EPRG WORKING PAPER

UNIVERSITY OF CAMBRIDGE

Electricity Policy Research Group

The Economics of the Nord Stream Pipeline System

EPRG Working Paper 1026

Cambridge Working Paper in Economics 1051

Chi Kong Chyong, Pierre Noël and David M. Reiner

Abstract

We calculate the total cost of building Nord Stream and compare its levelised unit transportation cost with the existing options to transport Russian gas to western Europe. We find that the unit cost of shipping through Nord Stream is clearly lower than using the Ukrainian route and is only slightly above shipping through the Yamal-Europe pipeline.

Using a large-scale gas simulation model we find a positive economic value for Nord Stream under various scenarios of demand for Russian gas in Europe. We disaggregate the value of Nord Stream into project economics (cost advantage), strategic value (impact on Ukraine's transit fee) and security of supply value (insurance against disruption of the Ukrainian transit corridor). The economic fundamentals account for the bulk of Nord Stream's positive value in all our scenarios.

Keywords Nord Stream, Russia, Europe, Ukraine, Natural gas, Pipeline, Gazprom

JEL Classification L95, H43, C63

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

Contact k.chyong@jbs.cam.ac.uk
Publication September 2010
Financial Support ESRC TSEC 3

The Economics of the Nord Stream Pipeline System[1]

Chi Kong Chyong* [*]
Electricity Policy Research Group (EPRG),
Judge Business School, University of Cambridge (PhD Candidate)

Pierre Noël
EPRG, Judge Business School, University of Cambridge

David M. Reiner
EPRG, Judge Business School, University of Cambridge

1. The context

In 2009 Russia's natural gas exports to markets in the European Union and the Commonwealth of Independent States (CIS) generated around 4.5% of Russia's GDP, or half of Gazprom's total revenue.[2] Tax receipts from gas exports amount to 30% of Russia's defence budget.[3] On other hand, one quarter of the EU's natural gas consumption, or 6.5% of the bloc's total primary energy supply, is covered by Russian gas (Noel, 2008, Noel, 2009). Two countries, Italy and Germany, account for about half of all contracted Russian exports to the EU, with France the third biggest importer. The 12 newer member states of Central and Eastern Europe together represent about a third of all EU imports of Russian gas.

The EU-Russia gas trade is highly dependent on Ukraine as three-quarters of gas exports to Europe transit through Ukrainian pipelines (see Appendix A for description of Gazprom's current gas export routes). Russia-EU gas trade relations have been complicated by frictions between Russia and the key transit

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[1] This working paper presents preliminary research findings, and you are advised to cite with caution unless you first contact the author regarding possible amendments.
[*] Corresponding author – ESRC Electricity Policy Research Group, EPRG, University of Cambridge, Judge Business School, email: k.chyong@jbs.cam.ac.uk
[2] This includes revenues from all commercial activities (gas, oil, electricity, transportation and others) of Gazprom and its affiliates.
[3] Authors' own calculations based on Gazprom (2010a) and Russian Federal State Statistics Service (2010)

countries on its Western border - Belarus and Ukraine. There have been several major gas transit disruptions including through Belarus shortly in 2004 and for 3 days in June 2010, and through Ukraine for 4 days in January 2006 and three weeks in January 2009, including two weeks of total disruption affecting millions of customers in South-Eastern Europe and the Western Balkans (Pirani et al., 2009, Silve, 2009, Kovacevic, 2009).

Since the breakdown of the Soviet Union, Gazprom has pursued a strategy of diversifying its export options to Europe which began with the construction of the Yamal-Europe pipeline in the 1990s (Victor and Victor, 2006). It continued more recently with the Nord Stream and South Stream projects – under the Baltic and Black Sea, respectively –promoted by Gazprom and its large west-European clients. Once operational, these two projects would have a capacity larger than the current volume of gas being transported through Ukraine to Europe.

We focus on an economic analysis of the Nord Stream pipeline system[4] (for details on the project see Appendix B). Our aim is to assess the economic benefits of the project to its owners and particularly to Gazprom. We will do so in two steps: first, using detailed analysis of the Nord Stream project (see appendix C) we derive its total costs and compare the levelised unit transportation cost through Nord Stream and the existing routes; then we estimate the profits of Gazprom with and without Nord Stream under various scenarios of gas demand in Europe, using a computational game-theoretic model of Eurasian gas trade. Details on the mathematical formulation of the gas model are provided in (Chyong and Hobbs, 2010).

The rest of the paper is organized as follows. In the next section, we discuss the existing economic literature on Nord Stream. Section 3 summarises the structure and the scope of the model. Then, in Section 4 we briefly discuss some key market development scenarios used in the analysis. Our results are presented in Sections 5-8. We summarise our findings and conclude in Section 9.

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[4] By Nord Stream pipeline system, or NSPS, we mean all pipelines (including the Gryazovets-Vyborg pipeline in Russia, Nord Stream offshore pipeline underneath the Baltic Sea, Opal and Nel pipelines in Germany and Gazelle pipeline in the Czech Republic) that are part of the new export route to Europe.

2. The existing literature

Nord Stream has been politically controversial but there has not been any attempt – at least publicly available – to examine the economics of the project in an in-depth manner and assess whether it is going to be profitable to its owners.

The applied game-theoretic literature has found some economic rationale for building a project such as Nord Stream (Hubert and Ikonnikova, 2003, Hubert and Suleymanova, 2006) and the Yamal-Europe pipeline (Hirschhausen et al., 2005). The economic and strategic insights from this literature are valuable, although authors may have underestimated the value of Nord Stream and the cost of using the existing transport routes. Hubert and Ikonnikova (2003) and Hubert and Suleymanova (2006), neglect the changing geography of Russian production, the expected transition from the traditional fields towards the Yamal peninsula (Stern, 2009). Nord Stream is a shorter route to transport gas from the Yamal peninsula to Western Europe than using the Ukrainian corridor and existing transmission grid in Russia. Therefore, once Gazprom's production moves north, the transportation cost through Ukraine will increase.

Using a strategic simulation model of European gas supply, Holz et al. (2009) find that Russian gas exports to Europe until 2025 would not exceed export capacity through the existing routes (i.e. 180 bcm/a through Ukraine and Belarus)[5]. They conclude that *"...the much debated Nordstream pipeline from St. Petersburg through the Baltic Sea into Germany lacks an economic justification"* (Holz et al., 2009, p.145). However, by suggesting that Nord Stream is economically justifiable only if Gazprom needs additional export capacity, the authors imply that shipping gas through Nord Stream would necessarily be more expensive than using the existing options. Yet they provide no analytical basis to support this assumption. Explicitly or implicitly, the idea that Gazprom would need additional net transport capacity to justify Nord Stream economically stands behind most claims that Nord Stream is a purely geopolitical project (see for example Christie (2009a) and Christie (2009b)).

[5] We should note that the export capacity of the Ukrainian route through Slovakia to Western Europe is 92.6 bcm/a (Naftogaz of Ukraine, 2010). One has to consider this net export capacity when analyzing Nord Stream, not the total transit capacity though Ukraine which is approximately 150 bcm/a.

We have not encountered any in-depth, publically available analysis of the economics of Nord Stream in the literature, which would allow for a rigorous comparison of the cost of building and using the new pipeline versus the existing transit corridors, and assess the benefits of Nord Stream to its owners.

3. Model summary

Computational gas market models have been used extensively in recent research on structural issues of European and Global gas market developments (e.g., Holz et al. (2008); Boots et al. (2004); Zwart and Mulder (2006); Zwart (2009); Lise and Hobbs (2009); Egging et al. (2009)) [6]. Security of gas supply to Europe (both long-term resource and infrastructure availability and short-term gas disruption events) has also been analyzed using gas market models (e.g., Holz (2007); Egging et al. (2008); Lise et al. (2008)).

We use a strategic gas simulation model developed by Chyong and Hobbs (2010) to quantify the economic value of the Nord Stream pipeline project in a systematic way. The model contains all major gas producers and consumption markets in Europe (see Figure 1).

The market structure assumed in the model is as follows. Market participants include producers, transit countries, suppliers, consumers, transmission system operators (TSO) and LNG liquefaction and regasification operators. The objective of market participants in the model is to maximize their profit from their core activities.

Producers and consumers are connected by pipelines and by bilateral LNG shipping networks. Therefore, producers have to contract with pipelines and LNG operators to transport gas to consuming countries. It is assumed that producers can exercise market power by playing a Cournot game against other producers. Further, we assume that transmission costs through pipelines are priced efficiently, i.e. it is assumed that TSOs behave competitively and grant access to the pipeline infrastructure to those users who value transmission

[6] For an exhaustive and insightful review of gas simulation models applied to the analysis of European gas markets see e.g. (Smeers, 2008).

services the most[7]. This would result in transmission charges based on long-run marginal cost and a congestion premium in case pipeline capacity constraints are binding. The behavioural assumption of LNG liquefaction and regasification is similar to the one assumed for TSOs, i.e. LNG liquefaction and regasification services are priced efficiently by an independent operator of LNG facilities. Although producers can exercise market power by manipulating sales to suppliers, it is assumed that producers are price-takers with respect to the cost of transmission and LNG liquefaction and regasification services. These assumptions on transmission and LNG services are consistent with other strategic gas models (Egging et al., 2008; Lise and Hobbs, 2008; Boots et al., 2004).

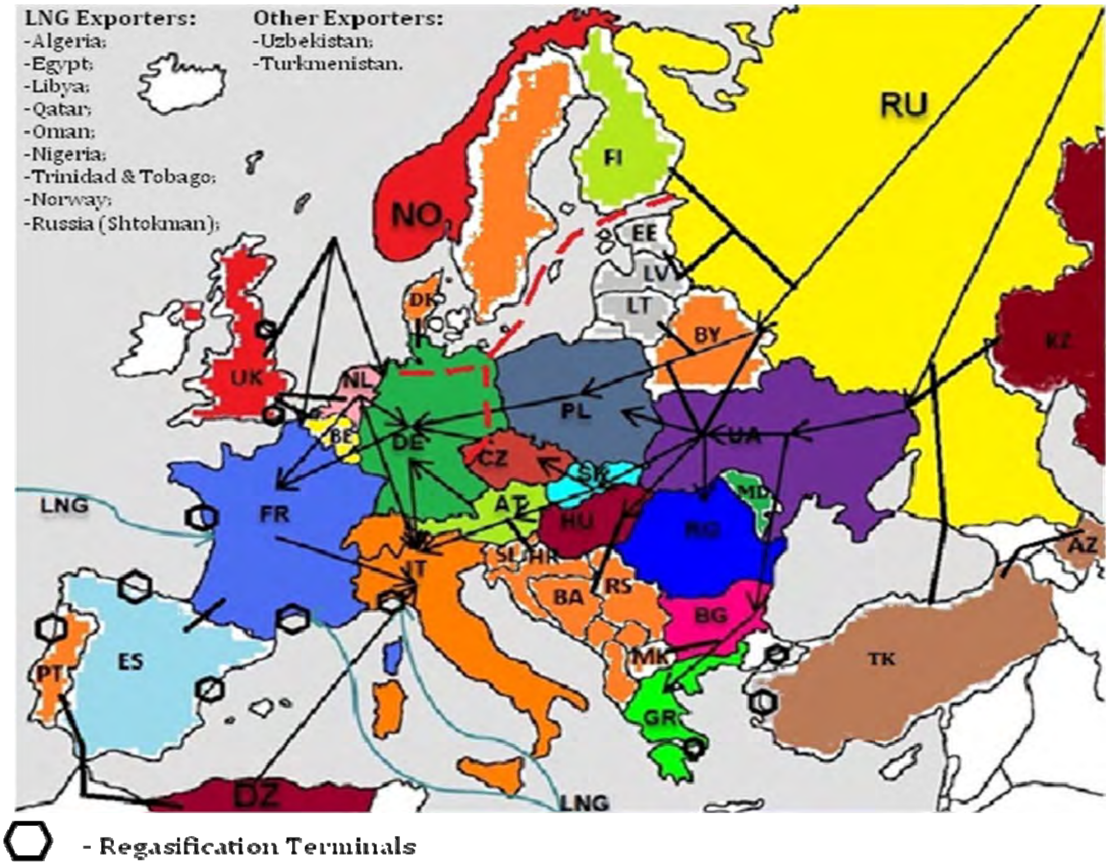

Figure 1 Major gas producing and consuming countries in the model[8]

[7] As Smeers (2008) argues, the assumption on the efficient pricing of transmission costs is somewhat optimistic and diverges from the reality of natural gas transmission activities in European markets. However, recent agreements between private companies and European antitrust authority (such as capacity release programme agreed between GDF SUEZ, ENI, E.ON and EC) promise a much more competitive access to both transmission pipelines and LNG import terminals (EC, 2009a; EC, 2009b; EC, 2010).

[8] The pipeline links on the map do not represent real pipeline networks. They only represent major (not all) gas flows and market interconnections assumed in the gas model.

In each consuming country there are a certain number of gas suppliers who buy gas from producers and re-sell it to final customers, paying distribution costs. Following Boots et al. (2004), the operation of suppliers is modelled implicitly via effective demand curves facing producers in each country[9]. For this analysis we assume that suppliers are competitive.

Natural gas prices might differ substantially among countries. Countries that are closer to gas sources enjoy lower prices than countries that are further from gas sources, because of the considerable transportation cost including possible congestion fees on transmission pipelines and transit countries' mark-up due to the exercise of market power. Apart from differences in transport costs, gas prices can also differ significantly due to different degrees of competition among producers supplying a particular national market. For example, well diversified markets in Western Europe have lower prices (on average) than prices enjoyed by some countries of Central and Eastern Europe (some Central and Eastern European countries have only one source of gas supplies[10]).

4. Market development assumptions

The economics of the Nord Stream project depends greatly on future developments of gas demand in Europe as well as on the LNG market developments. In this section, we present three scenarios of European gas demand and our assumptions about LNG market development.

[9] In the derivation of the effective demand curve, suppliers operating in each country are assumed identical. As Smeers (2008) argues, this assumption does not correspond to the reality of European downstream markets.

[10] For a detailed discussion of gas markets in Central and Eastern Europe see e.g. Noel (2008) and Noel (2009).

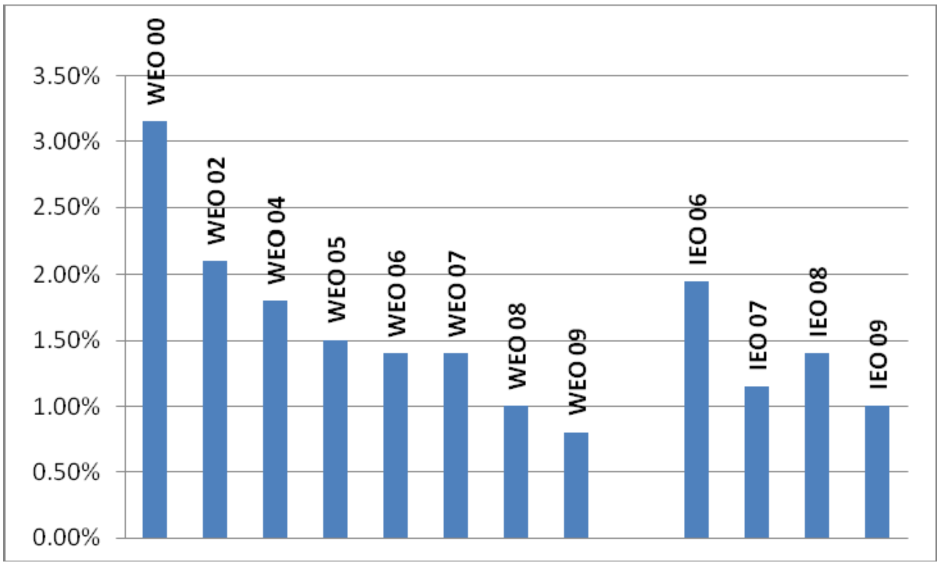

Figure 2 Evolution of Gas Demand Outlooks[11]

A decade of forecasts by the International Energy Agency (IEA) and the US DOE's Energy Information Administration (EIA) illustrates the energy experts' downward trend in their view of future growth in European gas demand (Figure 2). Our base case scenario is based on the IEA's 2009 forecast (IEA, 2009) while for our high demand case we average the projected growth rates from the IEA's *World Energy Outlook* (WEO) published between 2000 and 2005. For our low demand case we assume that European gas consumption would decline 0.2% annually, similar to the WEO 2009's "450 Scenario". (See Table 1).

	High Demand Case	**Base Case**	**Low Demand Case**
Western and Southern Europe	+2.14%	+0.7%	-0.2%
Central and Eastern Europe	+2.14%	+0.8%	-0.2%
Balkan Countries	+2.14%	+0.8%	-0.2%

Table 1 Assumed growth rate of gas consumption: 2010-2030

LNG regasification capacities for major gas markets in Europe are assembled from Gas Strategies Database of LNG regasification terminals up to 2030 (Gas Strategies, 2007). We assume that 50% of all projects announced in the Gas Strategies database would be realised as it was assembled in 2007 during a period of high gas demand and prices in Europe. The resulting LNG regasification capacities in Europe are reported in Table 2.

[11] This figure is adapted from Noel (2009).

	2010	2020	2030	2040
UK	43	67	67	67
Germany	0	15	15	15
Netherlands	9	30	30	30
Italy	12	65	65	65
France: Mediterranean	17	17	17	17
France: Atlantic	13	23	23	23
Belgium	9	18	18	18

Table 2 Assumed regasification capacities in major Western European markets (bcm/a)

LNG export capacities are assumed to be equal to the difference between production capacities and domestic demand, as taken from the reference case of IEA's WEO 2009. Table 3 shows the LNG export capacities of major gas producers in the Middle East and North Africa, and Latin America (Trinidad & Tobago).

	2010	2020	2030	2040
Qatar	81	150	185	229
Algeria	65	86	103	125
Egypt	18	15	7	0
Libya	11	19	35	65
Nigeria	38	56	109	148
Trinidad & Tobago	34	38	48	59

Table 3 Export Capacities of Major Gas Producers of MENA and Latin America (bcm/a)

5. The Cost of Building and Using the Nord Stream Pipeline System

We compare the different export routes available to Gazprom (Nord Stream, the Ukrainian route and the Belarusian one) on the basis of levelised transportation costs between Gazprom's production field and a particular final gas market.

The levelised transportation cost through Nord Stream is obtained by dividing the total investment cost of the Nord Stream pipelines system by the volumes transported over forty years. We calculate the total investment cost using the methodology and data described in appendix C. Figure 3 shows the minimum, the average and the maximum values for each component of the pipeline system. These figures include the construction cost, the cost of compressors and the cost of debt financing.

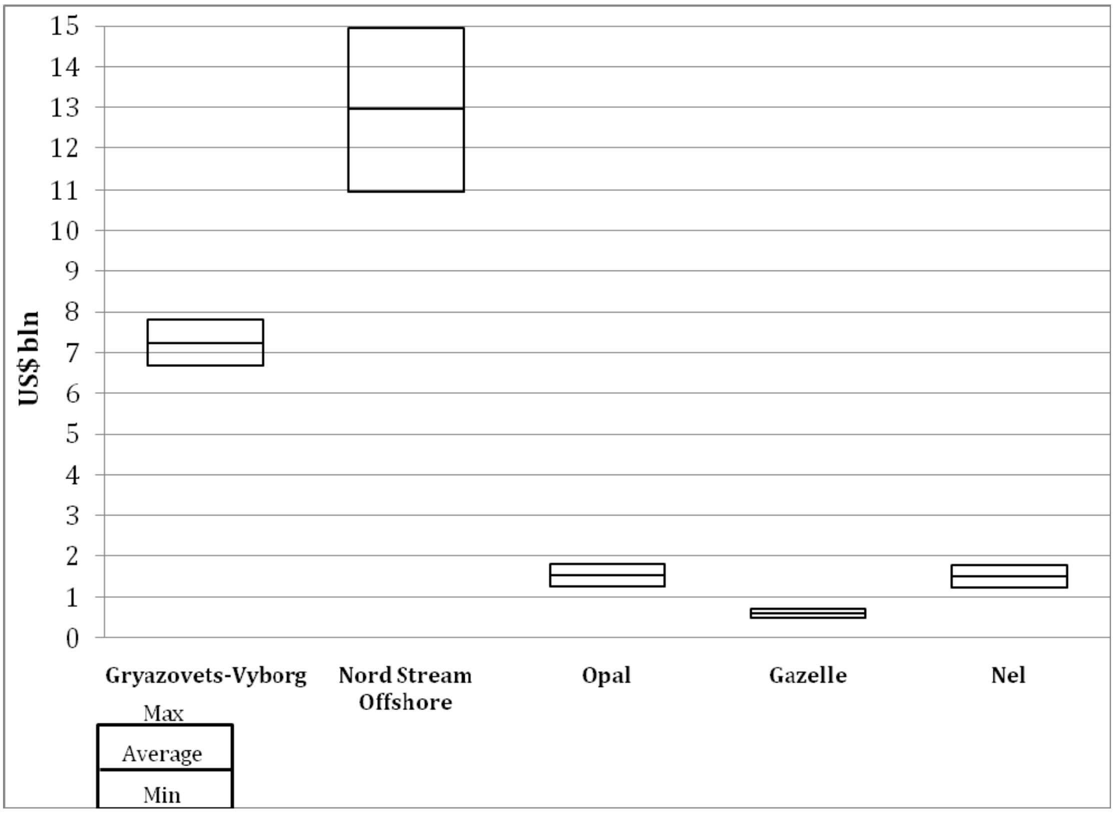

Figure 3 Investment Costs of the Nord Stream system

The total investment costs of the Nord Stream system varies between US$ 19.9 bn and US$ 23 bn. As might be expected, the single largest component of the Nord Stream system is the offshore pipeline underneath the Baltic Sea, which accounts for about 56% of the total capital cost of the system.

Table 4 shows the levelised transportation cost for each section of the pipeline system, assuming they would be fully utilised during their economic life-time (results under alternative assumption are also shown later). The figures in Table 4 represent how much each pipeline should charge in order to pay back its investment costs, annual O&M costs and earn 1% above the weighted-average cost of capital (WACC) for the investors[12].

[12] The choice to use 1% above WACC is discussed in appendix C.

		Gryazovets-Vyborg	Nord Stream Offshore	Opal	Gazelle	Nel
Levelized Transport Cost, $/tcm	Average	28.7	21.2	5.0	2.7	12.8
	Max	37.7	28.2	6.4	3.3	15.7
	Min	20.9	14.9	3.7	2.1	10.0

Table 4 Levelized Transportation Cost through the Nord Stream system

To compare the Nord Stream system with the Ukrainian and Belarusian routes we assume that all transit fees (through Belarus, Poland, Ukraine[13], Slovakia and the Czech Republic) would remain at the level of 2009-2010. The cost of fuel gas as a component of the transit fee has been omitted from this analysis.[14]

Following the International Energy Agency (IEA, 2009) we assume that by 2030 at least 75% of Gazprom's total gas production would come from new fields on the Yamal Peninsula.[15] This gradual shift of production to the north, as the Nadym-Pur-Taz region declines, has important implications for the relative costs of the transportation options. It positively affects the competitiveness of both the Nord Stream and Belarusian routes and disfavours the Ukrainian route. This is because the distance from the Yamal Peninsula to the Russia-Ukraine border is longer than the distance from the Yamal Peninsula to the Nord Stream entry point (Vyborg) or to the Russia- Belarus border (Smolensk).

As shown in Figure 4 building and using the Nord Stream system is cheaper for Gazprom than using the Ukrainian route. If the Nord Stream system is utilized at 75%, then, during 2011-2021, using the Ukrainian route is cheaper. However, as Gazprom's production moves to the Yamal Peninsula, it becomes relatively more expensive to use the Ukrainian route (see table D2 in Appendix D for the transmission costs between the production sites and the Russian border).

[13] We examine alternative transit pricing strategies for Ukraine in Section 8.
[14] Most transit/transmission operators in Europe (e.g. BOG in Austria, NET4GAS in Czech Republic, and Eustream in Slovakia) ask shippers to provide fuel gas in kind. In any case, the cost of fuel gas is rather small (e.g., 0.2% of the total transported quantity per 100 km of distance).
[15] The (long-run marginal) cost of developing and producing gas from the Yamal Peninsula has been taken into account in the gas model. However, we are not taking into account possible gas shipments from the Shtokman field due to the high level of uncertainty regarding the implementation of this project.

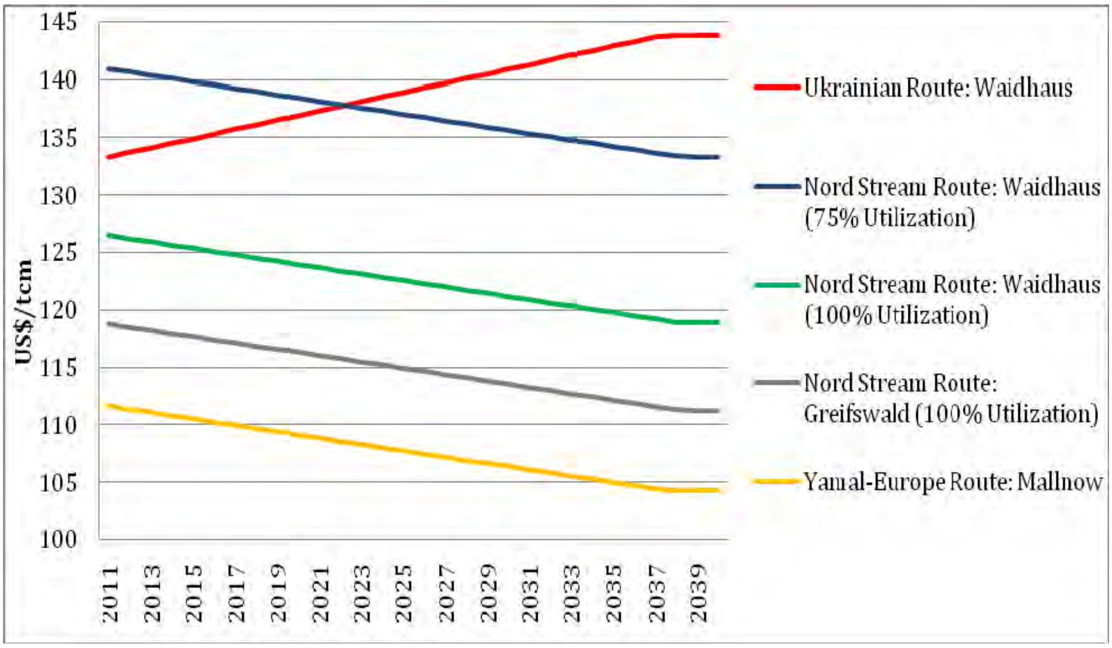

Figure 4 Transportation Costs from Gazprom's Production Fields to Germany

Comparing the Belarusian and Nord Stream routes is not as straightforward since the end points differ. We choose to compare the levelised transportation costs to Greifswald (on the German northern coast) for Nord Stream with Mallnow (at the German-Polish border) for the Yamal-Europe I pipeline, which are close enough to each-other.

Since Gazprom owns the Belarusian section of the Yamal-Europe pipeline, it pays only 0.49 US$/tcm/100km to Beltransgaz, operator of the Yamal-Europe pipeline in Belarus (Ryabkova, 2010). This fee includes only the operatorship and O&M costs of the pipeline. Therefore, an unbiased comparison between these two routes should include the capacity cost of the Yamal-Europe pipeline as well. Using the same procedure as for the levelised costs, we have calculated the annualised capacity cost through the Yamal-Europe I pipeline in Belarus assuming that it has been fully utilized since it began operation (in 2001). Various sources have reported the capital cost for Belarusian part to be around US$1.6 bln excluding any cost of finance (Interfax, 2000). This is similar to the capital cost of the Yamal-Europe I pipeline section in Poland, which has almost the same length and number of compressor stations (Europol Gaz s.a., 2010). We use this figure to obtain an estimate of the annualized unit capacity cost for the Belarus section. The result is remarkably similar to those set by the Polish energy regulator for the Yamal-Europe pipeline in Poland (€1.108/tcm/100km in 2009) (A'LEMAR, 2009).

The results of these calculations show that the Belarusian route appears to be less costly than the Nord Stream route (see Figure 4), although only slightly (~US$7/tcm). It should be noted that we assume transit fees through Belarus and Poland at the level of 2009. However, there is, of course, no assurance that the transit fees through Poland and Belarus will not be changed through 2040.

6. The Economic Value of the Nord Stream System

The economic value of the Nord Stream system is calculated by comparing Gazprom's anticipated total profit between 2011 and 2040[16] when the Nord Stream system is built with Gazprom's profit when Nord Stream is not built. This is shown in the following equation:

$$PV^{NS} = \sum_{n=2011}^{2040} (\mathrm{Profit}_n^{+NS} - AC_n^{NS} - \mathrm{Profit}_n^{-NS})(1 + \mathrm{Discount\ Rate})^{-(n-2011)} \qquad (1)$$

where PV^{NS} is the present value of Nord Stream system, $Profit_n^{+NS}$ is Gazprom's annual profit when the Nord Stream system has been built, AC_n^{NS} is annualized total costs of the Nord Stream system as derived from project based-analysis (see details in Appendix C) and $Profit_n^{-NS}$ is Gazprom's annual profit in case the Nord Stream system has not been built.

Figure 5 shows the economic value of the Nord Stream system under our three demand scenarios. The black boxes with solid lines represent the minimum, average and maximum values of the Nord Stream system assuming average investment costs (the variability is due to the variance in discount rate only). The dashed lines show the impact on the project's maximum and minimum NPV, of capital expenditures reaching their maximum and minimum value.

In all scenarios analysed, the Nord Stream system has a positive net present value. Assuming that transit fees and other transportation costs through existing routes remain unchanged over time, higher gas demand in Europe increases the economic value of the new pipeline system over its life-time. The

[16] Our analysis covers the economic life of the Nord Stream system, which is assumed to be 30 years (2011-2040).

average NPV of the Nord Stream system is US$4 bln in the low demand case, US$6.9 bln in the base case and US$20 bln in the high demand case.

In the best case when gas demand in Europe would be relatively high (CAGR of +2.14%) and the investment costs in the Nord Stream system low, the economic value of the pipeline could be as high as US$30 bln over the lifetime of the system. However, even in the worst case (i.e. a combination of the highest total investment costs and lowest gas demand scenario) the economic value of the Nord Stream system would still be positive, at around US$ 500 mln over the lifetime of the pipeline.

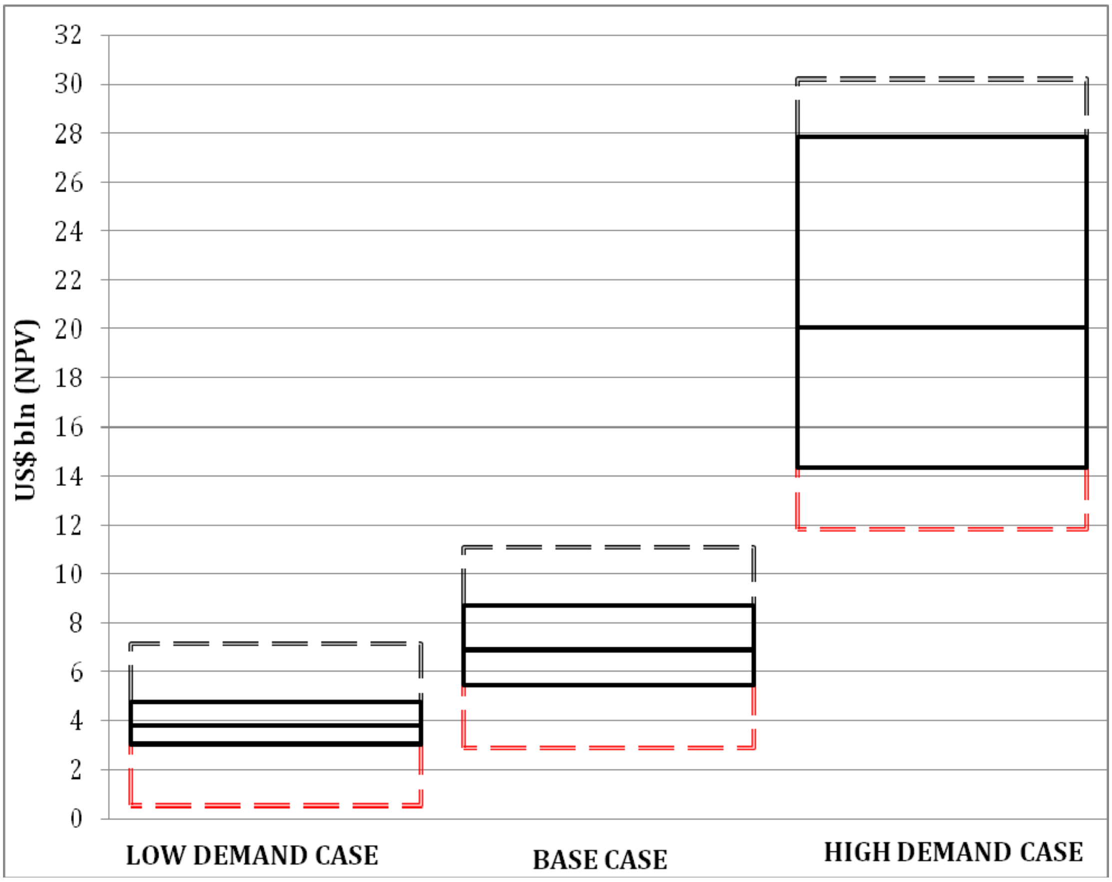

Figure 5 Economic Value of the Nord Stream system over its life time under different market scenarios

7. The Impact of Transit Disruption Risks

Nord Stream's sponsors argue that the project will improve the security of gas supplies to Europe (Nord Stream AG, 2010e, E.ON, 2010, BASF, 2010b, GDF

SUEZ, 2010, Gasunie, 2010). This argument has gained traction after the sustained disruption of the Ukrainian transit corridor in January 2009.

To quantify the contribution of the Nord Stream pipeline system to the security of the Russian-European gas trade, we evaluate the impact of the unreliability of transit through Ukraine on the economic value of the Nord Stream pipeline system, or to put it differently, how much Gazprom might save from reduced transit disruptions once Nord Stream is built. Equation (2) below computes Nord Stream's value including the risks of transit disruptions during the economic life of the pipeline system:

$$PV_d^{NS} = PV^{NS} + p_n\left[\sum_{n=2011}^{2040}\left(Profit_{n,d}^{+NS} - AC_n^{NS} - Profit_{n,d}^{-NS}\right)(1 + \text{Discount Rate})^{-(n-2011)} - PV^{NS}\right] \quad (2)$$

where PV_d^{NS} is the present value of the Nord Stream system under transit disruption scenario *d*, $Profit_{n,d}^{+NS}$ is Gazprom's profit under transit disruption scenario *d* when Nord Stream is built, AC_n^{NS} is annualized total costs of the Nord Stream system, $Profit_{n,d}^{-NS}$ is Gazprom's profit under transit disruption scenario *d* in case the Nord Stream system has not been built, p_n is the probability of transit disruption through Ukraine in year *n* and is assumed to be a random variable with uniform distribution in [0;1][17].

We run our simulation model under two different disruption scenarios for the Ukrainian route (see table 5).[18]

[17] To simplify the analysis, we assume that probabilities of disruptions in any period are independent (e.g. gas transit disruption in 2009 through Ukraine has no effect on probabilities of future disruption through Ukraine.)

[18] The disruption scenarios are for analytical purposes only and do not constitute forecasts of transit disruptions through Ukraine. To simplify the analysis, we assume that the probabilities of disruptions in any period are independent (e.g. gas transit disruption in 2009 through Ukraine has no effect on the probability of future disruptions through Ukraine.). Also, we do not distinguish when exactly the disruption would occur during a particular year (winter or summer times), which would require explicit modelling of storage in the gas simulation model. Therefore, the results should be treated as annual average values.

Disruption Scenarios	Duration of Disruptions	Frequency of Disruptions	Total days of disruptions
Moderate Disruption Case	3 weeks	5 disruptions in 2011-2040	105 days
Severe Disruption Case	6 weeks	10 disruptions in 2011-2040	420 days

Table 5 Transit Disruption Scenarios through Ukraine

Figure 6 presents the results under different scenarios of demand growth in Europe.

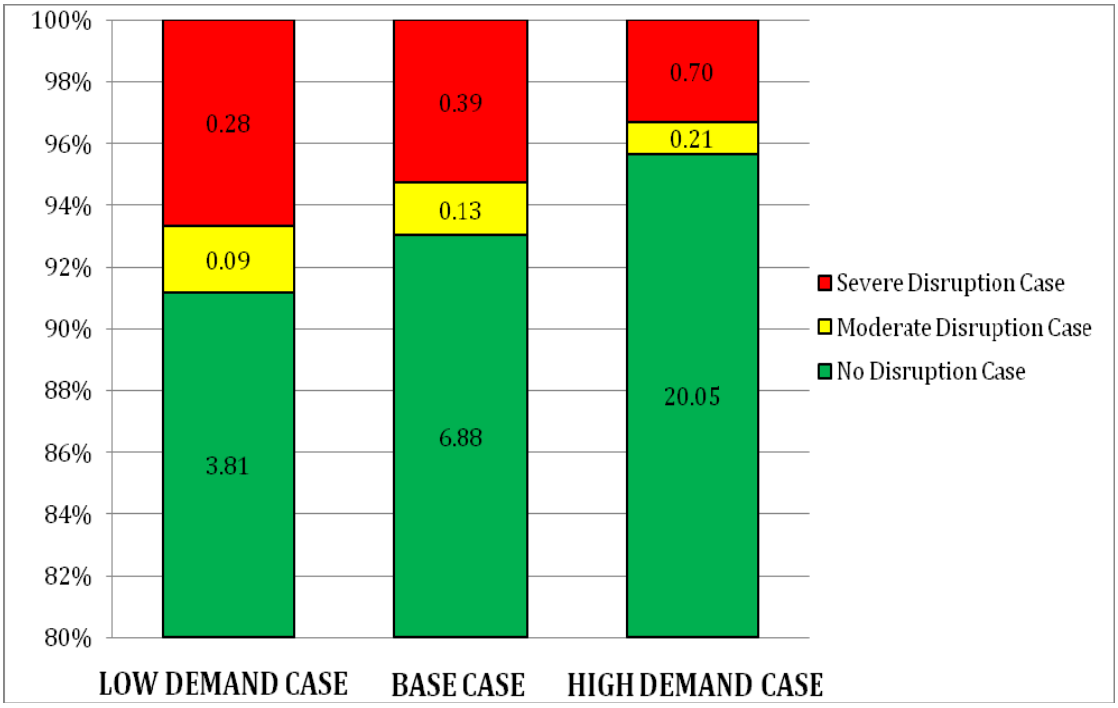

Figure 6 Expected Economic Value of the Nord Stream system under transit disruption scenarios[19]

Under the low demand scenario and without any disruption the average NPV of the system is US$ 3.8 bn. In the moderate disruption case, the expected additional NPV of the system, reflecting its security value, is US$89 mln, or about 2% of the maximum achievable NPV of the system. Under the severe transit disruption scenario, the security value of the Nord Stream system would be US$368 mln (89.4+278.9), or 9% of the maximum possible value.

Under all demand scenarios analyzed at least 90% of the NPV of the pipeline system comes from the economic fundamentals of the project – lower transportation cost compared to the existing export routes; the security value of the project never represents more than 9% of the expected total value.

[19] The values inside the bars are the average values of the NPV in US$ bln (equivalent to the middle lines of the solid boxes in figure 5).

8. The impact of Ukraine's Transit Pricing Decisions

We have so far assumed that the Ukrainian transit fee over time is determined according to the long-term transit contract[20] signed after the January 2009 gas crisis. However, one would think that Ukraine would respond to the emergence of a new competing option by adapting its transit fee. If the quantity of gas transported through Ukraine decreases (e.g. because of diversion of gas flows to the Nord Stream system) then Ukraine's rational reaction would be to slash its transit fee so that it would be more profitable for Gazprom to export gas through the Ukrainian route than through the bypass pipeline[21]. Conversely, increased demand for transportation through Ukraine would allow it to charge a higher fee.

In this section we quantify the impact of Ukraine's transit pricing decisions on the economic value of the Nord Stream system[22]. We compare, under our three demand scenarios, the value of Nord Stream when the Ukrainian transit fee is fixed, to its value when the transit fee is a function of Gazprom's demand for transit services through Ukraine (that is, a function of the gas transported through Ukraine, for details see appendix E).

Figure 7 shows the value of the Nord Stream system when the Ukrainian transit fee is fixed (based on the long-term transit contract) and when the fee responds to the construction of the 'bypass' pipeline. A responsive Ukrainian fee has a positive impact on the NPV of the Nord Stream pipeline system, all the greater than gas consumption growth in Europe is stronger. Under the base case demand scenario, Ukraine's rational pricing behaviour increases the value of Nord Stream by 67%. In the low demand case the impact of Ukraine's transit pricing policy increases the value of the Nord Stream system by 29% 'only',

[20] The full text (in Russian) of the contract has been published on the website of Ukrainian newspaper "Ukrainska Pravda" shortly after its signature (Ukrainska Pravda, 2009).
[21] The implicit assumption here is that Gazprom has bargaining power vis-à-vis Ukraine, which, in light of recent and also past developments of Russo-Ukrainian gas relations, seems justifiable.
[22] For our future research we will include another scenario – Gazprom acquisition of Naftogaz of Ukraine. Indeed, Ukrainian government officials have explicitly acknowledged that they cannot "stop" the construction of Nord Stream, as it has already started, and therefore, the Ukrainian government has suggested that Gazprom and European gas companies invest in refurbishing Ukrainian transit pipelines and co-manages the transit system instead of constructing the second "bypass" pipeline – South Stream (Korrespondent.net, 2010).

because the quantity exported through Ukraine is relatively small. Under the high demand scenario, Ukraine responds to the high demand for using its transit pipelines by increasing the transit fee very substantially[23] (figure 8), limiting the additional net value of the Nord Stream system to 34%.

However, moving away from the current transit pricing arrangement to rational economic pricing, only benefits Ukraine if gas demand in Europe grows at a compound annual rate of over 2% (which is highly unlikely). In the low demand and base case scenarios lower transit fees do not encourage Gazprom to use the Ukrainian pipelines more because of the negative implications on European gas prices. Therefore in case of low or moderate demand growth in Europe, Ukraine gains little from pricing rationally and might be tempted by short-term, opportunistic behaviour. Reciprocally, in the high demand scenario, Gazprom would be better off if Ukraine's transit fee remained determined by the long-term transit contract of January 2009.

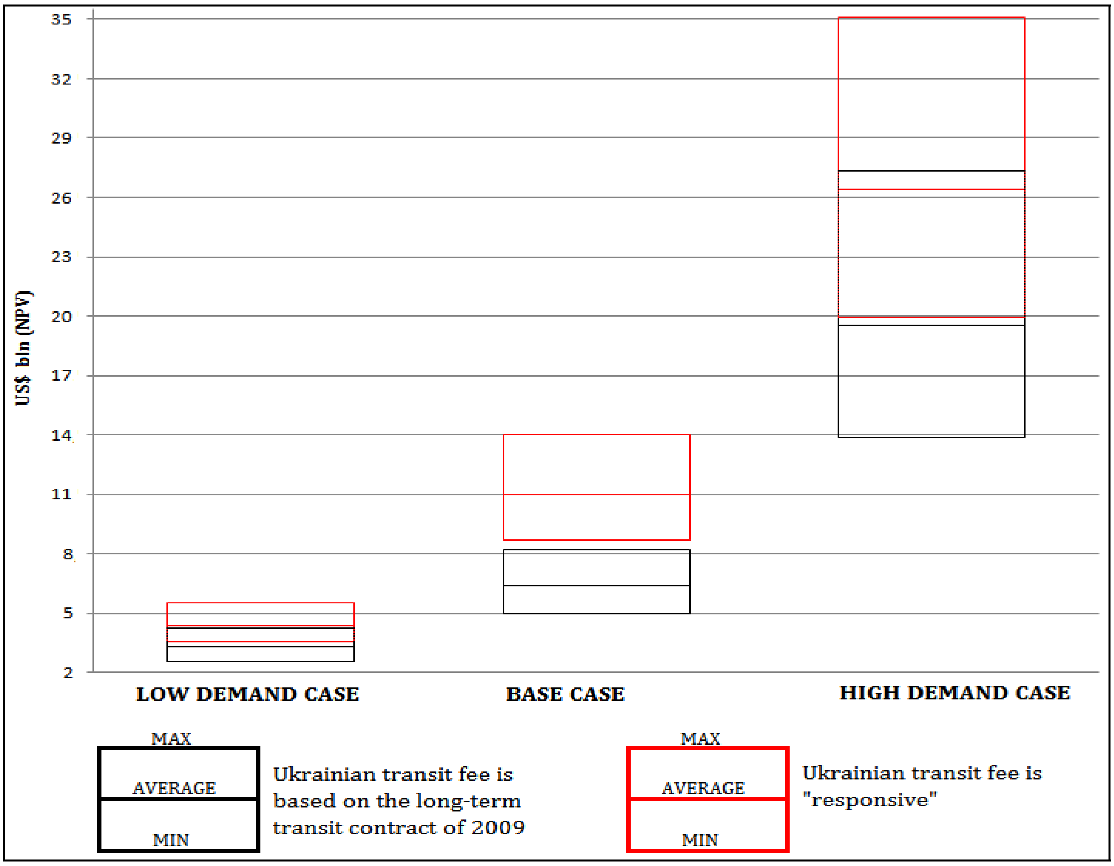

Figure 7 Impact of Ukrainian transit fee on the value of the Nord Stream system

[23] Due to increased demand in Europe, the Nord Stream and Yamal-Europe routes are saturated and therefore, Gazprom has to use the Ukrainian route.

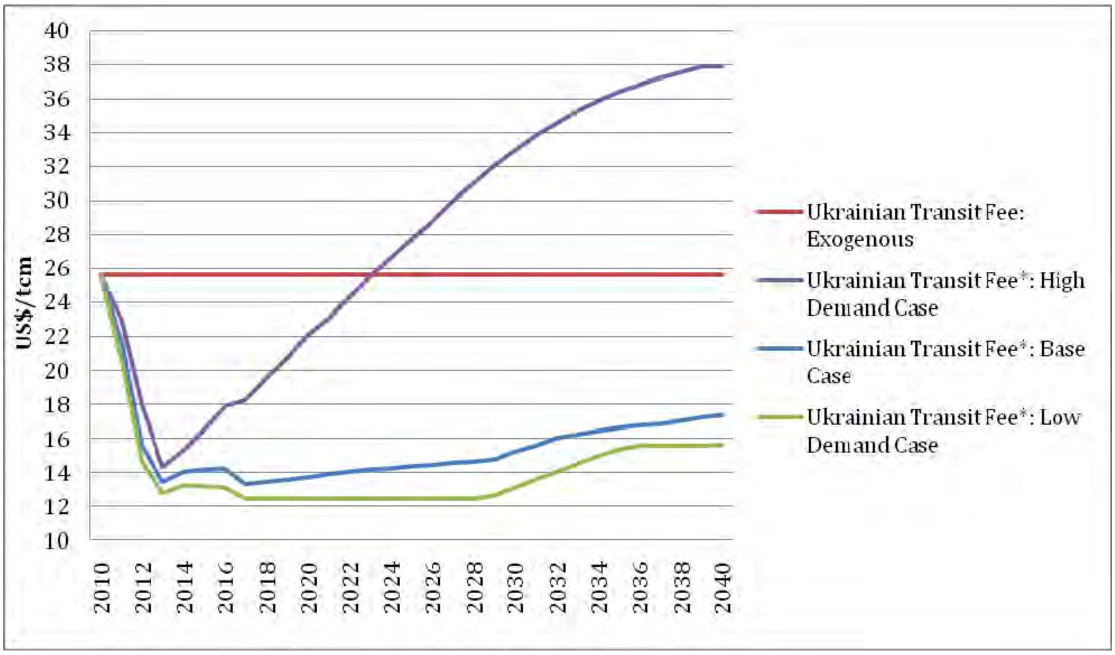

Figure 8 Ukraine's transit fee under different assumptions and scenarios

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9. Summary and conclusions

Three factors contribute to the positive economic value of the Nord Stream pipeline system: the lower transportation cost compared to existing options (the economic fundamentals of the project); the impact of Nord Stream on lowering Ukraine's transit fee; the insurance against transit disruption risks through Ukraine.

Our results show (Figure 9) that the economic fundamentals guarantee that the pipeline's owners will get 55% of the maximum achievable net present value under the base case demand scenario. In the low and high demand cases, the economic fundamentals of the project contribute about 70% to the maximum achievable project value. If Ukraine reduces its transit fee because of the building of Nord Stream, this is worth 35% of the maximum achievable value of the project in the base case demand scenario, about 20% and 25% for the low and high demand cases respectively. The contribution of the insurance against transit disruption to the value of Nord Stream is relatively modest at about 12% in the low demand case and less than 10% in the two other scenarios.

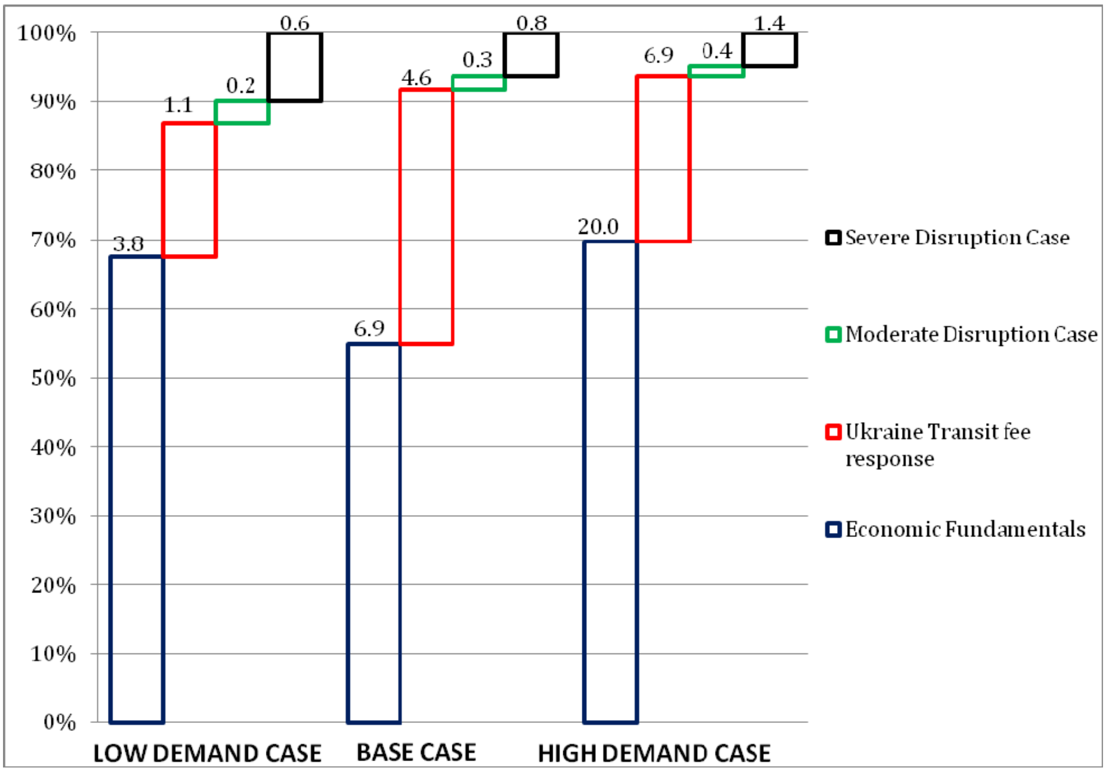

Figure 9 Maximum NPV of the Nord Stream system over its life-time[24]

As mentioned at the beginning of this article the policy literature about Nord Stream generally presents the project as uneconomic and concludes it is more part of Russia's foreign policy than Gazprom's business strategy (see e.g., Christie 2009b). We find Nord Stream to be profitable even under a scenario of declining gas demand in Europe. Our results tend to give credence to claims by an executive of E.On Ruhrgas, the second largest shareholder in Nord Stream, that *"we expect to get our money back in the long run"* (cited in Gilbert, 2010, p.40). However, our analysis does not uphold the idea, widespread among German politicians and commentators that Nord Stream is primarily about additional net European imports from Russia. Our results show that the economic case for Nord Stream primarily rests on overcoming the dominant position of Ukraine as a provider of transit services. In our base case scenario for EU gas demand, more than 90% of the gas flowing through Nord Stream over the lifetime of the project is diverted away from the existing transit corridors, mainly Ukraine. Finally, Nord Stream's positive net present value does not mean that the project has no serious political implications for Europe (Middleton, 2009), but discussing them is beyond the scope of this paper.

[24] Figures above each bar is in US$ bln (present worth).

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Appendix A Russia's Current Gas Export Routes to Europe

As of 2008, Russia's overall gas export capacity through pipelines to Europe, including Turkey, is around 214 billion cubic metres (bcm) (see table A1). There are two main routes which Gazprom currently uses to export gas to Europe: through Ukraine and Belarus.

Transit		
Final Markets	Design Capacity, bcm/a	Actual volume transported in 2008, bcm/a
Through Ukraine		
To Western and Eastern Europe	92.6	75.5
To Poland	5.0	4.8
To Hungary, Serbia and Bosnia-Herzegovina	13.2	12.1
To Romania	4.5	2.0
To Romania, Bulgaria, Greece, Macedonia and Turkey	26.8	22.5
Through Belarus[25]		
To Poland and Germany	36.3	35.2
To Lithuania	6.4	2.8
Direct Sales		
To Finland	8.1	4.8
To Latvia and Estonia	5.4	1.3
To Turkey via Blue Stream	16.0	9.3
Total	214.3	170.3
Share of Ukraine in Transportation of Russian Gas Exports, %	66.3	68.6
Share of Belarus in Transportation of Russian Gas Exports, %	19.9	22.3

Table A1 Gazprom's Existing Export Options

Sources: Own calculations based on ENTSOG (2010), Gazprom (2010a) Naftogaz of Ukraine (2010), Yafimava (2009)

Direct gas sales constitute some 9% of total exports to Europe (including Turkey). The rest of Gazprom's exports are transported through Ukraine and Belarus. Before 2003, nearly 95% of all Russian gas exports went through Ukraine[26]. Due to past conflicts between Russia and Ukraine over terms of gas trade, Russia has initiated several pipeline projects to bypass Ukraine. One of these projects is the Yamal-Europe I gas pipeline which traverses Belarus and Poland. The total throughput of Yamal I is 30.6 bcm/year (ENTSOG, 2010). Yamal-Europe I serves as the basis of Russia's northern gas export corridor to Europe. The delivery point through Yamal-I is at the Germany-Poland border, Mallnow (near Frankfurt-am-Oder).

The majority of Russian gas exports to Europe still traverses through the southern gas export corridor, via Ukrainian territory. In 2008, around 68% (see table A1) of all Russian gas exports to Europe was transported through Ukraine. The delivery points of Russian gas through Ukraine are: (i) Ukrainian-Slovak border, (ii) Baumgarten Gas Hub (Austria) and (iii) Czech-German border (Waidhaus and Olbernhau).

[25] We only report export capacity through Belarus to Poland and Germany, export capacity through Northern Light which re-enters Ukraine has been omitted in this table for simplicity.

[26] Authors' own calculations based on Gazprom (2010a), Naftogaz of Ukraine (2010), Yafimava (2009).

Appendix B The Nord Stream pipeline system

The Nord Stream pipeline system is Gazprom's third gas export corridor alongside its traditional Ukrainian route and Belarus-Poland-Germany route as described in Appendix A. The Nord Stream system consists of four pipelines:

1. *Onshore Connection in Russia: Gryazovets-Vyborg Pipeline*

This pipeline is intended to connect Russia's gas transmission system with the offshore section of the Nord Stream pipeline system. The pipeline length is 917 km and design capacity is 55 bcm/a. The pipeline runs from Gryazovets in Russia's Vologda Oblast to Vyborg northeast of St Petersburg on the Gulf of Finland. According to Gazprom, as of December 2009, 597 km of pipeline was constructed. The pipeline will start operation in 2011 and will reach designed capacity by late 2012. The estimated cost of the pipeline is around €4.5 bln (for details see appendix C).

2. *Offshore Pipeline Underneath the Baltic Sea*

For the purpose of carrying out a feasibility study, building and operating the offshore pipeline, Nord Stream AG was incorporated in 2005. Nord Stream AG is jointly owned by Gazprom (51%), BASF SE/Wintershall Holding AG (15.5%), E.ON Ruhrgas AG (15.5%), N.V. Nederlandse Gasunie (9%) and GDF Suez (9%). The length of the offshore line is 1220 km and will be laid across the Baltic Sea, from Vyborg, Russia, to Greifswald, Germany. The pipeline will consist of two parallel lines. The first one, with a capacity of 27.5 bcm/a is due for completion in late 2011. The second line is due to be completed in late 2012, doubling annual capacity to 55 bcm. According to Nord Stream AG, total investment in the offshore pipeline is projected at €7.4 billion (Nord Stream AG, 2010a).

3. *Onshore Connection in Germany: NEL and OPAL pipelines*

The OPAL[27] pipeline is intended to connect the landing point of Nord Stream's offshore part at Lubmin near Greifswald to Germany's existing gas pipeline grid. The line will carry natural gas from Lubmin to Olbernhau on the Czech border. The length of the pipeline is 470 kilometres south to Olbernhau on the Czech border. The capacity of the project is 35 bcm/a. The line is planned to operate from late 2011. According to the project sponsors, the estimated cost of the line is around €1 bn (OPAL, 2010).

The NEL[28] pipeline will bring gas coming from Nord Stream offshore westward, with the possibility of supplying the Netherlands and beyond through BBL/IUK to the UK gas market. The pipeline is expected to start operation in late 2012. The line will run from Lubmin to Achim, near Rehden (~440 km) with design capacity of 20 bcm/a. The official cost estimate of the pipeline is €1 bn (NEL, 2010).

4. *Onshore Connection in Czech Republic: Gazelle pipeline*

[27] Ostsee-Pipeline-Anbindungs-Leitung – Baltic Sea Pipeline Link
[28] Norddeutsche Erdgas-Leitung – Northern German Gas Link

The Gazelle pipeline will be connected with OPAL at Hora Svaté Kateřiny to bring gas from Nord Stream across Czech Republic to Rozvadov, near Waidhaus on the Czech-German border. The pipeline length is between 166-235 km with a design capacity of 30-33 bcm/a. According to the project investor, NET4GAS (Czech's TSO), the investment cost is estimated at €400 mln and the pipeline will start operation in 2011 (NET4GAS, 2010). Formally, Gazelle pipeline is not part of Nord Stream system. NET4GAS, which is the owner of Gazelle project, has no stake in Nord Stream AG, the operator of Nord Stream, but for simplicity we consider the project to be part of the overall Nord Stream system.

Figure B1 Gryazovets-Vyborg Pipeline in Russia
Source: Gazprom (2010b)

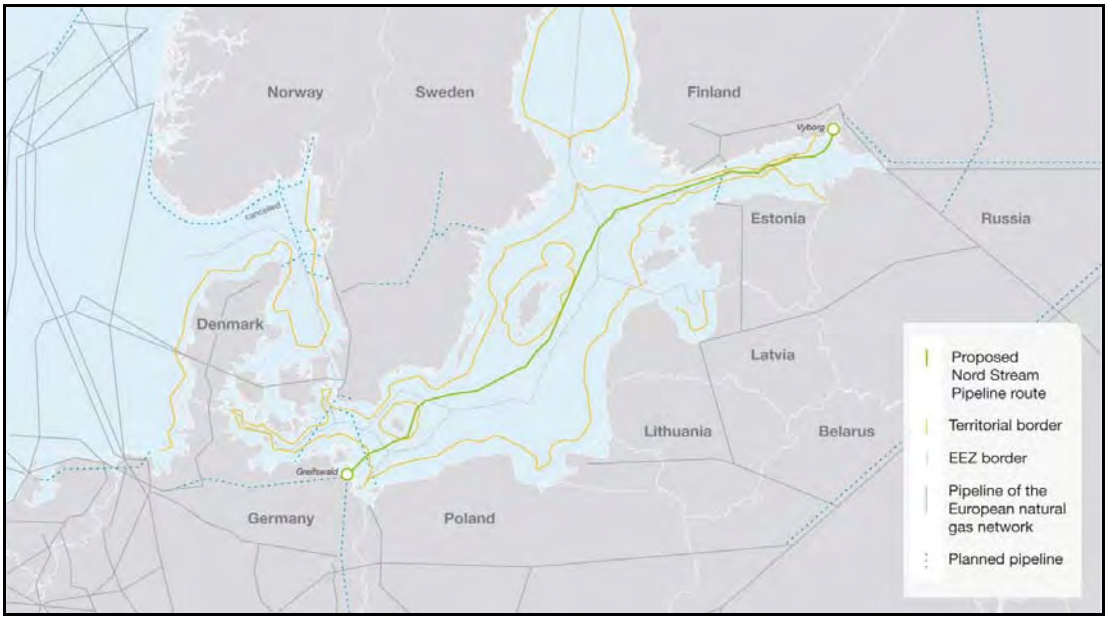

Figure B2 Nord Stream Offshore Pipeline
Source: Nord Stream AG (2010d)[29]

[29] With permission from Nord Stream AG

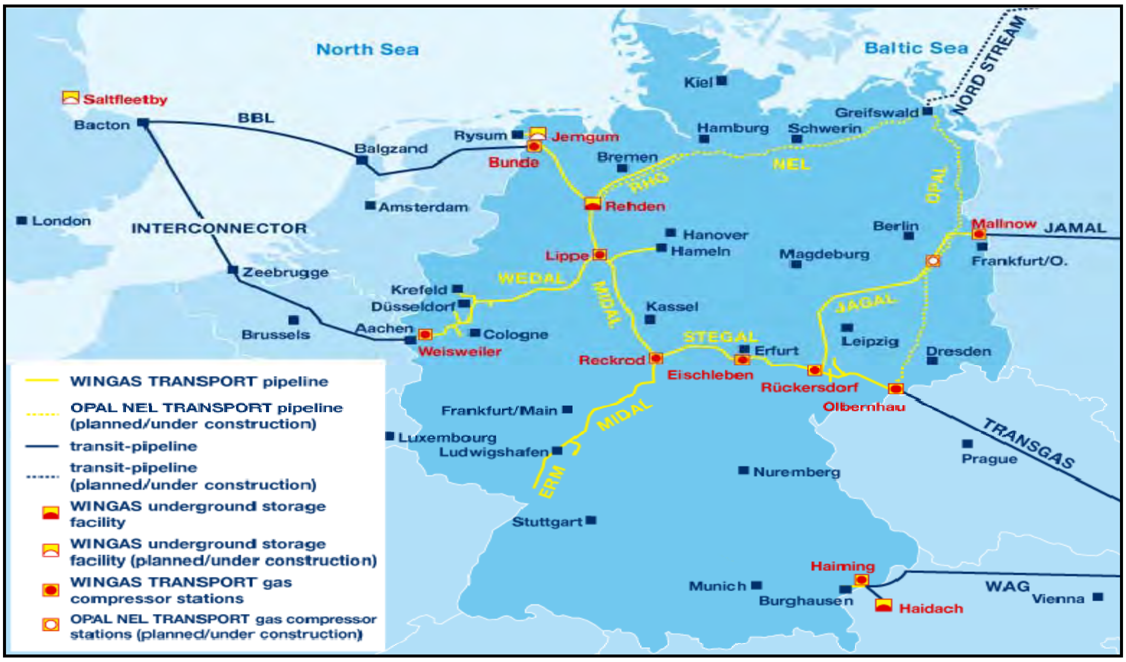

Figure B3 Onshore connection in Germany: Opal and Nel pipelines
Source: Wingas (2010)[30]

Figure B4 Gazelle Pipeline in Czech Republic
Source: original map from ENTSOG (2010)

[30] With permission from WINGAS

Appendix C Project-Based Analysis

C1. Levelized Transportation Cost Calculation

The levelized transportation cost is calculated as follows:

$$LTC = \frac{\text{PV of Total Life-cycle Cost}}{\text{PV of Total Gas Transported over the economic life of the pipeline}} \qquad (3)$$

<u>Present Value of Total life-cycle cost = (1)+(2)+(3)+(4)+(5)</u>

(1)	**Investment Costs** = E(PCC) + E(CCS) + other costs; $E(PCC) = IEC_p \times CF_p$ (1.1) $E(CCS) = IEC_c \times CF_c$ (1.2)	**E(PPC)** is Expected Pipeline Construction Cost; **E(CCS)** is Expected Cost of Compressor Stations; $\mathbf{IEC_p}$ is Initial Estimated Cost of constructing a particular pipeline of the Nord Stream system; $\mathbf{CF_p}$ is uncertain cost factor of pipeline construction. This is a random variable which is uniformly distributed between [0.9; 1.3]; [31] $\mathbf{IEC_c}$ is Initial Estimated Cost of compressor stations; $\mathbf{CF_c}$ is uncertain cost factor for compressor stations. Again, this is a random variable which is uniformly distributed between [1; 1.4]; **Other costs include:** - Upfront payment to obtain financing (in case of Nord Stream offshore only) – this is a one-off payment to secure the financial proposal by lenders issued to the borrower (usually termed commitment fees).
(2)	$-\sum_{n=1}^{N} \frac{\text{Depreciation}_n}{(1+\text{Discount Rate})^n} \times \text{Tax Rate}$	This is the present value of depreciation tax benefit over the economic life of the pipeline (N=30). The depreciation is determined by straight-line method. For simplicity we assume zero scrap value and decommissioning costs at the end of the depreciation period. The assumption is made because the depreciation period is much shorter than technical lifetime of a gas pipeline.

[31] The lower bound represents a 10% discount on the initial cost estimates because in 2006-2009 steel and construction prices increased far above historical rates. The upper bound (1.3) allows the cost of the Gryazovets-Vyborg pipeline to be inflated by 30% from IEC_p. An increase in cost by 30% from initial project budget is based on Barinov (2007) who surveyed the cost overruns (and their reasons) of capital intensive projects with a focus on oil and gas industry in the CIS.

(3)

$$+\sum_{n=1}^{N}\frac{O\&M_n}{(1+\text{Discounr Rate})^n}\times(1-\text{Tax Rate})$$

This is the present value of annual operating and maintenance costs of the pipeline and compressor stations. Annual O&M for the pipeline is determined as % of the capital costs of the pipeline (item 1 above).

(4)

$$+\sum_{n=1}^{N}\frac{\text{Cost of Debt Financing}_n}{(1+\text{Discount Rate})^n}\times(1-\text{Tax Rate})$$

Present value of annual payment for debt financing (where applicable) is added to the total life-cycle costs of the pipeline.

(5)

$$+\sum_{n=1}^{N}\frac{\text{Loan Amortization}_n}{(1+\text{Discount Rate})^n}$$

This is the present value of loan amortization (where applicable). In case of 100% equity financing (e.g. the Gryazovets-Vyborg pipeline on Russian territory) this item is not included in the total lifecycle cost of the pipeline.

<u>Present Value of Total gas transported over the life-cycle cost is derived as follows:</u>

(6)

$$\sum_{n=1}^{N}\frac{\text{Utilization Rate}\times\text{Pipeline Design Capacity}}{(1+\text{Discount Rate})^n}$$

Utilization rate (%) is an average rate of using the transportation capacity over the economic life of the pipeline (N=30). We assume 100% utilization rate but we also show calculations for the case of 75% utilization rate.

Box C1 Calculation of levelized transportation cost

All necessary inputs and assumptions for the calculation of levelized transportation costs are provided in section C2 of this appendix.

C2.Data and Assumptions

1. Investment Costs

1.1.Gryazovets-Vyborg Pipeline

The initial estimates of construction costs of Gryazovets-Vyborg (GV) pipeline in Russia were obtained from Gazprom (see table C1 below).

	Construction Cost (US$ mln)[32]	Length of Pipeline laid (km)	Average cost per km (US$ mln/km)
2006	729	144	5.07
2007	1048	156	6.72
2008	880	163	5.40
2009	1388	134	10.36
Average over the period 2006-2009			6.88

Table C1 Initial Estimates of Construction costs of the Gryazovets-Vyborg pipeline

[32] Based on the official average annual exchange rates for the respective years obtained from Central Bank of Russian Federation (CBR, 2010).

Source: Korchemkin (2010), Nazarova (2010), Nazarova (2009), Gazprom (2005)

Based on data from the table C1 we have derived the initial estimates of construction costs of the Gryazovets-Vyborg pipeline. During 2010-2011, Gazprom will have to finish laying down the rest of the Gryazovets-Vyborg pipeline (320 km). Therefore, the expected cost of the Gryazovets-Vyborg pipeline is estimated as follows.

$$E(PCC_{GV}) = US\$4045mln + 320km \cdot 6.88\frac{US\$\ mln}{km} \times CF_p \quad (4)$$

The total cost of compressors to be installed along the Gryazovets-Vyborg pipeline was derived as follows. The Ukrainian producer of industrial equipments, Frunze, reported that it has produced four 25 MWh compressor units for installation at the beginning of the Gryazovets-Vyborg pipeline (Frunze, 2010). The reported total cost of these compressors is US$52 mln (Ukrrudprom, 2010). Thus, if the total compressor power along the pipeline will be 1266 MWh, then the estimated cost of compressors to be equipped along the pipeline should be around US$ 660 mln. However, as was reported by Gazprom, the Portovaya Compressor station (366 MWh), which will compress gas before entering the Nord Stream offshore line, will be equipped with Rolls-Royce's compressor units with very advanced technology (52 MWh per compressor unit) (Gazprom, 2010c). It is thus reasonable to assume that 366 MWh of compressors purchased from Rolls-Royce might cost Gazprom considerably more than those from the Ukrainian producer. We have factored this in as a cost overrun on purchasing compressors for the pipeline. Therefore, expected costs of the compressor stations along the Gryazovets-Vyborg pipeline is calculated as:

$$E(CCS_{GV}) = 1266MWh \cdot US\$52mln \cdot CF_C \quad (5)$$

1.2. Nord Stream Offshore

Initial estimates of construction costs of the Nord Stream offshore (NSO) is based on official figure of €7.4 bln, quoted by Nord Stream AG (NSAG) (Nord Stream AG, 2010a). However, as noted above there might be overruns or delays which would affect project costs.[33] Major drivers of construction cost uncertainty include the uncertain costs of steel, construction, and engineering and procurement costs. The expected construction cost for the offshore pipeline is:

$$E(PCC_{NSO}) = €7.4 \times CF_C \quad (6)$$

1.3. Opal, Nel and Gazelle Pipelines

[33] Indeed recent news, quoting a representative of the Nord Stream pipeline, reported that the cost of the offshore pipeline could rise to €8.8 bln (Neftegaz, 2010).

The capital costs of Opal and Nel are quoted at €1 bln each (OPAL, 2010, NEL, 2010). For Gazelle project, the official figure for the capital cost is €400 mln (NET4GAS, 2010). As a starting point for the calculation of expected construction costs of these pipelines we use these official figures:

$$E(PCC_{Opal}) = €1bln \times CF_p \quad (7)$$

$$E(PCC_{Nel}) = €1bln \times CF_p \quad (8)$$

$$E(PCC_{Gazelle}) = €400mln \times CF_p \quad (9)$$

2. *Financial Costs: Discount and Interest Rates*

2.1. Gryazovets-Vyborg Pipeline

Since Gazprom is financing the construction of the Gryazovets-Vyborg pipeline, the discount rate applied to the project is based on Gazprom's weighted-average cost of capital, WACC, in 2003-2009 (see table C4). We treat WACC as a random variable which is uniformly distributed from [8.89; 15.41] with lower (upper) bound corresponding to the minimum (maximum) WACC in 2003-2009. We apply an investment rule of WACC+1% for the discount rate of the Gryazovets-Vyborg pipeline, following E.On's rule for investments in new pipelines (Schenck, 2010).

2.2. Nord Stream Offshore (NSO)

- *Debt Financing*

At the end of August 2009, Nord Stream's offshore owner and operator, NSAG, confirmed that Request for Proposals for the raising of senior debt for financing Phase 1 development have been issued to the commercial bank market.

According to NSAG, the construction of the offshore pipeline is to be financed with 30% equity from shareholders (Gazprom, BASF/Wintershall, E.ON Ruhrgas, Gasunie and GDF-Suez) and 70% senior debt. As of mid March 2010, NSAG has completed the financial deal with commercial banking market on the financing of the first phase of construction. NSAG has procured the total debt requirement of approximately €3.9 bln for Phase 1 from a combination of the following (Mangham, 2009):

- A syndicated covered loan of up to €3.1 bln provided by a pool of 26 commercial banks. The loan is covered by Export Credit Guarantee Programmes of Germany (Hermes) and Italy (SACE) as well as the Untied Loan Guarantee Programme of Germany, UFK;
- A syndicated loan facility on an uncovered basis in an amount of up to € 800 mln.

The structure of the loan guarantee is as follows:

  – € 3.1 bln loan is a 16-years loan facility covered by export credit agencies Hermes, Sace, as well as by Germany's loan guarantee programme UFK which covers political and commercial risk similar to Hermes. Hermes will cover €1.6 bln, UFK - €1 bln and Sace - €500 mln;
  – There is also an €800 mln, 10-year uncovered commercial loan.

The pricing of the debts is as follows:

– The €800 mln commercial uncovered loan pays a margin of 275 basis points (bps) over EURIBOR pre-completion, 430 bps until year 7 and 450 bps thereafter. The commitment fee is 110 bps.
– The Hermes, UFK and Sace loans pay a margin of 160 bps, 180 bps and 165 bps over EURIBOR respectively. The commitment fees are 65 bps, 75 bps and 65 bps, respectively.

Based on these financial conditions, the interest rate on the debt finance is expressed as follows:

$$I^{D}_{NSO} = c \times \left(\sum_{j} a_{j} \times [p_{j} + \text{EURIBOR}]\right) + (1 - c) \times \left(\sum_{T} a_{T} \times [p_{T} + \text{EURIBOR}]\right) \quad (10)$$

where c is the share of covered loan in the total debt finance, a_j is the share of each export credit agency in total covered loan, p_j is the price of each covered loan, a_T is the share of total length of covered loan with a price p_T, EURIBOR is the Euro interbank deposit rate.

As can be seen from financial conditions for phase I, the loan is the long-term deal and the pricing of that loan is based on EURIBOR, which would need the trend of EURIBOR for 16 years in the future (the length of the covered loan). We assume that EURIBOR is a random variable with a distribution similar to its trend in 1999-2009. This makes the EURIBOR trend in our cash-flow model (2010-2040) random.

- *Equity Financing*

Since there are no details yet for the financial conditions of the second phase of the Nord Stream offshore pipeline, we assume that the remaining investment costs are financed by NSAG shareholders. The cost of equity financing is discussed below.

- *Project Discount Rate*

Taken into account the cost of debt financing and using the data on the cost of capital for the investors (i.e., Gazprom, BASF/Wintershall, E.On Ruhrgas, Gasunie and GDF SUEZ) we have derived the WACC of the offshore pipeline which serves as the basis for the discount rate of the cash-flow model. In its presentation of annual report 2009 (Bernotat, 2010), E.On reported that the company's WACC during 2003-2009 varied between 9% and 10% (see table C3). E.On also indicated that its investments in new-build pipelines should exceed its WACC by at least 1%. Thus, we require the discount rate of the project to exceed the project WACC by 1%. Therefore, the project discount rate, DR, is derived as follows:[34]

$$DR_{NSO} = \left[d_{NSO} \times I^{D}_{NSO} + (1 - d_{NSO}) \times \left(\sum_{i} e_{i} \times WACC_{i}\right)\right] + 1\% \quad (11)$$

[34] We assume that WACC of the other two NSAG shareholders, Gasunie and GDF SUEZ, is similar to those of E.On and BASF since data on capital costs of Gasunie and GDF SUEZ was not publicly available. This assumption would not substantially undermine our results since both Gasunie and GDF SUEZ have relatively small shares in NSAG.

where d_{NSO} – is the share of debt financing in the NSO project, e_i - share of each shareholder in equity financing, $WACC_i$ – is the cost of capital of each shareholder respectively, I_D – is weighted-average interest rate on debt.

The WACC of each investor in the project is assumed to be a random variable which is uniformly distributed with minimum and maximum values specified in table C2.

	Gazprom	BASF	E.On Ruhrgas
2002	n/a	n/a	n/a
2003	8.98%	n/a	10%
2004	9.03%	n/a	9%
2005	8.91%	n/a	9%
2006	9.13%	10%	9%
2007	11.32%	9%	9%
2008	15.07%	10%	9%
2009	15.41%	9%	9%
Min	8.98%	9%	9%
Max	15.41%	10%	10%

Table C2 WACCs of Companies involved in the Nord Stream offshore pipeline

Source: Bernotat (2010), BASF (2010a), BASF (2007)

2.3. Opal, Nel and Gazelle

According to BASF's annual report 2009 (BASF, 2009), Wingas has borrowed €500 mln to finance the Opal project. The interest rate, I^D_{opal}, on this loan is 2.5%. However, no information on the length of this loan has been provided. Thus, we assume that it is a short-term loan (3 years) taking into account its relatively small size. We run sensitivity analysis on this assumption and found that a short-term loan of 3 years will result in just a 7.8% increase in the levelized transportation cost compared to a longer-term loan of 10 years. Thus, the assumption on the length of the loan contributes minimally to the cost calculations. The discount rate for the Opal project is derived as follows:

$$DR_{opal} = \left[d_{opal} \times I^D_{opal} + \left(1 - d_{opal}\right) \times WACC_{opal}\right] + 1\% \qquad (12)$$

where d_{opal} is the share of debt financing, I^D_{opal} is the interest rate on the loan, $WACC_{opal}$ is the cost of capital of Opal's major investor (BASF and E.ON), and is treated as a random variable with uniform distribution from [9%; 10%].

No public information is available on the details of financing the other two pipelines, Nel and Gazelle. We assume that they are fully financed by project sponsors, i.e. Wingas and NET4GAS (former RWE Transgas Net, owned by RWE AG (RWE, 2010a)). We use BASF and E.ON WACC (see table C3) for the discount rate in cost calculations for the Nel project. For Gazelle project discount rate we use RWE's WACC (9%-10%) in 2002-2009 (RWE, 2010b). The investment rule of WACC+1% is also applied here.

3. O&M Costs

Information on operating and maintenance (O&M) costs of pipelines is difficult to obtain because the considered pipelines are not yet in operation so we follow common practice in the literature and assume O&M costs to be a fixed fraction of investment costs of the pipeline (see e.g., ECT (2006); Krey and Minullin (2010)). We assume the annual cost of O&M of onshore pipelines to be 1.5% of their expected pipeline construction costs. For Nord Stream offshore pipeline, the O&M costs of the line are relatively lower than those of onshore pipes (Nord Stream AG, 2010b) so we assume O&M for offshore part to be 1% of the expected pipeline construction costs.

For O&M costs of compressor stations we use data from (Anders et al., 2006), who assume that each 1 horsepower (HP) used in a compressor station incurs $0.008 in O&M costs per hour of operation. For example, using a conversion factor 1341 HP per MWh and assuming that compressors are used continuously (i.e., 8760 hours per annum), annual O&M costs of compressor stations for the Gryazovets-Vyborg pipeline are:

$$1266\ \text{MWh} \times 1341 \frac{\text{HP}}{\text{MWh}} \times 0.008 \frac{\text{US\$}}{\text{HP/hr}} \times 8760\text{hr} \cong \text{US\$119 mln/a}$$

We applied the same calculation for the Opal pipeline and the resultant O&M costs of compressor station is $8.5 mln per annum.

The information on compressor stations of Gazelle and Nel pipeline were not publically available so we assumed that O&M costs of compressors would be reflected in O&M costs of these pipelines. Sensitivity analysis on this assumption shows that if we factor in $8.5 mln of annual O&M costs for a hypothetical compressor station (assuming a total power of 90 MWh, as in Opal pipeline, which would be too high for Gazelle as the distance is half the length of the Opal line), this would result in an increase of 4.7% on average in the total life-cycle cost for Nel pipeline and 12.2% for Gazelle pipeline and consequently would increase the levelized transportation cost by 4.8% for Nel and 11.9% for Gazelle. Thus, a one per cent increase in total life-cycle costs of the project gives around a one per cent increase in the levelized costs, which means a linear relationship between project costs and levelized costs. Thus excluding the O&M costs of compressor stations would not substantially affect our results.

4. Taxation and Depreciation

Depreciation and taxation is based on the taxation system of the country through which the pipeline passes. For pipelines in Germany (Opal and Nel) the effective corporate tax rate, including trade tax and solidarity tax, is between 29-32% (CFE, 2010), so we assume a rate of 30%. For the Gazelle pipeline, according to KPMG, the relevant corporate tax in the Czech Republic in 2010 would be 19% (KPMG, 2009).

For the Nord Stream offshore pipeline, according to Nord Stream AG, the taxation issue would mainly be under Swiss jurisdiction as the company is registered in Kanton Zug with a headquarters of around 140 staff (Nord Stream AG, 2010c). According to the tax system of Switzerland and Kanton Zug (Müller-Studer, 2009), Nord Stream AG enjoys special tax privileges because the company falls under the category of 'mixed company' i.e. a company whose main operations are not in Switzerland[35]. This type of company has to pay Direct Federal Tax of 8.5% on total profit and 6.5% on 25% the total profit. This results in an effective corporate tax of 10.125% of total profit for Nord Stream AG.

[35] At least 80% of operations should be outside Switzerland (Müller-Studer, 2009).

Appendix D Transmission costs in Russia

Following (The World Bank, 2009) we assume that at least transmission costs for gas exports should be priced at LRMC of a new transmission pipeline. Since we have analyzed in details the new transmission pipeline Gryazovets-Vyborg we apply its costs in calculation of transmission costs in Russia.

As noted above, Gazprom's future gas production should come from existing fields (NPT) and increasingly from the Yamal Peninsula. We have calculated the distance from these two production regions to each entry point of Gazprom's export routes (table D1).

FROM \ TO		Russia-Ukraine border36	Russia-Belarus border	Vyborg (Nord Stream route)
Production Region	Nadym-Pur-Taz[37]	2960 km	2850 km	3130 km
	Yamal Peninsula[38]	3330 km	2590 km	2870 km

Table D1 Distance between Gazprom's production sites and export points

Source: Derived based on EIA (2010)

Since the pipeline costs are essentially linear in terms of distance over similar terrain (ECT, 2006), the LRMC of gas transmission from production sites to each border point can then be derived as follows:

$$LRAIC_{m,b} = \frac{LTC_{GV}}{d_{GV}} \times d_{m,b} \tag{13}$$

where m and b are indices denoting the production region (NPT or Yamal) and border point (Russia-Ukraine, Russia-Belarus or Vyborg) respectively, LTC_{GV} is the levelized transportation cost through the Gryazovets-Vyborg pipeline, d_{GV} is the length of the Gryazovets-Vyborg pipeline, $d_{m,b}$ is the distance between production sites and border points.

Following eq. (13) and using data from table D1, we calculated the approximation of LRMC of gas transmission in Russia. The results are presented in table D2.

FROM \ TO		**Russia-Ukraine border**	**Russia-Belarus border**	**Vyborg (Nord Stream route)**
Production Region	Nadym-Pur-Taz (US$/tcm)	92.7	89.2	98.2
	Yamal Peninsula (US$/tcm)	104.4	81.1	90.0

Table D2 Transportation cost within Russia

[36] Gas metering station "Sudja"
[37] Urengoi field was taken as representative of NPT production region
[38] Bovanenkovo field was taken as representative of Yamal Peninsula production region

Appendix E Modelling Transit Pricing through Ukraine

Below we provide briefly how transit pricing through Ukraine is modelled, since the transit pricing behaviour affects directly our results. The result of modelling transit cost through Ukraine is described by eq. (14):[39]

$$tc_u = w_u tf_u + (1 - w_u)tf_u^* + w_u p_u \quad (14)$$

$$tf_u = mc_u - \frac{q_u}{\sigma_u} \quad (15)$$

$$\sigma_u = \frac{\partial q_u}{\partial tf_u} < 0 \quad (16)$$

where w_u is 0-1 parameter: w_u=0 if transit pricing is assumed exogenous, w_u=1 if we want to model transit cost endogenously; tf_u^* is exogenous transit fee (see below); mc_u>0 is marginal cost of using transit pipelines, q_u is total gas transport quantity through Ukraine, and p_u is a congestion fee (it is positive if a capacity constraint on transit pipelines are binding), σ_u is conjectured transit parameter measured in bcm/US$/tcm.

The behavioural assumption described by parameter σ_u can be summarized as follows. If Ukraine increases its transit fee by some units (Δtf_u) then Gazprom will reduce transportation (by $\sigma_u \times \Delta tf_u$) through Ukraine (if Gazprom has free capacities on other export routes). If parameter $|\sigma_u|$ is large enough, then a small change in transit fee would cause a large change in transport quantities through Ukraine. This situation is possible when Gazprom has substantial bargaining power vis-a-vis Ukraine (either by having substantial "bypass" capacities or through other mechanism, such as manipulation with import prices for Ukraine). However, if $|\sigma_u|$ is negligible any changes in transit fee have little effect on Gazprom's quantity shipped through Ukraine. In this case, Ukraine is assumed to have substantial bargaining power vis-a-vis Gazprom (e.g., because Gazprom has no free capacities on alternative export routes to Europe).

- *Exogenous transit fee through Ukraine*

According to the current long-term transit contract between Gazprom and Naftogaz of Ukraine (Ukrainska Pravda, 2009), since 2010 the transit fee, tf_n^*, is determined as follows[40]:

$$tf_n^* = A_n + K_{nj} \quad (17)$$

$$A_n = 0.5 \times A_{2010} + 0.5 \times [A_{n-1} \times (1 + I_{n-1})] \quad (18)$$

$$K_{nj} = \frac{0.03 \times P_{nj}}{L} \times 100 \quad (19)$$

where A_{2010}=US$2.04/tcm/100km; for 2010, $A_{n-1}=A_{2010}$; I_n inflation rate in the European Union; for 2010 I_{n-1}=0; K_{nj} is the 'petroleum' component of transit fee formula which is determined monthly; P_{nj} is Ukrainian import price; L – transit distance through Ukraine (1240 km); Subscript n – relevant year of transportation and j – relevant month of gas transportation in year n.

We have calculated the forecast of the transit fee through Ukraine until 2040 based on the transit pricing formula specified by eq. (17-19). Since

[39] For details on derivation of eq. (14) and (15) see Chyong and Hobbs (2010)

[40] Note that we omit subscript *u* denoting transit through Ukraine for ease of reading the formulas.

calculation of the transit fee requires forecasting the inflation rate, we have simulated possible future values of the inflation rate, taking its value as an uncertain variable with historical distribution of average inflation rate in 1997-2009. The average value of the transit fee obtained from the simulations is US$25.6/tcm.[41]

[41] The minimum value is US$25.5/tcm and the maximum value is US$25.8/tcm. This value does not include fuel cost to transport gas through Ukraine.