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Conference Paper

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Beiträge zur Jahrestagung des Vereins für Socialpolitik 2014: Evidenzbasierte Wirtschaftspolitik
- Session: Energy Markets, No. G11-V1

Provided in Cooperation with:

Verein für Socialpolitik / German Economic Association

Suggested Citation: Orlova, Ekaterina; Hubert, Franz (2014) : Network Access and Market Power, Beiträge zur Jahrestagung des Vereins für Socialpolitik 2014: Evidenzbasierte Wirtschaftspolitik - Session: Energy Markets, No. G11-V1, ZBW - Deutsche Zentralbibliothek für Wirtschaftswissenschaften, Leibniz-Informationszentrum Wirtschaft, Kiel und Hamburg

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Network Access and Market Power

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first draft: September 2013

this version: January 2014

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. 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. This effect, however, completely vanishes, when network power is assessed with the nucleolus.

Keywords: Network Access, Natural Gas, Countervailing Power, Shapley Value, Nucleolus

JEL class.: L1, L95

We are thankful to Johannes H. Reijnierse for providing us with MATLAB code for calculating the nucleolus.

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 identified the liberalization of access to gas pipelines as the key element for success. Transparent and fair access to the bottle neck facility creates a level playing field, which will allow competition to flourish. It is expected that consumers will benefit from a diversified choice of suppliers and competitive prices. But according to the Commission not only customers are supposed to gain from open 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.”²

Skeptics, however, point out that two thirds of the Union’s gas consumption is imported from a small number of producers beyond EU jurisdiction. 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 Union, not from owning pipelines within. In their opposition to the Commission’s policy, national champions, and often their respective governments, claim that a limited number of strong European market players is needed to counter the power of these outside producers. It is argued that by dismantling the European champions, the Commission fosters the dominance of outside producers.³

The notion that it takes strong buyers to create ‘countervailing power’ against powerful sellers has been controversial among academic economists ever since it was coined by Galbraith (1952). The literature on deregulation and liberalization tends

¹Obviously, this is an idealized description, fitting nicely to France/GdF, Austria/OMV, Italy/Eni. In Germany, however, there is E.ON-Ruhrgas, which 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.

²Commission (2007) Prospect for the internal gas and electricity market, communication from the commission to the council and the European Parliament, Brussels, COM(2006) 841 final, p. 5.

³For a summary of the arguments see Energy Sector Inquiry-second phase (public consultation).

to emphasize potential efficiency gains. In the gas industry, however, sunk investment in gas fields and pipelines creates 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.

The theoretical literature has proposed several models of bargaining in vertical structures, but it did not develop a canonical setting for the analysis of market power in vertical structures.⁴ Previous studies on the impact of liberalization on the European gas market used a non-cooperative approach, e.g. Golombek & Gjelsvik & Rosendahl (1995), Boots & Rijkers & Hobbs (2004), Egging & Gabriel (2006), and Holz & von Hirschhausen & Kemfert (2008). Notwithstanding a number of differences, this literature analyzes the gas industry as a succession of activities (production, transport, distribution), where the interaction among players of the same level of activity is modeled as a non-cooperative game either in linear prices or quantities. In addition, it is often assumed that the different levels decide in a given order, which essentially implies that those who move first, usually the producers, have the ability to commit, whereas those who move later, i.e. transit countries or importers, cannot commit.

We do see several important conceptional shortcomings of the non-cooperative approach. First, the distribution of market power is largely determined by ad hoc assumptions on (i) the type of interaction at the different levels of the value chain and (ii) the sequencing of actions, hence, the ability to commit. Second, the literature assumes that the players are setting either quantities or (linear) prices, whereas in reality, most pipeline gas is delivered under negotiated, comprehensive price-quantity-contracts.⁵ This counter-factual assumption implies double marginalization, an inefficiency, which is reduced if competition is enhanced through liberalization. It is worth emphasizing that the contracts which are widely used in the real world gas industry can exactly avoid this inefficiency. We suspect that the non-cooperative literature underestimates the ability of the actors to make efficient use of the existing pipeline system and, therefore, overestimate possible efficiency gains from liberalization.

In this paper we analyze the inter-dependencies among the players as a *cooper-*

⁴See among others Horn & Wolinsky (1988), von Ungern-Sternberg (1996), Snyder (1999), Chae & Heidhues (2004), Inderst & Wey (2003).

⁵The European pipeline system was developed under long-term agreements with so called 'take-or-pay' provisions. Contracts stipulate prices *and* quantities to ensure the efficient usage of the capacities and to avoid double marginalization (see Energy Charter Secretariat (2007) for details). Contracts with transit countries also cover tariffs *and* quantities.

ative game. Thereby, we avoid assumptions on details of the negotiation process altogether and give none of the players an a-priori strategic advantage. Instead, the power of a player is derived endogenously, entirely determined by his control over gas fields, pipelines and customers. In this way we also separate the issue of power from the issue of efficiency. In our framework liberalizing pipeline access has no effect on the efficiency of the industry, it will only affect the power structure. This allows us to focus on the alleged trade-off between enhancing customer's power on the one hand and keeping a lid on the power of external producers on the other.

There are several solutions for cooperative games. In this paper the emphasis is on the well known Shapley value. Following Shapley & Shubik (1954) the Shapley value has regularly been used as a power index for voting games, both in political science (Brams (2004)) as well as in corporate finance (Crama & Leruth (2013)). Myerson (1980) initiated a 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 use as it does not yield a unique solution. Following Montero (2005), we consider the nucleolus as an alternative power index. The nucleolus is of interest because it is in the core and can be considered as the lexicographical center of the game (Maschler & Peleg & Shapley (1979)).

We are not concerned with the institutional details of liberalization, i.e. whether it is achieved by regulated third party access or by ownership unbundling. However, the distinction between access to high pressure trunk pipes, which are needed for *gas transit* across Europe and access to low pressure distribution networks, which allow for *access to customers* in a region, will be crucial. Conceptually, the Commission does not draw such a distinction, though in practice, the liberalization of transmission networks is advancing at a faster pace.⁶

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 free transit, we obtain a regime which we call an *integrated market*. Local champions, as well as external producers, can ship their gas freely within the Union, but the champions remain the gatekeepers of access to local customers.

⁶In the year 2003 the Directive 2003/55/EC specified deadlines for legal unbundling of July 2004 and July 2007 for transmission and distribution networks, respectively.

This intermediate scenario roughly corresponds to the current status of the implementation of reforms. 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 against each other and the outside producers for customers, which are free to choose among suppliers. We take this scenario to reflect the final aim of the Commission'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 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 Union. 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.⁷

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. But it is difficult to imagine how such a move could strengthen the bargaining position of European energy companies, as it is claimed by the Commission's statement cited above.

If network power is assessed with the Shapley value, our quantitative results support this intuition. Overall, we find modest and heterogeneous effects for the open-

⁷These regional effects have been analyzed in detail in Hubert & Orlova (2012).

ing of access to transit pipelines. Customers in the union 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 suppliers access. All these effects, however, are fairly small and the aggregate impact on the balance of power between customers and champions within the European Union on one side, and outside producers and transit countries on the other side is negligible.

If we add the liberalization of access to distribution networks, thus moving on to a completely *liberalized market*, the effects are amplified by 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 European Union, while the power of the old champions, now reduced to local producers, is dramatically diminished. Roughly a quarter of the joint share of the European players is redistributed through the reform. However, more than a 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', benefiting outside producers.⁸

When the nucleolus is used to measure the power structure, we again obtain a very substantial redistribution through the full liberalization. Surprisingly however, with the nucleolus outside producers do not benefit from 'cutting out the middlemen'. All the losses of the local champions are transferred to the European customers.

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 & Ikonnikova (2011a), Hubert & Ikonnikova (2011b) and Hubert & Suleymanova (2008) pioneered the use of cooperative-game theory in the analy-

⁸So far the liberalization of the gas sector has moved at low speed. According to our analysis the move from a fragmented to an integrated market has small impact on the power distribution in the Gas sector, which is in line with the limited empirical evidence (Haase & Bressers (2010)). However, the next step towards a fully liberalized market has a large potential to enhance the power of outside producers. This might justify protective measures, such as the strategic diversification of gas supplies as analyzed in Hubert & Cobanli (2012), or the use of trade quotas as discussed in Ikonnikova & Zwart (2014).

sis 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. Variants of this model are used in Hubert & Orlova (2012) to analyze the regional effect of market integration and the incentives for mergers and cartels and in Hubert & Cobanli (2012) to investigate strategic pipeline investments. The present paper differs (a) in its focus on the distribution of power between customers and local champions and (b) in its analysis of access to distribution systems.

Looking beyond gas and regulation, the paper contributes to a small strand of literature applying cooperative game theory to the analysis of vertical structures. There exists a very substantial theoretical literature on the various solutions for cooperative games, their relations among each other, possible non-cooperative foundations, and computational issues. But with the notable exception of voting games and the allocation of common cost, the latter being mainly normative, this sophisticated theory had little impact on applied research. As a result, little is known about the practical differences of the various solution concepts, their intuitive appeal in the understanding of power relations and their predictive power. Our results for access regulation in the European gas network show that the Shapley value nicely corresponds to the intuition that ‘cutting out the middlemen’ benefits both sides of the market. The nucleolus in contrast, allocates all the increase in power to one side of the market, the customers.

2 The Model

Network. The analysis is based on a quantitative model of the Eurasian gas network consisting 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 $p_j(f_{ij})$. The details of the calibration of this model are described in a technical appendix.⁹

Game. The inter-dependencies among the players can be represented by a game in value function form (N, v) , where N is the set of players and the value (or characteristic) function $v : 2^{|N|} \rightarrow R_+$ gives the maximal payoff, which a subset of players $S \subseteq N$, also called coalition, can achieve. The legal and regulatory framework determines the access rights of the various players. So for any coalition $S \subseteq N$ we have to determine to which links $L(S) \subseteq L$ the coalition S has access. 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 . 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 :

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

subject to

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

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, ϕ_i , $i \in N$. It is

⁹The additional material is available at <http://www.ms-hns.de/paper-network-access>.

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.¹⁰ Formally, it is calculated as player i 's weighted contribution:

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

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 . Here, we consider only payoff vectors x which are efficient $\sum_{i \in N} x_i = v(N)$ and individually rational $x_i \geq v(i)$, so called imputations I . The excess e is the difference between what a coalition can achieve alone and what it receives $e(S, x) := v(S) - x_S$. 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: $c(\epsilon) := \{x : e(S, x) \leq 0, \forall S \subset N\}$.

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 this is not empty. Moreover it can be interpreted as the lexicographic center of the game (Maschler & Peleg & Shapley (1979)). Originally, the nucleolus has been proposed as the imputation which minimizes 'inequity' among coalitions (Schmeidler (1969)). Let $\theta(x)$ be the vector of excesses arranged in decreasing order for a payoff vector x and let \leq stand for lexicographical smaller. The nucleolus, denoted μ , is defined as

¹⁰The Shapley value has several axiomatic foundations. Surprisingly, it is the only rule of dividing the gains from cooperation featuring *monotonicity*: a player's share never decreases when his contributions weakly increase (Young (1985a), Young (1985b)). It is also the unique rule with so called *balanced contributions*: For any two players i and j it is true that i loses as much if j withdrew from the game, as j loses if i withdrew. Hence, if a player objects the Shapley allocation by pointing out the damage he can impose on another player through a boycott of cooperation, his opponent can always counter the argument (Myerson (1980)). In this sense it is often considered as a 'fair' division. Finally, the Shapley value can be considered as the expected utility of a player from participating in the game (Roth (1977)). The Shapley value can be supported as the subgame-perfect equilibrium of several non-cooperative models of structured bargaining processes, i.e. Gul (1989), Evans (1996), Stole & Zwiebel (1996a), Stole & Zwiebel (1996b), Inderst & Wey (2003).

the imputation which minimizes the excess in lexicographic ordering: $\mu := \{x \in I : \theta(x) \leq \theta(y) \text{ for all } y \in I\}$. It can be computed by solving a nested sequence of linear optimization problems. First excess is made minimal for the coalitions, which are doing worst. Then excess is reduced for the coalitions, which come second, and so on.¹¹

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. As this number increases fast in the number of players, we have to aggregate regions and players in order to economize on computing time. To keep the number of players small we leave out producers which appear to be of minor strategic relevance and aggregate 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 European Union.¹² 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 (34%), Norway (32%) and Netherlands (25%). 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 (38%), Algeria (18%) and Russia (18%).

¹¹In the terminology of operation research computation of the nucleolus is a ‘hard’ problem for which we use an algorithm proposed by Potters & Reijnierse & Ansing (1996) who also provided us with the MATLAB code.

¹²Figures are calculated for the year 2009 from British Petrol (2010).

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, which together account 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 "Balkan & Turkey". The region has only weak links to other European regions and imports mainly Russian gas. For these regions we can only identify 'regional' effects. 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, which 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* we need the local champion also to access 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. Only in the *fully liberalized* market, the local champion is reduced to his role as local producer and LNG-importer, while local customers can access all suppliers on their own.

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. Such a period allows to ignore the seasonal pattern of demand and the possibility of gas storage.¹³ It is also long enough to convert existing pipeline to bidirectional

¹³In Europe storage facilities help to smooth seasonal patterns of consumption, but at present they

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 and even some production capacities 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.¹⁴

Cost and demand. 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 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 replicate flows in 2009. The slope parameters of demand are estimated as to replicate the consumption in 2009. The most important implication of our calibration of demand in relation to cost is that the pipeline system as existing in 2009 is sufficient. Given the willingness to pay and the cost of producing gas the network is able to deliver the efficient amount of gas into the different consumption nodes. Nevertheless, the options to change the network will affect bargaining power in a long-term assessment, because it enables coalitions, which do not have access to the full network, to adjust it to their needs.

The calibration ensures that the main difference between customers is the size as measured by total consumption, and network connection on which we have solid

are too low to act as a strategic reserve for longer periods.

¹⁴The distinction between status-quo/shortsighted and flexible/farsighted is borrowed from Hubert & Ikonnikova (2011a). 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.

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. We discuss the robustness of our results with respect to changes in these parameters at the end.

3 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 function 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: the impact of trunk pipe liberalization ($\Delta\phi^1 = \phi(v^1) - \phi(v^0)$), the incremental impact of access to distribution networks ($\Delta\phi^2 = \phi(v^2) - \phi(v^1)$), and the total impact of the ongoing reforms ($\Delta\phi^{12} = \phi(v^2) - \phi(v^0)$). The corresponding values for the nucleolus are $\Delta\mu^1$, $\Delta\mu^2$, and $\Delta\mu^{12}$.

Before we look at the details for individual players, we assess the importance of the reforms. As liberalization will benefit some of the market participants while hurting others, its overall impact can be measured by the fraction of the surplus, which is redistributed as a result of the reforms. Summing up the gains for those who benefit (or the losses of those who are hurt) we obtain one figure R^j , $j \in \{1, 2, 12\}$, for each of the three differences mentioned above.¹⁵

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 given. We also assume a rather large difference between demand intercept and production cost of 1500 Euro. Then we briefly discuss the robustness of the results as to changes of parameters and scope. All figures are rounded to the first decimal.

¹⁵Our focus is on the impact of liberalization, hence the differences in the power index. These differences are the same whether we normalize the game or not. When looking at the fraction of surplus which is redistributed, we refer to the surplus of the non-normalized game.

Table 1: Overall Impact (Shapley Value)

	Redistribution in per cent of initial share		
	step 1: transmission <i>fragmented to integrated market</i>	step 2: distribution <i>integrated to liberalized market</i>	both together <i>fragmented to liberalized market</i>
All players $100 * R^j / v^0(N)$	2.0	12.4	13.0
European players only $100 * R^j / \phi_{EU}(v^0)$	4.0	25.4	26.6

Shapley Value

Table 1 displays the redistribution as a percentage of the initial rent of all players $v^0(N)$ and as a percentage of the joint shares of the EU players before the reform, $\phi_{EU}(v^0)$. 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 or to one quarter of the joint rents of the European players. The second step, the liberalization of access to distribution networks, appears to be decisive. Its incremental impact is six times larger than that of the initial step, the opening of access to trunk-pipes.¹⁶ Liberalization had progressed slowly during a time when the European gas market was subjected to several outside shocks, first the long international boom before 2008, then the fallout of the financial crisis, then 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 & 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, now measured in percentage of the overall redistribution of the full reform (R^{12}). For convenience we also report the aggregated figures for some groups of players (given in italics). In the first column we give the figures for the impact of opening access to trunk pipes. The move from a fragmented to an integrated market figures yields rather heterogeneous effects. Within Europe, we observe the strongest effect for the champion in *Center*: a loss of well over six percentage points. The region is well connected to competing suppliers, Russia, Norway, Netherlands, hence there

¹⁶Since the direction of redistribution is reversed in some cases, the final volume of redistribution is not 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 <i>fragmented to integrated market</i> $100 * \Delta\phi^1 / R^{12}$	step 2: distribution <i>integrated to liberalized market</i> $100 * \Delta\phi^2 / R^{12}$	both together <i>fragmented to liberalized market</i> $100 * \Delta\phi^{12} / R^{12}$
<i>Outside Countries</i>			
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
<i>Netherlands</i>	0.2	1.3	1.5
champion	0.3	-6.6	-6.3
customers	-0.1	7.9	7.8
<i>Center-East^a</i>	1.4	-5.3	-3.9
champion	-0.6	-13.0	-13.6
customers	1.9	7.7	9.6
<i>Italy</i>	3.8	-9.6	-5.8
champion	1.1	-23.1	-21.9
customers	2.7	13.4	16.1
<i>Center^b</i>	-5.9	-12.6	-18.5
champion	-6.6	-30.8	-37.4
customers	0.7	18.2	18.9
<i>South-West^c</i>	1.5	-7.8	-6.3
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
<i>all champions</i>	-5.1	-93.1	-98.2
<i>all customers</i>	5.9	59.1	65.1
<i>European Union^e</i>	1.5	-34.7	-33.2

^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

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.¹⁷ 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 Union tend to gain. Altogether they improve by almost 6 per percentage 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 a fragmented market.

Considering customers and champions together, we find some regional redistribution within the Union. The *Center* loses power while Italy and the South-West gain 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 Union. Russia loses 7 percentage 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 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 Union, but there is no rent leakage to outside countries. Instead, there is even a small gain of the Union.

The picture changes dramatically when moving on to the second step, the liberalization of access to the distribution systems. With the notable exception of Ukraine and Belarus, the incremental impact of this step is much larger, sometimes by 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

¹⁷At 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 & Orlova (2012).

amount to 98 percent of the total volume of redistribution. Essentially, the full liberalization of pipeline access in the EU has one big effect: it destroys much of the 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 Italian Eni. Its initial gain of 1.1 percentage 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 percentage points.¹⁸

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 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 Union, with Norway, Russia and Algeria being the main beneficiaries.¹⁹ Even for Russia, which was quite badly hurt from opening transit pipelines, the losses turn into a substantial net gain. Being able to sell gas directly to its customers turns out to be much more valuable than the partial protection against competing suppliers, which 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 Energy companies. 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. If power is assessed with the Shapley value, we also find support for concerns about the dominance of outside producers. For every two Euros which European customers gain in bargaining power, one Euro leaks to players outside the Union.

¹⁸This 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.

¹⁹Apart 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 in per cent of initial share					
	step 1: transmission <i>fragmented to integrated market</i>		step 2: distribution <i>integrated to liberalized market</i>		both together <i>fragmented to liberalized market</i>	
	<i>min</i>	<i>max</i>	<i>min</i>	<i>max</i>	<i>min</i>	<i>max</i>
All players $100 * R^j / v^0(N)$	1.9	2.0	12.0	13.4	12.6	13.7
European players only $100 * R^j / \phi_{EU}(v^0)$	3.8	4.0	24.7	27.2	26.0	27.9

Robustness In this section we briefly assess the robustness of the previous results by considering three 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, but it has a considerable impact on the relative bargaining power of the different players. 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 tend to neutralize the re-scaling 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 cost is reduced.

Instead of going in detail through all these variants, we simply report the minimum and maximum values achieved in any of the four variants in tables 3 and 4, which correspond to tables 1 and 2, respectively. The differences between the maximum value in any of the variants and the corresponding minimum value 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 26 and 27.9 per cent — or roughly a quarter of the joint rent of all European players. 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 again find that the players in the Union gain between 0.7 and 1.5 percentage points from the first step — a negligible amount. In contrast, they lose between 30.2 and 33.9 points, i.e. roughly a third, from the full implementation

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

	Change of Shapley Value [percentage of all gains]					
	step 1: transmission <i>fragmented to integrated market</i>		step 2: distribution <i>integrated to liberalized market</i>		both together <i>fragmented to liberalized market</i>	
	<i>min</i>	<i>max</i>	<i>min</i>	<i>max</i>	<i>min</i>	<i>max</i>
<i>Outside Countries</i>						
Russia	-7.2	-6.9	14.5	16.7	7.5	9.5
Belarus	3.1	3.2	-0.8	-0.4	2.2	2.7
Ukraine	1.8	2.0	-0.9	0.4	0.8	2.4
Algeria	-0.5	0.1	5.1	6.9	5.2	6.5
Libya	0.0	0.2	1.3	1.7	1.5	1.8
Norway	0.9	1.1	10.0	12.1	10.9	13.1
<i>Netherlands</i>	0.2	0.2	1.0	1.6	1.2	1.8
champion	0.3	0.4	-7.3	-6.2	-7.0	-5.8
customers	-0.2	-0.1	7.8	8.3	7.6	8.2
<i>Center-East^a</i>	1.4	1.9	-5.3	-4.6	-3.9	-2.7
champion	-0.6	0.2	-13.0	-12.5	-13.6	-12.3
customers	1.8	2.0	7.7	7.9	9.6	9.7
<i>Italy</i>	2.8	3.8	-9.7	-8.4	-6.0	-5.6
champion	0.5	1.1	-23.1	-22.4	-22.0	-21.7
customers	2.2	2.7	13.3	14.0	15.9	16.1
<i>Center^b</i>	-6.1	-5.7	-12.6	-11.2	-18.7	-16.9
champion	-6.8	-6.3	-30.8	-29.9	-37.5	-36.2
customers	0.6	0.7	18.1	18.8	18.8	19.3
<i>South-West^c</i>	1.1	1.5	-7.9	-7.3	-6.4	-6.3
champion	0.6	0.7	-21.8	-19.7	-21.2	-19.0
customers	0.5	0.8	11.9	14.5	12.6	14.9
Poland	-0.1	0.1	-0.6	-0.5	-0.6	-0.4
Belgium	-0.5	-0.2	-1.1	-0.8	-1.6	-1.0
United Kingdom	-0.1	0.1	0.8	1.2	0.7	1.3
Turkey & Balkan ^d	0.7	0.9	-0.5	-0.3	0.4	0.5
<i>all champions</i>	-5.3	-4.6	-93.9	-92.6	-98.5	-97.9
<i>all customers</i>	4.9	6.0	58.8	63.3	64.7	68.2
<i>European Union^e</i>	0.7	1.5	-34.9	-31.3	-33.9	-30.2

^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 5: Overall Impact (nucleolus)

	Redistribution in per cent of initial share		
	step 1: transmission <i>fragmented to integrated market</i>	step 2: distribution <i>integrated to liberalized market</i>	both together <i>fragmented to liberalized market</i>
All players $100 * R^j / v^0(N)$	2.0	16.1	18.1
European players only $100 * R^j / \mu_{EU}(v^0)$	4.0	31.8	35.7

of reforms.

These observations suggest that our results for the change in power as measured by the the Shapley are 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

For some coalitions opening access to pipelines will increase the value. Others might be unaffected, but the value will never be reduced. Hence, the excess will (weakly) increase and the core will be compressed. The nucleolus is a unique point in the core, which, in addition, is the lexicographical center of the game.

The pattern of the aggregated impact look similar for the nucleolus and for the Shapley value (compare tables 5 and 1). The impact of the first step is essentially of equal magnitude and in both cases the second step appears decisive. 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, or 35.7 per cent of the joint share of the EU players.

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 percentage points compared to 5.1 under the Shapley value. Customers gain 6.3

Table 6: Liberalization and Power-Structure (nucleolus)

	Change of nucleolus [percentage of all gains]		
	step 1: transmission <i>fragmented to integrated market</i> $100 * \Delta\mu^1 / R^{12}$	step 2: distribution <i>integrated to liberalized market</i> $100 * \Delta\mu^2 / R^{12}$	both together <i>fragmented to liberalized market</i> $100 * \Delta\mu^{12} / R^{12}$
<i>Outside Countries</i>			
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
<i>Netherlands</i>	0.1	0.0	0.1
champion	-1.4	-12.6	-14.0
customers	1.4	12.6	14.1
<i>Center-East^a</i>	0.3	0.0	0.3
champion	-1.0	-10.8	-11.8
customers	1.3	10.8	12.1
<i>Italy</i>	0.0	0.0	0.1
champion	-1.6	-19.7	-21.3
customers	1.6	19.7	21.4
<i>Center^b</i>	-0.3	0.0	-0.3
champion	-2.1	-27.3	-29.5
customers	1.9	27.4	29.2
<i>South-West^c</i>	0.1	0.0	0.1
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

^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 in per cent of initial share					
	step 1: transmission <i>fragmented to integrated market</i>		step 2: distribution <i>integrated to liberalized market</i>		both together <i>fragmented to liberalized market</i>	
	<i>min</i>	<i>max</i>	<i>min</i>	<i>max</i>	<i>min</i>	<i>max</i>
All players $100 * R^j / v^0(N)$	0.9	2.0	15.3	16.6	16.6	18.1
European players only $100 * R^j / \mu_{EU}(v^0)$	1.8	4.0	30.7	32.7	33.2	35.7

compared to 5.9. There is some redistribution between regions resulting in a gain of 2.7 percentage points by the European Union. 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 the Union. The effect of the second step on customers and champions is again larger by 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 Union or spillovers to players outside. In spite of a dense pipeline network, 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 measured 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 are true. In particular, the rent, which is redistributed through the full liberalization constitutes roughly a third of the joint share of EU players for all scenarios and the second step is clearly decisive. The smaller regional effects result entirely from liberalizing transit, while opening access to cus-

Table 8: Robustness: Power-Structure (nucleolus)

	Change of Nucleolus [percentage of all gains]					
	step 1: transmission		step 2: distribution		both together	
	<i>fragmented to integrated market</i>		<i>integrated to liberalized market</i>		<i>fragmented to liberalized market</i>	
	<i>min</i>	<i>max</i>	<i>min</i>	<i>max</i>	<i>min</i>	<i>max</i>
<i>Outside Countries</i>						
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
<i>Netherlands</i>	0.1	0.2	0.0	0.0	0.1	0.2
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
<i>Center-East^a</i>	0.2	0.3	0.0	0.0	0.2	0.3
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
<i>Italy</i>	-0.3	0.0	0.0	0.0	-0.2	0.1
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
<i>Center^b</i>	-0.8	-0.3	0.0	0.1	-0.8	-0.3
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
<i>South-West^c</i>	0.1	0.3	0.0	0.0	0.1	0.3
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
<i>all champions</i>	-6.0	-1.6	-94.7	-88.8	-97.0	-94.6
<i>all customers</i>	1.2	6.3	88.9	94.9	94.4	97.1
<i>European Union^e</i>	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

tomers redistributes power at a large scale, but only within the region.

4 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 European Union, 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 Union might enhance the market power of external suppliers. The Commission 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 between 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 derive the 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 power 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 approximately one third of champions' losses leaks to external suppliers, whose power is increased substantially. The interpretation is straightforward. In a fragmented market, local champions secure their position as a 'middle men' through their control of pipelines. Liberalization essentially 'cuts out the middlemen' to the benefit 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 and again the second step turns out to be decisive. 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 result, outside producers would not benefit from liberalized access to customers if market power is assessed with the nucleolus. This finding clearly contradicts the intuition gained from the 'middle-men' story.

In a nutshell: independently of whether power is assessed with the nucleolus or the Shapley value, we do not find support for the claim that European energy 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 & Ikonnikova (2011a)) and from recent investments in strategic pipelines (Hubert & Cobanli (2014)). 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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