = 5/16$. The surplus of consumer and producer is increased by $x_U^\Delta = +3/16$ and $x_P^\Delta = +4/16$, respectively. Although the producer appropriates the larger share, the gain of the consumer still overcompensates the loss of the pipeline owner. If consumer and pipeline owner reside in the same country, the country would clearly benefit from the liberalization.

It is worthwhile stressing that the initial inefficiency is a result of restrictions on the contracting process which do not exist in the real world gas industry. Even with market power at all levels of the value chain, widely used price-quantity-contracts can avoid exactly this inefficiency in the first place. We suspect that non-cooperative models underestimate the ability of players in the market to make efficient use of the existing pipeline system. Hence, they overestimate possible efficiency gains and underestimate the risk of single countries or entire regions to lose out under liberalization of pipeline access.

The cooperative approach, in contrast, is compatible with comprehensive contracts and gives none of the players an a-priory strategic advantage. The power of a player is entirely determined by his control over gas fields, pipelines and appliances for gas consumption. But there is also one important drawback: There is no general consensus on the best solution for cooperative games. In this paper the emphasis is on the well known Shapley value. Following Shapley and Shubik (1954) the Shapley value has regularly been used as a power index for voting games, both in political science (Brams (2013)) as well as in corporate finance (Crama and Leruth (2013)). Myerson (1980) initiated a strand of literature, where the Shapley Value is applied to communication structures and social networks, but so far only few attempts have been made to investigate the power structure in industrial networks. The main alternative to the Shapley value is the core which is, however, difficult to

[5]To push this point further, suppose we would allow the *buyer* to set a price at which he is willing to buy whatever quantity and force the seller to accept the price and select a quantity. An equilibrium would look as follows: the customer sets $p_C^o = 0$ and the pipeline owner sells $q_T^o = 1$ which he buys for $p_T^o = 0$ from the producer. This solution is fully efficient and the consumer appropriates the whole surplus.

use as it does not yield a unique solution. Following Montero (2005) we consider the nucleolus (Schmeidler (1969)) as an alternative power index. The nucleolus is of interest because it is derived from similar consideration as the core but it is unique and it is in the core, provided the core is not empty.

The focus on the power of external producers and use of a cooperative approach separates this paper from previous literature on gas market reforms mentioned above. Hubert and Ikonnikova (2011a), Hubert and Ikonnikova (2011b) and Hubert and Suleymanova (2008) all make use of cooperative game theory in the analysis of the gas industry. However, these papers consider a small sector in North-Western Europe and focus on pipeline investments not on access rights. For this paper we develop a much larger model of the natural gas network, covering the whole of Europe and its major suppliers. Similar scale models have been used in Hubert and Cobanli (2016) to investigate strategic pipeline investments and in Hubert and Orlova (2014) to analyze the regional effect of market integration and the incentives for mergers and cartels. The present paper differs from the latter in its analysis of third party access to distribution systems and in its focus on the distribution of market power between customers, external producers and local champions.

3 Model and Calibration

In this section we briefly describe the representation of the physical network, the cooperative game, the solution concepts and the model calibration. More details are given in the technical appendix and at `http://www.ms-hns.de/paper_network_access_market_power.html`. While addressing a different topic, this paper uses a similar approach as Hubert and Orlova (2014), Hubert and Cobanli (2016), and Cobanli (2014). Hence, there is some overlap with the corresponding sections in these papers but there are major differences in the calibration.

The Network Game

Network. The model of the Eurasian gas network consists of a set of nodes R which may be production sites R_P , customers R_C, or pipeline inter-connectors R_T, and a set of directed links L. Each link $l = \{i, j\},\ i \neq j \in R$ connects two nodes. Let f_{ij} denote gas flows, with negative values indicating a flow from j to i. For those links which connect a producer to the network or the network to a customer, flows have to be positive ($f_{ij} \geq 0,\ \forall\, i \in R_P$ or $j \in R_C$). Links between inter-connectors which represent the trunk pipelines can be used in both directions. For each link $\{i, j\}$ we have a capacity limit k_{ij} and link specific transportation cost $T_{ij}(f_{ij})$ which includes production cost in case of $i \in R_P$. For existing capacities, transportation costs consist only of operation costs, because investment costs are sunk. When allowing for investments to increase k_{ij}, the annualized capital costs for new capacities are added to the transportation costs. Each customer is connected through a single dedicated link to the network. So consumption at node $j \in R_C$ is equal to f_{ij}. The inverse demand is $p_j(f_{ij})$.

Game. The inter-dependencies among the players are represented by a game in value function form (N, v), where N is the set of players and the value (or characteristic) function $v : 2^{|N|} \to R_+$ gives the maximal payoff which a subset of players $S \subseteq N$, also called coalition, can achieve. Later we will calibrate the model with 20 players. As a result we have to consider over a million possible coalitions. The legal and regulatory framework determines the access rights of the various players. Access to the link $\{i, j\},\ i \in R_P$ is equivalent of having access to production at i. Access to $\{i, j\},\ j \in R_C$ yields access to customer j. For any coalition $S \subseteq N$ we have to determine to which links $L(S) \subseteq L$ the coalition S has access. The value function is obtained by maximizing the joint surplus of the players in S using the gas-flows in the pipelines which are accessible for S:

$$v(S) := \max_{\{f_{ij} | \{i,j\} \in L(S)\}} \left\{ \sum_{\{i,j\} \in L(S),\, j \in R_C} \int_0^{f_{ij}} p_j(z)dz - \sum_{\{i,j\} \in L(S)} T_{ij}(f_{ij}) \right\} \tag{1}$$

subject to

$$\begin{array}{rcll} \sum_i f_{it} &=& \sum_j f_{tj}, & \forall\, t \in R_T(S) \quad \text{(node-balancing)} \\ |f_{ij}| &\leq& k_{ij}, & \forall\, \{i, j\} \in L(S) \quad \text{(capacity constraints)} \\ f_{ij} &\geq& 0, & \forall\, i \in R_P \text{ or } j \in R_C \quad \text{(non-negativity)} \end{array}$$

The value function captures the essential economic features, such as the geography of the network, different cost of alternative pipelines, demand for gas in the different regions, production cost etc. It also reflects the institutional framework, such as ownership titles and access rights through its dependence on $L(S)$. By defining a new system of access rights, each step of reform yields a new value function.

Solutions. Cooperative game theory has developed a number of solutions for games in value function form. In the following we emphasize the Shapley value (Shapley (1953)) which assigns a unique payoff to each player, $\phi_i,\ i \in N$. It is based on the contribution $v(S \cup i) - v(S)$ which a player i can make to the various subgroups of other players S. The Shapley Value nicely captures the intuition, that a player's payoff from cooperation, interpreted as his power in the game, should increase with his importance for other players, as measured by the value of his contributions. Formally, it is calculated as player i's weighted contribution:

$$\phi_i = \sum_{S:i \notin S} P(S)\,[v(S \cup i) - v(S)] \tag{2}$$

where $P(S) = |S|!\,(|N| - |S| - 1)!/|N|!$ is the weight given to S. For convenience ϕ denotes the vector of Shapley Values and $\phi_S = \sum_{i \in S} \phi_i$ the sum of Shapley Values of a coalition S.

The other major solution concept for the cooperative games is the core. Let x be a payoff vector and $x_S := \sum_{i \in S} x_i$ be the total payment to the members of S. Let I be the set of imputations, that is payoff vectors x which are efficient $\sum_{i \in N} x_i = v(N)$ and individually rational $x_i \geq v(i)$. The excess $e(S, x) := v(S) - x_S$ is the difference between what a coalition can achieve alone and what it receives under a given payoff x. The larger the excess is, the 'worse' is the coalition doing under x. If the excess is positive, the coalition should reject (block/veto) a proposed x, because it can do better on its own. The core is the set of imputations for which no coalition has positive excess: $c(\epsilon) := \{x \in I : e(S, x) \leq 0,\ \forall S \subset N\}$.

If not empty, the core is typically not unique and its characterization through $2^{|N|} - 2$ inequalities is cumbersome if the number of players is large. Instead, we use the nucleolus which always exists, is unique and in the core if it is not empty (Schmeidler (1969)). Like the core, the nucleolus builds on the excess of a coalition, but instead of considering only its sign, the nucleolus attempts to minimize the excess, be it positive or negative, for coalitions which are treated worst in lexicographical order. Let $\theta(x)$ be the vector of excesses arranged in decreasing order for a payoff vector x and let $\preceq$ stand for lexicographically smaller. The nucleolus, denoted μ, is defined as the imputation that minimizes the excess in lexicographic ordering: $\mu := \{x \in I : \theta(x) \preceq \theta(y) \text{ for all } y \in I\}$. It can be computed by solving a nested sequence of linear optimization problems. First the excess is minimized for the coalition which is doing worst. Then excess is minimized for the coalition which comes second, and so on. For an interpretation of the nucleolus as the lexicographic center of the game see Maschler et al. (1979). For the computation of the nucleolus we use an algorithm proposed by Potters et al. (1996) who also provided us with the MATLAB code.

Specification & Calibration

Regional scope and players. The biggest practical challenge is the calculation of the value function, for which we have to solve $2^{|N|} - 1$ optimization problems. In order to economize on computing time we have to limit the number of players $|N|$, leaving out producers which appear to be of minor strategic relevance and aggregating European regions into larger areas.

As to outside producers we focus on Russia, Norway, Algeria, and Libya which together cover about 85% of the gas imports into the EU in the base year 2009 (figures are from BP (2010)). We also account for Belarus and Ukraine which are major transit countries for Russian gas. These producers and transit countries are represented by one player each.

We collect Austria, Czech Republic, Slovakia, Hungary, Slovenia, and Serbia in one region called “Center-East”. The countries in the region exhibit similar consumption and import dependency patterns. With very little alternative supplies the region depends with 80 % of its imports on Russia. While the pipeline networks are largely privatized, some owned by Western importers, the Austrian OMV can be seen as the dominant private supplier in the region. Germany, Switzerland, Denmark and Luxembourg are bundled to “Center”. In terms of consumption the region is clearly dominated by Germany which is also home of large Gas suppliers E.ON-Ruhrgas and Wintershall. The region covers more than three quarters of gas consumption by imports, but its pipeline imports are well diversified between Russia (35%), Norway (34%) and Netherlands (26%). We aggregate France, Spain and Portugal in a region labeled “South-West” which hosts two large champions, Gaz de France and ENAGAS. More than half of the gas consumption in the region is covered by LNG imports. Pipeline imports are diversified between Norway (39%), Algeria (18%) and Russia (18%).

For Center-East, Center, and South-West, as well as for Netherlands and Italy, we distinguish explicitly between a fictive regional champion and a fictive regional customer. Only for these five regions accounting for 71 % of the EU’s gas consumption, we can analyze how liberalization affects customers as compared to champions. Having only one player on each market side, we abstract from competition between different customers or different champions within the region.

There are four more regions which are represented by one player only. Belgium, Poland and UK correspond to their respective countries. Finally, we collect Romania, Bulgaria, Greece and Turkey in a region called “Turkey & Balkan”. The region has only weak links to other European regions and imports mainly Russian gas. With these aggregations and simplifications we are left with 20 players, hence a little more than a million possible coalitions.

Regarding access rights, we assume that outside EU every country has unrestricted control over its pipelines, customers and gas fields. Hence a coalition that does not include Russia, has no access to Russian gas. If it does not include Ukraine, Ukraine’s transit pipelines cannot be used to transport gas from Russia to Europe etc. Access to resources and consumers within Europe depends on the regulatory regime. Under any scenario the local champion enjoys exclusive ownership of local gas production and import terminals for liquefied natural gas (LNG-imports). In a *fragmented market* the local champion also controls access to transit pipes and local customers. In an *integrated market*, European transit pipelines are available to all players, but a local customer can only be reached with the collaboration of the local champion. In the *fully liberalized* market, all customers can connect to all producers, provided both are connected to the European grid.

Temporal scope / network flexibility. We assume a stationary environment with constant demand, technology and production cost etc. The value of a coalition, nevertheless, depends on the temporal scope of the model. In the short run, the architecture and the capacities of the network are given, but in the long run the network is flexible.

First we consider a rather short time horizon of one year up to perhaps three years. That is long enough to ignore the seasonal pattern of demand and the possibility of gas storage. In Europe storage facilities smooth seasonal patterns within a year but at present the capacities are too small to act as a strategic reserve for longer periods. The period is also long enough to convert existing pipeline to bidirectional usage but too short to build new pipelines or develop new fields. We refer to this variant as the ‘status-quo’ variant, because pipeline capacities are static. It can also be interpreted as a ‘shortsighted’ assessment of power, because the effects of adjustments which take longer than two or three years to be achieved are simply ignored.

We reckon that decision makers, when assessing bargaining power, may look beyond such a short period. To assess the robustness of our results, we also consider a longer time span. Here we envisage a scenario in which transport capacities on existing pipelines can be increased so that the network capacity is flexible. As these investments will take at least a couple of years to become effective, we consider a period starting some three years ahead from the date for which we assess the power structure. We refer to this variant as flexible network, because a coalition can use (almost) all investment possibilities to enhance its value. It can be also considered as a 'farsighted' assessment of power because it ignores the period which is needed to bring new capacities on stream.[6]

Cost, demand and network capacity. The purpose of the numerical calculation is to have a model in which observable variables, such as the consumption in the different areas, are consistent with the hypothesis that the players coordinate efficiently. In other words, given the assumed cost of production and transport and the demand functions for the different nodes, the welfare maximizing consumption in the different nodes should be close to observed consumption in the reference year.

The details of the numerical calibration are given in a technical appendix. Here we outline only the main principles. We assume piece-wise linear production cost for each producer and linear demand functions with the same intercept for all regions. The main difference between customers is their size as measured by total consumption and their network connection. These are parameters for which we have solid information. The main difference between producers is production capacity and pipeline connections to the markets for which data are good, and not differences in wellhead production cost which are difficult to estimate. The overall size of the surplus is largely determined by our assumption on the difference between the common production cost and the common demand intercept, for which we consider two variants.

The model is calibrated using data on consumption in the regions and flows between the regions from 2009. Production cost have a common base, to which we make minor regional adjustments to closer replicate flows in 2009. The slope parameters of demand are then estimated as to replicate the consumption in 2009. With the slope coefficients provided in the appendix table 9, the welfare maximizing

[6]The distinction between status-quo/shortsighted and flexible/farsighted is borrowed from Hubert and Ikonnikova (2011b). It is worth remembering that many gas contracts are long-term covering periods from 5 to 20 years, so we would expect that the conditions agreed on, reflect long term considerations. On the other hand, the further one projects into the future, the more uncertain the prospects become, so that the clearer short term options may exert a stronger influence on relative power.

consumption deviates from consumption as observed in 2009 in all areas by less than 0.8% (except Spain & Portugal for which the difference is 1.33%). The calibration of demand in relation to cost of supply and transport also ensures that the pipeline system as existing in 2009 had sufficient capacity to deliver the efficient amount of gas into the different consumption nodes. A social planner would have neither invested to increase production nor to increase pipeline capacity.

In 2009 gas consumption in European levelled off and after a short recovery from the impact of the financial crisis it entered into a phase of steady decline in 2012 increasing the slack in the pipeline system. In addition the new export pipeline for Russian gas, NordStream, became operational creating a direct link between Russia and Germany. We account for these developments by analyzing variants which include the capacity of NordStream, by considering a low demand scenario, and by recalibrating demand with consumption data for 2015 obtained from BP Statistical Review of World Energy (June 2016).

4 Network Access and Power

We imagine the liberalization of the European market for natural gas to be achieved in two steps: first, by opening access to high pressure trunk pipes, and second by liberalizing access to low pressure distribution networks. So we compute the value functions for three access regimes: the fragmented market v^0, the integrated market v^1 and the fully liberalized market v^2. Then we solve the games, either with the Shapley value ϕ or the nucleolus μ, and compute three differences for each player i: the impact of trunk pipe liberalization ($\phi^{\Delta 1} = \phi(v^1) - \phi(v^0)$), the incremental impact of access to distribution networks ($\phi^{\Delta 2} = \phi(v^2) - \phi(v^1)$), and the total impact of the ongoing reforms ($\phi^{\Delta} = \phi(v^2) - \phi(v^0)$). The corresponding values for the nucleolus are $\mu^{\Delta 1}$, $\mu^{\Delta 2}$, and μ^{Δ}.

Before we look at the details for individual players, we assess the overall impact of the reforms. Each step of reform will benefit some of the market participants while hurting others. The impact is measured by summing up the gains for those who benefit which yields the same figure as summing up the losses of those who are hurt. For both steps together: $R^{\Delta} = \sum_{\{i|\phi_i^{\Delta} \geq 0\}} \phi_i^{\Delta}$, and correspondingly $R^{\Delta 1}$ and $R^{\Delta 2}$ for the first and second step, respectively.[7]

[7] At each step we sum only over positive differences. As a result the total impact is sub-additive in the single steps $R^{\Delta} \leq R^{\Delta 1} + R^{\Delta 2}$. If there are players who gain at the first step and loose at the second (or vice versa), then the first effect is (partly) undone at the second step and the final volume

Table 1: Overall Impact (Shapley Value)

Redistribution [percent of the total surplus]		
step 1: transmission *fragmented to integrated market* $100 \cdot R^{\Delta 1}/v^0(N)$	step 2: distribution *integrated to liberalized market* $100 \cdot R^{\Delta 2}/v^0(N)$	both together *fragmented to liberalized market* $100 \cdot R^{\Delta}/v^0(N)$
2.0	12.4	13.0

We first report our point estimates for one particular calibration of the model: the short-sighted or status-quo variant, in which pipeline capacities are static and Nord-Stream is available with full capacity. Demand is assumed to be high, with a difference between demand intercept and production cost of 1500 Euro/tcm. Then we briefly discuss the robustness of the results as to changes of parameters and scope. All figures are rounded to the first decimal.

Shapley Value

Table 1 displays the redistribution as a percentage of the total benefit from producing, transporting and consuming gas $v^0(N)$. The figures show that the total impact of the reforms on the European gas market will be quite substantial. The rent which some players lose, and others gain, through the full liberalization adds up to 13% of the total rent. The second step, the liberalization of access to distribution networks, appears to be crucial. Its incremental impact is six times as large than that of the initial step, the opening of access to trunk-pipes. Liberalization had progressed slowly during a time when the European gas market was subjected to several outside shocks, first the long international boom in energy prices before 2008, then the fallout of the financial crisis, later the shale gas revolution. The comparably modest impact of the first step will make it difficult to trace results in empirical data so far (Haase and Bressers (2010)). But from the failure to do so one must not conclude that future steps have little impact as well.

The two steps differ not only in their overall relevance, they also affect the various players in markedly different ways. In table 2 we report the gains and losses of the different players. For convenience we rescale the figures, presenting all in percent

of redistribution is strictly smaller than the sum of the two incremental effects.

Table 2: Liberalization and Power-Structure (Shapley Value)

	Change of Shapley Value [percentage of all gains]		
	step 1: transmission *fragmented to integrated market* $100 \cdot \phi_i^{\Delta 1}/R^{\Delta}$	step 2: distribution *integrated to liberalized market* $100 \cdot \phi_i^{\Delta 2}/R^{\Delta}$	both together *fragmented to liberalized market* $100 \cdot \phi_i^{\Delta}/R^{\Delta}$
Outside Countries			
Russia	−7.0	14.7	7.7
Belarus	3.1	−0.4	2.7
Ukraine	1.9	0.4	2.4
Algeria	−0.5	6.8	6.3
Libya	0.0	1.6	1.7
Norway	0.9	11.6	12.5
Netherlands			
champion	0.3	−6.6	−6.3
customers	−0.1	7.9	7.8
Center-East[a]			
champion	−0.6	−13.0	−13.6
customers	1.9	7.7	9.6
Italy			
champion	1.1	−23.1	−21.9
customers	2.7	13.4	16.1
Center[b]			
champion	−6.6	−30.8	−37.4
customers	0.7	18.2	18.9
South-West[c]			
champion	0.7	−19.7	−19.0
customers	0.7	11.9	12.6
Poland	0.1	−0.6	−0.4
Belgium	−0.4	−1.0	−1.4
United Kingdom	0.1	1.2	1.3
Turkey & Balkan[d]	0.7	−0.3	0.4
all champions	−5.1	−93.1	−98.2
all customers	5.9	59.1	65.1
European Union[e]	1.5	−34.7	−33.2

Except for rounding errors, the first two columns sum up to the third. All positive figures in the third column sum up to +100, while all negative numbers sum up to -100.

[a] Austria, Czech Republic, Slovakia, Hungary, Slovenia and Serbia

[b] Germany, Switzerland, Denmark and Luxembourg

[c] France, Spain and Portugal

[d] Romania, Bulgaria and Greece

[e] Including Turkey

of the redistribution caused by full access liberalization (R^{Δ}). A positive number indicates how much a player gains from increased market power relative to all gains. Adding up the positive numbers for all players in the last column yields +100 (except for rounding errors). A negative number shows his loss relative to all losses. Adding up the negative numbers yields -100. The first two columns split the overall effect into the separate effects of the two steps. For example Russia's overall gain in market power is worth 7.7 percent of the redistributed wealth. This gain in market power is the result of two opposing effects. The first step of reform harms Russia: it looses 7.0 percentage points. But this loss is overcompensated by a gain of 14.7 percentage points from the second step.

The move from a fragmented to an integrated market figures yields rather heterogeneous effects (first column). Within Europe, we observe the strongest effect for the champion in *Center*: a loss of well over six points. The region is well connected to competing suppliers, Russia, Norway, Netherlands, hence there is little to gain from improved access to additional suppliers. At the same time its strategic location with respect to gas shipments earned him substantial transit rents which are now lost.[8] Champions which are located more at the periphery, e.g. in Italy or in the South-West, gain more from improved access to suppliers than they suffer from the loss of transit rents.

The customers in the EU tend to gain. Altogether they improve by almost 6 points which is a little more than what the champions lose. The only exception are the customers in the Netherlands, which, given ample local supplies, enjoyed a privileged position in the fragmented market.

Considering customers and champions together, we find some regional redistribution within the EU. The *Center* loses power while Italy and the South-West gain market power. The liberalization of trunk pipes becomes effective only for those within the jurisdiction of the EU. Access to pipelines in Russia, Ukraine and Belarus is still exclusive. Nevertheless we find a rather strong regional redistribution outside the EU. Russia loses 7 points, the largest figure in this column. This big loss of an outside producer is largely compensated by gains of Ukraine and Belarus, as well as Norway, Russia's strongest competitor. Belarus has no own natural gas production and Ukraine consumes much more than it produces. Both countries

[8] At first glance Center's role as a transit region may appear to be modest. With 4.3 bcm/a and 9.1 bcm/a gas flows through Center to France and to Italy, respectively, are not particular large. However, the region is Europe's most important *potential* gas hub. Whenever one of the major producers is taken out of the picture, Center becomes an important transit region. For more details see Hubert and Orlova (2014).

totally depend on Russia for their very substantial imports. With the liberalization of shipment through the EU they can more easily access gas from Norway which increases their bargaining power vis-a-vis Russia.

Overall, the first step of reforms produces modest redistribution from champions to customers within the EU, but there is no rent leakage to outside countries. Instead, there is even a small gain for the EU.

The picture changes dramatically when moving on to the second step, the liberalization of access to the distribution systems. With the notable exception of transit regions such as Ukraine, Belarus and to a smaller extent Turkey& Balkan, the incremental impact of this step is much larger, sometimes by an order of magnitude, and clearly dominates the total effect. Thus, we confine our interpretation to the last column in table 2 which describes the effect of both steps together.

Here we find a very clear pattern. All champions lose and their aggregated losses amount to 98 percent of all losses. Essentially, the full liberalization of pipeline access in the EU has one big effect: it reduces market power of the established regional champions which apparently depended more on controlling access to local customers than on controlling transit. This is true even for those champions which gained from improved access to alternative supplies or additional customers during the first phase of the reform, such as Italien Eni. Its initial gain of 1.1 points turns into a loss of 21.9 points, the second biggest loss of all. It is only surpassed by the Center's champion, whose initial loss of 6.6 points is amplified to a loss of 37.4 points.[9]

Dismantling the power of regional champions is, first of all, to the benefit of the customers. In all the regions customers gain from full liberalization, often by an order of magnitude more than from liberalizing only transit. With the exception of Netherlands, however, the customers gain less than the champions lose. On average, one third, of what is taken away from the champions does not end up with customers but leaks to players outside the EU, with Norway, Russia and Algeria being the main beneficiaries.[10] Even for Russia which is quite badly hurt from opening transit pipelines, the losses turn into a substantial net gain. Being able to

[9]This last figure, however, has to be interpreted with care. As mentioned before, assuming only one champion for the central region is a rather strong simplification as we have at least two substantial players, E.ON-Ruhrgas and Wintershall, in reality. In addition, these players had only rather incomplete control of distribution networks before the reforms.

[10]Apart from that, there is only very limited regional redistribution from Poland and Belgium on one side to the UK and the Balkans on the other. These are regions, for which we did not separate between customers and champions.

Table 3: Robustness: Overall Impact (Shapley Value)

Redistribution [percent of total surplus]					
step 1: transmission *fragmented to integrated market*		step 2: distribution *integrated to liberalized market*		both together *fragmented to liberalized market*	
min	*max*	*min*	*max*	*min*	*max*
1.6	2.0	12.0	13.4	12.6	13.7

sell gas directly to its customers turns out to be much more valuable than the partial protection against competing suppliers that it enjoyed in the fragmented market.

Taken together, these results suggest that the Commission's claim quoted in the introduction has some merit for the first step of reform. Liberalizing access to the high pressure transmission system strengthens the bargaining power of at least some European gas companies and benefits the EU as a whole. However, it is grossly misleading for the second step. The liberalization of access to the distribution systems clearly weakens the old incumbents through tougher competition both among each other as well as with outside producers. Except for the Netherlands the gains of the customers are everywhere smaller than the losses of the local champions. Overall, the EU clearly loses from complete liberalization of pipeline access if market power is determined by the Shapley value. For every two Euros which European customers gain at the expense of local champions, one Euro leaks to players outside the EU in our base variant.

Robustness. In this section we briefly assess the robustness of the previous results by considering four more variants. First, we changed the temporal scope of the analysis by analyzing a 'flexible' network, in which the capacities of the pipelines can be increased through investment. This change does not affect the overall surplus from the gas trade because the pipeline system is already optimal given our calibration. Second, we reduced the difference between the base cost of production and the demand intercept, hence the absolute surplus from gas trade, by two thirds, both for the static and the flexible network. We express all our results as percentage of surplus which tends to neutralize the rescaling of the surplus. Nevertheless, the power-structure is affected because transportation and investment cost have a larger impact when the difference between demand intercept and production

Table 4: Robustness: Power-Structure (Shapley Value)

	Change of Shapley Value [percentage of all gains]					
	step 1: transmission *fragmented to integrated market*		step 2: distribution *integrated to liberalized market*		both together *fragmented to liberalized market*	
	min	*max*	*min*	*max*	*min*	*max*
Outside Countries						
Russia	−7.2	−5.9	9.7	16.7	3.9	9.5
Belarus	3.1	4.0	−0.8	−0.4	2.2	3.3
Ukraine	−0.2	2.0	−0.9	0.8	0.6	2.4
Algeria	−0.9	0.1	5.1	6.9	5.2	6.5
Libya	−0.1	0.2	1.3	1.7	1.3	1.8
Norway	0.1	1.1	9.3	12.1	9.5	13.1
Netherlands						
champion	0.0	0.4	−7.3	−5.7	−7.0	−5.7
customers	−0.2	0.0	7.8	8.3	7.6	8.2
Center-East[a]						
champion	−0.6	0.2	−13.0	−11.5	−13.6	−11.6
customers	1.4	2.0	7.7	7.9	9.2	9.7
Italy						
champion	0.5	1.3	−24.3	−22.4	−23.0	−21.7
customers	2.2	2.7	13.3	16.1	15.9	18.3
Center[b]						
champion	−6.8	−5.5	−30.8	−29.9	−37.5	−36.2
customers	0.6	0.7	18.1	20.5	18.8	21.1
South-West[c]						
champion	0.6	0.7	−23.0	−19.7	−22.3	−19.0
customers	0.5	0.8	11.9	15.1	12.6	15.8
Poland	−0.1	0.4	−0.6	−0.5	−0.6	−0.2
Belgium	−0.5	−0.1	−1.1	−0.4	−1.6	−0.9
United Kingdom	−0.1	0.2	0.8	2.6	0.7	2.8
Turkey & Balkan[d]	0.7	1.1	−0.5	−0.3	0.4	0.8
all champions	−5.3	−3.5	−95.3	−92.6	−98.9	−97.9
all customers	4.9	6.0	58.8	67.5	64.7	72.4
European Union[e]	0.7	3.0	−34.9	−27.0	−33.9	−24.0

[a] Austria, Czech Republic, Slovakia, Hungary, Slovenia and Serbia

[b] Germany, Switzerland, Denmark and Luxembourg

[c] France, Spain and Portugal

[d] Romania, Bulgaria and Greece

[e] Including Turkey

cost is reduced. Finally, we calibrate the model with consumption data from 2015 which are lower so that there is more slack capacity in the transport system. This slack tends to reduce the impact of liberalizing access rights and shift the gains from doing so more to the customers at the cost of outside producers.

Instead of going in detail through all these variants, we simply report the minimal and maximal values achieved in any of the variants in tables 3 and 4 which correspond to tables 1 and 2, respectively. The differences between the maximal values in any of the variants and the corresponding minimal values are surprisingly small. With minor modifications all previous statements could be repeated independently of whether we take the largest or smallest value.

Take for example the overall impact of full liberalization (table 3). Depending on the variant, it redistributes between 12.6 and 13.7 per cent economic rent. The overall effect is clearly dominated by the impact of opening access to distribution systems, the incremental impact of which is about six times larger than that of the first step. If we look at the power structure (table 4) we find that the players in the EU gain between 0.7 and 3 points from the first step — a small amount if compared to what they lose by the full implementation of reforms: between 24.0 to 33.9 points.

These observations suggest that our results for the change in power as measured by the the Shapley are reasonably robust with respect to changes in the parameters of the model. We turn next to the question, whether they are also robust with respect to the solution concept.

Nucleolus

The nucleolus The patterns of the overall impact look similar for the nucleolus and for the Shapley value (compare tables 5 and 1). The impact of the first step is of similar magnitude and in both cases the second step is dominant. For the nucleolus the increment of the second step is even more significant, redistributing 16.1 per cent of total surplus instead of 12.4. Moreover for the nucleolus, the two steps work into the same direction, whereas there was some partial offset under the Shapley value. As a result, the aggregate impact of both steps together is stronger. If power is measured with the nucleolus, redistribution through full liberalization, is equal to 18.1 per cent of the total surplus.

A closer look at the power structure, however, reveals striking differences between the two solutions (compare tables 6 and 2). The impact of the first step, free access to transit pipelines, is still similar. With the nucleolus the champions lose 6 points

Table 5: Overall Impact (nucleolus)

Redistribution [percent of the total surplus]		
step 1: transmission *fragmented to integrated market* $100 \cdot R^{\Delta 1}/v^0(N)$	step 2: distribution *integrated to liberalized market* $100 \cdot R^{\Delta 2}/v^0(N)$	both together *fragmented to liberalized market* $100 \cdot R^{\Delta}/v^0(N)$
2.0	16.1	18.1

compared to 5.1 under the Shapley value. Customers gain 6.3 compared to 5.9. There is some redistribution between regions resulting in a gain of 2.7 points by the EU. As before, Russia is the biggest single loser, but the effect on outside producers and transit countries tends to be smaller in magnitude.

The surprising differences come from the liberalization of access to distribution systems, hence, customers. For the nucleolus, there are essentially no effects on outside producers and transit countries, while there is a massive redistribution of surplus from champions to customers within each region. The effect of the second step on customers and champions is again larger by an order of magnitude. For example, the Italian champion loses 1.6 points with the first step and another 19.7 points with the second; for Center the corresponding losses are 2.1 and 27.3. In contrast to the Shapley value, whatever the champions lose in the second step is now gained by their respective customers. There are no additional regional effects within the EU or spillovers to players outside. In spite of a dense pipeline network within Europe, liberalizing access to customers appears to be a local affair under the nucleolus. It affects the power distribution only in the respective region. Although, access liberalization 'cuts out the middlemen', outside producers and transit countries cannot benefit, if market power is determined by the nucleolus.

Robustness. We again check the robustness of the results with respect to changes in demand and network flexibility. As before we report only the smallest and largest values of all variants (tables 7 and 8). While the numbers change slightly, all qualitative statements of the previous section remain true. In particular, if assessed with the nucleolus, the rent which is redistributed through the full liberalization is even larger than for the Shapley value and the second step is clearly dominant. The smaller regional effects result entirely from liberalizing transit, while

Table 6: Liberalization and Power-Structure (nucleolus)

	Change of nucleolus [percentage of all gains]		
	step 1: transmission *fragmented to integrated market* $100 \cdot \mu_i^{\Delta 1}/R^{\Delta}$	step 2: distribution *integrated to liberalized market* $100 \cdot \mu_i^{\Delta 2}/R^{\Delta}$	both together *fragmented to liberalized market* $100 \cdot \mu_i^{\Delta}/R^{\Delta}$
Outside Countries			
Russia	−4.9	0.0	−5.0
Belarus	0.1	0.0	0.1
Ukraine	1.7	0.0	1.7
Algeria	0.1	0.0	0.1
Libya	0.1	0.0	0.1
Norway	0.2	0.0	0.2
Netherlands			
champion	−1.4	−12.6	−14.0
customers	1.4	12.6	14.1
Center-East[a]			
champion	−1.0	−10.8	−11.8
customers	1.3	10.8	12.1
Italy			
champion	−1.6	−19.7	−21.3
customers	1.6	19.7	21.4
Center[b]			
champion	−2.1	−27.3	−29.5
customers	1.9	27.4	29.2
South-West[c]			
champion	0.0	−18.3	−18.3
customers	0.1	18.3	18.4
Poland	0.0	0.0	0.0
Belgium	0.0	0.0	0.0
United Kingdom	−0.2	0.0	−0.2
Turkey & Balkan[d]	2.6	0.0	2.6
all champions	−6.0	−88.8	−94.9
all customers	6.3	88.9	95.1
European Union[e]	2.7	0.1	2.8

Except for rounding errors, the first two columns sum up to the third. All positive figures in the third column sum up to +100 while all negative numbers sum up to -100.

[a] Austria, Czech Republic, Slovakia, Hungary, Slovenia and Serbia

[b] Germany, Switzerland, Denmark and Luxembourg

[c] France, Spain and Portugal

[d] Romania, Bulgaria and Greece

[e] Including Turkey

Table 7: Robustness: Overall Impact (nucleolus)

Redistribution [percent of total surplus]					
step 1: transmission *fragmented to integrated market*		step 2: distribution *integrated to liberalized market*		both together *fragmented to liberalized market*	
min	*max*	*min*	*max*	*min*	*max*
0.9	2.0	15.3	16.6	16.6	18.1

opening access to customers redistributes power at a large scale, but mainly within the region. Outside producers do not gain if market power is evaluated with nucleolus.

5 Conclusion

Opening access to bottleneck facilities such as electric power grids, rail tracks, communication lines and pipeline systems has been a corner stone of market liberalization and deregulation of network based industries throughout the last decades. Moreover, in the EU, open network access is also necessary to overcome the national and regional fragmentation of the respective industries, hence, for the establishment of a common market. The general thrust has been to limit public regulation to the network itself, a natural monopoly, and allow for free competition in the provision of services or commodities using the network. It is argued that such liberalization increases the efficiency of the industry and that customers gain from enhanced competition between service providers.

However, the natural gas industry in Europe is peculiar in the sense that a small number of external suppliers such as Russian Gazprom or Norwegian Statoil will retain substantial market power through their control of gas fields beyond the jurisdiction of the EU. Given this dependency on few outside producers, a policy which weakens the national champions within the EU might enhance the market power of external suppliers. The EC argues to the contrary, claiming that European energy companies might even gain from better access to customers and more diverse supply options.

In this paper we studied the impact of liberalization on the balance of power between regional champions, customers and outside producers differentiating be-

Table 8: Robustness: Power-Structure (nucleolus)

	Change of Nucleolus [percentage of all gains]					
	step 1: transmission *fragmented to integrated market*		step 2: distribution *integrated to liberalized market*		both together *fragmented to liberalized market*	
	min	*max*	*min*	*max*	*min*	*max*
Outside Countries						
Russia	−4.9	−2.8	−0.2	0.0	−5.0	−2.8
Belarus	0.1	0.2	0.0	0.0	0.1	0.2
Ukraine	0.4	1.7	0.0	0.0	0.4	1.7
Algeria	0.1	0.4	−0.1	0.0	0.1	0.3
Libya	0.1	0.2	0.0	0.0	0.1	0.3
Norway	0.2	0.8	0.0	0.0	0.2	0.7
Netherlands						
champion	−1.4	0.0	−13.1	−12.6	−14.0	−13.0
customers	0.1	1.4	12.6	13.0	13.2	14.1
Center-East[a]						
champion	−1.0	0.2	−11.2	−10.8	−11.8	−11.0
customers	0.1	1.3	10.8	11.2	11.3	12.1
Italy						
champion	−1.6	−0.5	−20.4	−19.7	−21.3	−20.9
customers	0.2	1.6	19.7	20.4	20.7	21.4
Center[b]						
champion	−2.1	−1.3	−28.3	−27.3	−29.8	−29.2
customers	0.5	1.9	27.4	28.3	28.9	29.2
South-West[c]						
champion	−0.2	0.1	−21.9	−18.3	−22.1	−18.3
customers	0.1	0.3	18.3	22.0	18.4	22.2
Poland	0.0	0.1	0.0	0.0	0.0	0.1
Belgium	0.0	0.1	0.0	0.0	0.0	0.1
United Kingdom	−0.5	−0.2	0.0	0.0	−0.5	−0.2
Turkey & Balkan[d]	1.6	2.6	0.0	0.1	1.7	2.6
all champions	−6.0	−1.6	−94.7	−88.8	−97.0	−94.6
all customers	1.2	6.3	88.9	94.9	94.4	97.1
European Union[e]	0.8	2.7	0.1	0.3	1.1	2.8

[a] Austria, Czech Republic, Slovakia, Hungary, Slovenia and Serbia

[b] Germany, Switzerland, Denmark and Luxembourg

[c] France, Spain and Portugal

[d] Romania, Bulgaria and Greece

[e] Including Turkey

tween opening access to trunk pipes and additionally liberalizing access to distribution systems, hence customers. Access to trunk pipes, here considered to be the first step of reform, allows for free transit of gas within EU and moves the industry from a fragmented to an integrated market. In a second step access to distribution networks is also opened which establishes a fully liberalized market. In contrast to earlier studies, we use cooperative game theory which allows us to derive the market power of the players endogenously from their role in the network without resorting to ad hoc assumptions about the nature of the strategic interaction. All our results are reasonably robust with respect to changes in the model calibration but it makes a substantial difference whether we assess network power with the Shapley Value or with the nucleolus.

For the Shapley value we find a heterogeneous impact of the first step of reform on the power structure. Overall, there is modest redistribution from champions to customers, but there is no leakage of surplus to outside producers. The picture changes dramatically with the second step. The incremental impact of the liberalization of access to customers clearly dominates the total effect. In a fully liberalized market the power of all European champions is decreased. Dismantling the power of champions is to the benefit of customers, but a quarter up to one third of the champions' losses is appropriated by external suppliers. The interpretation is straightforward. In a fragmented market, local champions secure their position as 'middlemen' through their control of pipelines. Liberalization essentially 'cuts out the middlemen' strengthening the market power of customers and external producers.

If we use the nucleolus as the power index, the pattern of power redistribution from the first step of reform is similar. However, the pattern for the second step of reform is strikingly different. While local champions are again badly hurt, their losses are transferred one to one to their respective customers. For all other players the incremental effect of this step is essentially zero. As a result, outside producers would not benefit from liberalized access to customers if market power is assessed with the nucleolus. This finding is difficult to reconcile with the intuition gained from the 'middlemen' story.

In a nutshell: independently of whether market power is assessed with the nucleolus or the Shapley value, we do not find support for the claim that European gas companies might be strengthened through full liberalization of pipeline access. Quite to the contrary, under both solutions they will eventually lose a very substantial part of their original power. Whether powerful outside producers are able to appropriate part of this loss, in contrast, depends entirely on the solution concept.

It is beyond the scope of this paper, to investigate which of the two concepts yields better empirical predictions. As the liberalization developed slowly over the last fifteen years, it seems impossible to disentangle its impact from the effects of changes in LNG supplies, new pipeline links and the business cycle. There is, however, some evidence that the Shapley value is a better predictor for this industry obtained from transit agreements between Russia, Ukraine and Belarus (Hubert and Ikonnikova (2011b)) and from recent investments in strategic pipelines (Hubert and Cobanli (2016)). Hence, the possibility that the power of external producers is enhanced by Europe's liberalization of pipeline access is not to be easily dismissed.

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A Appendix

Calibration

In this section we describe the functions and parameters used for the calculation of the value function (equation (1) in the main text). Let f^*_{ij}, $\{i, j\} \in L(N)$ denote the solution to the program in (1) when solved for the grand coalition, which has access to all resources. To calibrate the model, we have to determine p_j and T_{ij} such that f^*_{ij} are reasonably close to observed consumption patterns and flows. As we assume that the players cooperate effectively, they will make efficient use of the existing network. Hence, in each region the marginal willingness to pay for gas, $p_j(f_{ij})$, will be equal to the local marginal cost of supplying gas, the nodal cost $c_j(f_{ij})$, which take into account the physical constraints of the system. We use this feature to calibrate first inverse demand and then supply cost using data on consumption and flows.

Demand

Transport costs within Europe are small compared to the cost of producing gas and transporting it to Europe's borders. As a first approximation, we neglect the small differences among local cost and assume a common constant supply cost c.[11] For each consumption region we assume a linear inverse demand function. To reduce the number of parameters we assume the same demand intercept $(a + c)$ for all regions. Efficiency requires $p_j(f_{ij}) = a + c - b_j f_{ij} = c$ for each region j. The slope parameters b_j are then calibrated as to replicate the consumption in 2009: $b_j = a/f_{ij}$, where f_{ij} is the consumption of gas in region j compiled from IEA (2010) and IEA (2011).[12] See table 9 for the resulting parameter values.

The common supply cost c acts as a shift parameter, which does not affect the consumer surplus. A decrease of a, with b_j being adjusted, affects all players proportionally. Such a change has little impact on the *relative* Shapley value (measured in per cent of the surplus), hence, will have little effect on our index for bargaining power.

[11] For none of the links within Europe the capacity constraints were binding in 2009/10. So nodal cost differ only by the variable transportation cost between connected nodes which are small.

[12] All quantities are quoted in bcm/a. All prices or cost are quoted in mn €/bcm (giving the same figure as the more common €/tcm).

Table 9: Pipeline Network: Consumption links

Links		Consumption	Slope		Players
			baseline	low	needed
		[bcm/a]	scenario	surplus	for
			$a = 1500$	$a = 500$	access[a]
from	to	f_{ij}	b_j	b_j	
Russia	RussiaC	426.4	3.5	1.2	Russia
Belarus	BelarusC	17.9	83.9	28.0	Belarus
Ukraine	UkraineC	53.3	28.1	9.4	Ukraine
Belgium	BelgiumC	16.9	88.9	29.6	Belgium
Poland	PolandC	16.0	93.8	31.3	Poland
UK	UKC	90.5	16.6	5.5	UK
Balkan[b]	BalkanC	20.2	74.3	24.8	Turkey & Balkan[c]
Turkey	TurkeyC	36.4	41.2	13.7	Turkey & Balkan
Regions with champion and customers					
Center[d]	CenterC	104.6	14.3	4.8	The champion and the customers in a region.*
Center-East[e]	Center-EastC	41.4	36.2	12.1	
Italy	ItalyC	75.6	19.8	6.6	
Netherlands	NetherlandsC	48.3	31.1	10.4	
South-West					
France	FranceC	44.1	34.0	11.3	
SpainPort[f]	SpainPortC	38.8	38.6	12.9	

[a] We list the players which are needed in the fragmented and the integrated market. We mark with a * those cases, where there is a change for the liberalized market. In the liberalized market only customers in a region are needed for the access to the consumption link.

[b] Romania, Bulgaria and Greece

[c] Balkan and Turkey are aggregated into one player 'Turkey & Balkan'.

[d] Germany, Denmark, Switzerland and Luxembourg

[e] Austria, Hungary, Czech Republic, Slovakia, Serbia, Slovenia

[f] Spain, Portugal

Production

For each region we introduce a production link, which connects the production site and the network. We present the parameter values for the production links in table 10.

Our focus is on the imported pipeline gas, which is considered to be the marginal source of gas. For Russia, Belarus and Ukraine welfare includes the benefits from local consumption. We treat Norway, Algeria and Libya as pure producers which benefit only from export earnings. For these countries we consider only production which could be made available for exports to Europe and Turkey after deducting own consumption and exports to other markets. For all players, except Russia, we restrict the capacities of the production links to be equal to the respective production volumes in 2009. The data on production volumes are collected from IEA (2010) and IEA (2011).

The differences in the operating cost of producing from existing fields are small compared to differences in the cost of developing new fields. In addition, meaningful information on wellhead production cost is difficult to obtain. As with demand we make a bold assumption by introducing a common production cost parameter c^P with some adjustments (Δ_{ij}) for few cases. Since it is more difficult to produce at maximal capacity k_{ij}, we assume production cost to be piecewise linear : $T_{ij}(f_{ij}) = (c^P + \Delta_{ij})(\min[f_{ij}, 0.75 * k_{ij}] + 1.2 \max[f_{ij} - 0.75 * k_{ij}, 0])$. Per unit production costs are constant, but only up to 75% of the pipe capacity and increased by 20% for the remaining 25%. These adjustments help to get more realistic flows for the network, but have only a negligible impact on our estimate of bargaining power. Since the demand system is adjusted to any choice of c^P, its absolute value is rather irrelevant and arbitrarily set as $c^P = 20$. To account for the regional differences in wellhead production cost we compute Δ_{ij} based on Table 13.6 (IEA (2009)). For most EU regions, as well as for Belarus and Ukraine, we ignore any cost of own production.

LNG

In case of all market structures a local champion (or a region itself) controls not only own production, but also LNG-imports. For all EU players we introduce LNG links, which represent the LNG terminals. The parameter values are reported in table 11. The data on LNG-imports are collected from GIE (2010), IEA (2010) and IEA (2011). With respect to Table 13.5 and Table 13.6 in IEA (2009) we set the total costs of using LNG to be equal to $2c^P$ which gives LNG a slight disadvantage

Table 10: Pipeline Network: Production links

Links from	Links to	Capacity [bcm/a]	Flow [bcm/a]	Operating Cost $c^P + \Delta_{ij}$ [€/tcm]	Players needed for access
Production outside EU					
RussiaP	Russia	650.8	550.5	c^P	Russia
NorwayP	Norway	99.4	99.4	$c^P - 7$	Norway
AlgeriaP	Algeria	77.7	77.7	$c^P - 5$	Algeria
LibyaP	Libya	15.9	15.9	$c^P - 8.8$	Libya
BelarusP	Belarus	0.2	0.2	0	Belarus
UkraineP	Ukraine	21.9	21.9	0	Ukraine
Production within EU					
BalkanP	Balkan	10.8	10.8	0	Turkey & Balkan[a]
BelgiumP	Belgium	0	0	0	Belgium
CenterEastP	CenterEast	4.9	4.9	0	champion in CenterEast
FranceP	France	0.9	0.9	0	champion in South-West[b]
CenterP	Center	23.7	23.7	0	champion in Center
ItalyP	Italy	8.1	8.1	0	champion in Italy
NetherlandsP	Netherlands	78.7	78.7	$c^P - 4.4$	champion in Netherlands
PolandP	Poland	5.8	5.8	0	Poland
SpainPortP	SpainPort	0	0	0	champion in South-West
TurkeyP	Turkey	0.7	0.7	0	Turkey & Balkan
UKP	UK	62.1	62.1	0	UK

[a] Balkan and Turkey are aggregated into one player 'Turkey & Balkan'.

[b] Spain, Portugal and France are aggregated into one region South-West.

Table 11: Pipeline Network: LNG links

Links from	Links to	Capacity [bcm/a]	Flow [bcm/a]	Operating Cost $c^P + \Delta_{ij}$ [€/tcm]	Players needed for access
Production outside EU					
RussiaP	Russia	650.8	550.5	c^P	Russia
NorwayP	Norway	99.4	99.4	$c^P - 7$	Norway
AlgeriaP	Algeria	77.7	77.7	$c^P - 5$	Algeria
LibyaP	Libya	15.9	15.9	$c^P - 8.8$	Libya
BelarusP	Belarus	0.2	0.2	0	Belarus
UkraineP	Ukraine	21.9	21.9	0	Ukraine
Production within EU					
BalkanP	Balkan	10.8	10.8	0	Turkey & Balkan[a]
BelgiumP	Belgium	0	0	0	Belgium
CenterEastP	CenterEast	4.9	4.9	0	champion in CenterEast
FranceP	France	0.9	0.9	0	champion in South-West[b]
CenterP	Center	23.7	23.7	0	champion in Center
ItalyP	Italy	8.1	8.1	0	champion in Italy
NetherlandsP	Netherlands	78.7	78.7	$c^P - 4.4$	champion in Netherlands
PolandP	Poland	5.8	5.8	0	Poland
SpainPortP	SpainPort	0	0	0	champion in South-West
TurkeyP	Turkey	0.7	0.7	0	Turkey & Balkan
UKP	UK	62.1	62.1	0	UK

[a] Balkan and Turkey are aggregated into one player 'Turkey & Balkan'.
[b] Spain, Portugal and France are aggregated into one region South-West.

compared to pipeline gas. As before, we assume a piecewise linear cost function: $T_{ij}(f_{ij}) = 2c^P * (\min[f_{ij}, 0.75 * k_{ij}] + 1.2 * \max[f_{ij} - 0.75 * k_{ij}, 0])$, where k_{ij} denotes the capacity of the link. We restrict the capacities of LNG links to the respective flows in 2009.

Transport

The total cost of transporting gas consists of operating cost and capacity cost. In the shortsighted assessment of power, capacity costs of existing pipelines are sunk and we do not take them into account. This simplification is based on the assumption that bargaining among rational players should not be influenced by sunk cost.

The operating cost is composed by management & maintenance cost and energy cost, which are proportional to the length of the pipeline as well as to the quantity of gas transported. Since it is difficult to run a pipeline throughout the year at maximal

Table 12: Pipeline Network: Transit

Links from	Links to	Capacity [bcm/a]	Flow [bcm/a]	Operating Cost c^T_{ij} [€/tcm]	Capacity Cost[a] c^K_{ij} [€/tcm/a]	Players needed for access[b]
Transit outside EU						
Russia	Belarus	100	49.2	2.1	-	Russia, Belarus
Russia	RussiaN	165	0	2.3	-	Russia
Russia	RussiaS	240	8.9	2.1	-	Russia
Russia	UkraineE	415	109.1	2.0	-	Russia, Ukraine
RussiaS	UkraineE	200	24.6	1.2	-	Russia, Ukraine
UkraineE	Ukraine	122	95.1	2.5	12.6	Ukraine
TurkeyE	Turkey	20	11.8	2.4	12.1	Turkey & Balkan[c]
Transit into (out of) EU						
Algeria	Italy	30.2	25.4	6.2	-	Algeria*
Algeria	SpainPort	12	9.2	4.5	-	Algeria*
Libya	Italy	11	9.0	4.7	-	Libya*
Belarus	Poland	33	31.3	1.4	8.9	Belarus*
Norway	Belgium	15	12.2	5.2	-	Norway*
Norway	France	18.3	15.0	5.9	-	Norway*
Norway	Center	46	29.2	5.2	-	Norway*
Norway	UK	46.4	24.0	4.9	-	Norway*
UkraineE	Balkan	31.3	16.5	3.4	4.0	Ukraine*
Ukraine	Center-East	105.8	77.0	1.9	9.5	Ukraine*
Ukraine	Poland	5	3.2	1.2	6.0	Ukraine*
RussiaN	Center	55	0	6.9	26.8	Russia*
Balkan	Turkey	16.3	8.9	1.8	9.2	Turkey & Balkan
RussiaS	Balkan	0	0	5.6	23.8	Russia*
RussiaS	Turkey	16	8.9	4.8	11.9	Russia, Turkey & Balkan
Transit within EU						
Belgium	France	30	14.9	0.8	4.0	In the integrated and the liberalized market access to transit pipelines within EU is free.*
Belgium	Center	26	1.0	0.6	3.0	
Center-East	Balkan	1.7	1.0	3.3	16.5	
Center-East	Center	77.8	18.4	2.4	12.0	
Center-East	Italy	37.0	21.3	2.7	13.5	
Center	France	28	4.3	1.4	7.1	
Center	Italy	20.2	9.1	3.5	17.3	
Netherlands	Belgium	53	10.7	0.5	2.6	
Netherlands	Center	80	11.7	0.6	3.0	
Netherlands	UK	15.3	7.0	1.0	3.5	
Poland	Center	31.4	24.4	3.2	16.1	
UK	Belgium	25.5	7.5	1.5	4.9	
France	SpainPort	4.7	1.1	3.2	15.8	
Balkan	Italy	0	0	3.9	28.5	
Out of regional scope						
Azerbaijan	RussiaS	0	0	3.8	-	Russia
Azerbaijan	TurkeyE	4.5	4.5	2.4	-	Turkey & Balkan
Iran	TurkeyE	7.2	7.2	1.2	-	Turkey & Balkan
Iraq	TurkeyE	0	0	1.7	-	Turkey & Balkan
Kazakhstan	Russia	0	0	5.1	-	Russia
Kazakhstan	RussiaS	32.3	32.3	3.6	-	Russia

[a] In the farsighted scenario we allow for investments in the links within EU and in the pipelines for Russian gas.

[b] We list the players which are needed in the integrated and the liberalized market. We mark with a * those cases, where there is a change for the fragmented market. Then either both players from the left column are needed or the champions in the respective regions are needed (if the champion was introduced explicitly for the region).

[c] Balkan and Turkey are aggregated into one player 'Turkey & Balkan'.

capacity, we assume a piecewise linear function: $T_{ij}(f_{ij}) = c^T_{ij} * (\min[f_{ij}, 0.75 * k_{ij}] + 1.2 * \max[f_{ij} - 0.75 * k_{ij}, 0])$, where k_{ij} denotes existing capacity. Per unit transportation costs are constant, but only up to 75% of the pipe capacity and increased by 20% for the remaining 25%. Capacities of the links between the transit nodes are compiled from ENTSOG (2010) and public sources. The data on flows are collected from IEA (2010) and IEA (2011). Capacities of the links, which are connected to the areas outside of the regional scope, are limited to the respective flows in 2009.

To calculate the link specific cost parameter c^T_{ij}, we assume universal operating cost of 0.3 €/tcm/100km for onshore pipelines. For offshore pipelines we assume operating cost to be 50% higher to account for higher pressure and increased cost of maintenance. These coefficients are then multiplied by the distance between the nodes to obtain the link specific operating cost shown in table 12 column 4.

Investment

In the farsighted scenario we allow for investment in new capacity for links within EU and in the pipelines for Russian gas. For additional capacities we add annualized capacity cost to the operating cost. To obtain capacity expenditures for new projects and enlargement of existing pipeline networks we refer to public sources for costs estimates of the project consortia, which are supplemented by own estimates if figures are unavailable. To simplify the analysis we abstract from economies of scale and assume constant capacity cost. We use a rather high discount rate of 15% to translate capital expenditures into annualized capacity cost. This rate is a common hurdle rate in the gas industry and reflects the real option nature of the investment and depreciation. For those links where investment is possible, transportation cost are given as: $T_{ij}(f_{ij}) = c^T_{ij} * (\min[f_{ij}, 0.75 * k_{ij}] + 1.2 * \max[f_{ij} - 0.75 * k_{ij}, 0]) + c^K_{ij} \max[f_{ij} - k_{ij}, 0]$, where c^K_{ij} denotes annualized capacity cost, measured in € per tcm per year (for figures see table 12 column 5).