Pipeline Power:
A Case Study of Strategic Network Investments

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Abstract

We use the Shapley value and the nucleolus to analyze the impact of three controversial pipeline projects on the power structure in the Eurasian network for natural gas. Two pipelines, 'Nord Stream' and 'South Stream', allow Russian gas to bypass transit countries, Ukraine and Belarus. The third project, 'Nabucco', aims at diversifying Europe's gas imports by accessing producers in Middle East and Central Asia. For the Shapley Value we obtain a clear ranking of the projects which corresponds to the observed investment patterns. Nord Stream's strategic value is huge, easily justifying the high investment cost for Germany and Russia. The additional leverage obtained through South Stream is much smaller and Nabucco is not viable. For the nucleolus in contrast, none of the pipelines has any strategic relevance at all, which contradicts the empirical evidence on investment.

Keywords: Cooperative games, Networks, Strategic Investment, Natural Gas, Shapley Value, Nucleolus
JEL class.: C71, L5, L95, O22

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1 Introduction

Pipeline gas from the Russian Federation accounts for a quarter of the consumption in the European Union (EU) and for more than 40% of its imports. Until 2011 essentially all of these imports depended on transit through either Belarus or Ukraine, both being major importers of Russian gas themselves. On both routes conflicts over transit fees and gas prices led to several interruptions of supply, the most serious one in January 2009 when transport through Ukraine was shut down for three weeks with dire consequences for heating and power supply in the Balkans.[1] European power companies and policy makers are struggling to find a coherent response to these challenges. On the one hand, new pipeline links with Russia diversify transit routes for Russian gas. On the other hand, such pipelines have the potential to further increase the dependency on Russian gas and reduce the viability of investments securing supplies from alternative sources.[2]

The Eurasian pipeline network can be seen as a specific example of a network, which enables the parties to trade. Its architecture determines not only the actual trade flows but also the power of the parties, i.e., how they will share the gains from trade. Hence, the actors are trying to shape the network to their own advantage. By opening new options for trade a new link can decrease the value of established links if substitutable, or increase their value if complementary.

That the formation or severance of trade links can be used to enhance the power of a nation has been recognized long ago (Hirschman (1969)). But no generally accepted approach has been established for the assessment of power relations in networks. Analyzing communication networks Myerson (1980) proposed to use cooperative game theory, and more specifically the Shapley value as a power index. Jackson and Wolinsky (1996) and Jackson (2010) extended the idea to general networks and delineated two stages. In a first, non-cooperative stage, players can change the network architecture by adding or removing links. In a second stage, a cooperative game defined by the existing network determines the final payoffs. Brandenburger and Nalebuff (1997) coined the term 'bi-form games' to emphasize that different approaches are used to determine outcomes at the two stages, but they argue that the cooperative stage should be solved with the core, instead of the Shapley value. The core, if not empty, is typically not unique, so they resort to an ex-

[1] For a comprehensive account of major conflicts over transit through Belarus and Ukraine see Bruce (2005) and Pirani et al. (2009), respectively.

[2] Although the recent escalation of the territorial conflicts in eastern Ukraine has not let to interruptions of supply so far, this possibility was clearly a major concern in international politics.

ogenous assumption on the the 'players' confidence' in their own bargaining power to solve the indeterminacy. In addition, there is a literature on non-cooperative, decentralized bargaining in networks, which invokes specific bargaining protocols to single out particular solutions (e.g., Manea (2011), Elliott (2011)). In this paper we avoid exogenous assumptions on bargaining power or bargaining protocols and use the nucleolus instead of the core. The nucleolus is unique and in the core, provided the latter is not empty.

There are good reasons to analyze gas trade in a given network, the second stage, as a cooperative game. Most pipeline gas is traded under negotiated, comprehensive price-quantity-contracts with so called 'take–or–pay' provisions. By stipulating prices and quantities, contracts can ensure the efficient usage of the existing capacities and avoid double marginalization. Contracts with transit countries also cover tariffs and quantities.[3] So we assume that the pipeline system will be used efficiently and the surplus is shared through negotiations among the partners.[4]

When the network is changed trough a new pipeline at the first stage, we obtain a different game entailing gains for some and losses for other players. We say that a project is a viable strategic option if the gains of the winners are larger than the cost of the pipeline. Strategic viability does not necessarily imply that the pipeline will be built. First, those players who would benefit, have to succeed in setting up a consortium, sharing costs and benefits, etc., which might be difficult if the gains spread over many regions or if some players cannot make credible long term commitments. Second, those players who are set to lose power might dissuade those who will gain from carrying out the project. Such a move might also require a substantial amount of cooperation.

Again, there is no generally accepted approach to determine the equilibrium network investments at the first stage. Obviously, some impediments to cooperation have to be assumed, otherwise the two stages could be collapsed into a single cooperative game, yielding efficient investment and trade. With imperfect coordination at the investment stage inefficiencies may arise: under-investment, due to potential hold up, and over-investment to improve the bargaining position.[5] In this paper we

[3]For details on the contractual formats see Energy Charter Secretariat (2007).

[4]There is also a literature using large scale non-cooperative models of gas trade with players acting in a Cournot or Betrand fashion. See Smeers (2008) for a review and Hubert and Ikonnikova (2011b) for a critic of the assumptions.

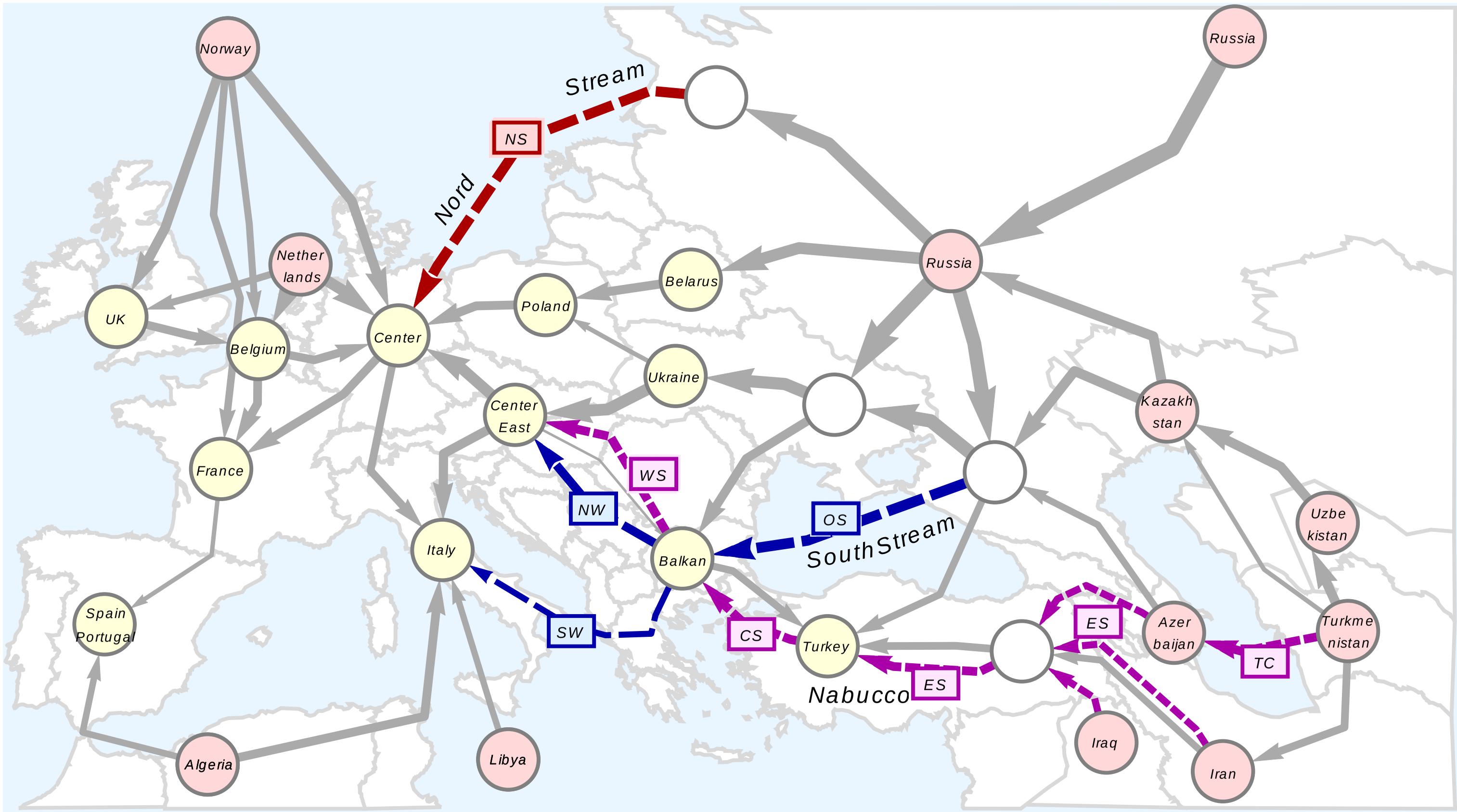
[5]The literature on incomplete contracts and the resulting issues of under-investment as well as over-investment is extensive. For networks see among others Bloch and Jackson (2007), and Elliott (2011), for gas pipelines Hubert and Ikonnikova (2011a), and Hubert and Suleymanova (2008).

do not try to predict the equilibrium network structure. Instead we simply quantify the impact of a possible pipeline link on the power structure as measured by the Shapley value or the nucleolus and compare it to its cost.

This framework is used to investigate three controversial pipeline projects, which have the potential to thoroughly transform the Eurasian supply system for natural gas (for an illustration see figure 1). In the North, the offshore twin-pipeline *Nord Stream* establishes a direct link between Russia and Germany through the Baltic Sea. Initiated in 2005, it faced strong opposition from Poland and some Baltic states. Nevertheless it received EU support as a strategic infrastructure project and was completed in 2012. Further to the South, Italy and Russia discuss another offshore pipeline through the Black Sea, called *South Stream*. If realized, it would provide a direct connection between Russia and Bulgaria, from where gas should flow to Central Europe, Italy and Turkey. By bypassing the transit countries, Belarus and Ukraine, both projects diversify transit routes for Russian gas. However, critics argue that they will also increase Europe's dependency on Russian exports and safeguard Russia's dominance in European markets by preempting investments into alternative gas supplies.[6] The EU's support for South Stream has been lukewarm and the Commission clearly favors a third project, *Nabucco*, aiming at diversifying gas imports. It would open a southern corridor through Turkey connecting Europe to new suppliers in the Middle East and the Caspian region. Nabucco also offers a new transit option to producers in Central Asia, which currently ship gas through Russia. The EU made Nabucco a major strategic project under its Trans-European Energy Networks (TEN-E), but the project failed to raise sufficient support from national governments and the private sector.

[6] South Stream and Nabucco are often portrayed as competing projects because South Stream might drain Nabucco of potential gas supplies in Central Asia.

Figure 1: The Network and the Projects



Solid gray arrows represent the pipeline network as existing in 2010. Pipeline projects which we consider in detail are dashed: Nord Stream in red (NS), South Stream in blue (with sections: OS, NW, SW), and Nabucco in Magenta (with sections: TC, ES, CS, WS). The arrows point in the direction of the typical flow and line thickness indicates capacity. Light red nodes represent major exporters, and yellow nodes are importers.

Our focus is on the *strategic* role of the pipelines. Even if not needed to transport *additional* gas, pipelines may have a substantial impact on the balance of power in the network. In fact, the size of these projects appears out of range with both production possibilities and market demand. With 55 bcm/a and 63 bcm/a, respectively, Nord Stream and South Stream would increase transport capacities for Russian gas by 63% from app. 186 bcm/a to almost 304 bcm/a. If compared to the peak of actual gas deliveries in 2008, the increase is almost 80% (BP (2010)). Given growing domestic consumption and slow progress in developing new fields in Western Siberia, Russia will not be able to produce enough gas to make use of the additional offshore transport capacity any time soon.[7] Taken together all three pipelines would increase the European import capacity by 150 bcm/a (47%). While declining production in the EU makes an increase of imports a likely scenario, pipeline gas faces stiff competition from liquefied natural gas (LNG), which experienced a sharp drop in prices due to decreasing cost and competing supplies of non-conventional shale gas. Hence, we consider it as very unlikely that demand could take up so much additional pipeline gas in the foreseeable future.[8]

When assessing the power structure with the *Shapley Value* we find that Nord Stream's strategic value is huge, easily justifying the high investment cost for Germany and Russia. It severely curtails the power of the transit countries, Belarus and Ukraine, outside producer Norway, and the EU's main producer, Netherlands. In principle, South Stream fulfills a similar strategic role. However, with Nord Stream already in place, the additional leverage obtained through South Stream is too small to make the project viable for its main beneficiaries; Russia, Germany and some central European countries. Nabucco has a large potential to curtail Russia's power, but the benefits accrue mainly to Turkey, which will diversify its gas imports and become a major potential hub. The gains for the consortium, composed of companies from the EU, in contrast, are negligible. With financial support from Turkey some sections appear viable but our results cast doubts on the prospects of raising the necessary funds within the EU. Somewhat surprisingly, South Stream has little effect on Nabucco's attractiveness. The European Commission's concern

[7]For the long term perspectives for Russian gas production see Stern (2005).

[8]It is misleading to relate the projects to import needs projected for 2030 or later. While a pipeline might last more than 40 years, the decision to invest at a given time should be based on a much shorter forecasting range. Once the 'go ahead' is given, it will take 3-7 years before the pipeline is ready to deliver gas. Hence, if demand forecasted for a decade ahead is too low or too uncertain to justify the project, the investment should be *delayed* though not necessarily scrapped. For the option like nature of sunk investment under uncertainty see Dixit (1994).

(or Russian hopes) that South Steam might preempt the investment in a southern corridor through Turkey appears unfounded.

Our results for the *Shapley value* nicely explain real investment patterns. Nord Stream was swiftly build by those players for whom we predict large gains. South Stream, in contrast, has been struggling to move on from the planning stage. After several postponements and some preparations onshore, it was unclear for a long time whether the offshore section will be built. Shortly after Russia started to order pipes, the crisis in Eastern Ukraine brought the project again to standstill and in December 2014 Russia declared to abandon the project altogether. Finally, in spite of substantial support from the EU, no lasting European consortium could be established to launch Nabucco. Recently Turkey, the only player for which the Shapley value predicts large gains, took the initiative with respect to the eastern section of the project, Trans Anatolian, which will carry Azerbaijani supplies to the Turkish-EU border.

When using the *nucleolus* as a power index instead, we receive results which are difficult to match with the empirical evidence. None of the projects has any strategic value at all. Nord Stream's and South Stream's impacts on the power structure are so tiny that no one would be interested in the pipelines, even if investment cost were negligible. Nabucco has some minor effects but these are smaller than project cost by order of magnitude. Essentially, all these pipeline are completely irrelevant for the power structure if it is measured with the nucleolus.

Given that all projects attracted a great deal of interest, both from governments and the private sector, that resources have been spend on project consortia, feasibility studies, etc., and that Nord Stream has been build, we conclude that the Shapley value gives a better prediction how major players in the industry assess the strategic impact of pipelines than the nucleolus.

2 The Framework

In the following we briefly describe the model 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-gas-pipeline-power`. As this paper is part of a larger collaborative research project sharing the same database and modeling approach, this section and the technical appendix contain material of a joint documentation (available at `http://www.ms-hns.de/research-gas`) parts of which are also used in Hubert and Orlova (2014a), Hubert and Orlova (2014b), and Cobanli (2014). Given considerable overlap with the corresponding sections in these papers, the reader may skip this section if familiar with any of these.

2.1 The Network Game

Network. The analysis is based on a calibrated 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 hubs 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 hubs 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. 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. For a given network, gas trade is represented by a game in value function form (N, v), where N is the set of players. Let 2^N denote the set of all subsets of N. 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 links 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 adding a pipeline to the system we obtain a new network, which in turn defines a new value function.

Solutions. Cooperative game theory has developed a number of solutions for games in value function form. In the following we start with the Shapley value (Shapley (1953)), which assigns a unique payoff to each player $i \in N$. 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.[9] Formally, it is calculated as player i's weighted contribution:

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

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.

[9] The Shapley Value is the only rule of dividing the gains from cooperation featuring *monotonicity*: a player's share never decreases when his contributions weakly increase (Young (1985b), Young (1985a)). 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. Due to these intuitive features, the Shapley Value is often considered to be a 'normative' concept rather than a likely bargaining outcome. It is worth mentioning that, independently of whether it is in the core or not, the Shapley value can also be supported as the subgame-perfect equilibrium of several non–cooperative models of structured bargaining processes, i.e. Gul (1989), Evans (1996), Inderst and Wey (2003), and with some additional requirements Stole and Zwiebel (1996a), Stole and Zwiebel (1996b).

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. 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. 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 as an alternative power index, which always exists, is unique and in the core if this is not empty. 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 the imputation which minimizes the excess in lexicographic ordering: $\mu := \{x \in I : \theta(x) \leq \theta(y) \text{ for all } y \in I\}$, where I denotes the set of imputations. It can be computed by solving a nested sequence of linear optimization problems (Maschler et al. (1979)). 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. In this sense, the nucleolus can be interpreted as the lexicographic center of the game.[10]

2.2 Specification & Calibration

Regional scope and players. To obtain a detailed representation of the various customers, owners of pipelines, gas producers, etc. we would like to consider a large set of players. Unfortunately, computational complexity increases fast in the number of players as we have to solve $2^{|N|} - 1$ optimization problems to calculate the value function. It is for computational reasons that we restrict the geographical scope by aggregating customers into large markets and leaving out producers which appear to be of minor strategic relevance.

As to producers, we focus on Russia, the supplier for Nord Stream and South Stream, its main competitor Norway, and those countries in the Middle East and

[10] In the terminology of operation research computation of the nucleolus is a 'hard' problem for which we use an algorithm proposed by Potters et al. (1996), who also provided us with the code for the calculation.

Central Asia which have a potential to serve Nabucco: Iraq, Iran, Azerbaijan, and Turkmenistan. The player “Turkmenistan” embraces all production and transport in Central Asia (Uzbekistan, Kazakhstan, Turkmenistan).[11] Main transit countries are Belarus and Ukraine. Turkey is a major consumer and a potential transit country for Middle Eastern and Caspian gas. We aggregate customers and producers within the EU into eight regional players. France, Italy, Poland, Netherlands, and Belgium correspond their respective countries. In each of these countries a national champion dominates imports and local supply (GDF, ENI, PNGiG, Gasunie and Fluxys, respectively). We collect Austria, Czech Republic, Slovakia and Hungary in one region called “Center-East”. South Stream and Nabucco will end in Center-East, from where gas will be distributed to other areas in Europe. The countries in the region exhibit similar consumption and import dependency patterns. With very little alternative supplies the region depends with almost 90 % of its consumption on imports from Russia. The pipeline networks are largely privatized. 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 imports are well diversified between Russia (40.2%), Norway (38.1%) and Netherlands (29.3%).[12] Finally, we collect Romania, Bulgaria and Greece in a region called “Balkan”. The region has only weak links to other European regions and its imports depend largely on Russian gas.

We aggregate all pipelines and interconnection points between any two players into one link. The arrows in figure 1 indicate the direction of net flows between the regions according to IEA (2010). The new projects, Nord Stream, South Stream and Nabucco, are shown as dashed arrows. Their arrows display the direction of flow as expected by their initiators, namely from East to West.

As to access rights, we assume that outside EU every country has unrestricted control over its pipelines and gas fields. For the regions within the EU, in contrast, we assume that common market rules ensure open third party access to the international high pressure transport pipelines. Hence, regions within the EU cannot derive bargaining power from blocking gas transit.

[11] Preliminary calculations have shown that Algeria, Libya and Spain would hardly be affected by the pipelines we consider in this paper.

[12] Calculated from BP (2010), and IEA (2011).

Temporal scope / network flexibility. We assume a stationary environment with constant demand, technology, production cost, etc. The value of a coalition, nevertheless, depends on the temporal scope of the model. In the short run, the pipeline network is essentially static. The longer one projects into the future, however, the more options to invest in pipes, compressors etc. can be exploited, hence the more flexible the transport system becomes. Here, we adopt a rather short horizon assuming that all pipelines can be made bi-directional, but capacities cannot be increased.[13]

Cost and demand. The details of the numerical calibration are given in a technical appendix. Here we outline only the main idea. We calibrate the model using data for 2009 from IEA (2010) and IEA (2011) on consumption and production in the regions and flows between the regions from November 2009 to October 2010 taken from IEA (2010). We assume piecewise constant transportation and production cost and linear demand functions with the same intercept for all regions. The slope parameters are then estimated as to replicate the consumption in 2009, given our assumption on production and transportation cost.[14] The most important implication of our calibration of demand in relation to cost is that the pipeline system as existing in 2009 is efficient. Given the willingness to pay and the cost of producing gas, it is able to deliver the efficient amount of gas into the different consumption nodes. Thus, none of the expensive pipeline projects considered in this paper can be justified in narrow economic terms. The grand coalition of all players, or a benevolent central planner maximizing welfare, would not invest in any of the projects. Only a subgroup of players might find investment beneficial because it increases their bargaining power at the cost of the others.

This approach also ensures that the main difference between the regions is consumption and how it relates to own production on which we have solid information and not our assumption on demand intercepts on which information is poor. The main difference between producers is production capacity and pipeline connections to the markets, for which data are reasonably good, and not differences in wellhead production cost, which are difficult to estimate.

A critical part of the calibration is the relation of the common demand intercept and

[13] See Hubert and Ikonnikova (2011a) for a more detailed analysis of the static/shortsighted versus the flexible/farsighted approch.

[14] As a result of our assumptions on functional forms, we obtain a quadratic programming problem with linear constraints. Details of the programming code are available in a technical documentation available on request.

production cost, which largely determines the overall surplus from gas trade. The relative shares of different players, measured in percent of total surplus, tend to be rather robust with respect to a change of demand intercept in relation to production cost. However, an increase of demand, keeping production and transportation cost constant, will increase total surplus and as a result more pipeline projects will become strategically viable for given investment cost. In our baseline scenario we assume a difference of 1500 €/tcm between demand intercept and supply cost, yielding a total surplus of app. 167 bn €/a.[15] As previous research has revealed strong incentives to invest for strategic reasons (Hubert and Ikonnikova (2011a)), we use a rather high discount rate of 15% to account for depreciation and the real option nature of the investment when annualizing investment cost or discounting cash flows. In our baseline scenario the resulting present value of total surplus is app. 1112 bn €.

3 Evaluating Network Power with the Shapley Value

Since a player's Shapley value is the weighted sum of his contributions to the values of possible coalitions of other players, any change in bargaining power can be traced back to changes of these contributions. The value of a coalition depends on its access to pipelines, markets and gas fields. Hence, a player can increase the coalition value by providing additional markets, additional supply or by improving connections through transit. In any case, the value of his contribution will depend on how well his resources complement what is already at the coalition's disposal. Adding a market to other markets with no access to production helps little compared to making the same market available to several producers, which are short of customers. Generally speaking, a pipeline benefits a player by improving his access to inputs complementary to his own. It hurts him by improving others players' access to resources, which are substitutable to his own. The effects are complicated by the fact that most countries play multiple roles. While Norway is a pure producer in our model, Russia and the Netherlands are producers as well as a customers. Belarus and Ukraine are main transit regions but they are also customers and Ukraine has own production. Moreover, the role of a player depends on the coalition against which he is evaluated. For example, Turkey is an net-importer when all players are

[15]As usual in cooperative game theory surplus is measured by the difference between economic rent derived from jointly using the resources of the system minus the sum of the economic rents of the individual players acting in autarky (zero-normalized game). Economic rent is given by the sum of the customer rents minus the cost of producing and transporting gas (equation 1).

in the coalition. However, it becomes a transit country for Russian gas in a smaller coalition, for which neither transit through Belarus nor Ukraine is available. Multiple and changing roles make it sometimes difficult to predict what the overall impact of a new pipeline on a player will be.

Given our calibration of demand, the new pipeline projects do not create value. They can only change the power structure. First, we measure the impact of a pipeline on the power structure by the change of the players' percentage shares in the total surplus. Extensive checks have shown that these figures are quite robust with respect to different calibrations of demand and production cost. Second, we convert the differences to absolute values and compare them to our information on investment cost.

3.1 Nord Stream

Nord Stream bypasses the transit countries in the Northern corridor and connects Russia via a twin offshore pipeline through the Baltic Sea to Germany. The project was initiated by Russian Gazprom and the German companies EON-Ruhrgas and Wintershall in 2005 and completed in late 2012 providing a pipeline capacity of 55 bcm/a. We estimate total cost including complementary pipelines in Russia and Germany at app. 15 bn €.[16]

Table 1 exhibits Nord Stream's effect on the players' relative power. For each player we report the Shapley value in percent of the total surplus without and with the pipeline as well as the difference between the two measuring the project's impact. The shares of suppliers reflect their production capacities as well as their dependency on the transit countries to access to consumer markets. Although Russia exports more gas than Norway to the European markets, Norway's surplus without Nord Stream (13.0%) is slightly larger than Russia's (12.8%). Norway has direct access to the European pipeline network while Russia depends on the transit countries, Ukraine and Belarus, to ship gas to the European markets. The shares of Ukraine and Belarus, 9.4% and 6.7%, respectively, reflect their differences in own consumption and production as well as the different transport capacities. The largest European producer, Netherlands obtains 6.0%. The other European re-

[16]Published figures on investment cost have been revised several times. Nord Stream's consortium put the cost at 7.4 bn € (Nord Stream (2013)). However, this figure does not include complementary infrastructure onshore. We assume 5.3 bn € for the Gryazovets-Vyborg line on the Russian side and 1 bn € for OPAL and NEL, the two links on the western shore (EEGA (2010)). These numbers would add to a total cost of 14.7 bn €.

Table 1: Nord Stream's Impact on Bargaining Power

Players[a]	Shapleyvalue [%]		
	without Nord Stream	with Nord Stream	difference
Russia	12.8	15.9	3.0
Ukraine	9.4	6.9	−2.5
Belarus	6.7	5.9	−0.8
Norway	13.	10.5	−2.5
Netherlands	6.	5.	−0.9
UK	1.9	1.9	0.
Center	16.7	18.2	1.5
Center-East	8.9	9.7	0.8
Italy	3.1	3.4	0.4
Poland	1.7	1.8	0.2
France	6.6	7.3	0.7
Belgium	3.1	3.4	0.3
Balkan	0.8	0.8	0.
Turkey	7.6	7.6	0.

[a]Turkmenistan, Iraq, Iran, and Azerbaijan are omitted because they are not affected by the project. For full results see the technical appendix.

gions are net importers, hence their benefits tend to increase with the size of their markets and their dependence on pipeline gas. The figures reflect the gains from trading gas, not the gains from consuming gas. A country whose own production or LNG imports are large enough to cover its demand will gain little from participating in the gas trade even if its gas market is large. The EU as a whole obtains 48.8%, with Center, Center-East and France having the largest shares. Turkey benefits from its consumption of pipeline gas as well as its potential transit position between Balkan and suppliers such as Russia, Iran and Azerbaijan.

The last column in Table 1 presents Nord Stream's impact on the players' surplus in terms of the differences. Russia gains 3.0 percentage points, an increase of app. one fourth of its share in the benchmark case. Increased transport competition mitigates the power of Ukraine and Belarus, which loose 2.5 and 0.8, respectively. The transit countries together lose one fifth of their relative power in the benchmark case. Due to intensified supply competition in the European markets, Norway and Netherlands suffer losses of 2.5 and 0.9 points, respectively. The European players together benefit from increased transport and supply competition, gaining 3.0 points. With 1.5 points Center has the largest increase in the EU.

Nord Stream's total strategic value for the initiators of the consortium, in our model

Center and Russia, is huge. With our baseline assumptions on demand and interest rate, a gain of 4.5 percentage points translates into a gain of 50 bn €, which clearly exceeds the project's cost of 15 bn € and yields a cost benefit ratio of more than 1:3.[17] It is worth stressing that the project is beneficial because it increases the bargaining power of the consortium vis-a-vis other players. Given our calibration of demand, the pipeline is not needed to transport additional gas.[18]

3.2 South Stream

South Stream can be seen as the Black Sea twin of Nord Stream. Russia pushed the project since 2008 to bypass Ukraine when supplying gas to Central and Southwestern Europe. According to the initial planning it consisted of three sections: offshore, northwestern and southwestern.

OS: The offshore section crosses the Black Sea and connects Russia directly to Bulgaria with a capacity of 63 bcm/a. The consortium for the offshore section includes Gazprom of Russia, Eni of Italy and EDF of France. Onshore the pipeline splits in two sections.

NW: The northwestern section runs from Bulgaria to Baumgarten in Austria via Serbia and Hungary with a capacity of 30 bcm/a. The section would greatly improve the connection between central Europe and the Balkans, which currently is only 1.7 bcm/a. The European Commission demanded that the pipeline is subjected to general rules of third party access, which would allow producers such as Norway or Netherlands to use the link in reverse direction, selling gas in the Balkans and even to Turkey. To protect its strong position in South Eastern Europe, Russia pushed for exemption from TPA rules.[19] We asses the impact of South Stream for both scenarios.

[17] For similar results see Hubert and Ikonnikova (2011a), Hubert and Ikonnikova (2011b), and Hubert and Suleymanova (2008)).

[18] After Russia and Germany kicked off the project, the consortium was joined by Gasunie of Netherlands and GDF Suez of France, each with a share of 9%. In view of our results, the participation of Gasunie is surprising, since Netherlands supplies 15% of the EU's consumption and is set to loose from intensified supply competition. Our interpretation is the following. Not being able to prevent Nord Stream, Gasunie joined in anticipation of its changing role in the system. Due to declining reserves, Netherlands will become a net importer around 2025. The country also intends to become a gas hub in Northwestern Europe transiting Russian gas from Germany to UK (Netherlands Ministry of Economic Affairs, Agriculture and Innovation (2010)).

[19] To incentivize new investment in infrastructure projects, the European Commission can grant for so called 'regulatory holidays' (for details see EU (2009)).

SW: The southwestern section connects Bulgaria to Italy via Greece and a short offshore pipeline through Adriatic Sea with a capacity of 10 bcm/a.

The different national sections of the northwestern and southwestern tracks were to be undertaken by a joint-venture between Gazprom and the national gas companies of the respective countries. In November 2012, Gazprom scaled down the project and abandoned the southwestern section.[20] Apparently, Gazprom started to order pipes for South Stream's offshore section in January 2014 although major issues such as the financing, the northwestern section's final route, etc. had not been cleared yet. At that time, first deliveries through the offshore pipeline were planned for late 2015 while full service was scheduled for the end of 2018. However, over the crisis in eastern Ukraine the European Commission's position on third party access hardened and in late 2014 Russia announced that it will abandon the project altogether.

There is substantial uncertainty about the expected cost of the project. Here we take 30 bn €, double the cost of Nord Stream, as a reasonable estimate.[21]

Since Nord Stream became operational, before the construction of South Stream even started, the impact of South Stream has to be assessed for a network which already includes Nord Stream (the right panel of Table 2). Nevertheless, it is instructive to study the counterfactual case first (left panel of Table 2). In favour of Russia we assume that the new pipelines are exempted from European rules third party access. The comparison of left panel's last column in Table 2 and the last column in Table 1 shows that South Stream and Nord Stream alter the power structure in a similar way. It does not matter much whether Russian gas is injected at the German border or in the Balkans if third party access to the existing European

[20] However, a similar pipeline may still be build. The Trans Adriatic Pipeline was selected as a left-over from ambitious plans for the new Southern Corridor. It is scheduled to carry Caspian supplies through a slightly different route, but with the same capacity from the Turkish-Greek border to Southern Italy. UK's BP, Azerbaijan's SOCAR, Norway's Statoil and Belgium's Fluxys are the major members of the project's consortium while France's Total, Germany's E.ON and Switzerland's Axpo have smaller shares (TAP (2013)).

[21] South Stream's consortium did not release transparent estimates of the project's cost. In 2009, Gazprom CEO Alexei Miller mentioned a cost of 8.6 bn € (Rianovosti (2009)), apparently referring to the offshore section only. Since then, figures have increased steadily. In 2010, the aggregate cost of the three sections was supposed to amount to 15.5 bn € (South Stream (2010)). Later, the offshore southwestern section was cancelled, but the project's expected cost remained the same. Referring to the need of upgrading Russia's domestic onshore pipelines, Gazprom raised cost estimates first to 29 bn €, and then to 33.6 bn € (Reuters (2013b), Reuters (2013c)). However, some sources expect that the project's total cost might exceed 56 bn € (Natural Gas Europe (2013)).

Table 2: South Stream's Impact on Bargaining Power

	without Nord Stream		*with Nord Stream*			
	Shapley value [%]	Impact[a] OS, NW, SW	Shapley value [%]	Impact of pipeline sections[b] OS	OS, NW	OS, NW, SW
	NW is exempted from rules on third party access					
Russia	15.8	2.9	16.7	0.3	0.8	0.8
Ukraine	7.	−2.4	6.	−0.3	−0.8	−0.9
Belarus	6.1	−0.7	5.7	0.	−0.2	−0.2
Norway	10.9	−2.1	9.8	0.	−0.5	−0.6
Netherlands	5.2	−0.8	4.8	0.	−0.2	−0.2
UK	1.9	0.	2.	0.	0.	0.
Center	17.9	1.2	18.7	0.	0.4	0.5
Center-East	9.6	0.7	9.9	0.	0.2	0.2
Italy	3.4	0.3	3.5	0.	0.1	0.1
Poland	1.8	0.1	1.9	0.	0.	0.
France	7.2	0.5	7.5	0.	0.1	0.2
Belgium	3.4	0.2	3.5	0.	0.1	0.1
Balkan	1.	0.2	1.	0.2	0.2	0.2
Turkey	7.6	0.	7.6	0.1	0.1	0.1
Iran	0.9	−0.1	0.9	−0.1	−0.1	−0.1
Azerbaijan	0.5	−0.1	0.5	−0.1	−0.1	−0.1
Turkmenistan	0.1	0.	0.1	0.	0.	0.

[a]difference to column 1 table 1

[b]difference to column 2 table 1

network is assured while Russia's dominance in Southeastern Europe remains protected. However, the gains in bargaining power by Russia and its major customers in Europe are somewhat smaller than in the case of Nord Stream while the cost of South Stream would twice as large, which explains why Nord Stream was given precedence.

What are the effects of South Stream once Nord Stream is already in place (the right panel of Table 2)? We start with the impact of the offshore section alone (the column headed 'OS'). The leverage gained is very small, since the gas could only be transported to Balkan, a small market, and Turkey, which is already accessible through Blue Stream. Without substantial onshore investments the offshore section is of little strategic use. If both complementary sections are added the picture, we obtain a scaled down version of the counterfactual case. Russia gains 0.8 points, while Ukraine and Belarus suffer from transit competition and Netherlands and Norway from intensified supply competition. Surprisingly, Center, which does not participate in the consortium obtains the largest gains in the EU. It is also worth noting that the southwestern section has very little impact on the power structure. With Nord Stream and the northwestern section in place, there is already a large amount of spare capacity to transport Russian gas to Central Europe and Italy.[22] Adding a 10 bcm/a link through the Adriatic Sea makes hardly a difference. In view of this finding Gazprom's decision to abandon the southwestern section of South Stream appears rational.

Finally, we again ask whether the project is worth the cost. As an *alternative* to Nord Stream, South Stream would be viable for the broad consortium (Russia, Italy, France, Center-East and Balkan). The gains of 4.6 percentage points translates to 51.1 bn €, which is well above our cost estimate of 30 bn €. At the same time the cost benefit ratio is clearly worse than for Nord Stream. With Nord Stream in place, however, South Stream's impact on bargaining power is much diminished which casts doubts on its strategic viability. In the baseline scenario the consortium gains 1.5 percentage points, amounting to 16.7 bn €, which is only about half of the expected cost. The prospects were to become even worse with the European Commission insisting on free third party access. In this case, Russia's strategic gains from bypassing Ukraine would be largely offset by losses due to increased competition from Dutch and Norwegian gas. The consortium's gains decrease from 1.5 to 1.2 percentage points, while the joint loss of Norway and Netherlands is decreased from -0.8 to -0.4 and Turkey's gains is increased from 0.1 to 0.6.

Russia enjoys a very strong bargaining position in Southeastern Europe. Competing producers such as Norway or Netherlands cannot reach this region since the transport capacities between Balkan and Central Europe are very small (1.7 bcm/a). The northwestern section improves the connection between Center and Balkan; thus, it has a potential to increase competition for Russian gas in Balkan and Turkey. However, we assume that the consortium will seek exemption from the European third party access (TPA) rules, so that Gazprom can prevent its competitors from using the pipeline.

In summary, considered as an alternative, both South Stream and Nord Stream have similar effects on the power structure, since both projects bypass the transit countries and allow Russia to compete more effectively with Norway and Netherlands, without loosing its strong position in the Southeast. However, in the presence of Nord Stream's large capacities, South Stream provides much less additional

[22] The northwestern and offshore sections of South Stream and Nord Stream together increase pipeline capacities between Russia and Europe (except Balkan) from 140 bcm/a to 225 bcm/awhile in 2008 the demand for Russian gas in the area was 108.3 bcm (BP (2009)).

leverage. The gains for the consortium appear too small to compensate for the project's high cost.

3.3 Nabucco

Plans for a new 'Southern Corridor' have been discussed for almost two decades. In the 1990s the US government pushed for a 'Trans-Caspian Pipeline' from Central Asia through the Caspian Sea, Azerbaijan and Georgia into Turkey and further on to Southern Europe. The strategic aim was twofold: to reduce Turkey's and Europe's dependency on Russian gas and to decrease Russia's leverage in the newly independent former Soviet republics. However, US energy companies dragged their feet over uncertain economic prospects. These worsened when Russia started to contract large volumes of gas from Turkmenistan in 2002 at much higher prices than before. With the US' support withering the Europeans took over the initiative. A consortium lead by OMV of Austria and Botas of Turkey (later joined RWE of Germany) coined the new name 'Nabucco' in 2002.[23] The focus of the new project has shifted, in the East from Central Asia towards suppliers in the Middle East and in the West towards extending the pipeline into the heart of Europe. The EU made Nabucco a major strategic project under its Trans-European Energy Networks (TEN-E). The European Bank for Reconstruction and Development, the European Investment Bank, and IFC (a member of the World Bank Group) tentatively earmarked 4 bn € for funding.[24] However, Nabucco had been postponed several times due to lack of supply commitments as well as its high investment cost. Nabucco's consortium downsized its project's range and capacity in May 2012. Called Nabucco-West, the new project would cover only the European section of the initial project and have one third of its capacity. In June 2013, the project was abandoned after Trans Adriatic was selected to carry Caspian supplies from Turkey to the Continental European markets.[25]

Here we consider the initial proposal for Nabucco, right after the last Russia-Ukraine gas dispute in January 2009. For the assessment of the pipeline's impact it is useful to divide it into four sections: Trans-Caspian, the eastern section, the central section and the western section.

[23]The consortium also included companies from transit countries: Bulgargaz of Bulgaria, Transgaz of Romania, and MOL of Hungary. In 2013, GDF Suez of France replaced RWE of Germany.

[24]For the position of the EU see EU (2006), EC (2007), and EurActiv (2011).

[25]For details on the competition between Nabucco-West and Trans Adriatic see Cobanli (2014).

TC: Trans-Caspian, for the purpose of this paper, is narrowly defined as the off-shore pipeline between Turkmenistan and Azerbaijan with a capacity of 30 bcm/a. For a while RWE of Germany and OMV of Austria, both also members of Nabucco's overall consortium, had the initiative, but at the time of writing European companies have lost their interest in the project. We estimate the cost at app. 5 bn €.[26]

ES: The Eastern section consists of several pipelines connecting Turkey with potential suppliers, Azerbaijan, Iran and Iraq. We include Iran even though at present this appears to be very unlikely for political reasons. The country has the second largest gas reserves in the world and Turkey already imports gas from Iran. Even though none of the parties involved in the project will openly admit, Iran is an important potential supplier for Nabucco. For the calculation we assume that the existing pipelines from Iran and Azerbaijan are enlarged by 15 and 45 bcm/a, respectively while a new feeder pipeline of 10 bcm/a connects Iraq to Eastern Turkey. The section from Turkey's East to the West is extended by 30 bcm/a. We estimate the total cost of these investments at app. 14.5 bn €.[27]

CS: The central section connects western Turkey with Balkan. It is important to note that existing pipelines with a capacity of app. 16 bcm/a are currently used to pump Russian gas into the opposite direction, from Balkan into Turkey. Nabucco plans to reverse the direction of the flow through the central section and expand its capacity by 30 bcm/a to an estimated total of 46 bcm/a. Based on distance and comparable projects we estimate the cost of the central section at 2 bn €.

WS: The western section connects Balkan to Center with a planned capacity of 30 bcm/a. Current connection with 1.7 bcm/a are used to pump gas into the opposite direction. The section is analogous to South Stream's NW section. The Nabucco consortium rallied political support in the EU arguing that it would

[26]There are also older estimates putting the figure slightly lower at 3.7 bn € (Jamestown Foundation (2006)).

[27]Again there is little solid information on the different sections. TANAP, a pipeline connecting Turkey's Eastern and Western parts with half of Nabucco's capacity, is expected to cost 5.9-7.4 bn € (Reuters (2013a)). Accounting for some economics of scale we estimate Nabucco's section at 10 bn €. Expanding the capacity of the South Caucasus Pipeline connecting Azerbaijan to Turkey from by 16 bcm/a is estimated at 2.2 bn € (Jamestown Foundation (2014)). Based on distance, we estimate the cost for connections to Iran and Iraq at another 2 bn €.

help to integrate the region to other European markets by eliminating the bottleneck. The pipeline is designed for bidirectional use and shall be open for gas transport for all interested parties. So, we assume that every player has access to Nabucco's western section, whereas we assumed exclusive access for South Stream's NW section. Based on distance we estimated the cost at 3.5 bn €.

Taken together we obtain a total cost for the project of 25 bn €, or 20 bn € if TC excluded.[28] These figures are in the upper range of estimates, but on the other hand we do not account for the cost of developing the fields to produce the gas in Azerbaijan, Iraq and Iran.

It is worth emphasizing that Nabucco's commercial prospects are built on reversing flows in the present network. Currently, gas flows in small quantities from Center to Balkan and in substantial quantities from Balkan to Turkey. Considering the pipeline in isolation, it is easy to underestimate how much additional gas in Turkey is needed to justify its capacity. Let's consider the central section of Nabucco. First, some 10 bcm/a are needed to substitute for the current flow from Balkan to Turkey. Second, existing capacities can be made bidirectional at modest cost to pump some 16 bcm/a from Turkey to Balkan without new pipelines. Third, 30 bcm/a are needed to fill the additional pipeline capacities. In total it would require app. 55 bcm/a additional gas in Turkey to make fully use of the new pipeline. As with Nord Stream and South Stream, many observers raised serious doubts as to whether such quantities can be provided anytime soon. We, rather optimistically, assume that Iraq, Azerbaijan and Central Asia could supply an additional 56 bcm/a and Iran another 15 bcm/a compared to the output in 2009.

In Table 3 we report selected results for the strategic impact of Nabucco. We focus on a scenario where Nord Stream is already completed and then Nabucco is added to the system (left panel). The first column shows the Shapley values for the completion of all sections in percent of the total surplus. It should be compared to column 2 in Table 1. The difference between the two, i.e., the impact of the whole project, is shown in column 4 under the header 'TC, ES, CS, WS'.

By bringing in new suppliers in the East and connecting them with the center of Europe's network Nabucco weakens the bargaining power of all established suppliers. With a loss of 3.1 points Russia is particularly hard hit. The lion's share of the benefits, however, accrues to Turkey, which gains 2.8 points and Azerbaijan gaining 0.7

[28] As usual, initial cost estimates have been much lower, as low as 7.9 bn € and then kept on rising to 14 bn € (New York Times (2011)) and 24-26 bn € (BP in Natural Gas Europe (2011)).

Table 3: Nabucco's Impact on Bargaining Power

	without South Stream				*with South Stream*	
	Shapley value [%]	Impact of pipeline sections[a] TC, ES	WS	TC, ES, CS, WS	Shapley value [%]	Impact[b] TC, ES, CS, WS
Russia	12.8	−2.3	−0.1	−3.1	13.4	−3.3
Ukraine	6.2	0.	−0.5	−0.7	5.7	−0.4
Belarus	5.9	0.	0.	0.	5.7	0.
Norway	9.7	−0.4	0.3	−0.8	9.1	−0.7
Netherlands	4.7	−0.2	0.1	−0.3	4.5	−0.3
UK	1.9	0.	0.	−0.1	1.9	−0.1
Center	18.5	0.1	−0.1	0.3	19.	0.3
Center-East	9.9	0.	0.	0.2	10.1	0.2
Italy	3.5	0.	0.	0.	3.6	0.
Poland	1.9	0.	0.	0.	1.9	0.
France	7.4	0.	0.	0.1	7.6	0.1
Belgium	3.5	0.	0.	0.1	3.5	0.1
Balkan	1.1	0.1	0.2	0.2	1.1	0.1
Turkey	10.4	1.7	0.6	2.8	10.2	2.6
Iraq	0.4	0.4	0.	0.4	0.4	0.4
Iran	1.	−0.1	−0.2	0.	0.9	0.1
Azerbaijan	1.2	0.4	−0.1	0.7	1.1	0.7
Turkmenistan	0.3	0.	0.	0.1	0.3	0.1

[a]difference to column 2 table 1

[b]difference to column 3 table 2

points while the impact on the regions within the EU is surprisingly small. Balkan and Center gain 0.2 and 0.3 points, respectively. Nabucco and the Trans Caspian Pipeline also do little to improve the position of Central Asian producers, here represented by Turkmenistan. We attribute this to the fact, that the new supply route has several transit countries of which Azerbaijan is also a competing producer.

In our baseline scenario, these percentage points amount to a gain of 7.8 bn € for the European members of the Nabucco consortium, 31.1 bn € for Turkey, and another 7.8 bn € for Azerbaijan. Comparing these figures to the cost of app. 25 bn € (incl. TC 30 bn €), it is not surprising that European consortium failed to fly, while Turkey and Azerbaijan took the initiative with some sections of Nabucco.

It is also instructive to consider the effect of the different sections separately. Suppose only the sections in the East are built (TC and ES), which connect Turkey to the producers in the Middle East and Central Asia (second column). As increased supply competition harms other producers, in particular Russia, it benefits Turkey and to a much lesser extend Balkan. The effects on other EU regions are negligible, which is not surprising in view of the bottleneck between Balkan and the rest of Europe. Taken altogether, the pipelines in the East appear to have little effect on the power of the various potential suppliers in the region, such as Iran, Iraq, and Turkmensitan, because they can be played off against each other.

Next, we consider only the western section (WS) connecting Balkan and Central Europe (column three). This pipeline with a capacity of 30 bcm/a will hardly be used. Nevertheless, the option to move gas from the Northwest to the Southeast intensifies competition for customers in the Southeast which benefits Turkey and Balkan as well as producers in Northwest at the cost of Russia and producers in the Middle East and Caspian region. Some regions in the EU, such as Center and Center-East are slightly harmed from increased demand competition since Norway and Netherlands will gain better access to other markets. Again the effect on the EU as a group is negligible. With a total gain of 13.3 bn € and cost of 3.5 bn € the section would be a viable option for producers in Northwest together with Turkey and Balkan. But it is difficult to envisage how such diverse players can implement a project, which has little potential to generate direct revenues. The ‘returns of the investment’ come only indirectly with Turkey paying less for gas from Russia and Iran and Central Europe paying more for gas from Norway and Netherlands.

Finally, we return to the perception that South Stream and Nabucco are competing projects and the concern that the former might preempt investment into the latter. In the right panel of Table 3 we show the strategic impact of Nabucco in a situation where South Stream and Nord Stream will be fully operational. Comparing the fourth column of the left and the second column of the right panel, we find very little difference. Even if fully implemented, South Stream has almost no impact on the strategic viability of Nabucco.

3.4 Evaluating Network Power with the Core & Nucleolus

In the previous sections we considered a number of cooperative games, one for each configuration of the gas network. All these games had a non-empty core, but the Shapley value was never in the core of the respective game. The same is also true for the games we analyzed for our robustness checks. This observation raises the question, whether we obtain very different results for the strategic value of pipelines if we solve the network game with the core or related concepts.

Adding a pipeline to the system will increase the value of some coalitions. Other coalitions will remain unaffected, but for no coalition the value will be decreased. As a result, the core will be compressed. But will the pipelines change the core systematically to the favor of the same players as they do for the Shapley value? As the core is a set, the answer will depend on which element in the core we select. Here, we consider the nucleolus which is in the core and can be considered as the lexicographical center of the game.

We computed the equivalent of tables 1-3 for the nucleolus to find results, which differ drastically from the previous ones. If power is measured with the nucleolus, none of the three projects has any strategic value at all — essentially because they have no significant impact on bargaining power. We abstain from printing the equivalent of tables 1-3 here, as all, but the few instances we discuss in the text below, are equal to zero when rounded to the first decimal. The tables are available in the appendix.

We start again with Nord Stream. There is only one country, which is slightly affected by this huge project: Russia. But surprisingly its power is *reduced* by 0.1 percentage points even though the project will (weakly) increase the value of coalitions which include this country.[29] For all other players the impact of Nord Stream is minute and lost when rounding to the first decimal. For South Stream we find no effect whatsoever, even if the project is considered as an alternative to Nord

[29] It is well known that the nucleolus is not monotone, i.e., a player's payoff can decrease even if its contributions to coalitions weakly increase. Our result for Nord Stream prove that this is not a theoretical oddity.

Stream. Nabucco has some minor effects. For the Non-European players the effects go in the same direction as under the Shapley value, but are smaller by order of magnitude. Russia and Ukraine lose 0.2 and 0.1 percentage points, respectively while Turkey gains 0.3 percentage points. Balkan, Azerbaijan and Iran benefit 0.1 percentage points each from the project. However, the European players, such as Center, Center-East and France, suffer by 0.1 percentage points each although coalitions containing them will gain from diversity of supplies. The remaining countries are not affected. Overall, the impacts of the pipelines on the the power structure are smaller by orders of magnitude than the cost of these projects. As a result, no project had any strategic value if the players would assess network power with the nucleolus.

We also computed the minimum and the maximum a player can obtain in the core. For most players these two values define a narrow range around the nucleolus. In this sense, the nucleolus gives a reasonably precise estimate of the possible effects of a pipeline to a players payoff in the core. We take Russia and Nord Stream as an example. The pipeline *decreases* both, Russia's minimal and maximal payoff in the core by a small amount — as it does for nucleolus. If we go to the extreme and pick the smallest possible value in the core without Nord Stream and the largest possible value with Nord Stream, the small loss would turn into a small gain. However this gain would still be only a tenth of what Russia gains under the Shapley value — not enough to make Nord Stream viable. Since similar claims can be made for all other important players, our results for the pipelines' impacts under nucleolus yield a good picture for any other possible solution in the core.

4 Concluding Remarks

We analyzed the strategic impact of three large pipeline projects, Nord Stream, South Stream and Nabucco. Starting with a disaggregated quantitative model of the Eurasian network for natural gas, consisting of its major producers, customers and trunk-pipelines, we calculate the value function to characterize the interdependencies among the main actors in the current system. We solve the game with the Shapley Value, and the nucleolus as alternative indexes for the power of the different players. Adding a new pipeline changes the network, hence the value function and as a result the power index. We identified those players who are set to gain in bargaining power from a specific pipeline link and those who will be harmed. Moreover, we obtain quantitative estimates of the size of these effects, which can be compared to the cost of the link.

For the Shapley value we obtain intuitive results, which help to make sense of major developments in the industry since 2005. If considered as an alternative, both South Stream and Nord Stream have very similar effects on the power structure in the Eurasian network for natural gas. The pipelines bypass the transit countries Belarus and Ukraine and allow Russia to compete more effectively with Norway and Netherlands. Nord Stream's strategic impact can hardly be overstated. For the initiators of Nord Stream, Russia and Germany, the gains in bargaining power clearly justify the cost of investment. Russia had a very rocky relationship with the transit countries Belarus and Ukraine throughout the nineties and several attempts for a long-term solution covering transit fees, prices for gas imports and control of trunk-pipes have failed. In view of our results, it is not surprising that more cost efficient pipeline projects such as Yamal II through Belarus or the modernization of the Ukrainian system, have been abandoned in favor of the expensive direct offshore link.

The main beneficiaries of South Stream are Russia, Germany and some Central European countries. However, once Nord Stream's large capacities become operational, South Stream's additional leverage is much reduced, and the gain in power hardly compensates for the high cost. Not surprisingly, the project has been repeatedly delayed and if realized at all, it will be a scaled down version of the original plan.

Nabucco opens a southern corridor through Turkey connecting Europe to new suppliers in the Middle East and the Caspian region. It also offers a new option to the producers in Central Asia, which currently ship gas through Russia. Initiated in 2009 the EU made Nabucco a major strategic project under its Trans-European Energy Networks (TEN-E) and substantial public funds have been earmarked for the project. In view of our results, this policy is difficult to rationalize. The project has large potential to decrease Russia's power, but the benefits would accrue mainly to Turkey, which could diversify its gas imports and become a major potential hub. The gains for the players in the EU, in contrast, are negligible. Again, the empirical evidence supports this assessment. The original consortium has disintegrated because it failed to command enough support from private investors such as Austrian OMV and German RWE. Meanwhile, Turkey, the player who has to gain most according to our analysis, took the initiative. It agreed with Azerbaijan on a Trans-Anatolian pipeline from Shah Deniz gas field to Turkey's West, which corresponds to the eastern sections of Nabucco but has half of its capacity, 16 bcm/a (Businessweek (2011)).

If we assess network power with the nucleolus, however, we obtain results which appear strikingly counterintuitive and are difficult to reconcile with observed investments in Nord Stream. Under the nucleolus, none of these pipelines has any strategic value at all. The reward in terms of increased bargaining power is by order of magnitude smaller than the investment cost.

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A Appendix 1

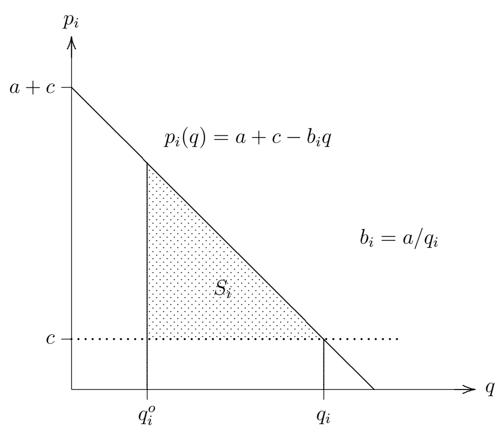
A.1 Calibration

This appendix describes 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, p_i and T_{ij} have to be determined such that f^*_{ij} are reasonably close to observed consumption and flows. As it is assumed that the players cooperate effectively, they will make efficient use of the existing network. Hence, for each player the marginal willingness to pay for gas, $p_i(q)$ will be equal to the local marginal cost of supplying gas, i.e., the nodal cost $c_i(q)$, which takes into account the physical constraints of the system. This feature is used 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, the small differences among local costs are neglected, and a common constant supply cost c is assumed. When the program is solved for the grand coalition, none of the links within Europe are capacity constrained. So, nodal costs differ only by the variable transportation cost between connected nodes which are small.

Figure 2: The Surplus (S_i)



Each consumption node's willingness to pay for gas is represented with a linear inverse demand function. To reduce the number of parameters, for all consumption nodes the same intercept $a + c$ is assumed. Efficiency requires $p_i(q) = a + c - b_i q = c$ for each consumption node i. The slope parameters b_i are then calibrated as to replicate the consumption in 2009: $b_i = a/q_i$, where q_i is the consumption of gas in the consumption node i. As illus-

Table 4: Consumption

Consumption nodes	Consumption[a] [bcm/a] q_i	Slope Baseline $a = 1500$ b_i	Slope Low surplus $a = 500$ b_i	Needed for access
AzerbaijanC	10,	150	50	Azerbaijan
BelarusC	17.9	83.9	28.	Belarus
IranC	136.5	11.	3.7	Iran
KazakhstanC	22.9	65.6	21.9	Turkmenistan[b]
RussiaC	426.4	3.5	1.2	Russia
TurkeyC	36.4	41.2	13.7	Turkey
TurkmenistanC	18.6	80.6	26.9	Turkmenistan
UkraineC	53.3	28.1	9.4	Ukraine
UzbekistanC	51.8	29.	9.7	Turkmenistan
BalkanC	20.2	74.3	24.8	Balkan
BelgiumC	16.9	88.9	29.6	Belgium
CenterC	104.6	14.3	4.8	Center
Center-EastC	41.4	36.2	12.1	Center-East
FranceC	44.1	34.	11.3	France
ItalyC	75.6	19.8	6.6	Italy
NetherlandsC	48.3	31.1	10.4	Netherlands
PolandC	16.	93.8	31.3	Poland
UKC	90.5	16.6	5.5	UK

[a]Data for consumption in 2009 are compiled from IEA (2010) and IEA (2011).

[b]To reduce the number of players, Turkmenistan stands for Kazakhstan, Uzbekistan, and itself.

trated in Figure 2, the surplus, which a player obtains from participating in the trade of pipeline gas, depends on three parameters: the difference between the demand intercept and the common supply cost a, its consumption in the base year q_i, and its indigenous production q_i^o. The common supply cost c acts as a shift parameter, which does not affect the surplus.

A change of a, with b_i being adjusted, affects all players proportionally. Such a change has little impact on the *relative* Shapley value (measured in percent of the total), hence, will have little effect on the relative index for bargaining power. However, a determines the absolute size of the surplus and thus, the *absolute* Shapley value, which is of relevance if the changes in bargaining power are compared to the cost of a pipeline project. It is difficult to support any assumption for a by hard data. Obviously, it will depend a lot on how much time customers are given to substitute to other sources of energy. Making a bold assumption, in the baseline variant a is set equal to 1500 mn €/bcm yielding a total surplus from consuming gas of 949.9 bn €/a. To check the robustness of the results, a ‘low-surplus’ scenario with $a = 500$ mn €/bcm is considered as well. In this case, the total surplus decreases to 334.3 bn €/a. Table 4 presents the resulting values of the slope parameter b_i depending on a. All quantities are quoted in bcm/a. All prices or costs are quoted in mn €/bcm, giving the same figure as the more common €/tcm.

The parameter c acts as a shift parameter for the demand system and supposed to reflect the typical production and the transportation cost. Accordingly, it is decomposed as $c = c^P + \bar{c}^T$, where c^P reflects a common production cost parameter and $\bar{c}^T$ an adjustment made for typical transportation cost. These values determine the patterns of production and transport which are presented next.

Production

Table 5 presents the players’ production capacities, production volumes as well as production costs. The production volumes in 2009 are collected from IEA (2010) and IEA (2011). For the players except Russia and Turkmenistan the production capacities are assumed equal to their production volumes in 2009.

The differences in the production cost of existing fields are small compared to differences in the cost of developing new fields. Since meaningful information on wellhead production cost is difficult to obtain, a common supply cost parameter c^P is introduced. In accordance with Table 13.6 in IEA (2009), Δ_i accounts for regional differences in wellhead production cost and adjusts c^P for each player. For the players, who are net importers, cost of using their indigenous production is ignored. Since it is more difficult to produce at maximal capacity k_{ij}, production cost is assumed to be piecewise linear : $T_{ij}(f) = (c^P + \Delta_i)(\min[f, 0.75 * k_{ij}] + 1.2 \max[f - 0.75 * k_{ij}, 0])$. These adjustments help to get more realistic flows for the network, but have only a negligible impact on the 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 $c^P = 20$ mn €/bcm.

Transport

The total cost of transporting gas consists of, in principle, operating cost and capacity cost. Since capacity costs of existing pipelines are sunk, they are not taken into account. This simplification is based on the assumption that bargaining among rational players should not be influenced by sunk cost. The operating

Table 5: Pipeline network: production

Links from	Links to	Capacity k_{ij} [bcm/a]	Flow [bcm/a]	Cost[a] $c_p + \Delta_i$ [€/tcm]	needed for access
Net Exporters					
AzerbaijanP	Azerbaijan	14.9[b]	14.9	$c_p - 5$	Azerbaijan
IranP	Iran	137.4[c]	137.4	$c_p - 16$	Iran
IraqP	Iraq	1.1[d]	1.1	$c_p - 8$	Iraq
KazakhstanP	Kazakhstan	27.2	27.2	$c_p + 1$	Turkmenistan[e]
NorwayP	Norway	99.4	99.4	$c_p - 7$	Norway
RussiaP	Russia	650.8	550.5	c_p	Russia
TurkmenistanP	Turkmenistan	70.9	38.3	$c_p + 3.4$	Turkmenistan
UzbekistanP	Uzbekistan	65.6	65.6	$c_p + 1$	Turkmenistan
NetherlandsP	Netherlands	78.7	78.7	$c_p - 4.4$	Netherlands
Net Importers					
BalkanP	Balkan	10.8	10.8	0.	Balkan
BelarusP	Belarus	0.2	0.2	0.	Belarus
BelgiumP	Belgium	0.	0.	0.	Belgium
CenterP	Center	23.7	23.7	0.	Center
Center-EastP	Center-East	4.8	4.8	0.	Center-East
FranceP	France	0.9	0.9	0.	France
ItalyP	Italy	8.1	8.1	0.	Italy
PolandP	Poland	5.8	5.8	0.	Poland
TurkeyP	Turkey	0.7	0.7	0.	Turkey
UKP	UK	62.1	62.1	0.	UK
UkraineP	Ukraine	21.9	21.9	0.	Ukraine

[a]The global parameter c_p is set equal to 20. Production cost of the players, who are net importers, is set equal to zero. The unit cost is given for flows up to 75% of the capacity. For the remaining 25% of capacity the numbers are increased by 20%.

[b]The Shah Deniz II field will increase Azerbaijan's current production capacity by 16 bcm/a and serve Nabucco.

[c]Investment in Iran's South Pars field will supply an additional 15 bcm/a to Nabucco.

[d]Northern Iraqi fields will produce an other 10 bcm/a to fill Nabucco's large capacities.

[e]To reduce the number of players, Turkmenistan stands for Kazakhstan, Uzbekistan and itself.

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. The operating cost is represented as a piecewise linear function: $T_{ij}(f) = c^T_{ij} * (\min[f, 0.75 * k_{ij}] + 1.2 * \max[f - 0.75 * k_{ij}, 0])$, where k_{ij} denotes maximal capacity. Per unit transportation costs are constant, but only up to three quarter of the pipe capacity and increased by 20% for the remaining quarter. Capacities of the pipelines linking the players' transit nodes are collected from ENTSOG (2010) and public sources. Flows in 2009 are compiled from IEA (2010) and IEA (2011). Capacities of the pipelines which are connected to areas outside of the regional scope are limited to flows through them in 2009. The pipeline capacities and the flows through them are presented in the first two columns of Tables 6 and 7.

To calculate the link specific cost parameter c^T_{ij}, for onshore pipelines universal operating cost of 0.3 mn €/bcm/100km is assumed. For offshore pipelines operating cost is 50% higher to account for higher pressure and increased difficulties of maintenance. These coefficients are then multiplied with the distance between the nodes to obtain the link specific operating cost as shown in column 3 of Table 6 and 7.

Having specified the production cost by c^P and Δ_i, as well as the link specific transportation cost by c^T_{ij}, the only free parameter is the 'typical' transport cost $\bar{c}^T$. To determine a value, the optimization program (1) is run for the grand coalition to find that $\bar{c}^T = 19$ mn €/bcm yields a solution f^*_{ij} which closely replicates the empirical data on consumption and flows in the system.

Table 6: Pipeline network A

Links from	Links to	Capacity [bcm/a]	Flow [bcm/a]	Operation[a] Cost: c^T_{ij} [mn €/bcm]	Needed for access
Transit outside EU					
Azerbaijan	RussiaS	13.	0.	3.8	Azerbaijan, Russia
Azerbaijan	TurkeyE	7.	4.5	2.4	Azerbaijan, Turkey
Iran	TurkeyE	13.7	7.2	1.2	Iran, Turkey
Iraq	TurkeyE	0.	0.	1.7	Iran, Turkey
Kazakhstan	Russia	49.	0.	5.1	Russia, Turkmenistan[b]
Kazakhstan	RussiaS	49.	32.3	3.6	Russia, Turkmenistan
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.	Russia, Ukraine
RussiaN	Center	0.	0.	6.9	Russia
RussiaS	Turkey	16.	8.9	4.8	Russia, Turkey
RussiaS	UkraineE	200.	24.6	1.2	Russia, Ukraine
TurkeyE	Turkey	20.	11.8	2.4	Turkey
Turkmenistan	Iran	20.	5.8	2.3	Turkmenistan, Iran
Turkmenistan	Kazakhstan	5.	0.	2.7	Turkmenistan
Turkmenistan	Uzbekistan	44.	10.7	1.7	Turkmenistan
UkraineE	Ukraine	122.	95.1	2.5	Ukraine
Uzbekistan	Kazakhstan	44.	22.5	1.8	Turkmenistan

[a] The unit cost is given for flows up to 75% of the capacity. For the remaining 25% of capacity the numbers are increased by 20%.

[b] To reduce the number of players, Turkmenistan stands for Kazakhstan, Uzbekistan and itself.

Table 7: Pipeline network B

Links from	Links to	Capacity [bcm/a]	Flow [bcm/a]	Operation[a] Cost: c^T_{ij} [mn €/bcm]	Needed for access
Transit into (out of) EU					
Balkan	Turkey	16.3	8.9	1.8	Turkey
Belarus	Poland	33.	31.3	1.4	Belarus
Norway	Belgium	15.	12.2	5.2	Norway
Norway	France	18.2	15.	5.9	Norway
Norway	Center	46.	29.2	5.2	Norway
Norway	UK	46.4	24.	4.9	Norway
UkraineE	Balkan	31.3	16.5	3.4	Ukraine
Ukraine	Center-East	105.8	77.	1.9	Ukraine
Ukraine	Poland	3.2	3.2	1.2	Ukraine
Transit within EU					
Belgium	France	30.	14.9	0.8	Free third party access to transit pipelines within the EU
Belgium	Center	26.	1.	0.6	
Center-East	Balkan	1.7	1.	3.3	
Center-East	Center	77.8	18.4	2.4	
Center-East	Italy	37.	21.3	2.7	
Center	France	28.	4.3	1.4	
Center	Italy	20.2	9.1	3.5	
Netherlands	Belgium	53.	10.7	0.5	
Netherlands	Center	80.	11.7	0.6	
Netherlands	UK	15.3	7.	1.	
Poland	Center	31.4	24.4	3.2	
UK	Belgium	25.5	7.5	1.5	
Out of Regional Scope					
Algeria	Italy	25.4	25.4	6.2	Italy
France	Iberia	1.1	1.1	3.2	France
Libya	Italy	9.	9.	4.7	Italy

[a] The unit cost is given for flows up to 75% of the capacity. For the remaining 25% of capacity the numbers are increased by 20%.

LNG

In the model the LNG gas is considered as nonstrategic since a single LNG exporter's market share in the Eurasian gas trade is small relative to the market power of the suppliers of the pipeline gas. Incorporation of the global LNG market into a cooperative game would be challenging. Since the LNG gas is a common source so that actions of players outside of the considered coalition would have to be taken into account. They will form alternative coalitions which may tap the LNG market and change the availability of the LNG supplies. Since the focus of the paper is on pipeline gas, the LNG market is not modeled explicitly.

The LNG regasification plants, also called terminals, are represented as LNG

Table 8: Pipeline network: LNG regasification plants

Links		Capacity	Flow	Cost[a]	needed
				$c_p + \Delta_i$	for access
from	to	[bcm/a]	[bcm/a]	[mn €/bcm]	
BalkanLNG	Balkan	0.8	0.8	$2c_p$	Balkan
BelgiumLNG	Belgium	3.	3.	$2c_p$	Belgium
FranceLNG	France	10.1	10.1	$2c_p$	France
CenterLNG	Center	0.	0.	$2c_p$	Center
ItalyLNG	Italy	2.9	2.9	$2c_p$	Italy
NetherlandsLNG	Netherlands	0.	0.	$2c_p$	Netherlands
PolandLNG	Poland	0.	0.	$2c_p$	Poland
TurkeyLNG	Turkey	6.1	6.1	$2c_p$	Turkey
UKLNG	UK	10.1	10.1	$2c_p$	UK

[a]The global parameter c_p is set equal to 20. The unit cost is given for flows up to 75% of the capacity. For the remaining 25% of capacity the numbers are increased by 20%.

links with capacities limited to flow in 2009. The LNG regasification capacities and imports through them are compiled from GIE (2010), IEA (2010) and IEA (2011). Comparing Tables 13.5 and 13.6 in IEA (2009), the total cost (sum of production, liquefaction, transportation and regasification costs) of gas which is imported through the LNG terminals is assumed as $2c^P$. Similar to the production and transportation costs, total cost of LNG is assumed to be piecewise linear : $T_{ij}(f) = 2c^P(\min[f, 0.75 * k_{ij}] + 1.2 \max[f - 0.75 * k_{ij}, 0])$. Figures for the LNG links are given in Table 8.

New Projects

Information about the pipeline projects is obtained from various public sources. Cost estimates of the project consortia are supplemented by own estimates if figures are unavailable, outdated or subject to review. A rather high discount rate of 15% is used 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. Table 9 collects the parameters for the new pipelines.

Table 9: Pipeline network: new pipelines

Links from	Links to	Capacity[a] old + new [bcm/a]	Flow[b] [bcm/a]	Operation Cost [€/tcm]	Capacity Cost [bn €]	required for for access
Nord Stream						
RussiaN	Center	0 + 55	0	6.9	12	Russia
South Stream						
RussiaS	Balkan	0 + 63	0	5.6	8.6	Russia
Center-EastSS	BalkanSS[c]	1.7 + 30	0.	3.3	3.5	Russia
Balkan	Italy	0 + 10	0	3.9	3.4	Russia
Nabucco						
Turkmenistan	Azerbaijan[d]	0 + 30	0	0.9	2.3	Azerbaijan, Turkmenistan
Azerbaijan	TurkeyE	8.8 + 45	4.5	2.4	7.5	Azerbaijan, Turkey
Iran	TurkeyE	13.7 + 15	7.2	1.2	5.4	Iran, Turkey
Iraq	TurkeyE	0 + 10	0	1.7	1.2	Iraq, Turkey
TurkeyE	Turkey	20 + 30	11.8	2.4	2.5	Turkey
Balkan	Turkey[e]	16.3 + 30	8.9	1.8	1.9	Turkey
Center-East	Balkan[c]	1.7 + 30	1	3.3	3.5	-

[a] Existing capacity as compiled from ENTSOG (2010) and public sources + planned capacity.

[b] Data are compiled from IEA (2010) and IEA (2011).

[c] Currently gas flows from Center-East to Balkan. The projects plan to revert the flow.

[d] This part of the project is referred to as Trans-Caspian.

[e] Currently gas flows from Balkan to Turkey. The project plans to revert the flow.

A.2 Tables for the Nucleolus

The following tables (10 to 12) give the results for the nucleolus. They correspond to tables 1 to 3 in the main text. The results are discussed in section 3.4.

Table 10: Nord Stream, Nucleolus

Players	Nucleolus [%] without Nord Stream	with Nord Stream	difference
Russia	0.8	0.8	−0.1
Ukraine	8.5	8.4	0.
Belarus	7.9	7.9	0.
Norway	1.2	1.2	0.
Netherlands	0.4	0.4	0.
UK	1.7	1.7	0.
Center	28.1	28.2	0.
Center-East	14.5	14.5	0.
Italy	5.4	5.4	0.
Poland	2.9	2.9	0.
France	11.2	11.2	0.
Belgium	5.1	5.1	0.
Balkan	1.5	1.5	0.
Turkey	10.8	10.8	0.
Iraq	0.	0.	0.
Iran	0.	0.	0.
Azerbaijan	0.	0.	0.
Turkmenistan	0.	0.	0.

Table 11: South Stream, Nucleolus

	without Nord Stream		*with Nord Stream*			
	Nucleolus [%]	Impact[a] OS, NW, SW	Nucleolus [%]	Impact of pipeline sections[b] OS	OS, NW	OS, NW, SW
Russia	0.8	0.	0.8	0.	0.	0.
Ukraine	8.4	0.	8.4	0.	0.	0.
Belarus	7.9	0.	7.9	0.	0.	0.
Norway	1.2	0.	1.2	0.	0.	0.
Netherlands	0.4	0.	0.4	0.	0.	0.
UK	1.7	0.	1.7	0.	0.	0.
Center	28.1	0.	28.2	0.	0.	0.
Center-East	14.5	0.	14.5	0.	0.	0.
Italy	5.4	0.	5.4	0.	0.	0.
Poland	2.9	0.	2.9	0.	0.	0.
France	11.2	0.	11.2	0.	0.	0.
Belgium	5.1	0.	5.1	0.	0.	0.
Balkan	1.5	0.	1.6	0.	0.	0.
Turkey	10.8	0.	10.8	0.	0.	0.
Iran	0.	0.	0.	0.	0.	0.
Azerbaijan	0.	0.	0.	0.	0.	0.
Turkmenistan	0.	0.	0.	0.	0.	0.

[a] difference to column 1 table 10

[b] difference to column 2 table 10

Table 12: Nabucco, Nucleolus

	without South Stream				*with South Stream*	
	Nucleolus [%]	Impact of pipeline sections[a] TC, ES	WS	TC, ES, CS, WS	Nucleolus [%]	Impact[b] TC, ES, CS, WS
Russia	0.6	−0.2	−0.1	−0.2	0.6	−0.2
Ukraine	8.3	−0.1	0.	−0.1	8.3	−0.1
Belarus	7.9	0.	0.	0.	7.9	0.
Norway	1.2	0.	0.	0.	1.2	0.
Netherlands	0.4	0.	0.	0.	0.4	0.
UK	1.7	0.	0.	0.	1.7	0.
Center	28.	−0.1	0.	−0.1	28.	−0.1
Center-East	14.5	−0.1	0.	−0.1	14.4	−0.1
Italy	5.4	0.	0.	0.	5.4	0.
Poland	2.9	0.	0.	0.	2.9	0.
France	11.1	0.	0.	−0.1	11.1	−0.1
Belgium	5.1	0.	0.	0.	5.1	0.
Balkan	1.6	0.1	0.1	0.1	1.6	0.1
Turkey	11.1	0.3	0.1	0.3	11.1	0.3
Iraq	0.	0.	0.	0.	0.	0.
Iran	0.1	0.1	0.	0.1	0.1	0.1
Azerbaijan	0.1	0.1	0.	0.1	0.1	0.1
Turkmenistan	0.	0.	0.	0.	0.	0.

[a]difference to column 2 table 10

[b]difference to column 3 table 11

A.3 Robustness

The results reported in the main text depend on a number of parameter assumptions and we will briefly discuss, how robust they are. All tables are given in appendix A.4.

Demand Intercept and Surplus

The power index, as measured by the relative Shapley Value, depends largely on the architecture of the current network and access rights, and it is quite robust with respect to a proportional change of surplus in all regions or a uniform modification of production cost of all suppliers. Our conclusion about the strategic viability of additional pipelines, however, compares absolute cost to absolute gains. To check robustness we reduced the surplus by uniformly decreasing the demand intercept for the customers to its one third (500 mn €/bcm) while adjusting the slope to replicate consumption in the reference year (see tables 13-15.). More pipelines and pipeline sections become strategically unviable, but the relative merits of the different projects do not change much. The benefit to cost ratio remains by far highest for Nord Stream, from the perspective of both the respective consortium and the EU. While for the EU Nabucco has the lowest benefit to cost ratio, South Stream remains the least attractive proposition for its consortium.

Our conclusions derived by the absolute and relative nucleolus are robust with respect to the reduction in surplus. Nord Stream and South Stream alter the power structure barely, and gains accruing from Nabucco to its consortium falls short to cover the project's large cost (see tables 16-18.).

Access Right Regime

Next, we reconsider our assumption of free third party access within the EU. When the EC started its policies to ensure a common market for natural gas in the late nineties, the situation was indeed very different. Most countries had a 'national champion' who monopolized the high pressure transportation grid, hence long distance transport, and one might argue that it is still a long way to overcome this fragmentation of the market. In a fragmented market, a region in the EU enjoys exclusive access to its trunk-pipes and can derive power by blocking gas shipments. As a rule, the European regions, which neighbor a producer or a transit country, gain transit power while importers without Non-European borders suffer in a fragmented market compared to an integrated one (see Hubert and Orlova (2014a) for a detailed analysis).

The impact of a change in the access right regime on the power structure is quite substantial. When assessed with the Shapley value, Nord Stream has still the highest benefit to cost ratio for the respective consortium, but its impact on the European regions is heterogeneous, harming the regions in Eastern Europe. Hence, we cannot conclude that the project is a common European interest. Benefits accruing from South Stream to its consortium doubles, barely covering the project's cost, but in the EU Center, the largest consumer, encounters losses. Nabucco is still the least attractive project for the EU. Turkey shares its large gains with the European members of its consortium, but Center loses power although it was one of the initiators of the project (see tables 19-21.).

The nucleolus is still in stark contrast with the Shapley value. In a fragmented European market Nord Stream and Nabucco have some strategic value while South Stream has again minute impact on the power structure. Nord Stream alters the power structure significantly. The project is strategically viable for the EU, but not for its respective consortium since large losses accrue to Russia, the initiator of the project. Nabucco brings larger benefits to the members of its consortium, but in total their gains are still lower than the project's cost (see tables 22-24.).

A.4 Tables for Robustness

Decreased Demand (Surplus) : Shapley Value

Table 13: Nord Stream, Shapley Value, Decreased Demand

Players	Shapleyvalue [%]		
	without Nord Stream	with Nord Stream	difference
Russia	13.	16.	3.
Ukraine	9.3	6.9	−2.4
Belarus	6.6	5.8	−0.8
Norway	14.	11.6	−2.4
Netherlands	6.2	5.3	−0.9
UK	2.	2.	0.
Center	16.2	17.6	1.4
Center-East	8.6	9.3	0.7
Italy	3.	3.3	0.3
Poland	1.6	1.8	0.2
France	6.5	7.1	0.6
Belgium	3.	3.3	0.3
Balkan	0.8	0.8	0.
Turkey	7.4	7.3	0.
Iraq	0.	0.	0.
Iran	1.	1.	0.
Azerbaijan	0.6	0.5	0.
Turkmenistan	0.2	0.2	0.

Table 14: South Stream, Shapley Value, Decreased Demand

	without Nord Stream		*with Nord Stream*			
	Shapley value [%]	Impact[a] OS, NW, SW	Shapley value [%]	Impact of pipeline sections[b] OS	OS, NW	OS, NW, SW
Russia	15.9	2.8	16.8	0.3	0.8	0.8
Ukraine	6.9	−2.4	6.	−0.3	−0.8	−0.9
Belarus	5.9	−0.7	5.6	0.	−0.2	−0.2
Norway	12.1	−2.	11.1	0.	−0.5	−0.6
Netherlands	5.5	−0.7	5.1	0.	−0.2	−0.2
UK	1.9	0.	2.	0.	0.	0.
Center	17.3	1.1	18.1	0.	0.4	0.5
Center-East	9.2	0.6	9.5	0.	0.2	0.2
Italy	3.3	0.3	3.4	0.	0.1	0.1
Poland	1.8	0.1	1.8	0.	0.	0.
France	7.	0.5	7.3	0.	0.1	0.2
Belgium	3.3	0.2	3.4	0.	0.1	0.1
Balkan	1.	0.2	1.	0.2	0.2	0.2
Turkey	7.4	0.	7.4	0.1	0.1	0.1
Iran	0.9	−0.1	0.9	−0.1	−0.1	−0.1
Azerbaijan	0.5	−0.1	0.5	−0.1	−0.1	−0.1
Turkmenistan	0.2	0.	0.2	0.	0.	0.

[a]difference to column 1 table 13

[b]difference to column 2 table 13

Table 15: Nabucco, Shapley Value, Decreased Demand

	without South Stream				*with South Stream*	
	Shapley value [%]	Impact of pipeline sections[a] TC, ES	WS	TC, ES, CS, WS	Shapley value [%]	Impact[b] TC, ES, CS, WS
Russia	13.	−2.3	−0.1	−3.1	13.5	−3.3
Ukraine	6.2	−0.1	−0.5	−0.7	5.6	−0.4
Belarus	5.7	0.	0.	−0.1	5.5	0.
Norway	10.8	−0.5	0.3	−0.8	10.3	−0.7
Netherlands	5.	−0.2	0.1	−0.3	4.8	−0.3
UK	1.9	0.	0.	−0.1	1.9	−0.1
Center	17.8	0.	−0.1	0.2	18.3	0.2
Center-East	9.4	0.	0.	0.1	9.6	0.1
Italy	3.3	0.	0.	0.	3.5	0.
Poland	1.8	0.	0.	0.	1.9	0.
France	7.2	0.	0.	0.1	7.3	0.1
Belgium	3.4	0.	0.	0.	3.4	0.
Balkan	1.1	0.1	0.2	0.2	1.1	0.1
Turkey	10.3	1.9	0.6	2.9	10.1	2.7
Iraq	0.4	0.5	0.	0.4	0.4	0.4
Iran	1.1	0.	−0.2	0.1	1.	0.2
Azerbaijan	1.3	0.6	−0.1	0.8	1.3	0.8
Turkmenistan	0.4	0.	0.	0.1	0.4	0.1

[a]difference to column 2 table 13

[b]difference to column 3 table 14

Decreased Demand (Surplus) : Nucleolus

Table 16: Nord Stream, Nucleolus, Decreased Demand

Players	Nucleolus [%]		
	without Nord Stream	with Nord Stream	difference
Russia	2.2	2.1	−0.1
Ukraine	8.3	8.2	−0.1
Belarus	7.6	7.6	0.
Norway	3.5	3.4	−0.1
Netherlands	1.1	1.	0.
UK	1.6	1.6	0.
Center	26.8	26.9	0.1
Center-East	13.8	13.9	0.
Italy	5.	5.1	0.
Poland	2.8	2.8	0.
France	10.6	10.7	0.
Belgium	4.9	4.9	0.
Balkan	1.2	1.3	0.1
Turkey	10.2	10.2	0.
Iraq	0.	0.	0.
Iran	0.1	0.1	0.
Azerbaijan	0.1	0.1	0.
Turkmenistan	0.1	0.1	0.

Table 17: South Stream, Nucleolus, Decreased Demand

	without Nord Stream		*with Nord Stream*			
	Nucleolus [%]	Impact[a] OS, NW, SW	Nucleolus [%]	Impact of pipeline sections[b] OS	OS, NW	OS, NW, SW
Russia	2.2	0.	2.1	0.	0.	0.
Ukraine	8.2	−0.1	8.1	−0.1	−0.1	−0.1
Belarus	7.6	0.	7.6	0.	0.	0.
Norway	3.5	0.	3.4	0.	0.	0.
Netherlands	1.1	0.	1.	0.	0.	0.
UK	1.6	0.	1.6	0.	0.	0.
Center	26.8	0.	26.9	0.	0.	0.
Center-East	13.8	0.	13.9	0.	0.	0.
Italy	5.1	0.	5.1	0.	0.	0.
Poland	2.8	0.	2.8	0.	0.	0.
France	10.6	0.	10.7	0.	0.	0.
Belgium	4.9	0.	4.9	0.	0.	0.
Balkan	1.3	0.1	1.3	0.	0.	0.
Turkey	10.2	0.	10.3	0.	0.	0.
Iran	0.1	0.	0.1	0.	0.	0.
Azerbaijan	0.1	0.	0.1	0.	0.	0.
Turkmenistan	0.1	0.	0.1	0.	0.	0.

[a] difference to column 1 table 16

[b] difference to column 2 table 16

Table 18: Nabucco, Nucleolus, Decreased Demand

	without South Stream				*with South Stream*	
	Nucleolus [%]	Impact of pipeline sections[a] TC, ES	WS	TC, ES, CS, WS	Nucleolus [%]	Impact[b] TC, ES, CS, WS
Russia	1.5	−0.6	−0.4	−0.6	1.5	−0.6
Ukraine	8.	−0.2	−0.1	−0.2	8.	−0.1
Belarus	7.5	−0.1	0.	−0.1	7.5	−0.1
Norway	3.4	0.	0.	0.	3.4	0.
Netherlands	1.	0.	0.	0.	1.	0.
UK	1.6	0.	0.	0.	1.6	0.
Center	26.6	−0.3	0.	−0.3	26.6	−0.3
Center-East	13.7	−0.2	0.	−0.1	13.7	−0.2
Italy	5.	−0.1	0.	−0.1	5.	0.
Poland	2.8	0.	0.	0.	2.8	0.
France	10.5	−0.1	0.	−0.1	10.5	−0.1
Belgium	4.8	−0.1	0.	−0.1	4.8	−0.1
Balkan	1.6	0.3	0.3	0.3	1.6	0.3
Turkey	11.	0.8	0.2	0.8	11.	0.8
Iraq	0.1	0.1	0.	0.1	0.1	0.1
Iran	0.3	0.2	0.	0.2	0.3	0.2
Azerbaijan	0.3	0.3	0.	0.3	0.4	0.3
Turkmenistan	0.1	0.	0.	0.	0.1	0.

[a]difference to column 2 table 16

[b]difference to column 3 table 17

A.5 Fragmented Market with Exclusive Access

Fragmented Market: Shapley Value

Table 19: Nord Stream, Shapley Value, Fragmented Market

Players	Shapleyvalue [%] without Nord Stream	Shapleyvalue [%] with Nord Stream	Shapleyvalue [%] difference
Russia	15.1	18.3	3.1
Ukraine	8.7	6.9	−1.8
Belarus	5.2	4.7	−0.5
Norway	10.5	8.	−2.6
Netherlands	5.4	4.3	−1.1
UK	2.	1.8	−0.2
Center	20.3	23.4	3.1
Center-East	8.2	7.8	−0.4
Italy	2.	2.3	0.3
Poland	2.2	1.8	−0.3
France	5.8	6.2	0.4
Belgium	4.4	4.4	0.
Balkan	0.9	0.9	0.
Turkey	7.2	7.2	0.
Iraq	0.	0.	0.
Iran	1.2	1.2	0.
Azerbaijan	0.7	0.6	0.
Turkmenistan	0.1	0.1	0.

Table 20: South Stream, Shapley Value, Fragmented Market

	without Nord Stream		*with Nord Stream*			
	Shapley value [%]	Impact[a] OS, NW, SW	Shapley value [%]	Impact of pipeline sections[b] OS	OS, NW	OS, NW, SW
Russia	16.6	1.5	19.3	0.3	0.8	1.1
Ukraine	6.7	−2.1	5.6	−0.3	−1.2	−1.3
Belarus	5.1	−0.2	4.6	0.	−0.1	−0.1
Norway	9.6	−0.9	7.6	0.	−0.3	−0.3
Netherlands	5.1	−0.3	4.2	0.	−0.1	−0.1
UK	2.	0.	1.8	0.	0.	0.
Center	20.1	−0.2	22.8	0.	−0.5	−0.6
Center-East	8.8	0.6	8.1	0.	0.6	0.3
Italy	2.4	0.4	2.5	0.	0.	0.2
Poland	2.	−0.1	1.8	0.	0.	0.
France	5.9	0.1	6.3	0.	0.	0.1
Belgium	4.4	0.	4.4	0.	0.	0.
Balkan	2.4	1.5	1.9	0.3	0.8	1.1
Turkey	7.2	0.	7.2	0.	0.	0.
Iraq	0.	0.	0.	0.	0.	0.
Iran	1.1	−0.1	1.1	−0.1	−0.1	−0.1
Azerbaijan	0.6	−0.1	0.6	−0.1	−0.1	−0.1
Turkmenistan	0.1	0.	0.1	0.	0.	0.

[a]difference to column 1 table 19

[b]difference to column 2 table 19

Table 21: Nabucco, Shapley Value, Fragmented Market

	without South Stream				*with South Stream*	
	Shapley value [%]	Impact of pipeline sections[a] TC, ES	WS	TC, ES, CS, WS	Shapley value [%]	Impact[b] TC, ES, CS, WS
Russia	15.3	−2.4	0.	−3.	16.1	−3.2
Ukraine	6.3	0.1	−0.2	−0.6	5.5	−0.1
Belarus	4.7	0.	0.	0.	4.6	0.
Norway	7.6	−0.1	0.	−0.4	7.3	−0.3
Netherlands	4.1	−0.1	0.	−0.2	4.	−0.2
UK	1.8	0.	0.	0.	1.8	0.
Center	22.9	−0.2	−0.1	−0.5	22.5	−0.3
Center-East	8.2	0.	0.1	0.4	8.4	0.3
Italy	2.2	0.	0.	0.	2.5	0.
Poland	1.8	0.	0.	0.	1.8	0.
France	6.3	0.	0.	0.	6.3	0.
Belgium	4.4	0.	0.	0.	4.4	0.
Balkan	1.8	0.4	0.1	0.9	2.6	0.7
Turkey	9.5	1.9	0.1	2.3	9.2	2.1
Iraq	0.5	0.5	0.	0.5	0.5	0.5
Iran	1.1	−0.2	0.	−0.1	1.1	−0.1
Azerbaijan	1.3	0.4	0.	0.6	1.2	0.6
Turkmenistan	0.2	0.	0.	0.1	0.2	0.1

[a]difference to column 2 table 19

[b]difference to column 3 table 20

Fragmented Market: Nucleolus

Table 22: Nord Stream, Nucleolus, Fragmented Market

Players	Nucleolus [%]		
	without Nord Stream	with Nord Stream	difference
Russia	4.9	4.3	−0.7
Ukraine	7.	6.8	−0.2
Belarus	7.6	7.8	0.2
Norway	1.7	1.	−0.6
Netherlands	0.3	0.3	0.
UK	1.8	1.8	0.
Center	28.2	28.3	0.1
Center-East	14.3	14.4	0.1
Italy	4.6	5.	0.4
Poland	2.7	2.9	0.2
France	10.5	11.1	0.6
Belgium	5.1	5.1	0.
Balkan	0.8	0.8	0.
Turkey	10.3	10.3	0.
Iraq	0.	0.	0.
Iran	0.	0.	0.
Azerbaijan	0.	0.	0.
Turkmenistan	0.	0.	0.

Table 23: South Stream, Nucleolus, Fragmented Market

	without Nord Stream		*with Nord Stream*			
	Nucleolus [%]	Impact[a] OS, NW, SW	Nucleolus [%]	Impact of pipeline sections[b] OS	OS, NW	OS, NW, SW
Russia	4.5	−0.4	4.4	0.	0.1	0.1
Ukraine	6.9	−0.2	6.8	0.	−0.1	0.
Belarus	7.7	0.1	7.8	0.	0.	0.
Norway	1.1	−0.5	1.	0.	0.	0.
Netherlands	0.3	0.	0.3	0.	0.	0.
UK	1.8	0.	1.8	0.	0.	0.
Center	28.3	0.	28.3	0.	0.	0.
Center-East	14.2	−0.1	14.2	0.	0.	−0.2
Italy	5.	0.3	5.	0.	0.	0.
Poland	2.9	0.2	2.9	0.	0.	0.
France	11.	0.5	11.1	0.	0.	0.
Belgium	5.1	0.	5.1	0.	0.	0.
Balkan	0.8	0.	0.9	0.	0.	0.
Turkey	10.3	0.	10.3	0.	0.	0.
Iraq	0.	0.	0.	0.	0.	0.
Iran	0.	0.	0.	0.	0.	0.
Azerbaijan	0.	0.	0.	0.	0.	0.
Turkmenistan	0.	0.	0.	0.	0.	0.

[a]difference to column 1 table 22

[b]difference to column 2 table 22

Table 24: Nabucco, Nucleolus, Fragmented Market

	without South Stream				*with South Stream*	
	Nucleolus [%]	Impact of pipeline sections[a] TC, ES	WS	TC, ES, CS, WS	Nucleolus [%]	Impact[b] TC, ES, CS, WS
Russia	1.7	−2.	−0.2	−2.6	1.9	−2.5
Ukraine	7.7	0.4	0.	0.8	7.6	0.8
Belarus	7.7	0.	0.	0.	7.7	0.
Norway	1.	0.	0.	0.	1.	0.
Netherlands	0.3	0.	0.	0.	0.3	0.
UK	1.8	0.	0.	0.	1.8	0.
Center	28.2	−0.1	0.	−0.1	28.2	−0.1
Center-East	14.5	0.	0.	0.2	14.4	0.2
Italy	5.	0.	0.	0.	5.	0.
Poland	2.9	0.	0.	0.	2.9	0.
France	11.1	0.	0.	0.	11.1	−0.1
Belgium	5.1	0.	0.	0.	5.1	0.
Balkan	1.7	0.8	0.2	0.8	1.7	0.8
Turkey	11.	0.8	0.	0.8	11.	0.8
Iraq	0.	0.	0.	0.	0.	0.
Iran	0.1	0.1	0.	0.1	0.1	0.1
Azerbaijan	0.1	0.1	0.	0.1	0.1	0.1
Turkmenistan	0.	0.	0.	0.	0.	0.

[a] difference to column 2 table 22

[b] difference to column 3 table 23