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Strategic Interdependence in the East-West Gas Trade

A Hierarchical Stackelberg Game Approach

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This Stackelberg game provides a framework for analyzing the strategic moves of three players in the East-West gas trade — a Western importer, a transiter, and a Russian supplier as the game leader — and gaining insights into their predictability.

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Summary findings

The current and potential benefits of the East-West gas trade are enormous for all participants. Realizing those benefits requires significant upfront investments. But the new, more complex structure of the gas transit system that has emerged following changes in Eastern Europe and the former Soviet Union has created uncertainties that bear on the expected benefits from investments.

Grais and Zheng argue for the existence of stable contracts that would create an environment more conducive to investments and allow all participants to benefit from expansion of the gas trade.

As a guide to formulating incentive-compatible, transparent, flexible contracts, they propose a framework based on a Stackelberg game, with three players (a supplier, a transiter, and an importer) under Russia's leadership. They use this framework to analyze the contract modifications that would ensue from changes affecting the gas trade. They conclude that:

- Increased competitiveness of the transiter and supplier through cost reductions would improve the payoffs to all players (the transiter's and supplier's profits and the Western importer's welfare). Strategic behavior on the part of the supplier and transiter would ultimately reduce the price to the importer, enlarging gas demand and reducing costs. If increased competitiveness is the outcome of more costly gas from sources other than Russia, both the supplier's and the transiter's payoffs would improve but the importer's welfare would deteriorate. The supplier and transiter would have leeway to strategically raise their price and transit fee, respectively, while gaining market share. But the importer would face rising costs for gas imports and would lose welfare.
- An increase in the scope for the importer to substitute between alternative sources of gas improves welfare for all three players. The perception by the supplier and transiter of increased threat of competition leads to a preemptive move not to lose market share. The transiter and supplier reduce the transit fee and supply price, respectively, allowing the importer to face a lower gas price. Import demand expands and welfare improves. The expanded trade more than compensates for the reduction in the transit fee and supply price and allows larger payoffs for transiter and supplier.
- The perception of increased reliability of Russian gas supplies expands demand for Russian gas and leads to the expansion of trade. The supplier and transiter can raise their respective charges with expanded volume, improving their payoffs. The importer's welfare deteriorates as the cost of importing gas rises.

The predictability of the players' reactions to changes in the environment would build confidence in the reliability of gas trade and allow its expansion, benefiting all participants.

This paper — a product of Europe and Central Asia, Country Department IV, Country Operations Division 2 — is part of a larger effort in the region to address the issues in the energy sector raised by the collapse of the fomer Soviet Union and the transition to market economies. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Kangbin Zheng, room H2-092, extension 36974 (22 pages). August 1994.

STRATEGIC INTERDEPENDENCE IN THE EAST-WEST GAS TRADE
— A Hierarchical Stackelberg Game Approach

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Summary

The current and potential benefits of the East West gas trade are enormous for all participants. The realization of these benefits require significant upfront investments. The new, and more complex, structure of the gas transit system that has emerged following the changes in Eastern Europe and the Former Soviet Union has created uncertainties however that bear on the expected benefits of the investments. This paper argues for the existence of stable contracts that would create an environment more conducive to the investments and allow all participants to benefit from the expansion of the gas trade. A framework based on a Stackelberg game with three players (a supplier, a transiter and an importer) under Russia's leadership is proposed as a guide to the formulation of incentive compatible, transparent and flexible contracts. The framework is used to analyze the contract modifications that would ensue from changes in the environment bearing on the gas trade. Three main conclusions can be drawn.

An increased competitiveness of the transiter and supplier through cost reductions would improve the pay-offs of all players in the game. The transiter's and supplier's profits as well as the western importer's welfare would improve. Basically it would induce a strategic behavior on the part of the supplier and transiter that would lead to a decline in the price faced by the importer, enlarging gas demand and reducing costs. If the increased competitiveness is the outcome of more costly gas from other sources than Russia, both the supplier's and transiter's pay-offs would improve but the importer's welfare would deteriorate. The supplier and transiter would have leeway to strategically raise their price and transit fee respectively while gaining market share. The importer however would face rising costs of gas imports and lose welfare.

An increase in the scope of substitution for the importer between gas from alternative sources improves on welfare of all three players. The perception on the part of the supplier and transiter of an enhanced threat of competition leads to a preemptive move to not lose market share. The transiter and supplier reduce the transit fee and supply price respectively allowing the importer to face a lower gas price. The latter's import demand expands and welfare improves. The expanded trade more than compensates for the reduction in the transit fee and supply price and allows for larger pay-offs for the transiter and supplier.

The perception of increased reliability of supplies of gas from Russia shifts outward the demand for gas from Russia and leads to the expansion of trade. The supplier and transiter have scope to raise their respective charges with expanded volumes improving their pay-offs. The importer's welfare deteriorates as the cost of importing gas rises.

The predictability of the players' reactions to changes in the environment would build confidence in the reliability of gas trade and allow its expansion benefitting all participants. The game proposed in the paper provides a framework for analyzing the strategic moves of the players and gaining insights on their predictability.

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I. Introduction: The Need for Stable Contracts

In 1992 Russia exported to Western Europe about 60 billion cubic meters (bcm) of gas at a value of $9 billion. Russia, the Western marketers (mainly Ruhrgas), and the transit countries received 43%, 47% and 10% respectively of the value of the gas delivered. Ukraine's and the then Czechoslovak's shares amounted to $100 and $730 million respectively. For foreign exchange strapped Russia and transit countries, gas exports are a critical source of revenue. They are also essential for the western European countries that rely for 25% of their gas consumption on Russian sources. The stakes are even much larger if one looks at the potential expansion of that trade. Europe is likely to increase its reliance on gas, notably because of environmental concerns, while Russia could generate and deliver large additional supplies[1].

Given the up front costs involved, to develop the East-West gas market and provide participants with the associated benefits, stability of contracts will be essential. That will require a perception of fairness on the part of all involved, as well as transparency and flexibility of the rules. Some of these features partially characterized gas trade while the Soviet Union existed. However the disintegration of the latter, the "velvet divorce" of the Czech and Slovak republics, and the transition to private market economies of the countries of central Europe and the former Soviet Union (FSU) have created new conditions and expressions of specific country interests that call into question previous arrangements.

This paper develops a framework within which fair, i.e. incentive compatible, transparent and flexible contract rules can be analyzed. In light of the emerging structure of the market, it identifies participants and looks at their sharing of rents as a non-cooperative non-zero-sum game.

Section II below briefly describes the structure of the market as it is emerging post the collapse of the FSU. Section III then delineates the interdependence and interactions in the East-West gas trade as a Stackelberg non-cooperative game with Russia as the leader, and discusses the equilibrium outcome of the game in general. Section IV develops a numerical application assuming a social welfare function for the western gas importer of the nested constant-elasticity-of-substitution (CES) type, under transparent assumptions and conditions prevailing around 1993. It analyzes how exogenous changes modify the outcome, offering an illustration of the transparency and flexibility of the rules. Conclusions and policy implications follow. The detailed mathematical structure of the game and the calibration of the initial conditions are presented in the Annex.

II. The Changing Structure of the East-West Gas Trade

The gas pipelines transit system channels Russian gas from Siberian fields northeast of Moscow through Ukraine, Slovakia and the Czech Republic to Germany. Some gas transits through Belarus, while Austria and Italy also receive deliveries.

Before the collapse of the Eastern Bloc, a stable market relationship existed between a monopoly supplier, Gazprom of the Soviet Union, and a monopsony buyer, Ruhrgas of Germany. Gazprom sold the gas at an agreed upon price at the western border of then Czechoslovakia and paid fees to local gas transit companies in Belarus, Ukraine and Czechoslovakia. Ruhrgas distributed the gas to industrial users and consumers in Germany.

Since 1989 Czechoslovakia split from the Eastern Bloc and then went through the "velvet divorce" between its two constituting components the Czech Republic and Slovakia. Meanwhile the dissolution of the Soviet Union allowed Belarus and Ukraine to emerge as independent states. Each of these new actors gained a monopolistic control on the portion of gas pipeline running through its territory.

These historical events put into question the stable monopolist-monopsonist relationship that existed previously. The transit countries, also dependent on Russia for their energy resources, sought to improve their situation by claiming a higher fee for the transit services they provide[2]. Meanwhile Gazprom is developing a new commercial and development strategy to maintain its dominant role in the transit system and the benefits associated with it. This strategy could include pursuing equity participation in the transit companies of other countries to exert some control on them, promoting construction of new pipeline routes to break the monopolies of transiters, forming partnerships with distributors, and gaining new clients to strengthen demand[3]. Finally western consumers, balancing costs and security of supplies, are considering alternative sources ranging from North African, Middle Eastern to Norwegian gas.

The terms of the East-West gas trade have become more complex. More participants are now involved. Each has the potential for disrupting supplies if it perceives unfairness and possible additional gains. Incentive compatible, transparent and flexible rules that can survive are needed even more now than previously.

III. A Game Theoretical Approach to the East-West Gas Trade

The following describes the East-West gas trade as a three-player, non-cooperative repeatable game with information asymmetry and behavioral coordination. The economic rationale for these assumptions are discussed below and lead into the formulation of a set of relationships whose solutions are the transit fee, the price of gas charged by Russia, and the amount of demand for gas by the importer.

A. Players

The current East-West gas trade can be modeled as a game among three players: a supplier (Russia), a transiter (Belarus, Ukraine, Slovakia and the Czech Republic) and a consumer (Western Europe). This grouping of participants reflects the common characteristics of interests within each group and captures the essential interdependence within the gas trade chain[4].

In a longer time perspective, more participants are likely to be involved in this trade. Turkmenistan and Kazkhstan, Norway, Middle East or African countries may contribute to supplies in competition with Russia. Poland is a major potential competitor to current transit countries. More Western European countries may want to have direct access to Russian gas. In addition increased private participation may add new transit and distributor companies. These developments would increase the number of participants in each of the three identified groups of players. Eventually a more competitive market could emerge.

B. Decision Variable of Each Player

One of Russia's major decisions is the price it would charge for the gas it exports, say P_R in rubles. Similarly one of the main concerns of transit countries is the transit fee, denoted by T in local currency, to be charged. Finally the importer's essential decision is the amount G of gas to buy from Russia. Assuming e_R and e_D to be the exchange rates between the Russian ruble and the transiter's local currency and between the latter and the importer's currency respectively, the three identified decision variables are linked in the following way

$$e_D \, P_G = T + e_R \, P_R \ , \qquad (1)$$

where P_G is the gas price the importer would pay in local currency, and this price would directly affect the demand G. Alternatively the foregoing relationship entails:

$$P_G = P_G(P_R \, , T \, , e_D \, , e_R) \ , \qquad (2)$$

reflecting the direct dependence of the local price paid by the Western importer on the Russian supply price, P_R, the transit fee, T, and the relevant exchange rates. It is not difficult to verify that[5] P_G will rise if Russia raises its export price, the transiter increases its transit fee, or the importer's currency appreciates.

For simplicity, the foregoing formulation assumes that each of the three participants concentrates on one major decision variable, or alternatively each one has a one-dimensional strategy space. In fact, every player's strategy space can be multi-dimensional, and each is likely to be able to influence a number factors. Russia could decide inter alia on the price and volume of the gas supplied for the domestic consumption of the transiter, the price and volume of oil deliveries, electricity exchanges and their tariffs, apart from the price to be charged to the final Western importer. Besides the transit fee, the transiter has discretion over the amount of storage it can offer, and the level and quality of services it provides. Finally apart from the volume of gas it imports from Russia, the importer would be deciding simultaneously on gas imports from other sources as well as on the use of alternative kinds of energy. The multi-dimensionality of each player's choices is very important in reality, and is a direction for further research.

C. The Players' Pay-off Functions

Each player's objective in the game is to choose its best strategy to maximize its payoff. The Western importer's pay-off function is the welfare associated with the volume of gas imported from Russia. Abstracting from institutional complexities and from the details of how gas contributes to welfare, one can assume a utility function[6], depending on the quantity G, a vector of quantities of other goods consumed Z, including gas and energy imported from other sources, and a vector of parameters A:

$$U = U(G, Z, A) . \qquad (3)$$

Based on the above utility function, the information on the prices charged for the various goods, including P_z, the price index of the composite good Z, and the available total expenditure Y, the Western importer's demand for Russian gas would result from utility maximization as

$$G = G(P_G, P_z, Y, A) . \qquad (4)$$

Naturally utility maximization would result in a parallel demand equation for the composite good Z.Under normal assumptions an increase in P_G would drive down G, and a decline in the price of energy from alternative sources, captured by a decrease of P_Z, would shift the demand curve outward. The vector of parameters A would include the perception of the reliability of supplies, among other factors not specifically spelt out here.

The transiter's pay-off is the profit it draws from the gas transit. This is defined assuming that the transiter is aware of the unit gas transit cost S, the fixed pipeline cost F_T, the price P_R Russia charges, the behavior "rule" of the Western importer (4), and the relationship (2) between prices and the transit fee. The pay-off function of the transiter is then:

$$\Pi^T(P_R, T) = (T-S)\,G[P_G(P_R, T)] - F_T \qquad (5)$$

For any given Russian supply price P_R, the transiter selects the transit fee T to maximize its profit. The transiter is here a Stackelberg follower as its behavior is a reaction rule to the price signal set by Russia as the leader. The maximization will lead the transiter to set the fee at the point where the marginal revenue of an increase in the transit fee is equal to the marginal cost[7]. The outcome will be a transit fee T that depends on the Russian supply price, P_R, the unit transit cost S, the relevant exchange rates, and the market import demand for Russian gas in western Europe:

$$T = T(P_R, S, F_T, e_D, e_R, P_z, Y, A) \qquad (6)$$

The Russian gas supplier is assumed to have full knowledge of the transiter's reaction function (6), of the Western importer's behavior (4) and of the relationship between the relevant prices (2). With C denoting the known unit cost for gas production and F_R the fixed cost, the Russian gas supplier's pay-off function is:

$$\Pi^R(P_R) = (P_R - C)G[P_G(P_R)] - F_R\ , \quad (7)$$

where the argument T in $P_G(.)$ has been replaced by the expression in (6) reflecting the transiter's behavior. The gas supplier will select P_R to maximize its profit as presented in (7). The price chosen will be the one at which the marginal revenue and cost of an increase in P_R are equal, the marginal cost being the revenue foregone by the ensuing decline in demand[8]. The profit maximization will result in a price P_R such as:

$$P_R = P_R(C, F_R, S, F_T, P_z, Y, e_D, e_R, A) \quad (8)$$

D. Interactions between Players

Russia is assumed to have a leadership role in the supply of gas to Western markets. It is the largest supplier that can satisfy Western Europe's demand at an economic cost in the short to medium term. This position gives it an influential role in the determination of the price it can charge. The above framework captures Russia's leadership role in the fact that the critical decision that determines the game outcome is the Russian gas supplier's determination of the price P_R. Once that decision is made, the other players in the chain will use their decision rule to react. The transiter and the Western importer will determine the transit fee T and the demand of gas G, respectively. The further assumption of behavioral coordination is based on the presumption that no player is expected to challenge the leadership role of the Russian supplier in the short to medium term (entailing that this hierarchical decision structure is likely to last for a while) and the players' acceptability of the sequential nature of the decision-making procedure in the chain. However, if developments render Russia desperate for foreign exchange, its leadership role may come into question and the framework proposed here would need to be modified.

The framework considered in the foregoing assumes an asymmetry in the availability of information to the players. In order to proceed with its decision-making on P_R, the Russian supplier needs to have access to information on other players' decision parameters (e.g., factors affecting demand in European markets, Y, A, P_z, i.e. the parameters entering the other players' decision rules). However the transiter needs only to observe the determinants of the Western importer's demand while the latter decides on the basis of only the price signal P_G and information on his own environment. The assumption on information asymmetry reflects the reluctance of Gazprom to allow foreign equity participation in either gas production or transit companies and its active efforts to get involved in downstream activities.

Before 1990, the transiters and the suppliers formed a coalition. Then Czechoslovakia, Ukraine, Belarus and Russia shared information, production resources and revenues in cooperation. The configuration of the transit system that emerged after 1991 has not allowed the pursuit of previous cooperation and is making attempts at reviving difficult. This feature is captured in the non-cooperative nature of the game framework proposed in the above[9].

Finally the decisions made can be undone and adjusted in response to changes in the environment of each participant. There is always the possibility of recontracting within the same framework which gives the game its repeatable feature.

E. A Summary Presentation of the Game

The behaviors outlined in the foregoing lead to two sets of equations. The first is composed of three relations that together determine the core variables namely the supplier's price P_R, the transit fee T and the importer's demand for gas G. These three equations (8), (6) and (4) respectively are gathered in the top panel of Table 1, and followed by relation (2) that link the price faced by the importer to that charged by the supplier and to the transit fee. The second set of equations are presented in the lower panel of Table 1. They permit the computation of the total rent accruing to both the transiter and the supplier and their respective shares, the profit of each of them, and the welfare index of the importer. This second set of variables can be derived once the three core ones are determined.

The recursivity of the set of the three core equations in the top panel of Table 1 reflects the Stackelberg leadership of the supplier. Equation (8) allows the supplier to determine his price on the basis of his information on costs, market conditions and the other players' reaction functions. Once the supplier sets a price P_R, then the transiter through equation (6) determines the transit fee T. Finally the importer can decide on the level of gas imports from Russia G.

Table 1

The System of Equations of Strategic Interdependence among Players

<table>
<tr><td colspan="2">Supplier's Price</td><td>P_R</td><td>$P_R = P_R(C, F_R, S, F_T, P_Z, Y, e_D, e_R, A)$</td></tr>
<tr><td colspan="2">Transit Fee</td><td>T</td><td>$T = T(P_R, S, F_T, e_D, e_R, P_Z, Y, A)$</td></tr>
<tr><td colspan="2">Demand for Russian Gas</td><td>G</td><td>$G = G(P_G, P_Z, Y, A)$</td></tr>
<tr><td colspan="2">Importer's Price</td><td>P_G</td><td>$P_G = \frac{T + e_R P_R}{e_D}$</td></tr>
<tr><td colspan="2">Demand for Other Goods</td><td>Z</td><td>$Z = Z(P_G, P_Z, Y, A)$</td></tr>
<tr><td colspan="2">Importer's Welfare Index</td><td>U</td><td>$U = U(G, Z, A)$</td></tr>
<tr><td colspan="2">Unit Rent</td><td>R</td><td>$R = e_D P_G - S - e_R C$</td></tr>
<tr><td colspan="2">Russia's Profit</td><td>Π^R</td><td>$\Pi^R = (P_R - C)G - F_R$</td></tr>
<tr><td colspan="2">Transiter's Profit</td><td>Π^T</td><td>$\Pi^T = (T - S)G - F_T$</td></tr>
<tr><td rowspan="3">Transiter's Share in</td><td>Revenue</td><td>ω_P</td><td>$\omega_P = \frac{T}{T + e_R P_R}$</td></tr>
<tr><td>Unit Rent</td><td>ω_R</td><td>$\omega_R = \frac{T - S}{T + e_R P_R - S - e_R C}$</td></tr>
<tr><td>Total Profit</td><td>ω_Π</td><td>$\omega_\Pi = \frac{\Pi^T}{\Pi^T + e_R \Pi^R}$</td></tr>
</table>

IV. Contract Modifications in Response to Exogenous Changes

In the following, we analyze how the game regains its equilibrium solution and the players change their strategy selections, in response to external shocks. These comparative statics analyses show that gas trade contracts with incentive compatibility as presented in our game solutions possess sufficient flexibility to be modified to reflect changes in the trade environment. Each player will act on its decision variable, that is the three core variables P_R, T, and G, depending on the strategic interactions specified in the game. The assumption on the behavior of the importer as reflected by the specification of the welfare function plays a critical role in determining the outcome of the game. Here we assume a nested CES type welfare index[10], which provides a reasonable first approach while allowing for ease of calibration. Table 2 presents the set of equations of the game with the assumption of a CES welfare index, while Tables 3 and 4 identify the signs of the partial derivatives and the elasticities of endogenous variables respectively in the neighborhood of the initial equilibrium, as calibrated on 1992 figures (see Annex). We first consider changes in the importer's environment and then in the transiter's and producer's. In each case, we look at modifications of the players' strategy choice, the payoffs, and the distribution of trade gains.

A. Changes in the Importer's Environment

The importer's decision environment can be affected by: i) an increased expenditure on gas as can result from a general expansion of the western economy or inter-fuel substitution between oil and gas due to stronger environmental concerns; ii) a shift in the western demand schedule of Russian gas either due for example to a changed perception of its reliability or the price behavior of competitors, and iii) increased competition in the gas market.

An increase of the expenditure on gas ($\Delta Y > 0$) relaxes the importer's budget constraint, and thus contributes to the expansion of demand for gas from all sources, as a direct result of the income effect in welfare maximization (Tables 3 and 4, collum 4). Strategic interactions in the competitive gas market force the supplier and the transiter not to raise their supply price and transit fee, respectively, in respond to a growing demand. Indeed any increase in the price of Russian gas charged to the importer would induce alternative suppliers to capture a larger share of the increased demand, compress Russia's market share, and limit the improvement in pay-offs to both the transiter and supplier below the one which could be obtained under a no-price-change strategy[11].

Consequently, all three players benefit from the stronger purchasing power of the importer and the enlarged volume of gas trade. Due to the homogeneity of degree one assumption of the welfare function, a one percent increase in Y leads to a one percent expansion of gas demand G, and improves the importer's welfare index by one percent. The transiter's and supplier's pay-offs improve by more than one percent each, because of the presence of fixed costs in their pay-offs[12].

Finally, it is noticeable that, though its profit rises, the transiter's share in the total profit becomes marginally lower, reflecting its lower fixed costs. However, the rent and revenue share of the transiter do not change as they depend only on prices which remain unchanged when the importer's expenditure on gas increases.

Table 2
Strategic Interdependence with a Nested CES Welfare Function for the Importer

Supplier's Price	P_R	$\frac{S+e_R P_R}{T(P_R)+e_R P_R} - \frac{T(P_R)-S}{P_R - C}\frac{T(P_R)+e_R C}{T(P_R)+e_R P_R}\frac{1}{e_R} = 1 - \frac{T(P_R)+e_R P_R}{\sigma[e_R P_R + S]} - \frac{T(P_R)+e_R P_R}{\sigma[T(P_R)-S]}$
Transit Fee	T	$\frac{T-S}{e_R P_R + S} = \frac{1}{\sigma-1}\left[\frac{\alpha}{1-\alpha}\left(\frac{T+e_R P_R}{e_D P_O}\right)^{1-\sigma}+1\right]$
Demand for Russian Gas	G	$G = \frac{\alpha e_D Y}{T+e_R P_R}\left[\alpha + (1-\alpha)\left(\frac{T+e_R P_R}{e_D P_O}\right)^{\sigma-1}\right]^{-1}$
Importer's Price	P_G	$P_G = \frac{1}{e_D}(T + e_R P_R)$
Demand for "Other" Gas	O	$O = \frac{1}{P_O}(Y - P_G G)$
Importer's Welfare Index	U	$U = CES[G,O;\alpha,\sigma] = \left(\alpha^{\frac{1}{\sigma}}G^{1-\frac{1}{\sigma}}+(1-\alpha)^{\frac{1}{\sigma}}O^{1-\frac{1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$
Unit Rent	R	$R = e_D P_G - S - e_R C$
Russia's Profit	Π^R	$\Pi^R = (P_R - C)G - F_R$
Transiter's Profit	Π^T	$\Pi^T = (T-S)G - F_T$
Share of Transiter in: Revenue	ω_P	$\omega_P = \frac{T}{T + e_R P_R}$
Share of Transiter in: Unit Rent	ω_R	$\omega_R = \frac{T - S}{T + e_R P_R - S - e_R C}$
Share of Transiter in: Profit	ω_Π	$\omega_\Pi = \frac{\Pi^T}{\Pi^T + e_R \Pi^R}$

An outward shift in the demand schedule for Russian gas can result, for instance, from a perception of increased supply reliability, which leads to an exogenous increase in Russia's market share ($\Delta\alpha > 0$) (Tables 3 and 4, col. 6), or from a rising price of competitors ($\Delta P_o > 0$) (Tables 3 and 4, col. 7). These developments will reduce, relatively, the competitiveness of non-Russian gas suppliers, and strengthen the negotiating power of the transiter and supplier. Therefore, they are provided with some leeway to increase their fee and price respectively, while continuing to benefit from a larger volume of trade. The importer has to rely more on the gas from Russia. For a given expenditure on gas imports, demand for gas from other sources is compressed to the extent more than the increased demand for Russian gas (i.e. $\Delta O + \Delta G < 0$). The average import cost is raised. Accordingly, the total consumption of gas declines.

As a result, Russia's and the transiter's pay-offs are improved, while the welfare index of the importer is worsened. Naturally the revenue, rent and profits of the supplier and transiter expand.

The distribution pattern of the trade gain changes mainly in response to the variations of the revenue-cost ratios. Because the percentage increase in transit fee is larger than that in the supplier's price, the transiter's share in revenue improves. However, both the supplier's variable and fixed costs are larger than those of the transiter. Therefore, the unit rent and profit of the supplier expand more than those of the transiter, whose shares in them deteriorate slightly.

The gas market in Western Europe may become more competitive. One reason, among others, can be a rise in the scope of substitutability for the importer between gas from alternative sources ($\Delta\sigma > 0$) (Tables 3 and 4, col. 5.). The increase in σ will result in the perception by both the supplier and the transiter of a weakening of their negotiation power and lead to a reduction of the supply price P_R and the transit fee T, to attain their maximal profits. The importer now faces a lower price P_G and demands more Russian gas. Gas from other sources is crowded out, but not as much as the incremental Russian gas supply.

One of the most important messages here is that stronger market competition benefits all agents in the market. The overall East-West gas trade expands. The average import cost declines. All three players harvest larger pay-offs. The importer consumes more gas thanks to that competition beats down prices. The transiter's and supplier's profits also improve, because the expansion in gas trade (+1.32) is relatively more important than the decline in the unit rent (-.63).

Nevertheless, the transiter's bargaining power shrinks more than that of the supplier, when the western European gas market becomes more competitive, due mainly to its position in this chain game as a Stackelberg follower. Hence, its shares in revenues, rents and profits deteriorate, leaving relatively more to the supplier. The larger decline in the transit fee (-.66) than in the supplier's price (-0.1) drives down the transiter's share in revenues. Similarly, the transiter gets a smaller share in the total rent (down by -.25) and the total profit (down by -.32).

Table 3

Directions of Variations of Endogenous Variables with Respect to Fluctuations of Exogenous Variables

(In the Neighborhood of the Initial Equilibrium Outcome)

Endogenous Variables and Parameters / Endogenous Variables		Importer's Parameters				Exchange Rates in Transiter's Currency		Gas Transit Cost		Gas Supply Cost	
		Expenditure on Foreign Gas Y	Substitution Elasticity σ	Russia' Market Share α	Price of "Other" Gas P_O	DM (e_D)	Rbl (e_R)	Unit (S)	Fixed (F_T)	Unit (C)	Fixed (F_R)
Supplier's Price	P_R	0	-	+	+	+	-	-	0	+	0
Transit Fee	T	0	-	+	+	+	-	+	0	-	0
Demand for Russian Gas	G	1	+	+	+	+	-	-	0	-	0
Importer's Price	P_G	0	-	+	+	-	+	+	0	+	0
Demand for "Other" Gas	O	1	-	-	-	-	+	+	0	+	0
Importer's Welfare Index	U	1	+	-	-	+	-	-	0	-	0
Unit Rent	R	0	-	+	+	+	-	-	0	-	0
Russia's Profit	Π^R	+	+	+	+	+	-	-	0	-	-
Transiter's Profit	Π^T	+	+	+	+	+	-	-	-	-	0
Transiter's Share in Revenue	ω_P	0	-	+	+	+	-	+	0	-	0
Transiter's Share in Unit Rent	ω_R	0	-	-	-	-	+	+	0	+	0
Transiter's Share in Total Profit	ω_Π	-	-	-	-	-	+	+	-	+	+

B. Changes In the Environment of the Transiter and Supplier

In the determination of their strategic moves, the transiter and supplier are affected by changes in their costs. The current framework allows us to analyze the effects of the following elements of costs: i) depreciations in the exchange rates of the transiter vis a vis both the importer's and supplier's currencies; ii) changes in the variable and fixed costs of both the transiter and the supplier.

The depreciations[13] of the transiter's currency vis a vis that of the western importer and the supplier have opposite effects. In the first case, the depreciation increases the competitiveness of the transiter's activity and improves the pay-offs of all participants. A one percent devaluation reduces by half a percentage point the price paid by the importer in local currency. Had there not been a strategic response by the supplier and transiter to increase their charges, the importer would have faced a price lower by also a one percentage point. But the devaluation provides leeway for both the transiter and supplier to raise their charges while still leaving the Russian gas more competitive on the importer's market. As a result of the lower price paid and the ensuing expansion of demand, the importer's welfare improves. The expansion of demand, together with the larger transit fee and supplier's price, contributes to the improved pay-offs of both. The relative position of the transiter improves in terms of revenue collection, since the transit fee rises (by 0.86) more than the Russian supply price (by 0.40). However, its shares in the total profit declines, mainly because Russia enlarges its profit (by 5.71) more than the transiter (by 4.48), taking advantage of its larger marginal profit and bigger fixed cost. Similarly, the transiter's share in the unit rent also deteriorates, because the increase in the transit fee (by 0.86) is significantly less than the increase in the unit rent measured in the transiter's local currency (by 1.41).

The depreciation of the transiter's currency vis a vis that of the supplier reduces the competitiveness of Russian gas on Western markets and worsens the pay-offs of the three players. Assuming the transiter buys the gas at the Russian border and resells it at its Western border, the cost of the main input has increased, putting upward pressure on the price to the Western importer. Were the one percent depreciation to be passed through to the importer, the price P_G would also increase by as much. That would entail a significant switch away from Russian gas and loss of welfare. The supplier and transiter contain that effect by reducing both the transit fee and the supply price, limiting the final increase in the importer price to less than half a percentage point, and the loss of market share. The average import cost increases, while the importer consumes less foreign gas.

With a larger marginal profit, Russia is affected more negatively than the transiter by a shrinking of the trade volume. Hence, the Russia's profit declines (by -5.15) more than that of the transiter (by 3.00), resulting in a relative improvement for the transiter's share in the total profit. Meanwhile, the transit fee is pressed less (by -0.09) than the unit share (by -0.36), leading the transiter gains a larger share in the unit rent, though its marginal transit profit shrinks. However, since the transiter's currency becomes less valuable against that of the suppliers, its share in the total sales revenue declines.

An increase in the variable cost of the supplier or the transiter also reduces the competitiveness of Russian gas on Western markets and worsens the pay-offs of all three players.

An increase in the supplier's variable cost affects negatively the pay-offs of all three players but improves the position of the transiter relatively to that of the supplier. The rise in the variable cost of the supplier reduces its rent and throws itself off the profit maximization equilibrium. In seeking a new one, the supplier raises the price to the point where the marginal revenue is equal to the marginal cost incorporating into this decision, because of its leadership position, the expected reactions of the importer and the transiter. The importer reduces demand in response to the price increase and hence the transiter's marginal revenue. In response the transiter reduces its transit fee. A one percent increase in the supplier's variable cost leads to a contraction of gas demand by more than 2.5 percent and an increase in the importer's price by almost half a percentage point. The latter's welfare index deteriorates. The supplier's pay-off contracts by almost 4 percent in spite of the marginal gain of slightly more than half a percentage point in the price charged. The contraction of the volume of gas traded pulls down also the transiter's profit by 3 percent, almost a percentage point less than that of the supplier. As a result of a rising supplier's price and a falling transit fee, the transiter's share in the total revenue declines. However, its share in the unit rent and the total profit improve.

A one percent increase in the unit transit cost will lead to an increase in the transit fee by about a quarter of one percentage point to the point where the marginal revenue is again set to be equal to the marginal cost. The ensuing upward pressure on the importer's price is contained by the supplier's price behavior. The importer still pays a higher price however, switches away from Russian gas and sees a deterioration in welfare. Both the supplier and transiter have also reduced pay-offs. The transiter's share in revenue improves as the transit fee increases while the supplier's price declines. The gains in rent and profits share are minor also.

The supplier and the transiter absorb increases in their own fixed costs and experience a deterioration in their own profits. Their respective shares in aggregate profits respond correspondingly. A variation in fixed costs does not affect marginal revenue or cost at the prevailing prices; it does not lead hence to a modification of the volume of trade and consequently of the existing equilibrium in strategy selections.

Table 4

SENSITIVITY ANALYSIS IN THE EQUILIBRIUM NEIGHBORHOOD
With a Nested CES Welfare Function for the Importer

Elasticities of the Endogenous Variables with respect to 1% change in the Exogenous Variables		Initial Values	Importer's Parameters				Exchange Rates in Transiter's Currency		Gas Transit Cost		Gas Supply Cost	
			Expenditure on Foreign Gas (Y)	Substitution Elasticity (σ)	Russia's Market Share (α)	Price of "Other" Gas (P_O)	DM (e_D)	Rbl (e_R)	Unit (S)	Fixed (F_T)	Unit (C)	Fixed (F_R)
Benchmark Value			$20.6 bn	7.25	25.0%	$86/tcm	1.0	1.0	$5/tcm	$100m	$50/tcm	$200m
Supplier's Price	P_R	$65.9/tcm	0.00	-0.10	+0.08	+0.40	+0.40	-0.38	-0.01	0.00	+0.62	0.00
Transit Fee	T	$20.1/tcm	0.00	-0.66	+0.18	+0.86	+0.86	-0.09	+0.24	0.00	-0.09	0.00
Demand for Russian Gas	G	60 bcm	+1.00	+1.32	+0.39	+1.79	+2.81	-2.55	-0.26	0.00	-2.55	0.00
Importer's Price	P_G	$86.0/tcm	0.00	-0.23	+0.11	+0.51	-0.49	+0.45	+0.05	0.00	+0.45	0.00
Demand for "Other" Gas	O	180 bcm	+1.00	-0.36	-0.16	-1.75	-0.77	+0.70	+0.07	0.00	+0.70	0.00
Importer's Welfare Index	U	100.0	+1.00	+0.06	-0.03	-0.87	+0.12	-0.11	-0.01	0.00	-0.11	0.00
Unit Rent	R	$31.0/tcm	0.00	-0.63	+0.30	+1.41	+1.41	-0.36	-0.04	0.00	-0.36	0.00
Russia's Profit	Π^R		+1.27	+1.15	+0.93	+4.40	+5.71	-5.15	-0.40	0.00	-3.93	-0.27
Transiter's Profit	Π^T		+1.12	+0.48	+0.71	+3.33	+4.48	-3.00	-0.30	-0.12	-3.00	0.00
Transiter's Share in: Revenue	ω_P	23.4%	0.00	-0.43	+0.08	+0.35	+0.35	-0.54	+0.19	0.00	-0.54	0.00
Transiter's Share in: Unit Rent	ω_R		0.00	-0.25	-0.05	-0.26	-0.26	+0.23	+0.02	0.00	+0.23	0.00
Transiter's Share in: Total Profit	ω_Π		-0.07	-0.32	-0.11	-0.50	-0.56	+1.08	+0.05	-0.06	+0.47	+0.13

V. Conclusions

The current and potential benefits of the East West gas trade are enormous for all participants. The realization of these benefits require significant upfront investments. The new, and more complex, structure of the gas transit system that has emerged following the changes in Eastern Europe and the Former Soviet Union has created uncertainties however that bear on the expected benefits of the investments. This paper argues for the existence of stable contracts that would create an environment more conducive to the investments and allow all participants to benefit from the expansion of the gas trade. A framework based on a Stackelberg game with three players (a supplier, a transiter and an importer) under Russia's leadership is proposed as a guide to the formulation of incentive compatible, transparent and flexible contracts. The framework is used to analyze the contract modifications that would ensue from changes in the environment bearing on the gas trade. Three main conclusions can be drawn.

An increased competitiveness of the transiter and supplier through cost reductions would improve the pay-offs of all players in the game. The transiter's and supplier's profits as well as the western importer's welfare would improve. Basically it would induce a strategic behavior on the part of the supplier and transiter that would lead to a decline in the price faced by the importer, enlarging gas demand and reducing costs. If the increased competitiveness is the outcome of more costly gas from other sources than Russia, both the supplier's and transiter's pay-offs would improve but the importer's welfare would deteriorate. The supplier and transiter would have leeway to strategically raise their price and transit fee respectively while gaining market share. The importer however would face rising costs of gas imports and loose welfare.

An increase in the scope of substitution for the importer between gas from alternative sources improves on welfare of all three players. The perception on the part of the supplier and transiter of an enhanced threat of competition leads to a preemptive move to not loose market share. The transiter and supplier reduce the transit fee and supply price respectively allowing the importer to face a lower gas price. The latter's import demand expands and welfare improve. The expanded trade more than compensates for the reduction in the transit fee and supply price and allows for larger pay-offs for the transiter and supplier.

The perception of increased reliability of supplies of gas from Russia shifts outward the demand for gas from Russia and leads to the expansion of trade. The supplier and transiter have scope to raise their respective charges with expanded volumes improving their pay-offs. The importer's welfare deteriorates as the cost of importing gas rises.

The predictability of the players' reactions to changes in the environment would build confidence in the reliability of gas trade and allow its expansion benefitting all participants. The game proposed in the paper provides a framework for analyzing the strategic moves of the players and gaining insights on their predictability.

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Notes:

1. An additional amount of about 30 bcm could be supplied with limited investments in the order of $325 million. Expansion of supplies by additional 60 bcm could be made with further investments at still a reasonable rate of return. Beyond these amounts transport costs rise significantly. Moreover, energy efficiency improvement in Russia through structural adjustment and appropriate energy pricing policies can also be expected to contribute to energy conservation in the domestic market and thus generate additional exportable gas.

2. In addition each transit country has its own privatization and corporatization objectives that bear on the fate of the companies managing the transit services and the commercial policies these would follow.

3. All of these policies seem to be pursued by Gazprom. For instance, in the fall of 1990 Gazprom joined Wintershall/BASF in a new partnership.

4. Considering individual countries as independent players can be done at some cost but would not add insights.

5. From (1) we have

$$\frac{\partial P_G}{\partial P_R}=\frac{e_R}{e_D}>0,\quad \frac{\partial P_G}{\partial T}=\frac{1}{e_D}>0,\quad \frac{\partial P_G}{\partial e_R}=\frac{P_R}{e_D}>0,\quad and\quad \frac{\partial P_G}{\partial e_D}=-\frac{P_G}{e_D}<0.$$

6. In fact one would take the utility function of a representative consumer and the size of the population. Here we abstract from that to simplify the presentation without loss of generality.

7. The first order condition for the transit revenue maximization can be written as

$$MR^T = G = (T-S)\left(-\frac{\partial G}{\partial P_G}\right)\frac{\partial P_G}{\partial T} = MC^T.$$

8. The first order condition for Russia's gas exports can be written as

$$MR^R = G = (P_R - C)\left(-\frac{\partial G}{\partial P_G}\right)\left(\frac{\partial P_G}{\partial P_R} + \frac{\partial P_G}{\partial T}\frac{\partial T}{\partial P_R}\right) = MC^R$$

9. Cooperation here is understood in the game theory terminology, i.e. sharing of information, of resources and pay-offs. Players would cooperate if they ex ante agree

to share. The recent joint venture between Gazprom and BASF/Wintershall is a cooperative feature, however it does not necessarily allow the latter to have full access to the information environment of Gazprom.

10. The annex specifies the welfare index and derives the demand equation. The CES form incorporates the assumption of strong separability between the demand for gas from alternative sources and the demand of other commodities. The elasticity of substitution between the sources of gas is independent of relative price changes of other goods.

11. One can calculate, in the neighborhood of the initial equilibrium, possible outcomes of the game generated from different price reactions from the supplier and the transiter. For instance, when Y increases by one percent, a one percent increase in the price of Russian gas would lead to about 5% loss in the sales volume and about 3% loss in the sales revenue, instead of any financial gains from the price hike.

12. Basically profits are not homogeneous of degree one with respect to demand, or alternatively the marginal profit is larger than the average. More specifically, one can derive that

$$\frac{\Delta\Pi^R/\Pi^R}{\Delta G/G} = \frac{P_R - C}{P_R - C - \frac{F_R}{G}} > 1, \quad \textit{and} \quad \frac{\Delta\Pi^R/\Pi^R}{\Delta G/G} = \frac{T-S}{T-S-\frac{F_T}{G}} > 1$$

for $F_R > 0$, and $F_T > 0$.

13. No benefits from arbitrage are assumed here as the model is calibrated in US dollars, to be coherent with our classification of players into groups. The exchange rate parity holds here, e.g., DM/$ = (K/$)/(K/DM).

Annex: Model Derivation and Calibration

This annex specifies the hierarchical Stackelberg game as established in the main text of the paper. An equilibrium is attained when no player has any incentive to further its own interest by unilaterally changing its strategy selection, given other players' behavioral choices. The equilibrium outcome of the game is characterized by individual rationale in terms that each player has maximized its own payoff in an environment of strategic interdependence, and by collective coherence in terms that each player views the equilibrium outcome as acceptable and better than any results otherwise.

The mathematical structure of the game is presented here in three steps. First, the players' decision problems are analyzed sequentially. This interactive optimization procedure guarantees the Pareto optimality of the equilibrium outcome of the game. Second, the behavioral consistency of strategy choices is checked to attain the Stackelberg equilibrium solution of this hierarchical game. Six endogenous variables, -- the gas supply price, the transit fee, and the import volume in the strategy bundle, and the gas supply profit, the gas transit profit, and the resultant social welfare level of the importing country in the payoff bundle, -- are explicitly linked to exogenous variables, including the importer's aggregate expenditure on gas, availability and substitutability of alternative gas supplies in the importer's market, the gas production cost, the gas transit cost, and the prevailing exchange rates. Finally, parameters in the game are calibrated using relevant statistics best available.

A. The Importer's Decision

The importer maximizes its utility on behalf of final gas consumers in the Western European market, subject to its budget constraint. We choose a utility function with a structure of multi-level nested constant elasticities of substitutions (MLN-CES) between goods and services consumed, in order to capture both income and substitution effects due to the price fluctuations and other external perturbations. We derive the gas demand function, which serves as the importer's strategy selection rule in response to other players' strategy choices, and calculate the (indirect) social welfare index at the equilibrium neighborhood. For presentational simplicity, we concentrate on the sub-branch containing only the imported gas from two different foreign sources, Russia and the other area. The assumption on an MLN-CES utility function helps conceptualize complementariness and substitution linkages between energy consumption and consumption of other goods at first, and then inter-fuel substitutions within the energy bundle. The important point here is that price changes of non-foreign gas are translated across the branches in the utility tree into an income change for decisions on gas importing. Hence, the expenditure on importing foreign gas can rise not only when the overall national income increases, but also the relative prices move in directions favorable to consumption of imported gas. Meanwhile, a rise in foreign gas prices will induce reallocation of money for increasing consumption of other goods, and will reshape the market shares of gas imported from different sources. Specifically, we assume

$$U = CES[G, O; \alpha, \sigma] = \left(\alpha^{\frac{1}{\sigma}} G^{1-\frac{1}{\sigma}} + (1-\alpha)^{\frac{1}{\sigma}} O^{1-\frac{1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \tag{1}$$

where

U	the utility level generated from consumption of foreign gas
G	consumption of Russian gas,
O	a composite commodity, composed of gas from all other sources,
α	Russia's share at the benchmark case,
σ	substitution elasticity between G and O.

Given prices P_G for G and P_O for O, the following budget constraint applies,

$$P_G G + P_O O \leq Y \qquad (2)$$

where Y is the total income allocated for gas consumption. Maximizing the utility in (1) subject to the constraint in (2) leads to the following expenditure function

$$E(P_G, P_O, u) = \left[\alpha P_G^{1-\sigma} + (1-\alpha) P_O^{1-\sigma}\right]^{\frac{1}{1-\sigma}} u \qquad (3)$$

and the indirect utility function

$$V(P_G, P_O, y) = \left[\alpha P_G^{1-\sigma} + (1-\alpha) P_O^{1-\sigma}\right]^{\frac{1}{\sigma-1}} y \qquad (4)$$

The demand function for Russian gas is then

$$G(P_G, P_O, y) = \left[1 + \frac{1-\alpha}{\alpha}\left(\frac{P_G}{P_O}\right)^{\sigma-1}\right]^{-1} \frac{Y}{P_G} \qquad (5)$$

which exhibits homogeneity of degree one in prices and income. The share of expenditure on Russian gas is

$$\frac{P_G G}{Y} = \alpha\left[\alpha + (1-\alpha)\left(\frac{P_G}{P_O}\right)^{\sigma-1}\right]^{-1} \qquad (6)$$

Hence, if the competition in the German market of foreign gas initially equalizes P_G and P_O, then α will be the share for Russian gas. In the case $\sigma=1$, i.e., a Cobb-Douglas utility function for the gas importer, the market share will not change with the relative price and thus remain constant, though the demand quantity will decline when its own price rises. The income elasticity of demand is

$$\eta = \frac{Y}{G}\frac{\partial G}{\partial Y} = 1 \qquad (7)$$

The price elasticity of demand is

$$\epsilon_{G,P_G} = \frac{P_G}{G}\frac{\partial G}{\partial P_G} = -\frac{P_G G}{Y}\eta - \sigma\left(\frac{1-\alpha}{\alpha}\right)\left(\frac{P_G}{P_O}\right)^{\sigma-1}\frac{P_G G}{Y} \qquad (8)$$

This is the Slutsky equation, in which the first term on the right hand side represents income effect and the second term represents the substitution effect due own price changes. As expected, a larger σ or α will generate a larger substitution effect in gas demand.

B. The Transiter's Decision

The transiter maximizes its transit profit by choosing a unit transit fee, T, for each given supply price set by the gas supplier and taking into consideration market reactions from the importer's side. Namely,

$$\max_{T>0} \Pi^U = (T-S)G - F_T \qquad (9)$$

where S is the unit transit cost, and F_T is the fixed cost for the gas transit system. For any given Russian gas supply price, P_R, the unit transit fee can be expressed as

$$T = e_D P_G - e_R P_R \qquad (10)$$

where e_D and e_R are exchange rates of the transiter's local currency against that of the importer and supplier, respectively. The first order condition for the profit maximization is

$$G = -(T-S)\frac{\partial G}{\partial P_G}\frac{\partial P_G}{\partial T} \qquad (11)$$

The transiter equalizes the marginal revenue and the marginal cost of raising its transit fee. When the supply price is fixed, a higher transit fee is passed through to a higher import price, which depresses the demand for gas. This first order condition can be rearranged into

$$\frac{T-S}{T} = \left[\left(-\frac{\partial G}{\partial P_G}\frac{P_G}{G}\right)\left(\frac{\partial P_G}{\partial T}\frac{T}{P_G}\right)\right]^{-1} \qquad (12)$$

This clearly states that the mark-up ratio of the transiter is determined as the inverse of the product of the price elasticity of gas demand and the elasticity of the gas price with respect to the transit fee. The transiter's optimal reaction function is thus implicitly defined by:

$$\frac{T-S}{e_R P_R + S} = \frac{1}{\sigma - 1}\left[\frac{\alpha}{1-\alpha}\left(\frac{T + e_R P_R}{e_D P_O}\right)^{1-\sigma} + 1\right] \qquad (13)$$

The left hand is the transiter's ratio of marginal profit and marginal cost, an index of the transiter's negotiation power. The right hand side is the market condition in terms of relative prices, expenditure shares and the elasticity of substitution. The transiter's optimal adjustments with respect to changes in the supply price can be thus derived as

$$\frac{\partial T}{\partial P_R} = \frac{e_R}{\sigma}\left[\frac{T + e_R P_R}{e_R P_R + S} + \frac{T + e_R P_R}{T-S} - \sigma\right] \qquad (14)$$

Hence, whether the transiter follows the supplier's price movement depends crucially on (a) the market reactions reflected from the elasticity of substitution, (b) the transiter's negotiation power reflected from the marginal profit-marginal cost ratio; and (c) the transiter's current profitability reflected from the price-cost ratio. If the transiter foresees that a big decline in gas demand may occur due to a price rise, it may be willing to reduce its transit fee to retain the quantity at the level which maximizes its transit profit.

C. The Supplier's Decision

Knowing how both the importer and the transiter adjust their strategies, the gas supplier as the Stackelberg leader determines a supply price, P_R, to maximize its profit. That is

$$\underset{P_R > 0}{Max}\ \Pi^R = (P_R - C)G - F_R \qquad (15)$$

where C is the unit production cost and F_R is the fixed supply cost. The first order condition is

$$G = -(P_R - C)\frac{\partial G}{\partial P_G}\left(\frac{\partial P_G}{\partial P_R} + \frac{\partial P_G}{\partial T}\frac{\partial T}{\partial P_R}\right) \qquad (16)$$

where the reaction of T with respect to change of P_R is determined through the transiter's best reaction function (10). This first order condition can be rewritten as

$$\frac{P_R - C}{P_R} = \left[\left(-\frac{\dfrac{\partial G}{G}}{\dfrac{\partial P_G}{P_G}}\right)\left(\frac{\dfrac{\partial P_G}{P_G}}{\dfrac{\partial P_R}{P_R}} + \frac{\dfrac{\partial P_G}{P_G}}{\dfrac{\partial T}{T}}\frac{\dfrac{\partial T}{T}}{\dfrac{\partial P_R}{P_R}}\right)\right]^{-1} \qquad (17)$$

Hence, the profit margin of the gas supplier is determined through both direct and indirect effects of price changes. Raising the supply price will not only push up directly the final sales price in the importing country, but also provoke the transiter to optimally adjust its transit fee setting. The decision rule is imbedded in the following implicit function,

$$\frac{(P_R-C)\left(e_R+\frac{\partial T}{\partial P_R}\right)}{T+e_RC-(P_R-C)\frac{\partial T}{\partial P_R}} = \frac{1}{\sigma-1}\left[\frac{\alpha}{1-\alpha}\left(\frac{P_G}{P_O}\right)^{1-\sigma}+1\right]$$

$$= \frac{T-S}{e_RP_R+S} \qquad (18)$$

Substituting the transiter's optimal reaction into the above equation, we have

$$\frac{S+e_RP_R}{T+e_RP_R} - \frac{T-S}{P_R-C}\frac{T+e_RC}{T+e_RP_R}\frac{1}{e_R} = \frac{1}{\sigma}\left[\sigma - \frac{T+e_RP_R}{e_RP_R+S} - \frac{T+e_RP_R}{T-S}\right] \qquad (19)$$

D. The Stackelberg Equilibrium Solution

An equilibrium in this game can be defined as a strategy profile (P_R^S, T^S, G^S), --where the superscript S indicates a Stackelberg solution--, which satisfies the following sequential optimization procedure:

(I) $\Pi^R(P_R^S, T^S, G^S) \geq \Pi^R(P_R, T^S, G^S)$ and $P_R^S > C$, for (T^S, G^S) as determined in (II) and (III);

(II) For any given P_R, $\Pi^U(P_R, T^S, G^S) \geq \Pi^U(P_R, T, G^S)$ and $T^S > S$, for G^S as determined in (III); and

(III) For any given P_R and G, CES(G^S,O; α, σ) $\geq$ CES(G,O; α,σ) and the budget constraint (2) is not violated.

Accordingly, the equilibrium payoffs in terms of the gas supply profit, the gas transit profit, and the importer's welfare index can be derived. Meanwhile, one can calculate the equilibrium gas price in the European market, and transiter's share in the total revenue.

E. Calibration of the Parameters

Eight parameters in the game model need to be determined to calibrate our bench mark case.

(1) Expenditure on gas , Y: About 25% of gas consumption in the Western Europe comes from Russia, which was 60 billion cubic meters valued at $9 billion in 1992. Hence, the total gas consumption should be 240 billion cubic meters. The suppliers and transiters in the East-West gas trade shared 57% of the total sales revenue, i.e. $5.16 billion in 1992. Assuming that gas from other sources are equally costly, we get <u>Y = $20.52 billion</u>.

(2) Price of Gas from Other Sources, P_O: The gas from Russia was priced on the German board at $86 per thousand cubic meters in 1992 ($5.16 billion/60 bcm). We take this as a price proxy for gas from other sources. Hence, <u>P_O = $86/tcm</u>. This leads to <u>α = 25%</u>.

(3) The fixed gas transit cost F_T and the fixed gas supply cost F_R do not affect players' decisions. However, they affect the distribution of the total profit. Our best rough estimates for these annulized fixed costs are F_T =$100 million and F_R =$200 million, respectively.

(4) The variable gas transit cost S is estimated to be $5. Russia's supply cost C, including the transit cost to the Ukrainian board, is estimated to be $50.

(5) Since we calibrate in US dollars, both e_D and e_R are artificially set to be unit.

(6) We select a $\sigma > 1$ to make the solution of the game as close as possible to our observed outcome: G = 60 bcm, P_G = $86/tcm.

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