

SNF-REPORT NO. 45/00

Market Integration for Natural Gas in Europe

by

**Frank Asche
Petter Osmundsen
Ragnar Tvetervås**

SNF-project no. 7212:
«Internasjonale skatte- og rammevilkår i petroleumsnæringen»

The project is financed by the Research Council of Norway

FOUNDATION FOR RESEARCH IN ECONOMICS AND BUSINESS ADMINISTRATION
BERGEN, SEPTEMBER 2000

© Dette eksemplar er fremstilt etter avtale med KOPINOR, Stenergate 1, 0050 Oslo. Ytterligere eksemplarfremstilling uten avtale og i strid med åndsverkloven er straffbart og kan medføre erstatningsansvar.

ISBN 82-491-0075-1

ISSN 0803-4036

Market Integration for Natural Gas in Europe¹

by

Frank Asche*, Petter Osmundsen** and Ragnar Tveterås*

* *Stavanger University College / Foundation for Research in Economics and Business Administration*

** *Stavanger University College / Norwegian School of Economics and Business Administration*

September 2000

Abstract

In this paper we examine the degree of market integration in French gas imports. Are there substantial price differences between gas from different export countries, and do prices move together? Furthermore, we analyze to what extent the French, German and Belgian markets are integrated. The long-term take-or-pay contracts are described and analyzed. Time series of Norwegian, Dutch and Russian gas export prices are examined for the period 1990-1997. Cointegration tests show that the different border prices for gas to France move proportionally over time, indicating that the Law of One Price holds. Although one could expect different producer countries to have different supply obligations, we do not find any significant differences in mean prices. When the study is extended to an inter-country analysis including Germany and Belgium, we find that national markets are highly integrated.

Keywords: Market Integration, Natural Gas, Gas markets, Cointegration

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

¹ Address of correspondence: Frank Asche, Stavanger University College, PO Box 2557 Ullandhaug, N-4091 Stavanger, Norway. Email: Frank.Asche@tn.his.no. Tel: +47 51 83 22 86.

1. Introduction

Increased market integration is a central motivation behind the liberalization of the natural gas market in the European Union. There seems to be some consensus that European gas markets until now have been poorly integrated. We examine this issue, with the aim of providing some estimates of the degree of market integration in the gas market during the 1990s.

Economic theory predicts that prices on homogenous products from different suppliers should follow the same pattern over time in an integrated market. With the exception of short-run movements, 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 market for natural gas. 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, as most of the natural gas is supplied from few countries, there may be elements of political risk that can influence relative prices.

In this paper we first focus on the degree of market integration in the French market for natural gas. Furthermore, we investigate the link between the French, German and Belgian market. We focus on the French imports from the three largest providers of natural gas – the Netherlands, Norway and Russia. This is similar to Asche, Osmundsen and Tveterås [1], where the relationship between natural gas from the three suppliers is investigated in Germany. However, in addition to investigating whether the French market for natural gas is integrated, we also investigate the link between the French and the German and Belgian markets. This is of interest, since it will give information about

the extent to which existing pipeline infrastructure and market structure allow efficient arbitrage between France and Germany/Belgium.

We investigate the degree of market integration in the French market by examining the relationship between the import prices from the three main suppliers, the Netherlands, Norway and Russia. The relationship between the French, German and Belgian markets is investigated using the prices on imports from the Netherlands. 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. For a more general presentation of the export strategies of these countries – as well as Algeria - see Mabro and Wybrew-Bond [2] and Stoppard [3].

With the exception of Asche, Osmundsen and Tveterås [1], little empirical work has been carried out with respect to the extent of the market for natural gas in Europe. However, the basic methodological approach has been used in several studies of US gas markets (Doan and Spulber [4], Walls [5], DeVanry and Walls [6], Serletis and Herbert [7]). 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, [8], [9]) 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 [10] have shown that when the Law of One Price holds, the generalized composite commodity theorem of Lewbel [11] will hold.

Hence, the market integration tests can also contain information about whether the goods in question can be aggregated.

The paper is organized as follows. Section two provides a presentation of the French natural gas market. In Section three the features of gas sales contracts are analyzed. 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 Natural Gas Market: France, Germany and Belgium

In this section we provide a description of important characteristics of the French natural gas market. We also touch upon the German and Belgian gas markets, since we will include these later in the market integration analysis.

Natural gas had a 12.4% share of total energy supply in France in 1997 [12]. This is somewhat smaller than in many other European countries. For example, in the two other countries we analyze in this study, Germany and Belgium, natural gas constituted 20.7% and 19.8%, respectively, of total energy supply. The main source of energy in France is nuclear power with a market share of 40.7%. However, natural gas is expected to obtain increasing market shares in the future.

In 1998 France consumed 37.9 billion cubic meter (bcm) of natural gas, making it the 4th largest market in continental western Europe. Indigenous production was only 2.1 bcm, or 6.3%, of total gross consumption, while 35.0 bcm was imported. In other words, the import share was 92.4%. For Germany and Belgium the import shares of domestic

consumption was 80.2% and 100%, respectively. French gas imports increased during the data period 1990-1998, but less than in Germany. The import share was above 90% in all years.

The main pipeline suppliers of natural gas to France are the Netherlands, Norway and Russia. In 1997 Norway was the largest supplier (10.59 bcm), followed by Russia (10.23 bcm) and the Netherlands (5.08 bcm) [13]. It should also be noted that Algeria supplied 9.44 bcm LNG to France in 1997.

The French gas sector is dominated by *Gaz de France* (GDF), a state-owned company, which until now has enjoyed monopoly rights over imports and exports, a large part of the transportation system, and the most of the distribution network. Most of the gas to end users served by the low pressure grid is supplied by GDF. A large proportion of the 17 non-GDF distributors are also supplied by GDF through its transportation system [13]. In Belgium, the company *Distrigaz* has enjoyed a similar position as GDF, with monopoly rights on imports and transportation. *Distrigaz* is also a major transit company for Dutch and Norwegian gas to France, and since 1998 for Interconnector gas from the UK to France, Germany and the Netherlands. The situation in the import and transmission segments has been somewhat different in Germany than in France and Belgium, with seven gas importers in 1996, although with *Ruhrigas* as the dominant importer, with 61% of total imports in 1996 [14]. In 1995, 18 transmission/merchant companies (*Ferngasgesellschaften*) were operating on the German market [13].

GDF's import monopoly means that it has negotiated French gas supply contracts with the Netherlands, Norway and Russia [15]. Hence, the company should have been in an excellent position to exploit arbitrage opportunities. However, this may not necessarily

imply that GFD has obtained the same prices for gas from these countries. Long-term contracts with foreign suppliers were signed in different time periods, the suppliers may not have been in the same bargaining position, and the contracts may also have had different requirements with respect to swing, etc.

3. The gas sales contracts

European import contracts have a number of detailed specifications on the gas to be delivered. The natural gas is processed from the sellers to satisfy strict requirements with respect to quality. 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, have 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 utilization. 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 are 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 France in the period 1990-1998 was sold on long term take-or-pay contracts, see Brautaset et al. [16]. 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 some flexibility. Substantial volume flexibility is also available on a daily basis.

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. 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). This is the structure of most natural gas contracts in Europe. Examples of alternative energy commodities used in pricing formulas for natural gas are light fuel oil, coal, and electricity. Usually a combination of alternatives is used for escalation purposes (weighted average). 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.

4. Price based test for market integration and aggregation

A number of market definitions are based on the relationship between prices. For instance, Stigler ([17], p. 85) defines a market as “the area within which the price of a good tends to uniformity, allowances being made for transportation costs”. Other influential economists like Cournot [18] and Marshall [19] provide similar definitions of a market. A similar definition can be used in product space, but where transportation costs are replaced by quality differences [20], [21]. Market definitions like these have 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 [22]. 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. 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

$$\ln p_{1t} = \alpha + \beta \ln p_{2t} \quad (1)$$

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. If $\beta=0$, there are no relationship between the prices, while if $\beta=1$ 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. One can also show that if β is negative, this implies that the goods in question are complements. Equation (1) 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 [23], [24]. It should be noted here that even when dynamics are introduced, the long-run relationship will have the same form as equation (1).

There is also a close link between market integration and aggregation. If $\beta=1$, not only do the Law of One Price hold, but also the composite commodity theorem of Hicks [25] and Leontief [26]. 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 a single 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 [11] provides an empirical useful generalization of the theorem that allows for some deviations from proportionality. 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 [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 our 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 than one, or the constant term α is larger or less than zero, there will be a price premium in one direction. Hence, in our 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.

Traditionally, relationships like equation (1) 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 [27]. Cointegration analysis is then the appropriate tool.

While stationary data series has constant mean and variance, nonstationary data series are in general characterized by a nonconstant mean and variance. Heuristically, one can say that a nonstationary data series has a structural break at each observation. This structural break is caused by an innovation, or in a market context, news relevant for the data series. There are several reasons for why economic price series can be expected to be nonstationary, where Samuelson's [28] proof that prices must be nonstationary for a market to be efficient most likely is the most cited.

The most common tool for testing whether a data series is nonstationary is the Augmented Dickey-Fuller (ADF) test. For each individual data series (x_t) the ADF statistic with a trend is measured from the following regression

$$\Delta x_t = \beta_0 + \beta T + \sigma x_{t-1} + \sum_{\gamma=1}^k \alpha_\gamma \Delta x_{t-\gamma} + \varepsilon_t \quad (2)$$

where Δ is the difference operator and T is a time trend. If the trend variable is removed from the regression, the test is referred to as an ADF test with a constant term. The lag length, k , is set to make the error term white noise [29]. Using the level forms of each series, the null hypothesis is that each data series is nonstationary. The alternative hypothesis of stationarity implies that σ is less than zero. If the hypothesis is not rejected, the test is repeated using the first-differences of each price series. In this case, the null hypothesis is nonstationary in first-differences.

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,

$$y_t - \psi x_t = \varepsilon_t, \quad (3)$$

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 $[1, \psi]$ as the cointegration vector [27]. This is straightforward to extend to a multivariate case. The relationship between Stigler's [17] 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 [27] and the Johansen test [8], [9]. 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, \mathbf{x}_t , containing the N variables to be tested for cointegration are assumed to be generated by an unrestricted k^{th} order vector autoregression in the levels of the variables;

$$\mathbf{x}_t = \Pi_1 \mathbf{x}_{t-1} + \dots + \Pi_k \mathbf{x}_{t-k} + \mu + e_t, \quad (4)$$

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;

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

with $\Gamma_i = -I + \Pi_1 + \dots + \Pi_i, i = 1, \dots, k-1$ and $\Gamma_k = -I + \Pi_1 + \dots + \Pi_k, i = 1, \dots, k-1$.

Hence, Π_K is the long-run 'level solution' to (4). If \mathbf{x}_t is a vector of $I(1)$ variables, the left-hand side and the first $(k-1)$ elements of (5) 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 $I(0)$; $\Pi_K \mathbf{x}_{t-k} \sim I(0)$. Hence, either \mathbf{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 \mathbf{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 \mathbf{x}_t . In this case one can factorize $\Pi_K; -\Pi_K = \alpha\beta'$, 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 [30]. 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 \mathbf{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 2×1 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 [31] 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:

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

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

[4], Sauer [32], Walls [5], Gjørlberg and Johnsen [32], DeVany and Walls [6], Serletis and Herbert [7] and Asche, Osmundsen and Tveterås [1].

5. Empirical results

We now turn to the empirical analysis. Our data set contain monthly French import prices on natural gas from the Netherlands, Norway and Russia for the period January 1990 to July 1997, and the Dutch export price to Germany for the same period, using data compiled by the *World Gas Intelligence Weekly* (WGI). These French import prices are shown in Figure 1 below. 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 analyses, should give an indication that the estimates are reasonably accurate.

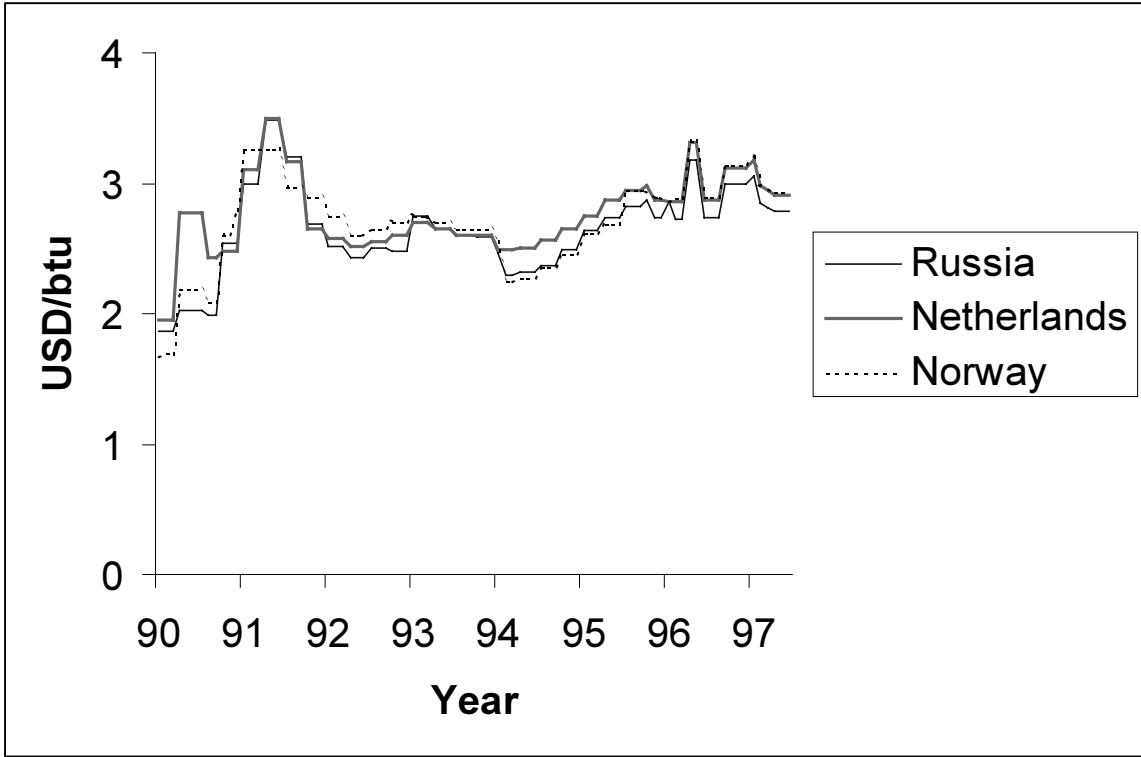


Figure 1. Import prices to France

Before a statistical analysis of the relationships can be carried out, we must investigate the time series properties of the data. Augmented Dickey-Fuller tests were carried out for the price series. The results are reported in Table 1 below.

Table 1. Dickey Fuller tests

Variable	Price levels		First differences	
	with constant	with trend	with constant	with trend
<i>Into France from...</i>				
Russia	-2.537	-2.543	-4.538*	-4.530*
Netherlands	-2.472	-2.705	-4.857*	-4.859*
Norway	-1.921	-1.860	-5.633*	-7.421*
<i>From Netherlands to...</i>				
Germany	-2.745	-2.263	-4.464*	-4.362*
Belgium	-1.543	-2.434	-5.397*	-7.908*

* 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.

All prices are found to be nonstationary, but stationary in first differences. The results are stable with respect to the choice of 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 French import 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; 1.222 (0.293), for Dutch gas; 2.076 (0.034) and for Norwegian gas; 1.043 (0.424). The results from the cointegration test are reported in Table 2 below.

Table 2. Multivariate Johansen Test of French Import Prices

H_0 :rank = p	Max test	Critical value 5%	Trace test	Critical value 5%
p == 0	42.35*	22.0	66.58*	34.9
p <= 1	19.48**	15.7	24.23**	20.0
p <= 2	4.74	9.2	4.74	9.2

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

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 holds. The test is distributed as $\chi^2(2)$ and the test statistic is 5.108 with a *p*-value of 0.077. We also test the hypothesis that there are no systematic differences in the price levels. The test is distributed as $\chi^2(2)$ and the test statistic is 5.606 with a *p*-value of 0.060. Hence, also this hypothesis is supported by the data, although with a *p*-value as low as 0.060, the support is not very strong. These results indicate that the gas from the three suppliers compete closely in the same market, as the prices move proportionally over time. Moreover, in contrast to the results of Asche, Osmundsen and Tveterås [1] for the German market, there does not seem to be any systematic differences in the price levels. Finally, the degree of market integration is so high that the generalized composite commodity theorem of Lewbel [11] 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 [31]. Hence, bivariate tests can in this case in principle provide the same information as a multivariate test. However, bivariate tests also allow us to focus on each relationship separately. We will here utilize this to further investigate the different relationships between the three prices. This approach is also of interest since bivariate relationships was the focus in most studies before cointegration analysis was introduced, and also in most studies using the Engle and Granger test for cointegration. However, a problem is that there are more potential pairs than uniquely identified cointegration vectors [10]. 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 the first section of Table 3.

Table 3. Bivariate Johansen tests for cointegration and LOP

Variables	H_0 :rank = p	Max test	Trace test	LOP ^a	Constant term with LOP imposed	No price difference ^b	AR(12) ^c
<i>Into France</i>							
Russia and Netherlands	p == 0	25.14*	34.35*	0.453 (0.501)	0.017	0.829 (0.362)	2.044 (0.0357)
Russia and Norway	p == 0	20.57*	26.99*	6.305 (0.012)**	0.015	5.041 (0.025)**	1.428 (0.179)
Netherlands and Norway	p <= 1	6.42	6.42				0.610 (0.825)
Netherlands and Norway	p == 0	35.44*	39.84*	3.269 (0.071)	0.001	3.346 (0.067)	1.448 (0.170)
Norway	p <= 1	4.39	4.39				0.895 (0.556)
<i>From Netherlands</i>							
France and Germany	p == 0	26.50*	32.95*	5.229** (0.022)	0.014	5.828** (0.016)	0.617 (0.819)
Belgium and France	p == 0	28.39*	29.19*	3.040 (0.081)	-0.005	3.514 (0.061)	0.560 (0.865)
France	p <= 1	0.80	0.80				1.178 (0.319)

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

All numbers in parenthesis are *p*-values.

^aThe test for the Law of One Price is distributed as χ^2 with 1 degrees of freedom

^bThe test for price equality is distributed as χ^2 with 1 degrees of freedom

^cAR(12) is a LM-test against autocorrelation up to the 12th order and is distributed as $F(12,59)$

Given that we found two cointegration vectors in the multivariate test for import prices into France, it is as expected that each of the bivariate tests indicates one cointegration vector. Furthermore, the LOP holds in all relationships, although there is some evidence against this hypothesis in the relationship between Russian and Norwegian gas, as the p -value is 0.012. Note also that there seems to be some evidence against the hypothesis that Russian and Norwegian prices have the same level, as the test here has a p -value of 0.025.

We then proceed to analyze the degree of market integration between selected European countries. The results in this paper indicate that there is one market for natural gas in France. Given the results of Asche, Osmundsen and Tveterås [1], we also know that there is one market for natural gas in Germany. It is therefore of interest to test whether these markets are linked. Given that all prices in each of the markets follow the same stochastic trend, this hypothesis can be tested by testing the relationship between any two prices from the two markets. We will here test the relationship between the Dutch import price to both France and Germany, and also test whether the Belgian market is related to the French market by testing the relationship between the Dutch import price to Belgium and France. The results are reported in the last section of Table 3. As one can see, the prices in both relationships are cointegrated. Moreover, the Law of One price also seem to hold, although there is some evidence against it in the relationship between the prices in France and Germany, as the p -value is as low as 0.022. Hence, the markets seems to be fairly well integrated, although it is not entirely clear whether the French and German markets are fully integrated, or whether there is a small wedge making the two

markets close but imperfect substitutes for Dutch sellers. There is also some evidence, although not very strong, that prices in Germany are systematically lower than in France.

6. Concluding remarks

In this paper we have examined border prices of natural gas delivered to France from Russia, Norway and the Netherlands in the period 1990-1998. Market integration tests show that the different beach prices for gas to France move proportionally over time, indicating an integrated gas market. In other words, the Law of One Price holds. Unlike our previous study of Germany, we find small differences in mean prices between the three suppliers. This is surprising, since the gas sold actually is a composite commodity containing the gas itself, swing services and other components. Dutch gas producers are known to have the best technical opportunities to supply swing service. Norway can supply a fair swing component, whereas the Russians can only deliver with a limited amount of swing. Despite this, our results suggest that the Netherlands and Norway have not obtained a price premium for their gas supplies relative to Russia.

We have also investigated the link between the French market and the German and Belgian markets. The market integration tests indicates that there is a close relationship between these markets as the prices follow a similar pattern over time, and is very much at the same level. Hence, despite the few sellers and importers of natural gas in these markets, the prices behaves as if the markets are well integrated.

Assessing the *take-or pay* contracts, it is evident that they represent a compromise between the seller's and the buyer'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 French gas import prices have in the period displayed a considerable volatility, indicating that the actual price formulas in the contracts contain high impact factors. 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 [34] and Salanié [35], and applications in the petroleum industry by Osmundsen [36]. 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.

What is most surprising with our results is that the high degree of correlation between prices from different suppliers and in different markets implies that the contracts all are very similar. Hence, it seems like the different structure in the energy sector in France from that in Germany does not lead to contracts which reflects that the importers are exposed to different risks.

Acknowledgements

We are grateful to Sigbjørn Tveterås for useful comments and suggestions. Financial support from the Norwegian Research Council is gratefully acknowledged.

References

1. Asche, F. Osmundsen, P. and Tveterås, R. (2000). European Market Integration for Gas? Volume Flexibility and Political Risk. SNF-Report no. 30/2000, Bergen, Norway.
2. Mabro, R. and I. Wybrew-Bond, eds., (1999), *Gas to Europe: The Strategies of Four Major Suppliers*. Contributors: Ali Aïssaoui, Ulrich Bartsch, Malcolm Peebles, Jonathan Stern and Ian Wybrew-Bond. Oxford Institute for Energy Studies.
3. Stoppard, M. (1996), *A New Order for Gas in Europe?*, Oxford Institute for Energy Studies.
4. Doane, M. J., and Spulber, D. F. (1994). Open Access and the Revolution of the U.S. Spot Market for Natural Gas. *Journal of Law and Economics* **37**, 477-517.
5. Walls, W. D. (1994). Price Convergence across Natural-Gas Field and City Markets. *Energy Journal* **15**, 37-48.
6. De Vany, A. S., and W. D. Walls. "Cointegration Analysis of Spot Electricity Prices: Insights on Transmission Efficiency in the Western US." *Energy Economics* 21(1999): 435-448.
7. Serletis, A., and Herbert, J. (1999). The Message in North American Energy Prices. *Energy Economics* **21**, 471-483.
8. Johansen, S. (1988). Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control* **12**, 231-254.
9. Johansen, S. (1991). Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Autoregressive Models. *Econometrica* **59**, 1551-1580.
10. Asche, F., Bremnes, H., and Wessells, C. R. (1999). Product Aggregation, Market Integration and Relationships Between Prices: An Application to World Salmon Markets. *American Journal of Agricultural Economics* **81**, 568-581.
11. Lewbel, A. (1996). Aggregation without Separability: A Generalized Composite Commodity Theorem. *American Economic Review* **86**, 524-561.
12. <http://www.iea.org/stat.htm>
13. IEA (1998), "Natural Gas Information 1997", section II.158.

14. Maissonier, G. (1997). *The European Gas Market Players*. CEDIGAZ. December 1997.
15. EJC (1998) *Natural Gas Trading in Europe: Liberalisation and its Impact on Long-Term Contracts*. Report, EJC Energy, April 1998, 248 p.
16. Brautaset, A., Høiby, E., Pedersen, R.O., and C.F. Michelet, (1998), *Norsk Gassavsetning, Rettslige Hovedelementer* (Norwegian Gas Sales, Principal Juridical Foundations), Sjørettsfondet, Oslo.
17. Stigler, G. J. (1969). "The Theory of Price," Macmillan, London.
18. Cournot, A. A. *Researches into the Mathematical Principles of the Theory of Wealth*. New York: A. M. Kelly, 1971.
19. Marshall, A. *Principles of Economics*. London: Macmillan, 1890.
20. Stigler, G. J., and Sherwin, R. A. (1985). The Extent of a Market. *Journal of Law and Economics* **28**, 555-585.
21. Sutton, J. *Sunk Costs and Market Structure*. Cambridge, MA: MIT Press, 1991.
22. Richardson, J. D. (1978). Some Empirical Evidence on Commodity Arbitrage and The Law of One Price. *Journal of International Economics* **8**, 341-351.
23. Ravallion, M. (1986). Testing Market Integration. *American Journal of Agricultural Economics* **68**, 102-109.
24. Slade, M. E. (1986). Exogeneity Test of Market Boundaries Applied to Petroleum Products. *Journal of Industrial Economics* **34**, 291-304.
25. Hicks, J. (1936). "Value and Capital," Oxford University Press, London.
26. Leontief, W. (1936). Composite Commodities and the Problem of Index Numbers. *Econometrica* **4**, 39-59.
27. Engle, R. F., and Granger, C. W. J. (1987). Co-integration and Error Correction: Representation, Estimation and Testing. *Econometrica* **55**, 251-276.
28. Samuelson, P. A. "Proof that Properly Anticipated Prices Fluctuate Randomly." *Industrial Management Review* (1965): 41-49.
29. Gordon, D. V., (1995) "Optional Lag Length in Estimating Dickey-Fuller Statistics: An Empirical Note," *Applied Economic Letters*, **2**, 188-90.

30. Johansen, S., and Juselius, K. (1990). Maximum Likelihood Estimation and Inference on Cointegration - with Applications to the Demand for Money. *Oxford Bulletin of Economics and Statistics* **52**, 169-210.
31. Johansen, S., and Juselius, K. (1992). Testing Structural Hypothesis in a Multivariate Cointegration Analysis of the PPP and the UIP for UK. *Journal of Econometrics* **53**, 211-244.
32. Sauer, D. G. (1994). Measuring Economic Markets for Imported Crude Oil. *Energy Journal* **15**, 107-123.
33. Gjølberg, O. and Johnsen, T. (1999). Risk Management in the Oil Industry: Can Information on Long-Run Equilibrium Prices be Utilized, *Energy Economics* **21**, Dec. 517-527.
34. Laffont, J.-J.(1989), *The Economics of Uncertainty and Information*, MIT-Press, Cambridge, Massachusetts.
35. Salanié, B., 1998, *The Economics of Contracts*, MIT-Press, Cambridge, Massachusetts.
36. Osmundsen, P. (1999), "Risk Sharing and Incentives in Norwegian Petroleum Extraction", *Energy Policy* **27**, 549-555.

Bibliographical notes

Frank Asche is professor of economics at the University College of Stavanger, Norway and the Foundation for Research in Economics and Business Administration, Bergen, Norway. His main research interests is in the fields of resource economics and markets for primary products.

Petter Osmundsen is associate professor of petroleum economics at the University College of Stavanger, Norway and adjunct professor at Norwegian School of Economics and Business Administration. His main research interests are in the fields of petroleum economics, contract theory, incentive theory, regulation and taxation.

Ragnar Tveterås is associate professor of economics at the University College of Stavanger, Norway and the Foundation for Research in Economics and Business Administration, Bergen, Norway. His main research interests is in the fields of resource economics, producer behavior and productivity analysis.