European Market Integration for Gas? Volume Flexibility and Political Risk*

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Abstract

Is the European gas market integrated? Are there substantial price differences between gas from different export countries? Time series of Norwegian, Dutch and Russian gas export prices to Germany in 1990-1998 are examined. Cointegration tests show that that the different beach prices for gas to Germany move proportionally over time, indicating an integrated gas market (the Law of One Price holds). We find differences in mean prices, with Russian gas being sold at prices systematically lower than Dutch and Norwegian gas. Surveying the features of the long term take-or-pay contracts for gas sales, we discuss possible explanations for the price discrepancy. Among the explanatory factors are differences in volume flexibility (swing) and perceived political risk.

Keywords: Market Integration, Gas Markets, Cointegration Test

Jel class.no.: C33,D43,L72, Q41

1. Introduction

This paper examines the degree of market integration of the European natural gas market, with a focus on German import from the Netherlands, Norway and Russia. Theory predicts that in an integrated market, prices from different suppliers should move in the same direction, and price differentials should only be present if there are differences in transportation costs or quality. However, the explanation behind price discrepancies may be somewhat more complicated in the European natural gas market. Natural gas is overwhelmingly sold on complex long-term contracts that have a number of features that may influence the contract price, and hence lead to price variations across contracts. Furthermore, there may be elements of political risk that can influence relative prices.

We will investigate the degree of market integration in the German market by investing the relationship between the import prices from the three main suppliers, the Netherlands, Norway and Russia. Since the prices appear to be nonstationary, cointegration analysis will be the empirical tool. We will also examine the underlying determinants of our empirical results, particularly on the impact of the contract structure. An analysis of the long term take-or-pay gas export contracts is given, and the export strategies of the Netherlands, Norway and Russia are examined in relation to our empirical findings.[1]Germany is a natural candidate for a case study since this is the largest national gas market on the Continent, has a central position with respect to the distribution of gas across the European market, and is one of the few markets where three of the largest producers all supply considerable quantities. Germany is also an interesting case in light of the EU Gas Directive, since the liberalisation of the German natural gas market will have a major influence on the development in the rest of Europe.

Empirical aspects of the degree of market integration of the European gas market has received scant attention by researchers. However, the basic methodological approach has been used in several studies of US gas markets (Doan and Spulber, 1994; Walls, 1994; Serletis and Herbert, 1999). We will use some recent development in methods and theory to increase the informational content of these tests. Since we use the Johansen test (Johansen, 1988) when testing for cointegration, we can also test parameter restrictions on the cointegration parameters. In this context it is of particular interest to test for the Law of One Price. Moreover, Asche, Bremnes and Wessells (1999) has shown that when the Law of One Price holds, the generalized composite commodity theorem of Lewbel (1996) will hold. Hence, the market integration tests can also contain information about whether the goods in question can be aggregated. Finally, in general in market integration analysis, the so-called proportionality coefficient has received little attention. Because of the importance of long-term contracts, also these parameters are of interest since they contain information about how different the prices are.

The paper is organized as follows. Section two provides a presentation of the German natural gas market. In Section three the features of gas sales contracts are analysed. Section four presents the market integration theory and test methodology that we utilize in our empirical analysis. The empirical analysis of import prices is undertaken and explanations for price differences are given in Section five. Finally, Section six provides concluding remarks.

2. The German Natural Gas Market

Natural gas has an increasing share of the German energy market, with a market share of 21% in 1998.[1] In 1998 natural gas imports had a 79 % share of the total supply of 83 Bcm to the German market, with domestic producers supplying the remaining quantities. Russia was the largest exporter to the German market, with a 35% share of total supply in 1998. The Netherlands provided 19 % of total supply, Norway 19 % and Denmark/UK 3 %.

The German market has the most complex structure of all the markets in continental Europe. An important reason for this is that all agents along the value chain, from wellhead producers to local distribution companies, sell to end users. Thus, figure 1 depicts only the main distribution channels for natural gas in the German market.

Figure 1 here

There were 18 transmission/merchant companies (*Ferngasgesellschaften*) operating on the German market in 1995 (IEA, 1998, pp. 168-169). Only seven of the

[1] For a more general presentation of the export strategies of these countries – as well as Algeria - see

transmission companies imported gas in 1996. The other companies bought gas from other transmission companies or domestic producers. *Ruhrgas* is the dominant importer, with 61% of total imports in 1996 (CEDIGAZ). It purchases gas from all the three major export countries supplying the German market. The second largest importer, BEB, owned by Shell and Exxon, had an 11% import share, followed by VNG (10%), Thyssengas (8%) and Wingas (7%).

The transmission companies supplied gas to 673 regional and local distribution companies (LDCs), and also to large end-users. A minority of the LDCs are pure gas distribution companies. Most of these supply electricity or water in addition to gas.

The ownership structure in the German natural gas market implies that there are several agents having vested interests in several parts of the value chain. Major international oil companies have ownership interests both in gas extraction (in Germany, the Netherlands, and Norway) and in import/transmission companies in Germany. The transmission companies often have a complicated owner structure. This applies in particular to the largest transmission company, Ruhrgas. Among the owners of Ruhrgas are major oil companies (BPAmoco, Shell, Exxon) and manufacturing companies (e.g. Mannesmann, Thyssen-Krupp). Oil companies also have considerable owner interests in several other transmission companies. For example, BEB is a joint venture between Shell and Exxon. Furthermore, transmission companies have large ownership interests in other transmission companies. Finally, transmission companies may have ownership interests in regional and local distribution companies.

The transmission and merchant companies purchase gas on long-term take-or-pay contracts (20-25 years) from producers abroad, and on depletion contracts from German producers (IEA, 1998, p. 175). Hence, they carry the volume risk under these contracts. The transmission companies try to reflect this in their sales contracts with LDCs which are long-term, up to 15-20 years, but normally do not have take-or-pay obligations. Earlier, the LDCs were obliged to buy all their gas from the merchant company. Recently, however, new contracts have been limited to specified volumes and have allowed the LDCs to buy from alternative suppliers. Contracts with large industrial users typically

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have a duration of 10-15 years, and normally have a take-or-pay clause. Contracts with power producers generally have the same structure as contracts with industrial users.

German gas demand exhibits considerable fluctuation both on a monthly and daily basis. In a typical year demand is roughly three times higher in the month with the highest demand than in the month with the lowest demand. The peak demand on a cold winter day may be roughly four times higher than on a warm summer day.

Existing and planned pipeline capacity of the major producers is expected to be larger than predicted demand in the coming years (Thackery, 1998). Germany, in particular, is expected to face a surplus supply of gas from the Netherlands, Norway and Russia (EJC, 1998).

Industrial consumers have been among the main driving forces for a liberalisation of the German market. German industry has paid some of the highest gas prices in Europe, and increased competition among energy suppliers would make German manufacturing industries more competitive abroad.

In the early 1990s Wingas, a partnership between Russian Gazprom and the BASF subsidiary Wintershall, entered the gas transmission and trading market. This has lead to a reduction in the prices of new long-term supply contracts, according to EJC (p. 1). Because of the absence of third party access, Gazprom and BASF were forced to build a huge transmission network. Wingas is now able to compete for customers in large parts of Germany. It has been argued that gas-to-gas competition has emerged in areas to which Wingas has extended its transmission grid. IEA (1998, p. 88-89) finds that gross margins has decreased in transmission and increased in distribution following the increased competition at the transmission level.

An obstacle to increased competition in Germany is the absence of full third-party access to pipelines. Negotiated third-party access, which will give pipeline owners considerable discretion, seems to be regime for the coming years.

3. The gas sales contracts

In the case of Germany gas import, negotiations were primarily undertaken bilaterally between the three suppliers - the Netherlands, Norway, and Russia - and a consortium of gas buyers comprised by Ruhrgas, BEB (a Shell/Exxon joint venture) and Thyssen Gas.

3.1. Contract Design and Negotiation Issues

European import contracts have a number of detailed specifications on the gas to be delivered. The natural gas is processed of the sellers to satisfy strict requirements with respect to quality. The calorific value of the gas differs, e.g., Norwegian and Russian natural gas in general has a higher calorific value than Dutch gas. Thus, for comparability, contract prices are often listed in terms of payment per calorific unit. In our data set prices are listed in USD per million Btu, see Figure 2.[2], which means that the difference in calorific value is accounted for.

In regulating contracting volumes, the exporting and the importing companies have conflicting interests. Since gas storage is expensive and in limited supply, the importer would like to have flexibility with respect to volumes, thus being able to adjust to changes in downstream demand. Demand fluctuates, especially over the seasons, with a higher demand in Winter than in Summer. The exporters, on the other hand, has to sink large irreversible investments in extraction, processing, and transportation facilities. Before doing so, they would like to have assurances that they will be able to sell the gas over a considerable period of time, thus securing a return on their investments. Also, to exploit the extraction, processing and transportation capacity, the seller would prefer to deliver a stable gas stream at maximum capacity utilisation. The exporter would – before making large irreversible investments – prefer a specific price, a minimum price, or other types of price guarantees for the entire period of delivery. The buyers, on the other hand, would like the gas price to be responsive to the price of substitutes (such as oil products), so that they will be able to sell the gas.

The challenging task for gas contract design is to trade off these conflicting interests with respect to volume and price. The exact contents of these contracts are secret, but the general contract structure is common knowledge in the gas industry. The major part of gas export to Germany in the period 1990-1998 was sold on long term *take-or-pay* contracts, see Brautaset et al. (1998). In these contracts, the buyer agrees to receive a certain volume of gas per year or, alternatively, to pay for the part of this gas volume that it does not like to receive. At the same time, the buyer has an option to take out more gas than these minimum annual amounts, thus conveying flexibility. A substantial volume flexibility is also available on a daily basis. The contracts specify two types of reference volumes, Daily Contract Quantity (DCQ) and Annual Contract Quality (ACQ). The annual flexibility is regulated by an interval around the ACQ, e.g., the buyer is committed to take or pay 85-95 per cent of ACQ, and may have specific options on annual volumes exceeding ACQ. As for the daily flexibility and commitments, the buyer may be committed to take or pay 40-50 per cent of DCQ, and the seller may be committed to deliver up to 110 per cent of DCQ. Additional flexibility for the buyer is provided by the right to receive at a later time gas that has been paid but not taken (*Make Up Gas*), and the right to reduce future delivery if gas take exceeds the commitments in some years (*Carry Forward Gas*).

The current price on gas delivered according to the long term take-or-pay contracts is determined by a price formula. The formula links the current gas price to the price of relevant energy substitutes, thus continuously securing the buyer competitive terms.[3] The price formula consists of two parts, a constant basis price (fixed term) and an escalation supplement linking the gas price to alternative forms of energy (variable term). Examples of alternative energy commodities used in pricing formulas for natural gas are light fuel oil, coal, and electricity. Usually a combination of alternatives are used for escalation purposes (weighted average).[4] The basis price (which is not subject to subsequent price revision) reflects the parties' evaluation of the value of the gas at the time of entering the contract. Each of the alternative energy commodities are assigned a certain weight in the escalation element, reflecting the competitive situation between natural gas and the substitute. The price change of each energy commodity is multiplied by an energy conversion factor, to make the substitute and natural gas commensurable. Thereafter, the individual escalation terms are multiplied by impact factors, i.e., the change in the price of the substitute is not fully reflected in the gas price. A typical price formula is given by

$$P = P_0 + \sum_j \alpha_j \left(AE_j - AE_{j0} \right) EK_{AEj} \lambda_j \, , \tag{1}$$

where P is the gas price, P_O is the basis price, α_j is the weight in the escalation element for subtstitute j (with $\sum_j \alpha_j = 1$), $\left(AEj - AEj_o \right)$ is the price change for substitute j (actual minus historic price), EK_{AEj} is an energy conversion factor, and λ_j is the impact factor for price changes in substitute j .

The impact factors are typically high, e.g., 0.85 or 0.90. Thus, natural gas prices in these contracts are highly responsive to price changes in substitutes, and exhibits a high volatility. This implies that the producers are carrying a large fraction of the price risk. Price adjustments for substitutes are based on the difference between current and historic prices. Current prices are calculated as average prices for a reference period, ranging from three to nine months. This gives reliable price data and implies a certain lag in the price adjustments. Under certain conditions and at certain time intervals the parties may demand price revisions. The basis for such renegotiations is that (outside the control of the contracting parties) the value of gas has changed substantially - relative to the available substitutes - in the buyer's home country.

3.2. Flexibility and regularity of supply

About ten per cent of natural gas consumed in Europe comes from Norwegian North Sea fields, and the market share is to expand in coming years. Norwegian gas suppliers achieved virtually 100 per cent delivery reliability last year. [5] The Norwegian gas transport network is highly flexible and can cope with the shut-down of individual fields. Moreover, various fields, e.g., Troll, Sleipner and Ekofisk can – if they are run at full capacity – compensate if one field drops out. The Troll field is the backbone of

Norwegian gas supplies, acting as the swing supplier. In addition, a quantity of Norwegian gas is stored at Etzel in Germany, to ensure flexibility in the receiving system.

The giant on-land Groningen field, twice the size of Norway's offshore Troll discovery, has a substantial swing capacity. After the 1973 oil crisis, the Dutch authorities decided to develop the countries' smaller fields. The companies were paid better for producing from smaller reserves, thus leaving much of the Groningen gas in the ground. This policy still prevails. Only half of the estimated 3000 billion cubic metres has been recovered. The Groningen thus guarantees security of supply and a considerable swing capacity. To ensure sufficient future peak winter capacity, three underground gas storages have been developed.

The very long supply distances for Russian natural gas imply that excess pipeline capacity to supply swing services would be very costly. Long supply lines also may involve a risk with respect to regularity. This risk is partly technical and partly political. As for the latter, Russia is strongly dependent on hard currency from the export of natural gas. Stable gas supplies have therefore a high priority, thus reducing the political risk. On the other hand, there is significant political risk connected to the transit countries, e.g., most Russian gas export to Europe goes through Ukraine. Transport tariffs to Ukraine are paid in terms of natural gas deliveries, where the Ukrainians themselves take out gas from the export pipeline. The extent of this compensation is subject to a constant debate, and at times the Ukrainians have taken out more natural gas than expected, leading to a lower pressure in the pipelines and a failure to reach contract obligations. However, the buyers have been able to adjust the fall in supply by making use of gas in storage, and they have been compensated for added costs.

4. Price based test for market integration and aggregation

4.1. Theory

A number of market definitions are based on the relationship between prices. For instance, Stigler (1969, p. 85) defines a market as "the area within which the price of a good tends to uniformity, allowances being made for transportation costs".[6] Market definitions like this has lead to an extensive literature testing for market integration based on the relationship between prices. In international markets, the prices must be compared in the same currency, and exchange rate movements can therefore also play a part (Richardson, 1978). However, in primary goods markets the price is often quoted in a single currency (normally USD), and even if this is not the case, one often assumes perfect exchange rate pass through, and denote the prices in a common currency.[7] Transportation costs and quality differences can also be modeled explicitly, but are in most cases assumed to be constant.

The basic relationship to be investigated when analyzing relationships between prices is then

$$\ln p_{1t} = \alpha + \beta \ln p_{2t} \tag{2}$$

where α is a constant term (the log of a proportionality coefficient) that captures transportation costs and quality differences and β gives the relationship between the prices.[8] If β=0, there are no relationship between the prices, while if β=1 the Law of One Price holds, and the relative price is constant. In this case the goods in question are perfect substitutes. If β is different from zero but not equal to one there is a relationship between the prices, but the relative price is not constant, and the goods will be imperfect substitutes. Equation (2) describes the situation when prices adjust immediately. However, often there will be a dynamic adjustment pattern, This can be accounted for by introducing lags of the two prices (Ravallion, 1986; Slade, 1986). It should be noted here that even when dynamics are introduced, the long-run relationship will have the same form as equation (2).

There is also a close link between market integration and aggregation. If β=1, not only do the Law of One Price hold, but also the composite commodity theorem theorem of Hicks (1936) and Leontief (1936). The composite commodity theorem is the first criterion used for aggregation in economics. This criterion is the first criterion used for aggregation in economics. It states that if prices of a group of goods move proportionally over time, these goods can be represented by a single price and quantity. A problem with the composite commodity theorem in empirical work is that for the theorem to hold, the prices must be exactly identical. However, Lewbel (1996) provides an empirical useful generalization of the theorem that allows for some deviations from proportionality.[9]

There are several ways to test for the generalized commodity theorem. In a market integration context, a simple test is whether the Law of One Price holds (Asche, Bremnes and Wessells, 1999).[10]

In most analyses, the proportionality coefficient does not receive much attention. This is only natural, since it is the relationship between the prices that give us information about the degree of market integration, and that is relevant for aggregation. However, in out context, also the proportionality term is of interest, as it holds information about the mean difference between the prices when the Law of One Price holds. If the proportionality coefficient is equal to one, the constant term α will be zero, and the two prices are identical except for stationary deviations. If the proportionality coefficient is larger or less then one, or the constant term α is larger or less then zero, there will be a price premium in one direction. Hence, in out case, with identical products delivered at the same location, a test of whether the constant term α is different from zero is a test for the existence of a risk premium.

4.2. Testing for market integration

Traditionally, relationships like equation (2) or its dynamic counterpart has been estimated with ordinary least squares (OLS). However, since the late 1980s one has become aware that when prices are nonstationary, traditional econometric tools cannot be used, since normal inference theory breaks down (Engle and Granger, 1987).[11] Cointegration analysis is then the appropriate tool.

The cointegration approach may be represented as follows. Consider two data series of economic variables, x_t and y_t. Each series is by itself nonstationary and is required to be differenced once to produce a stationary series. In general, a linear combination of nonstationary data series will be nonstationary. In this case there is no long-run relationship between the data series. However, when the data series form a long-run relationship, the data series will move together over time, and a linear combination of the data series,

$$y_t - \psi x_t = \varepsilon_t, \tag{3}$$

will produce a residual series ε_t which is stationary. In this case, the series x_t and y_t are said to be cointegrated, with the vector [1,ψ] as the cointegration vector (Engle and Granger, 1987). This is straightforward to extend to a multivariate case. The relationship between Stigler's (1969) market definition and cointegration is evident. In Stigler's definition, a stable long-run relationship between prices implies that goods are in the same market. For nonstationary price series, cointegration is the only circumstance when the prices form a stable long-run relationship.

Two different tests for cointegration are commonly used in the literature. They are the Engle and Granger test (Engle and Granger, 1987) and the Johansen test (Johansen, 1988; 1991). We will here use the latter, since hypothesis testing on the parameters in the cointegration vector is possible only in this framework.

The Johansen test is based on a vector autoregressive (VAR) system. A vector, $\boldsymbol{x}_t$, containing the N variables to be tested for cointegration is assumed to be generated by an unrestricted kth order vector autoregression in the levels of the variables;

$$\mathbf{x}_t = \Pi_1 \mathbf{x}_{t-1} + \ldots + \Pi_k \mathbf{x}_{t-k} + \mu + e_t \, , \tag{4}$$

where each of the Π_i is a ($N\times N$) matrix of parameters, μ a constant term and $\varepsilon_t \sim iid(0,\Omega)$. The VAR system of equations in (4) written in error correction form (ECM) is;

$$\Delta \mathbf{x}_t = \sum_{i=1}^{k-1} \Gamma_i \Delta \mathbf{x}_{t-i} + \Pi_K \mathbf{x}_{t-k} + \mu + e_t \tag{5}$$

with $\Gamma_i = -I + \Pi_1 + \ldots + \Pi_i$, $i = 1,\ldots,k-1$ and $\Pi_K = -I + \Pi_1 + \ldots + \Pi_k$. Hence, Π_K is the long-run 'level solution' to (3). If $\boldsymbol{x}_t$ is a vector of $I(1)$ variables, the left-hand side and the first (k-1) elements of (4) are $I(0)$, and the last element of (5) is a linear combination of $I(1)$ variables. Given the assumption on the error term, this last element must also be $I(0)$; $\Pi_K x_{t-k} \sim I(0)$. Hence, either $\boldsymbol{x}_t$ contains a number of cointegration vectors, or Π_K must be a matrix of zeros. The rank of Π_K, r, determines how many linear combinations of $\boldsymbol{x}_t$ are stationary. If $r=N$, the variables in levels are stationary; if $r=0$ so that $\Pi_K=0$, none of the linear combinations are stationary. When $0<r<N$, there exist r cointegration vectors—or r stationary linear combinations of $\boldsymbol{x}_t$. In this case one can factorize Π_K; $-\Pi_K = \alpha\beta'$, where both α and β are ($N\times r$) matrices, and β contains the cointegration

vectors (the error correcting mechanism in the system) and α the adjustment parameters. Two asymptotically equivalent tests exist in this framework, the trace test and the maximum eigenvalue test.

The Johansen procedure allows hypothesis testing on the coefficients α and β, using likelihood ratio tests (Johansen and Juselius, 1990). In our case, it is restrictions on the parameters in the cointegration vectors β which are of most interest. More specifically, in the bivariate case there are two price series in the $\boldsymbol{x}_t$ vector. Provided that the price series are cointegrated, the rank of $\Pi = \alpha\beta'$ is equal to 1 and α and β are 2x1 vectors. Of particular interest is the Law of One Price (LOP), which can be tested by imposing the restriction $\beta'=(1,-1)'$. In the multivariate case when all prices have the same stochastic trend, there must be n-1 cointegration vectors in the system and each cointegration vector must sum to zero for the LOP to hold. It then follows from the identification scheme of Johansen and Juselius (1992) that each cointegration vector can be represented so that all but two elements are zero. When the identifying normalization is imposed in the case with three price series, one representation of the matrix of cointegration vectors are:

$$\beta = \begin{bmatrix} 1 & 1 \\ -\beta_1 & 0 \\ 0 & -\beta_2 \end{bmatrix} \tag{6}$$

If both β parameters are equal to 1, the LOP holds.

Recently, a number of studies have used cointegration analysis to investigating relationships between prices. Examples related to energy markets are Doane and Spulber (1994), Sauer (1994), Walls (1994), Gjølberg and Johnsen (1999) and Serletis and Herbert (1999).

5. Empirical analysis

5.1 Empirical results

We now turn to the empirical analysis. At our disposition we had a data set of monthly German import prices on natural gas from the Netherlands, Norway and Russia for the period January 1990 to December 1997. Official publications of German import prices are not available. Only average total import prices are provided by government statistical agencies.[12] In this study we rely on prices compiled by the *World Gas Intelligence Weekly* (WGI). The data are collected from sources close to the buyers and sellers of natural gas, and are supposed to provide a good estimate of the contract prices. It is, of course, difficult to validate the reliability of the estimates. However, the fact that WGI prices are used by major buyers and sellers in their market analysis, should give an indication that the estimates are reasonably accurate.

Before a statistical analysis of the relationships can be carried out, we must investigate the time series properties of the data. Dickey-Fuller tests (Dickey and Fuller, 1979; 1981) were carried out for the price series. The lag length was chosen as the highest significant lag. Six lags were used for all prices in levels, and five for the first differences. All prices are found to be nonstationary, but stationary in first differences (Table 1). These results are independent of the selected lag length. Hence, cointegration analysis is the appropriate tool when investigating the relationships between the prices.

The first test we perform is a multivariate Johansen test on the three prices. Six lags seems to be sufficient to model the short-run dynamics, as LM-tests for autocorrelation up to the 12th order gives the following test statistics with p-values in the parenthesis: In the equation for Russian gas; 1.332 (0.229), for Dutch gas; 1.365 (0.212) and for Norwegian gas; 1.575 (0.128).[13] The results from the cointegration test are reported in Table 2. Both the *max* and the *trace* test indicate that there are two cointegration vectors, and hence one common stochastic trend. When we test for LOP, we cannot reject the null hypothesis that this hold. The test is distributed as $\chi^2(2)$ and the test statistic is 1.771 with a p-value of 0.412. However, when we also test whether there are no systematic differences in the price levels, this hypothesis is clearly rejected. The test is distributed as $\chi^2(4)$ and the test statistic is 20.396 with a p-value of 0.0004. These results indicate that the gas from the three suppliers compete closely in the same market, as the prices move proportionally over time, but at different price levels. Moreover, the degree of market integration is so high that the generalized composite commodity theorem of Lewbel (1996) holds. Hence, gas from the three suppliers can be aggregated into a single commodity with a single price.

In a system with n variables and n-1 cointegration vectors, one can always normalize the system so that one has n-1 pairwise relationships (Johansen and Juselius, 1992). Hence, bivariate tests can in this case in principle provide the same information as a multivariate test. However, bivariate test also allow us to focus on each relationship separately. We will here utilize this to further investigate the different relationships between the three prices. In particular, we are interested in the nature of the difference between the prices. However, a problem is that there are more potential pairs they uniquely identified cointegration vectors.[14] In our case we have three potentially pairs, of which only two are linearly independent. However, since the theory gives us no guidance about which price to normalize upon, we estimate all three potential pairs even though one of them is redundant.

The results are provided in Table 3. As expected, given that we found two cointegration vectors in the multivariate test, each of the bivariate tests indicates one cointegration vector. Furthermore, the LOP holds in all relationships, as we would expect since it holds in the system. To shed some light on the magnitudes of the constant term, we have included the estimated constant terms when the LOP are imposed in Table 3. As one can see, the difference is substantially less between Dutch and Norwegian gas then in any of the relationships with Russian gas. It is therefore not too surprising that we cannot reject the null hypothesis that the prices of Dutch and Norwegian gas are equal. However, we can reject both the hypothesis that the price of Dutch and Russian and Norwegian and Russian gas is equal. As the constant terms is negative this implies that the price of Russian gas is systematically lower then the price of Dutch and Norwegian gas. One can find the proportionality coefficient by taking the anti-log of the constant terms. This implies that the price of Russian gas on average is 83.5% of the price of Dutch gas and 87.8% of the price of Norwegian gas.

5.2. Explaining price differences

The empirical analysis indicates that despite the existence of a well intetgrated market for gas in Germany, there is systematic differences in the price levels. Russian gas is sold at consistently lower prices than Dutch and Norwegian gas, and Dutch gas is slightly more expensive than Norwegian gas. Since the gas prices move proportionally over time, though, indicating that the price discrepancy is in the basis price (fixed term) of the long term take-or-pay contracts.

A plausible explanation to the observed price differences is that they reflect different product attributes with respect to the flexibility of supply. The much longer transport distances make it much more expensive for the Russians to offer volume flexibility (*swing*), since this requires excess capacity in the pipelines. Swing services is can be provided at lower costs by suppliers that are situated close to the market, i.e., Norway and - in particular - The Netherlands. Volume flexibility is an important product attribute for the buyers that are facing fluctuating demand, implying differences in the willingness to pay. Our findings are that the natural gas is more expensive the closer the supplier is to the market. This is consistent with the fact that longer pipelines make it more expensive to offer swing services. To our knowledge, the gas supply contracts with The Netherlands specify the highest level of swing. Norway gas supplies to Germany are provided with a fair amount of swing, whereas the Russians supply a steady amount of gas.

Gas sales contracts to Germany from the three export countries were entered into at different points of time. Price differences may thus partly reflect differences in price expectations in different time periods.

The gas contracts we analyse for the period 1990-1998 are long-term contracts, many of which were entered into in the beginning of the 1980s or earlier. At his time there was a strong focus on security of supply of energy (as strategic commodities), i.e., net importing countries wanted to reduce technical and political supply risk. Due to the latter, the buyers adapted a policy of buying gas from several sources. In addition to the building of gas storages and the presence of dual burner capacity, European gas importing countries preferred to have several sources of gas deliveries to secure the supply. Thus, the Germans were willing to pay a gas price that made it possible to develop new Norwegian gas fields, in order to increase the security of supply. Price differences may also to some extent also reflect the market analytical skills and the bargaining competence of the three export countries. Since the natural gas from the three exporting countries is landed at different locations in Germany, part of the discrepancies in beach prices might also be justifies by differences in tariffs for domestic German transportation. Yet another potential explanatory factor is differences in the seller's bargaining position. The more patient player often strikes the better deal. Norway and the Netherlands – both with a healthy financial situation - might have had a strategic advantage relative to a Russia that was in need of hard currency. The need for foreign exchange and the long pipelines may have made Russia vulnerable to price discrimination by the monopsonistic gas consortium on the Continent. The price formulas specify a non-linear price structure for natural gas imports to Germany. Our empirical tests below indicate that the price differences from the three sources of supply are found in the basis price of the price formula. This supports the hypothesis that price differences are due to time invariant differences in supply elasticities among the suppliers, with the country with the highest elasticity (Russia) receiving the lowest price. Having similar escalation terms for the three suppliers, though, the gas prices follow the same time pattern, i.e., the gas market is integrated. For a presentation of price discrimination and optimal nonlinear pricing, see Wilson (1993).

6. Concluding remarks

Examining beach prices of natural gas delivered to Germany from Russia, Norway and the Netherlands in the period 1990-1998, we find primarily differences in mean prices between the three suppliers. Cointegration tests show that that the different beach prices for gas to Germany move proportionally over time, indicating an integrated gas market (the Law of One Price holds). The most plausible explanation to the difference in the basis price – the fixed term of the long term take-or-pay contracts, is that by having much longer transport distances, is making it much more expensive to offer value-generating volume flexibility (*swing services*) for the Russians and to some extent the Norwegians, since this would require excess capacity in the pipelines. This fact may explain our finding that Dutch gas is the most expensive gas, and that Norwegian gas is higher priced than Russian gas. Dutch gas contracts are known to specify highest volume flexibility. Norway has a fair swing component, whereas the Russians delivers the base load with a limited amount of swing. This seems to be a rational economic solution; swing services are supplied from the cheapest source, and suppliers with a long transport route have a considerably higher capacity utilisation in the pipelines.

In the initial phases of gas extraction in Russia, The Netherlands and Norway, the oil companies had to undertake large irreversible investments in extraction, processing, and transportation facilities. To secure a return on their investments, they required long term gas export contracts. This was acceptable by the buyers. Being regional or national monopolies, they operated in a stable environment. Focus was on security of supply of energy, i.e., avoidance of technical and political risk. Due to the latter, the buyers adapted a policy of buying gas from several sources. This is a possible supplementary explanations to our findings that Russian gas in the 1990s was sold at prices systematically lower than the price of Dutch and Norwegian gas. On the other hand, there were capacity constraints in Russian gas extraction, and Norwegian gas exports were at any rate needed to satisfy the increasing demand at the Continent.

Gas sales contracts to Germany from the three export countries were entered into at different points of time. Price differences may thus partly reflect differences in price expectations in different time periods. Yet another potential explanatory factor is differences in the seller's bargaining position. The more patient player often strikes the better deal. Norway and the Netherlands - with a healthy financial situation - might have had a strategic advantage relative to a Russia that was in need of hard currency. Lower prices on Russian gas may thus be the result of a rational price discrimination policy on behalf of the monopsonistic import consortium, exploiting the higher Russian supply elasticities.

Assessing the *take-or pay* contracts, it is evident that they represent a compromise between the seller's and the buyers's objectives with respect to volume guarantees and flexibility. As for price risk, the fixed term in the contracts implies stability for the seller, whereas the escalation terms in the price formula - linking gas prices to the price of substitutes – imply that the seller is carrying a price risk. The German gas import prices has in the period displayed a considerable volatility, see Figure 2, indicating that the producers are carrying a substantial part of the price risk.[15] According to contract and incentive theory, optimal contract design implies sharing the risk among the contracting parties according to their ability to carry risk (i.e., according to their risk aversion), see general analyses by Laffont (1989) and Salanié (1998), and applications in the petroleum industry by Osmundsen (1999). Thus, the risk sharing in the gas supply contracts is in accordance with theoretical recommendations only to the extent that the buyer's commercial activity is highly sensitive to inter-fuel competition.

The European gas market is now changing. A spot market is established in UK, and the Interconnector pipeline connects the gas markets in UK and the Continent. The simultaneous existence of several types of contracts - long term contracts linked to oil prices on the Continent, long term UK contracts linked to gas spot prices, and the spot market exchange in UK - raises a number of interesting questions. At the same time the EU Gas Directive opens up for negotiated third party access to pipelines. However, gas market reform may be a slow process.

The margins for the transmission and distribution companies are likely to decline over time, as competition is introduced. The effect on the producer prices, however, is uncertain. These changes are primarily affecting the distribution system. The suppliers are the same, and they have huge long term contracts to defend. Thus, they will be hesitant to trigger a price war, and they may be reluctant to stimulate spot trading that may undermine their vested interests in the long term *take-or-pay* contracts.

With more pipelines being built, and with emerging negotiated third party access, the European gas customers will have access to more sources of gas supply. Thus, the emphasis on security of supply is likely to be reduced. On the other hand, the basic sources of supply – the export countries – is not to be changed. Notably, there is currently demand for Norwegian gas from Italy and Spain. Transport costs are lower from Algeria, but buyers prefer to have multiple sources of supply. A denser grid of pipelines and the introduction of new gas buyers, make it more difficult to enforce effective price discrimination. On the other hand, alternative supply routes that involves transit through many countries may involve substantial transport tariffs.

Market developments are also likely to lead to demand for contracts of shorter duration. For new contracts this will be manageable for the exporters at this stage.

Becoming more mature producers, they may in many development projects be able to make use of existing processing and transport facilities. Mature extraction areas often also involve smaller fields with a shorter extraction period. The reduction in investments and extraction time reduces the producers’ need for long term volume commitments from the buyers.

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Table 1. Dickey Fuller tests

Variable	Price levels		First differences	
	with constant	with trend	with constant	with trend
Russia	-2.246	-2.649	-4.195*	-4.025**
Netherlands	-1.696	-2.263	-4.464*	-4.362*
Norway	-1.838	-2.154	-4.014*	-3.768**

*Indicates significant at a 1% level and ** indicates significant at a 5% level. Critical values are at a 5% level with constant -2.893 and with trend -3.451 (MacKinnon, 1991).

Table 2. Multivariate Johansen test

H_0:rank = p	Max test	Critical value 5%	Trace test	Critical value 5%
p == 0	28.23*	22.0	52.13*	34.9
p <= 1	17.71**	15.7	23.9**	20.0
p <= 2	6.19	9.2	6.19	9.2

*indicates significant at a 1% level and ** indicates significant at a 5% level.

Table 3. Bivariate Johansen tests for cointegration and LOP

Variables	H_0:rank = p	Max test	Trace test	LOP[a]	Constant term with the LOP imposed	LOP and no price difference[b]	AR(12) [c]
Netherlands and	p == 0	19.55**	27.48*	0.008	-0.003	0.555 (0.757)	1.612 (0.113)
Norway	p <= 1	7.92	7.92	(0.929)			1.226 (0.287)
Netherlands and	p == 0	24.39*	29.11*	0.221	-0.018	16.119 (0.0003)*	1.809 (0.067)
Russia	p <= 1	4.72	4.72	(0.638)			1.004 (0.457)
Norway and	p == 0	17.65**	27.02*	0.307	-0.013	8.573 (0.013)**	1.779 (0.073)
Russia	p <= 1	8.026	8.026	(0.579)			0.803 (0.645)

*indicates significant at a 1% level and ** indicates significant at a 5% level. Critical values at a 5% level is respectively 15.7 and 9.2 for the Max test and 20.0 and 9.2 for the Trace test.

All numbers in parenthesis are *p-values*.

[a]The test for the Law of One Price is distributed as χ^2 with 1 degrees of freedom

[b]The test for the Law of One Price and price equality is distributed as χ^2 with 2 degrees of freedom

[c]AR(12) is a LM-test against autocorrelation up to the 12th order and is distributed as $F(12,59)$

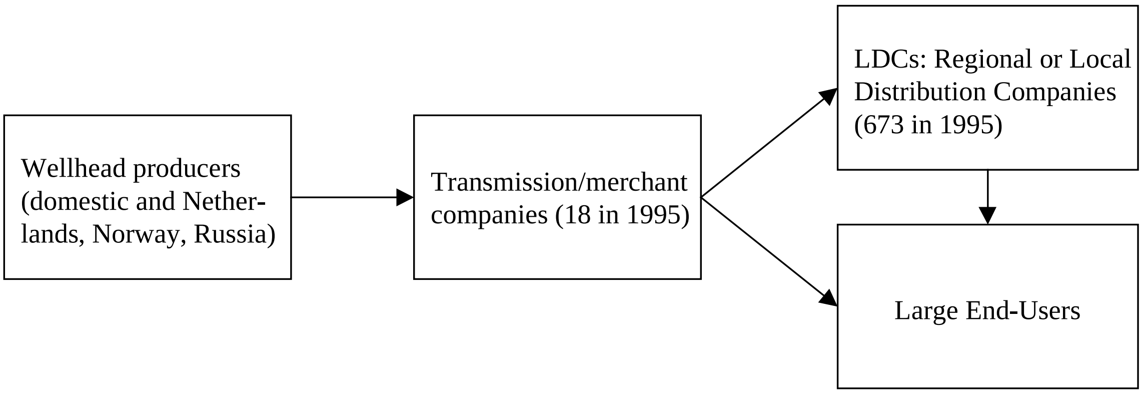

Figure 1. The Value Chain in the German Natural Gas Market

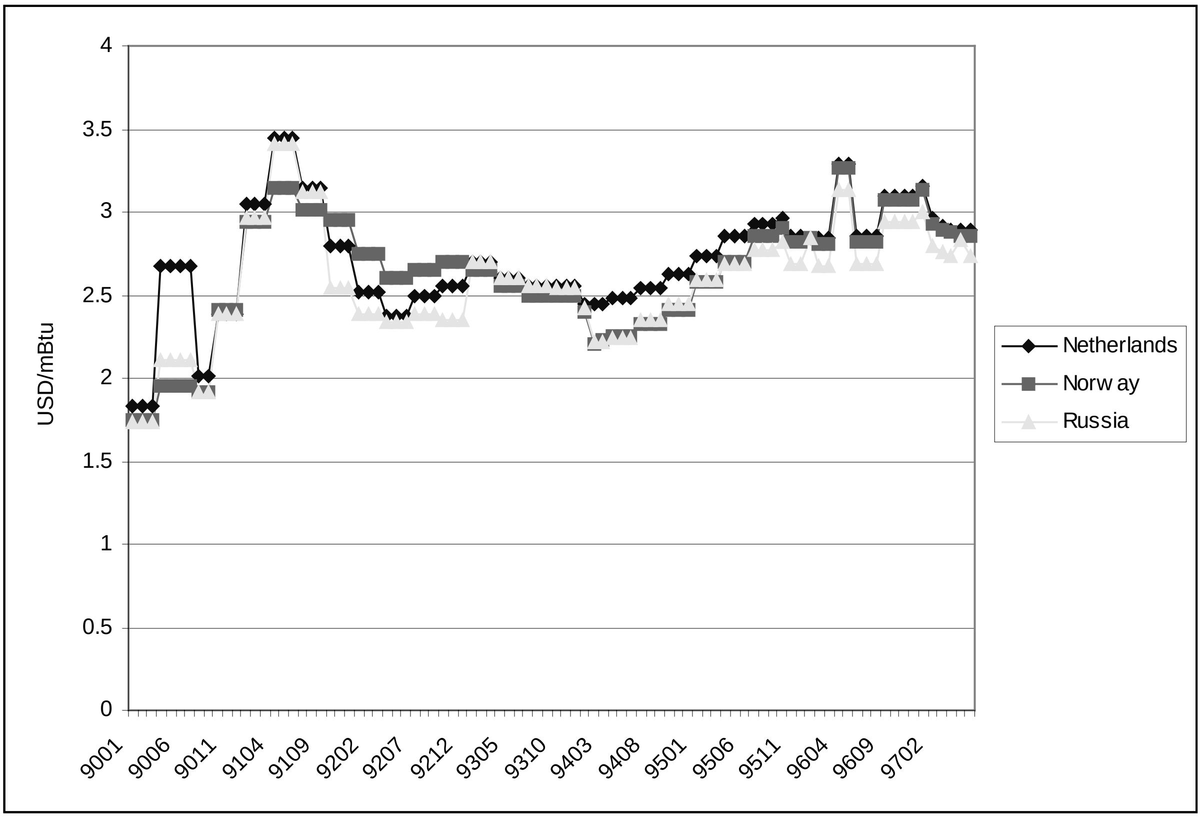

Figure 2. Import prices for natural gas from the Netherlands, Norway and Russia to Germany.

Footnotes

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Tel: 47 51 83 22 86.
[1] Measured in oil equivalents.
[2] Btu = British thermal unit. Amount of heat needed to increase the temperature of one pound of water by one degree Fahrenheit (252 calories). In terms of the joule one Btu is equal to 1055 joules; in engineering, a Btu is equivalent to approximately 0.293 watt-hour.
[3] Adjustments in the gas price is not automatically imposed, though, but by periodical (monthly or quarterly) recalculations of the contract price by using the price formula and updated prices on substitutes.
[4] Some contracts also contain adjustments for inflation.
[5] Norwegian Petroleum Diary, No 4, 1999.
[6] A similar definition, but where transportation costs are replaced by quality differences can be used in product space (Stigler and Sherwin, 1985).
[7] This might lead to a bias against a stable relationship between prices, since imperfect exchange rate pass-through is then not accounted for.
[8] In most analysis it is assumed that transportation costs and quality differences can be treated as constant. However, this can certainly be challenged, see e.g., Goodwin, Grennes and Wohlgenant (1990), since if the transportation costs are not constant, this can cause rejections of the Law of One Price.
[9] As always, there is some cost involved. Aggregates constructed using the generalized composite commodity theorem cannot be used in welfare comparisons.
[10] One should note that this test is more restrictive than necessary, as the theorem might hold even if the Law of One Price is rejected.
[11] See Froot and Rogoff (1995) for a discussion with respect to relationships between prices.
[12] See, for example, the monthly average total import prices provided by the International Energy Agency in the publication“Energy Prices & Taxes”.
[13] The tests are distributed as $F(12,53)$.
[14] See Asche, Bremnes and Wessells (1999) for a discussion of this issue.
[15] This indicates that the actual price formulas in the contracts exhibit high impact factors.