Pipeline Power

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Motivation

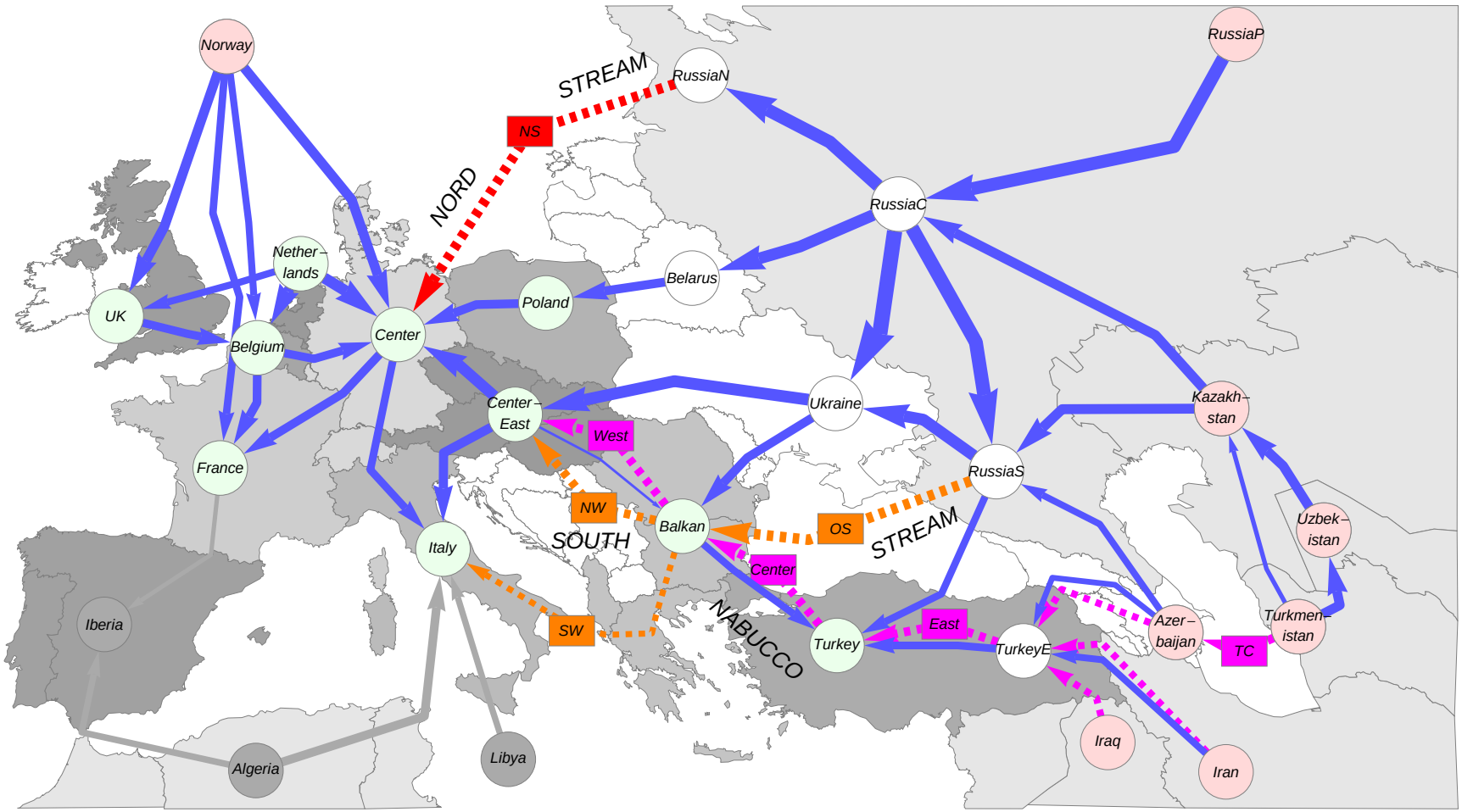
The EU's dependency on natural gas:

- Russia (40% of imports, 25% of consumption),
- The transit countries, Ukraine and Belarus (75% and 25% of Russian imports, respectively).

New pipeline links (Nord Stream & South Stream) with Russia:

- Diversify transit routes for Russian gas, but
- Increase dependency on Russia and may
- Reduce viability of investments in alternative sources (Nabucco)

Geography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The Puzzle

In 2008 Europe's

- Consumption: 489.7 bcm
- Production: 184.2 bcm
- Net imports: 305.5 bcm

(Source: BP (2009), Statistical Review of World Energy)

Three huge projects but neither adequate supply nor demand: Nord Stream (55 bcm/a), South Stream (63 bcm/a), Nabucco (31 bcm/a)

Nord Stream and South Stream will increase transport capacity for Russian gas from app. 186 bcm/a to 304 bcm/a (63%).

All three pipelines together will increase the European pipeline import capacity by 150 bcm/a (47%).

What we show (1)

Pipelines have a strategic role in changing the balance of power in the network.

Using a quantitative model, solved with the Shapley Value we show:

- Nord Stream's strategic value justifies high investment cost for Germany and Russia. It severely curtails power of Ukraine and Belarus.
- South Stream fulfils a similar role, but with Nord Stream already in place, the additional leverage obtained through South Stream is small.
- Nabucco has a large potential to curtail Russia's power, but benefits mainly accrue to Turkey. The gains for the EU, in contrast, are negligible.

What we show (2)

The Nucleolus is in stark contrast to Shapley value.

- Nord Stream and South Stream do not alter the power structure in the Eurasian gas trade.
- Nabucco benefits Turkey and harms Russia, but its impact is marginal.
- The Nucleolus cannot explain investment in Nord Stream and Nabucco's eastern section.

While the Shapley value nicely explains the investment patterns, results from the Nucleolus are difficult to match with empirical evidence.

Extensions

Cenral Asian gas in Eurasian power game

- Competition for Central Asian gas: Europe vs. China (via Turkmenistan-China pipeline)
- Projects in the Southern Corridor: TANAP, TAP, Nabucco-West, Trans-Caspian, and South Stream

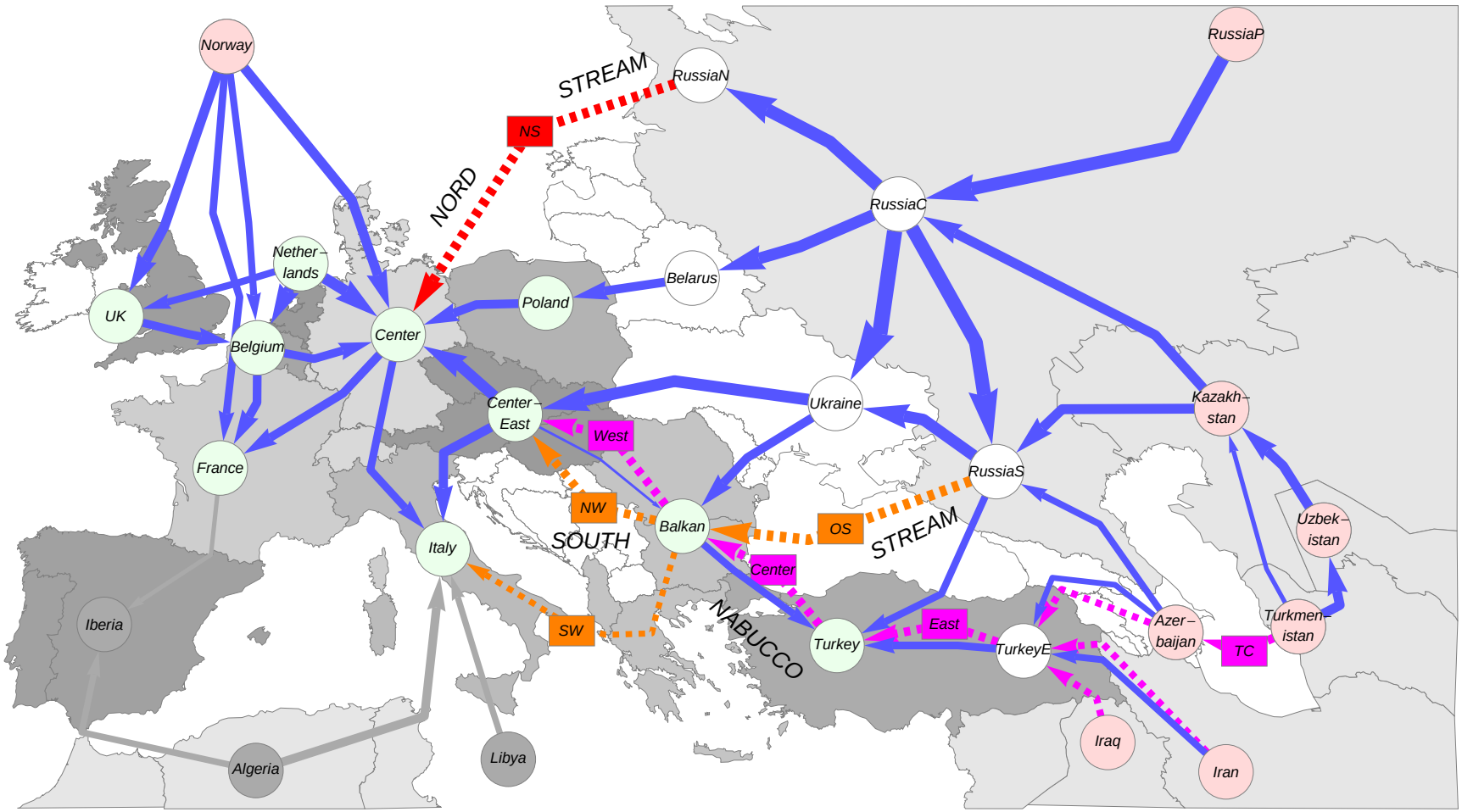
LNG: a game-changer for Europe?

- LNG market: interaction within suppliers of LNG and pipeline gas in Europe
- Scenarios: investment in European regasification capacities, increase in Asian demand, and the U.S.' LNG exports

Why Cooperative Game Theory?

- In line with long term contracts, it assumes that players use the network efficiently.
- It avoids assumptions about bargaining process and derives a player's power endogenously from its role in the gas trade.
- However, the regional scope is narrow since computation time increases exponentially with the number of players.

Model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Libya
Iran

The Network

Set of nodes R:

- R_P: Production
- R_T: Transit connections
- R_C: Customer

A link $l = \{i, j\},\ i \neq j \in R$ connects two nodes and has a capacity limit k_{ij} and specific transportation costs $T_{ij}(x)$.

f_{ij} denotes gas flows from i to j.

Value Function

The value (or characteristic) function $v : 2^{|N|} \to R_+$ gives the maximal payoff, which a subset of players $S \subseteq N$ can achieve.

The value function captures the essential economics features, such as the geography of the network, different cost of alternative pipelines, demand for gas in the different regions, production cost, ownership and access rights, etc.

For any coalition $S \subseteq N$ we have to determine to which pipelines $L(S) \subseteq L$ the coalition S has access.

Value Function

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

subject to

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

Solution

The Shapley value (ϕ) and **the Nucleolus** ($\mathcal{N}$) assign a share of the surplus from cooperation to each player.

A new pipeline project will alter the value function and consequently the solution of the game.

$\phi_i(v^1) - \phi_i(v^o)$ and $\mathcal{N}_i(v^1) - \mathcal{N}_i(v^o)$: the gross impact of the pipeline on the surplus of player i, which is then compared to the investment cost of the pipeline.

Solution: Shapley Value

ϕ_i, $i \in N$, which is player i's weighted contribution to possible coalitions:

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

where $P(S) = |S|! \left(|N| - |S| - 1 \right)! / |N|!$ is the weight of coalition S.

Solution: Nucleolus

The nucleolus of the game $[N, v]$ is the payoff vector $x \in R^n$ that minimizes θ in lexicographic ordering:

$$\mathcal{N}(v) = \{x \in Y |\ \theta_v(x) \preceq \theta_v(y) \ \ \forall y \in Y\} \tag{3}$$

where Y is a set of imputations, and

$\theta_v(x) \in R^{2n}$ is an excess vector, whose components are the numbers $e(S) = v(S) - x(S)$ for each S, $\ S \subseteq N$.

Institutional Framework

Access rights

- Within the EU: Open third party access (TPA) to the international high pressure transport pipelines.
- Outside the EU: Every country has unrestricted control over its pipelines and gas fields.

Short horizon

A stationary environment with constant demand, technology, production cost, etc. All pipelines can be made bi-directional, but capacities cannot be increased.

Calibration

Data for 2009 from IEA (2010a) on consumption and production in the regions and flows between the regions.

Constant production cost up to the production levels achieved in 2009.

Linear demand functions with the same intercept for all regions.

Slope parameters estimated as to replicate the consumption in 2009, given assumption on production cost.

No Non-strategic Benefits

The pipeline system as existing in 2009 is sufficient.

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.

None of the expensive pipeline projects considered in this paper can be justified in narrow economic terms.

Robustness

The relation of demand intercept and production cost determines the overall surplus from the gas trade.

With respect to an aggregate increase of demand in relation to production cost:

- the relative shares of different players tend to be rather robust.
- the absolute values of their shares will increase, and as a result more pipeline projects will become strategically viable for given investment cost.

Results - Russia's Nord & South Stream

Both South Stream and Nord Stream have almost identical effects on the power structure since both projects

- bypass the transit countries,
- allow Russia to compete more effectively with Norway and Netherlands,
- protects Russia's strong position in Southeast Europe.

Results - Nord Stream

- Transport competition mitigates the power of Ukraine and Belarus.
- Norway and Netherlands suffer due to supply competition in the European markets.
- Nord Stream's total strategic value for the initiators of the consortium, Wintershall and EON Ruhrgas of Germany and Gazprom of Russia (in our model Center and Russia) clearly exceeds the project's cost.
- It is in the interest of the EU to support the project.

Shapley: 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.

Results - South Stream

- As an alternative to Nord Stream, South Stream would be viable for the broad consortium (Russia, Italy, France, Center-East, and Balkan).
- With Nord Stream in place, South Stream provides much less additional leverage.
- The gains for the consortium appear too small to compensate for the project's high cost.

Shapley: 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
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

Results - Nabucco

- The lion's share of the benefits accrues to Turkey and Azerbaijan while the impact on the European regions is small. Hence, the EU's support makes little strategic sense.
- Pipelines between Azerbaijan and Turkey (TANAP) and between Iraq and Turkey (under consideration) promise large revenues for parties.
- Supply competition harms Russia.
- Nabucco does little to improve the position of Central Asian producers, such as Turkmenistan.
- South Stream has almost no impact on the strategic viability of Nabucco.

Shapley: 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

Nucleolus

Nucleolus is in stark contrast to Shapley value.

- Nord Stream and South Stream do not alter the power of the players although it is expected that bypass of the transit countries would benefit Russia and European consumers.
- Nabucco benefits Turkey and harms Russia as expected.
- None of the projects are strategically viable.

Nucleolus: Nord Stream's Impact on Bargaining Power

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.

Nucleolus: South Stream's Impact on Bargaining Power

	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

Nucleolus: Nabucco's Impact on Bargaining Power

	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

Thank you for your attention!

Questions?

Shapley Value - Example 1

$N = \{a, b, c\}$

$v(a) = 0; v(b) = 0; v(c) = 0$

$v(a, b) = 0; v(a, c) = 0; v(b, c) = 0$

$v(a, b, c) = 1$

Then, $\phi_a(v) = \phi_b(v) = \phi_c(v) = 1/3$

Shapley Value - Example 2

$N = \{a, b, c\}$

$v(a) = 0; v(b) = 0; v(c) = 0$

$v(a, b) = 1; v(a, c) = 0; v(b, c) = 0$

$v(a, b, c) = 1$

Then, $\phi_a(v) = \phi_b(v) = 1/2; \phi_c(v) = 0$