Policy measures targeting a more integrated gas market: impact on prices and arbitrages

Ekaterina DUKHANINA [a,b,*] **François LÉVÊQUE** [a,b] **Olivier MASSOL** [a,c,d,e]

Abstract

Nowadays the globalization of the gas market offers possibilities of trade linking different local and regional markets. In a way to an integrated market, policy makers need to find efficient measures aiming at an increase in liquidity on gas trading hubs. We consider a merger of two French gas trading zones as an example of a policy, targeting a more integrated market. In particular, we analyse the market integration and the market efficiency before and after the policy implementation by applying an empirical then a theoretical approaches. The empirical method gives us important insights about market behaviour and provides the results according to an empirical notion of market integration. The second method, which has not been applied yet to the research dealing with gas market integration, relies on a theoretical notion of integration and confirms the results of the empirical analysis. Following this relatively new method applied to the gas markets we use a parity bounds model to estimate the probabilities of observing a particular trade regime with positive, negative or zero arbitrage rent. We analyse changes in these probabilities after the policy implementation. Finally, taking into account the North/South gas flows and pipeline capacity constraints, we determine relation between estimated arbitrage regimes and the infrastructure load. Such application of spatial equilibrium theory can open a new page in the research related to gas market integration and assessment of policies. This will be useful taking into account European initiatives to create an integrated and liquid gas market.

---

a Chair on the Economics of Natural Gas, Mines ParisTech, 60 bd Saint-Michel, 75272 Paris Cedex 06, France.

b Centre for industrial economics, Mines ParisTech, 60 bd Saint-Michel, 75272 Paris Cedex 06, France.

c IFP Énergies Nouvelles, 1-4 av. de Bois Préau, F-92852 Rueil-Malmaison, France.

d Center for Economics and Management, IFP School, 228-232 av. Napoléon Bonaparte, F-92852 Rueil-Malmaison, France.

e Department of Economics, City University of London, Northampton Square, London EC1V 0HB, UK.

* Lead/Corresponding author. PhD Student, Chair on the Economics of Natural Gas, Mines ParisTech, 60 bd Saint-Michel, 75272 Paris Cedex 06, France. E-mail address: ekaterina.dukhanina@mines-paristech.fr

I. Introduction

The globalization of the gas market offers possibilities of trade linking different local and regional markets. Nowadays, we can technically supply the gas at almost any region. Even taking into account still existing infrastructure requirements, currently observed gas flows are determined by politico-economic and market mechanisms rather than by technical constraints, for instance, infrastructure unavailability, capacity constraints, etc. However, if such constraints come into play, this destabilises considerably the market.

For example in December 2013 we observed a bottleneck in the pipeline linking the North and the South French gas markets, caused by lack of LNG supply to a French southern receiving terminal that in turn has been provoked by lower LNG exports from Algeria due to maintenance works in the port of Skikda[1]. As a result the South-North spread marked its historical maximum for the period 2010-2017 climbing above 16 EUR/MWh (with average spread near 2 EUR/MWh over the period)[2]. This shows a case when the markets were insufficiently developed and liquid to absorb a supply shock. We can also notice that the North and the South markets were not sufficiently integrated.

According to the definition based on economic theory, two markets can be considered as integrated if the spatial price difference between them equals the unit transportation cost (Marshall, 1920). In other words, the same price should be set for the regions belonging to the same economic market, but a correction for interregional transportation costs is allowed. In reality, the price spreads can include eventual arbitrage rent that should not exist on an efficient and integrated market, because all arbitrage opportunities should be instantaneously exploited by traders. However, our case shows that the observed North/South price difference sometimes exceeds the transportation tariffs for the North-South link, which fluctuate about 0,5-1,5 EUR/MWh[3] over the period.

Broadly speaking, the market integration represents a further stage of development of a gas market, when it behaves as a unique structure, rather than a number of segmented markets. That means different gas trading points, or gas hubs, are interrelated. Some insights about this relation would give a better understanding of the market.

Understanding this relation will be helpful for the firms in their strategy and investment decision-making or for the policy makers who lead their actions on the market for general interest purposes. Having more integrated markets improves possibility to forecast and can preserve the market from such disturbances as in December 2013 in France. Thus, the policies aiming to provide additional market liquidity and to increase market efficiency are on the top of concerns of policy makers and energy regulatory authorities. The goal of our paper is to analyse whether such policies are efficient and whether they can make the gas market more integrated.

---

[1] http://www.cre.fr/documents/presse/communiques-de-presse/tensions-sur-le-marche-du-gaz-la-cre-rappelle-leurs-obligations-aux-acteurs-de-marche/tensions-sur-le-marche-du-gaz-la-cre-rappelle-leurs-obligations-aux-acteurs-de-marche

[2] According to the price data provided by Powernext

[3] According to the data provided by SmartGRTGaz

It should be noted that when we are speaking about efficient and integrated market we implicitly suppose that the market is liberalized. The Europe represents a particular case with ongoing liberalization process. The European initiatives to create an integrated gas market encounter different degrees of market development between its member states along with differences in cross country endowment and in infrastructure development. That is why the intra-community gas market continues to suffer from congestions on borders or within countries.

Generally speaking, there are two ways to encourage integration: by constructing additional infrastructure and by appropriate regulation. However, the first solution is costly, not always available or takes a lot of time. In practice, while waiting for new pipelines or LNG terminals to be constructed, policy makers have to find some efficient measures, aiming at an increase in liquidity on gas trading hubs, implementable in short term.

We consider a merger of two French gas trading zones as an example of a policy, targeting a more integrated market. In particular, we analyse the market integration and the market efficiency before and after the policy implementation. We suppose that the markets became more integrated and efficient. The intuition is based on a logic that the policy facilitated interaction between market agents and removed certain transaction barriers, for example, application of additional entry-exit tariff if the gas is sold in another zone. Taking into account planned measures to merge further gas trading zones in France, we try to answer the question whether the merger of two zones has helped to get a more integrated and efficient gas market.

The feature of our paper is in extended evaluation of the market integration according to its empirical and theoretical notions. Thus, we analyse the prices as well as spatial arbitrages between the Northern and the Southern French gas hubs by applying two methodologies.

Firstly, we analyse French gas market according to an empirical notion of integration. We test the prices for cointegration and look at the dynamics of pairwise price differentials in order to verify the law of one price. We detect changes in price behaviour through econometric modelling and state that the market became more integrated after the extension of the South trading region.

Secondly, we confirm the results about increased market integration, gathered through the empirical analysis, by studying the integration further, according to its theoretical notion. We complete our analysis by theory based spatial equilibrium approach and build a parity bounds model. This model confirms increased market integration after the zone merging showing a higher probability to observe the spatial equilibrium regime. That also indicates an increase in market efficiency.

Finally, taking into account the North/South gas flows and pipeline capacity constraints, we determine relation between estimated arbitrage regimes and the infrastructure load. Analysing this relation we find an improvement in market efficiency and in the efficiency of the infrastructure use after the merging of Southern gas trading zones.

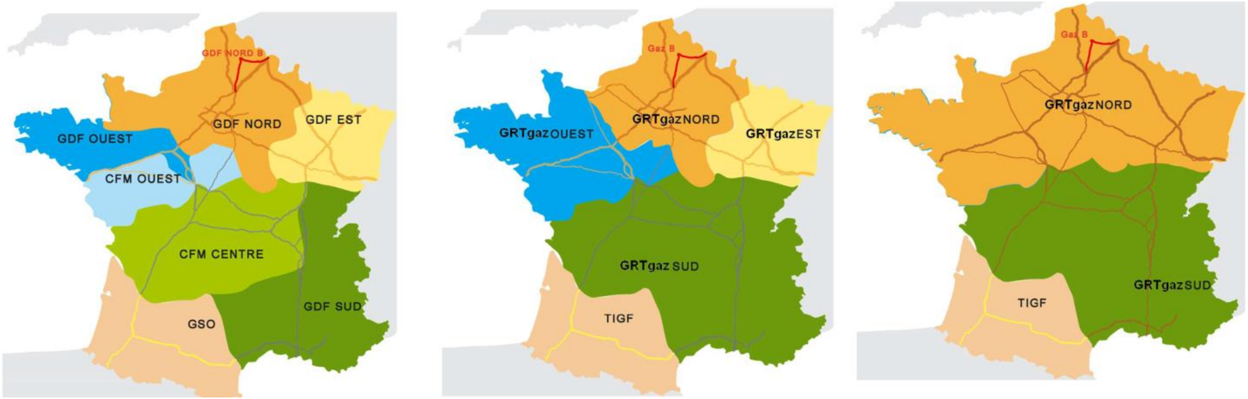
If the first econometric method provides us with an empirical estimation of the market integration before and after policy measures, the second method, which has not been applied yet to the research dealing with gas market integration, confirms the results thanks to a theory based spatial equilibrium model.

The paper is organised as follows: the second part characterises the French gas market and explains the policy decision to merge gas trading zones. The third section describes the data. The fourth section presents an econometric analysis. The section five deals with the spatial equilibrium theory. The sixth section concludes.

II. French gas market evolution

The French gas market has been historically operated by Gaz de France (GDF) created as a state company then partially privatised. The European liberalization, launched with the European directive of 1998 and aiming at opening the gas market to competition, separated transport and distribution activities of the historical operator, guaranteed third-party access to the infrastructure on a transparent and non-discriminatory basis and progressively brought newcomers to the French gas market. The process was gradual, allowing customers to choose their suppliers, starting from gross gas consumers to domestic customers.

France adopted an entry-exit system for setting gas transmission tariffs based on a contractual division of the territory into balancing zones. Initially in 2003 it had 1 zone for the low calorific value gas operated by GDF and 7 zones for high calorific value gas: 4 on the GDF grid (North H, South, East and West), 2 operated by CFM[4] (Center and West) and one on the GSO[5] grid. Then, in 2005 after the merging of GDF and CFM zones in West and in South, its number has been reduced to 5: 3 operated by GRTGaz (West, North, East), GRTGaz South zone and TIGF (former GSO) zone. In 2009 there were 3 zones in total (two zones, PEG North and PEG South, operated by GRTgaz and one zone operated by TIGF).



Picture 1. Gas trading zones in France as of January 1st 2003, 2005 and 2009. Source : CRE

However, these gas trading regions had their particularities. The Northern hub, benefiting mostly from pipeline supply, historically was more liquid. The two Southern hubs, depending on relatively more expensive liquefied natural gas (LNG), suffered from low liquidity. Pipeline bottlenecks between the Northern and the Southern trading regions prevented Norwegian and Russian pipeline imports from flowing to the South when needed. The Southern prices went up significantly in the periods of insufficient LNG supply and large price differentials with the North market have been observed. The French energy

---

[4] Compagnie Française du Méthane, an entity initially commercializing the gas extracted from the Lacq gas field

[5] Gaz du Sud-Ouest

regulating authority (CRE[6]) deployed measures to better link the two regions and to bring gas prices in the South down closer to levels in the North until new pipelines will be built, around 2018. An immediate merging of Northern and Southern zones was impossible because of congestion problems and high physical investments required to eliminate them. Therefore, the CRE introduced a coupling mechanism to improve the short term situation without making significant infrastructure investments. The mechanism consists in simultaneous and implicit allocation of interconnection capacities between North and South zones. It allows GRTGaz to commercialise its transmission services (capacity + molecule transmission) between PEG North and PEG South via the North-South link in both gas directions according to market conditions. In other words, it is a transmission capacity service proposed by GRTgaz, which facilitates transactions between PEG North and TRS. So, on July 1st 2011 the French gas market enters into a new stage of its development.

Finally, on April 1st 2015 the two southern zones PEG South and TIGF merged into Trading Region South (TRS). It was one more step ahead towards the creation of a single wholesale gas market in France by 2018 in order to equilibrate the prices in Northern and Southern regions for the benefits of industrial and domestic consumers located in the South.

Our study focuses on the last zone merger and tries to assess the efficiency of this policy measure. We are studying the price behaviour before and after the policy implementation and estimate the change in market conditions. The following section presents the data used for this research.

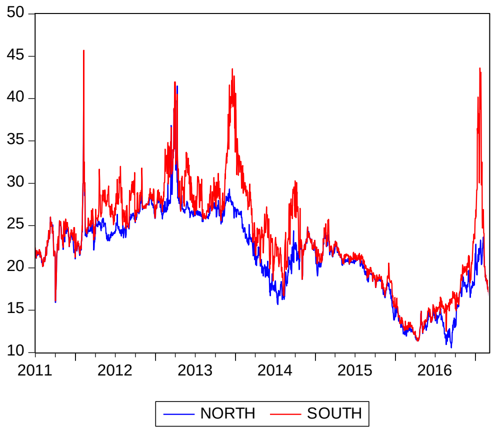
III. Data

We base our study on the price data available on the platform of Powernext exchange. We consider daily end of day spot prices in EUR/MWh from July 1st 2011 to March 6th 2017 on the PEG North (Northern French hub) and the TRS (South French hub). The dataset contains 2076 observations. We chose the period after introduction of the market coupling mechanism in order to be consistent in terms of market rules applied to the gas trading between the PEG North and the TRS. Data on daily average price are also available, but it has more missing values than the end of day price.

The price spread we consider is the difference between the price on the South and on the North hub. The following graph provides the series in levels.

---

[6] Commission de régulation de l'énergie



Graph 2. PEG North (North) and TRS (South) end of day gas prices, EUR/MWh. Source : Powernext

We observe higher spreads with significant fluctuations before 2015. We can see that usually peaks in the North/South spread occur in winter months. We also observe persistent high spread in winter 2013 after its peak in December.

Looking at the descriptive statistics, we can say that the average spread is about 2 EUR/MWh. The North and South prices and, in higher extent, their spread have leptokurtic distribution, resulting in high peak and fat tails. The Jarque-Bera statistic tells us about non-normal distribution for the Southern prices and the spread. The Northern prices distribution is closer to normal[7]. The skewness is negative and close to zero for the North prices meaning a distribution biased to the left. The South prices and, in a higher extent, the spread distributions are biased to the right. That is also a sign of non-normality.

	North	South	Spread S-N	Ln(North)	Ln(South)	Ln(South)-Ln(North)
Mean	21.73489	23.70006	1.965169	3.050608	3.132453	0.081845
Median	22.18500	23.50000	0.830000	3.099416	3.157000	0.038979
Maximum	45.40000	45.70000	21.65000	3.815512	3.822098	0.687594
Minimum	10.56000	11.37000	-0.980000	2.357073	2.430978	-0.023909
Std. Dev.	4.915823	5.932428	2.736776	0.245502	0.262518	0.101396
Skewness	-0.147714	0.261833	2.772980	-0.743638	-0.474766	1.984589
Kurtosis	3.129941	3.286029	14.09468	2.992102	2.965429	8.294142
Jarque-Bera	9.010058	30.79739	13307.98	191.3426	78.09263	3787.170
P-Value	0.011053	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	45121.63	49201.32	4079.690	6333.062	6502.973	169.9112
Sum Sq. Dev.	50143.04	73026.94	15541.63	125.0623	142.9999	21.33349
Observations	2076	2076	2076	2076	2076	2076

Table 3. Descriptive statistics of the North and the South prices and of their spread (in levels and in natural logarithms).

---

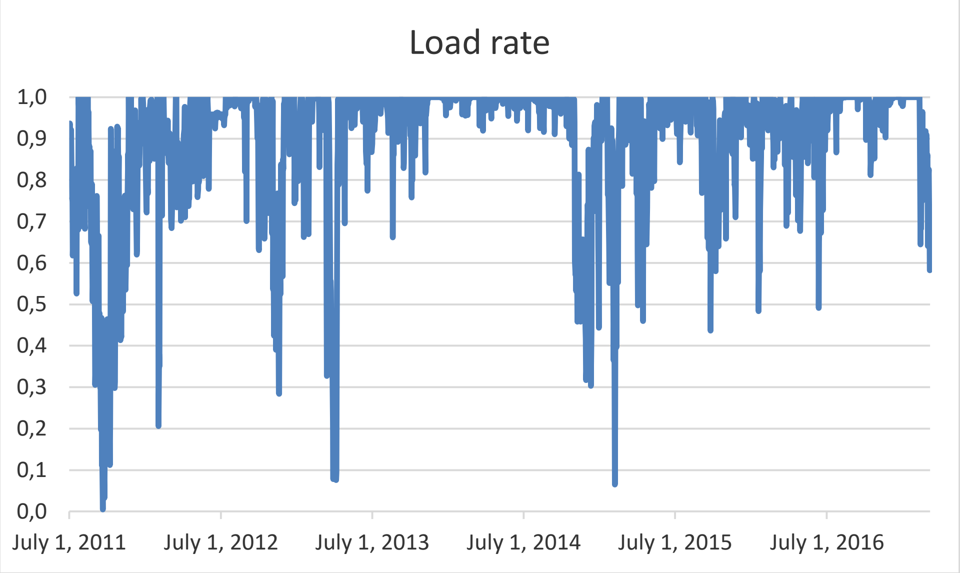
[7] Failure to reject the hypothesis of normality on 1% level.

In order to study the relation between the price spreads and the infrastructure use, we take the gas flows between the North and the South data available on the site of the French transmission system operator, GRTGaz.

We consider daily commercial net flows[8] on the link North-South measured in KWh (under 25°C temperature) for the same period as the prices. Analysing the net North to South flows we observe that the gas moves almost all the time from the North to the South. During the studied period we have only 2 cases of the opposite direction for net flows. This is exceptional event in the case of an oversupply to the South LNG terminals.

For the purpose of our research, we constructed an indicator of the infrastructure load. We calculated the load rate as a ratio of gas quantity allocated per day to the technical effective capacity for a given direction. The technical effective capacity is a theoretical maximum physical quantity of natural gas that can be carried at one contractual point on the network during one day. This value takes into account particular conditions such as maintenance, temperature, etc. It should be noted that the technical effective capacity is different for the North to South and the South to North directions. This is related to different power of compressors used to move the gas to one direction or another.

Looking at the graph of the load rate, calculated on the base of net flows and taking into account both directions North to South and South to North[9], we can see the periods of congestion in the North/South link.



Graph 4. Infrastructure load rate (Allocation/Technical effective capacity). Source : GRTGaz

For the period from July 1st 2011 to March 6th 2017 the average loading rate, based on the net gas flows was 90%. On the 2076 days of the studied period, the infrastructure has been loaded at more than 90% for

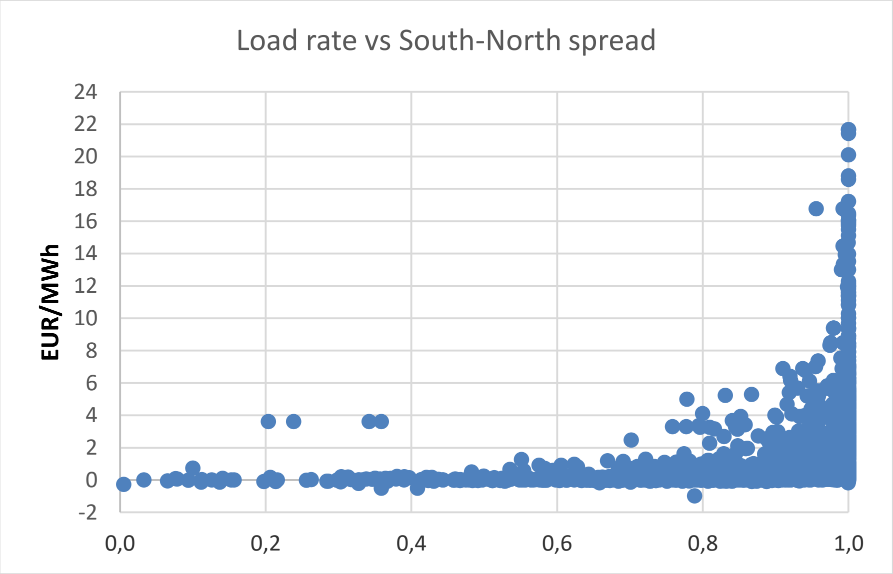
---

[8] For each day the net gas flows are calculated as follows: daily Allocation volumes North to South – daily Allocation volumes South to North.

[9] As the load rate cannot be negative, if the net gas flow North to South is positive, we divide by technical effective capacity for the North to South direction to obtain the load rate. If the net gas flow North to South is negative, it is divided by minus technical effective capacity for the South to North direction.

1467 days, 71% of time. We observed 508 days, 24 % of time, when the pipeline operated on its maximum capacity. This gives us an idea of the frequency of congestions on the North/South direction.

Plotting the two series together highlights the relation between the price spread and the load rate. We can see that the price difference increases exponentially when the load rates approaches 100%. However, it should be noted that for some values of the spread greater than 2 EUR/MWh, the pipeline capacity is not saturated. We can infer that the infrastructure is not optimally used. This tells us that all arbitrage opportunities have not been exploited. A possible explanation can be information gaps, unmeasured transaction costs, presence of eventual barriers to arbitrage, such as non-competitive pricing practices, legal issues, transaction limits or quotas. This indicates that the North and the South markets are not integrated.



Graph 5. Scatter plot of the Load rate (X axis) and the TRS - PEG Nord price spread (EUR/MWh, Y axis)

Using these data, in the next sections we study in depth the degree of market integration through econometric and theory based approaches. The latter allows us to infer about market efficiency and the efficiency of the infrastructure use before and after the merging of gas trading zones.

IV. Econometric analysis

A class of studies on the law of one price focuses on the price integration. These research works typically rely on local price data and assess the co-movements of prices at each location. Most of empirical studies related to natural gas markets examine the degree of spatial integration between gas hubs through price correlation, short and long term (cointegration) relations and price convergence using the time-series analysis. It is generally admitted that high degrees of correlation and/or cointegration between the price series tell us that the law of one price is being enforced through spatial arbitrages.

The earlier works assessed the correlations and prices co-movements. In particular Doane & Spulber (1994) used Granger causality tests to examine how natural gas price shocks are transmitted across interconnected wholesale markets. The cointegration tests to find a long-run relations in price series have been performed by De Vany & Walls (1993), Serletis (1997), Asche et al. (2002, 2013) and Siliverstovs et al. (2005).

King & Cuc (1996), Neumann et al. (2006), Neumann (2009) and Renou-Maissant (2012) analysed price convergence among different national markets rather than integration, using time-varying parameter models and applying the Kalman filter estimation. Cuddington & Wang (2006) verified the stationarity of pairwise price differentials between geographically diverse locations in order to conclude about integrated markets and used an autoregressive model of to estimate the speeds of adjustment toward equilibrium. Park et al. (2008), Brown & Yücel (2008), Olsen et al. (2015) assessed the degree of market integration and price transmission across natural gas markets using cointegration tests and error-correction model approach. Nick & Thoenes (2014) tried to explain the movements of gas prices by fluctuations of its fundamentals through the structural VAR approach. Schultz & Swieringa (2013) looked at the price formation through the prism of financial markets and used financial mathematics techniques applied to a multivariate VECM.

In application to our price data we follow Cuddington & Wang (2006) estimating the market integration through stationarity analysis. We go further and apply this technique in order to examine the integration before and after policy measures. Also we estimate price cointegration and test different models to find appropriate specification for the price spreads.

As usual, when working with high-frequency commodity price data, we take the natural logarithms of the prices in the North and the South French hubs and then calculate the spread. This transformation allows us to interpret the coefficients as elasticities.

The correlograms of prices and price spread in logarithms show positive autocorrelation with the highest one in the 1st lag. Ljung box statistics indicate a presence of joint autocorrelation in the first 20 lags and give a conclusion that the price series cannot be explained by White Noise process. The autocorrelation is lower for the series taken in first differences. We perform several unit root and stationarity tests for the three variables. We rely on the Schwarz Info Criterion to determine the lag length. The results are presented in the following table (Table 6).

Variable	ADF	Phillips-Perron	KPSS	Ng-Perron
North price	Unit root 2 lag	With trend*, With constant*: Unit root	Deterministic trend: series not stationary	Unit root 2 lag
South price	With constant*: Unit root 2 lag	With trend*, With constant: Unit root	Deterministic trend: series not stationary	Unit root 2 lag
Price spread (South – North)	With constant: No unit root 3 lag	With constant: No unit root	Deterministic trend: series not stationary With constant: stationary series	No unit root 3 lag

Table 6. Stationarity tests conclusions for the North and the South prices and their spread.
* 5% significance level. Other results are presented on 1% significance level.

We can conclude that the price series are not stationary and their modelling should include a constant and a deterministic trend. The selected lag length is 2 periods, it corroborates the hypothesis about presence of serial correlation. The price spread appears to be stationary with a constant having a "memory" of 3 periods. This is an important result for our research, because the conclusion about the first order integration of prices and zero order integration of their spread indicates that the law of one price holds. That means the North and the South natural gas markets are integrated or, in other words, lie on the same economic market.

The pairwise Granger causality test demonstrates that, on 1% level, we can reject the hypothesis that the North prices do not cause the South prices but fail to reject the hypothesis that the Southern prices do not cause the Northern ones. That clarifies the relation between the two markets: the Southern market is dependent on the Northern one. In reality the Northern market has more developed infrastructure and more supply sources than the Southern one. It makes the south prices dependent on the northern prices.

Now we try to find a good model for the price spread ΔP_t. The simple model with a constant can be interpreted as transportation costs α, supposed to be a constant, plus an arbitrage rent e_t, represented by a shock, that can be positive, negative or equal to zero (on an efficient integrated market):

$$\Delta P_t = \alpha + e_t$$

However, this model has a sign of serial correlation in the residuals. The residual correlogram, the Durbin-Watson statistic and Breusch-Godfrey Serial correlation LM test show a strong positive autocorrelation. Our price gap is stationary as confirmed by stationarity tests, but it has an autocorrelation problem.

We try to solve the autocorrelation problem by including one lagged price difference ΔP_{t-1}.

$$\Delta P_t = c + \lambda \Delta P_{t-1} + e_t$$

Putting $c = (1 - \lambda)\overline{\Delta P}$ we can interpret this specification for the price spread as an equilibrium value of spread $\overline{\Delta P}$ and deviations from it, where λ measures the speed of return to equilibrium:

$$\Delta P_t - \overline{\Delta P} = \lambda(\Delta P_{t-1} - \overline{\Delta P}) + e_t$$

This model specification allows a correction of the price spread towards an equilibrium price spread $\overline{\Delta P}$. The model gives better results in terms of Durbin-Watson statistic values, but the Breusch-Godfrey Serial correlation test along with the residual correlogram indicate a higher order autocorrelation. The models with higher lags indicate the same. Also we fail to reject the hypothesis of normality of residuals.

We cannot use the Cochrane-Orcutt procedure in order to correct for serial correlation as the error terms of the AR(1) regression of our "biased" residuals of the initial model do not follow WN process.

Trying to solve the problem, in order to take into account the "memory" of the residuals, we include in our model a moving average term with 3 lags.

$$\Delta P_t = \alpha + \lambda \Delta P_{t-1} + e_t + \gamma_1 e_{t-1} + \gamma_2 e_{t-2} + \gamma_3 e_{t-3}$$

That improves significantly our model and eliminates the autocorrelation. Thus we can say that the North-South price spread depends on its previous value and on the shocks of 3 previous periods. In other words, a shock on one of the markets today will impact the price spread for at least 3 further periods.

Now we study the impact of the merger of two southern gas trading zones on the behaviour of the price spread and analyse whether the market became more integrated after this zone merger. In particular, we compare the properties of the price differences before and after the zone merger.

We test for a break at the date of the policy implementation by Chow test, which indicates that the constant has been changed after the zone merging[10]. In fact, the average price spread has narrowed. Thus, we can rerun stationarity tests and compare it before and after the policy. The results are the following:

Variable	ADF	Phillips-Perron	KPSS	Ng-Perron
Price spread before zone merger	With constant* No unit root 6 lags	With constant: No unit root	With deterministic trend: not stationary	No unit root 6 lags
Price spread after zone merger	No unit root 5 lags	No unit root	With deterministic trend: stationary	No unit root 5 lags

Table 7. Stationarity tests conclusions for the South/North spread before and after the zone merger.
* 5% significance level. Other results are presented on 1% significance level.

If before, according to the ADF and the Phillips-Perron tests, we had the price gap stationary with a constant, after the zone merger we have no more constant in our specification. The KPSS test indicated that the price gap was not stationary, but after the merger it became stationary. As early mentioned, stationarity of price spread is associated with price integration. Therefore, in our case we have more integrated markets after the policy implementation. Moreover, the lag number has been reduced after the zone merger meaning that price values depend less on their past values. So, eventual shock is absorbed quicker by the market, which, becoming more integrated, reacts faster. To sum up, if before we had signs that the price gaps were not stationary, after the policy, we do not see any alerts for non-stationarity. Thus, we can say that after the merger of gas trading zones the law of one price holds in a stronger way than before. In other words the markets became more integrated.

To summarize, the econometric approach enables us to better understand the price dynamics and to state that the French gas market became more integrated after the merging of trading zones, according to the

---

[10] on 5% significance level

empirical notion of market integration. Our intuition is confirmed by stationarity and cointegration analysis. We discover that the price spread series is highly autocorrelated, thus the best fit is provided by an autoregressive moving average model. That means the spread depends on its previous value and the values of past shocks. Our estimates show that the North and the South prices are cointegrated, their spread gets stationary after the policy implementation and the market absorbs quicker the shocks. The time stability of the spread is crucial in the empirical notion of integration and it indicates that the two prices follow the same dynamics and react in the same manner to external shocks.

In order to confirm the results about increased market integration gathered through the empirical analysis and to verify the consistency with the theoretical notion of integration, we complete our research by a spatial arbitrage equilibrium model.

Moreover, the issue of natural gas market integration should be studied in a broader scope than a price relation. In our research we understand the integration as a deeper linkage between the markets than the price integration or convergence. We take into account not only market prices, but also the volumes exchanged, the direction of gas flows and the infrastructure capacities in order to evaluate market efficiency and integration.

V. Spatial equilibrium approach

The empirical results based on econometric techniques give us a first impression about markets and show their characteristics and other features the price dynamics can reveal. But the analysis of market integration would not be complete without an assessment of the behaviour of market agents, in particular buyers and sellers. It is true that the prices represent an indicator of their interaction, but the prices can be considered as signals to act as well as a result of actions. The empirical studies are not necessarily consistent with the theoretical notion of equilibrium that supposes all spatial arbitrage opportunities between two markets being exploited. In other words, according to the theoretical notion, in equilibrium, the observed price differences correspond to a profit maximizing strategy of traders.

The theoretical literature on spatial price equilibrium was developed by Enke (1951), Samuelson (1952), Takayama & Judge (1971) and Harker (1986). Based on this theory, Spiller and Huang (1985) constructed a parity bounds model consistent with the spatial equilibrium notion. The model uses a “switching regime” specification and estimates the probability to observe a particular trade regime. This model has been extended by Sexton et al. (1991), by specifying 3 regimes: arbitrage, autarchic and barriers to trade. The authors also included the analysis of lagged price effects. Complementarily, Barrett and Li (2002) proposed to make a distinction between market integration and equilibrium and consider trade flow data in their analysis in order to determine specific regimes depending on whether the trade occurs or not.

Theory based spatial equilibrium models, developed initially in agricultural economics, allow us to determine whether the market is in an efficient equilibrium or has some inefficiencies, such as autarchic regime periods with trade or presence of barriers to arbitrage. We consider this framework appropriate for the gas markets that move us forward in studying the degree of market efficiency and market integration.

Moreover it allows us to develop a convenient setup, following Negassa and Myers (2007) approach, in order to analyse the efficiency of the market before and after policy measures targeting a more integrated gas market.

We start with a standard parity bounds model.

Consider two markets *i* and *j* located in different regions that trade a homogenous commodity. According to a standard parity bounds model, the spatial price differences ΔP_{ijt} between the two markets should correspond to one of the three regimes, indicated in the following table:

Regime	Formula	Relation	Explanation
1	$\Delta P_{ijt} = C_{ijt}$	The spatial price difference ΔP_{ijt} is equal to transfer cost C_{ijt}	Spatial market efficiency irrespective of whether the trade occurs. If trade occurs the supply and demand shocks are transferred from one market to another
2	$\Delta P_{ijt} > C_{ijt}$	The spatial price difference ΔP_{ijt} is greater than transfer cost C_{ijt}	Opportunities for profitable arbitrage are not exploited, markets are not spatially efficient, irrespective whether or not trade occurs. Can be explained by Information gap, non-competitive pricing practices, capacity constraints, licensing or possible quotas
3	$\Delta P_{ijt} < C_{ijt}$	The spatial price difference ΔP_{ijt} is less than transfer cost C_{ijt}	No profitable arbitrages, the markets are efficient if there is no trade, market prices = autarky prices

Table 8. Three regimes in a standard parity bounds model, following Negassa and Myers (2007)

In application to our case the transport costs are assumed to be a constant plus a random shock, assumed to be normally distributed with zero mean and standard deviation σ_e. The conditions for the three regimes are the following:

$\Delta P_{ijt} - C_{ijt} = e_t$ for the first regime,
$\Delta P_{ijt} - C_{ijt} = e_t + u_t$ for the second regime and
$\Delta P_{ijt} - C_{ijt} = e_t - u_t$ for the third one.

Where u_t is non-negatively valued random variable assumed to be half-normal and distributed independently from e_t with standard deviation σ_u. This u_t measures negative and positive deviations from the price spread minus transfer costs and can be interpreted as an arbitrage rent.

The model estimates parameters λ_1, λ_2, and λ_3, which represent the probabilities of being in regimes 1, 2, and 3, respectively, with zero, positive and negative marginal rent to arbitrage. To derive the likelihood function, we define the random variable $\pi_t = \Delta P_{ijt} - C_{ijt}$ that gives the marginal profit from spatial arbitrage at time *t*. The joint density function for π_t is the mixture distribution:

$$f_t(\pi_t|\lambda,\theta) = \lambda_1 f_1(\pi_t|\theta) + \lambda_2 f_2(\pi_t|\theta) + \lambda_3 f_3(\pi_t|\theta)$$

Where $f_1(\pi_t|\theta)$ is normal density function; $f_2(\pi_t|\theta)$ and $f_3(\pi_t|\theta)$ are the density functions derived in Weinstein (1964) for the sum of a normal random variable and a centered-normal random variable truncated above (respectively below) at 0. θ is a parameter vector ($\alpha, \sigma_e, \sigma_u$) to be estimated. The likelihood function for a sample observations is

$$L(\lambda,\theta) = \prod_{t=1}^{T}[\lambda_1 f_1 + \lambda_2 f_2 + \lambda_3 f_3]$$

We adapt the methodology of Negassa & Myers (2007) by allowing probability change after the merger of the trading zones and introduce dummy variables for the policy.

$$f_t(\pi_t|\lambda,\theta) = (1 - D_t)\big(\lambda_1 f_1(\pi_t|\theta) + \lambda_2 f_2(\pi_t|\theta) + \lambda_3 f_3(\pi_t|\theta)\big) + \ D_t(\gamma_1 f_1(\pi_t|\theta) + \gamma_2 f_2(\pi_t|\theta) + \gamma_3 f_3(\pi_t|\theta))$$

Where λ_k is the probability of being in regime *k* before the policy implementation and γ_k measures the new probability of being in regime *k* after the policy. D_t is dummy variable that takes value 1 after zone merger. We suppose instantaneous adjustment in regime probabilities, because we consider the spot gas market, where traders react immediately on an extension of trading perimeter. The probabilities for different trade regimes are determined simultaneously for 2 periods: before and after the policy change. The new likelihood function is

$$L(\lambda,\theta) = \prod_{t=1}^{T}[(1 - D_t)(\lambda_1 f_1 + \lambda_2 f_2 + \lambda_3 f_3) + \ D_t(\gamma_1 f_1 + \gamma_2 f_2 + \gamma_3 f_3)]$$

It should be noted that the parameter of transfer cost also changes after the merger of trading zones, as the number of entry-exit zones has been reduced and now a unique tariff is applied in the South zone.

In order to deal with the problem of autocorrelation, revealed in the empirical part, we integrate a Bayesian approach of Kleit (2001) that consists in a correction for serial correlation for a particular observation using the information about expected values of shock in previous period.

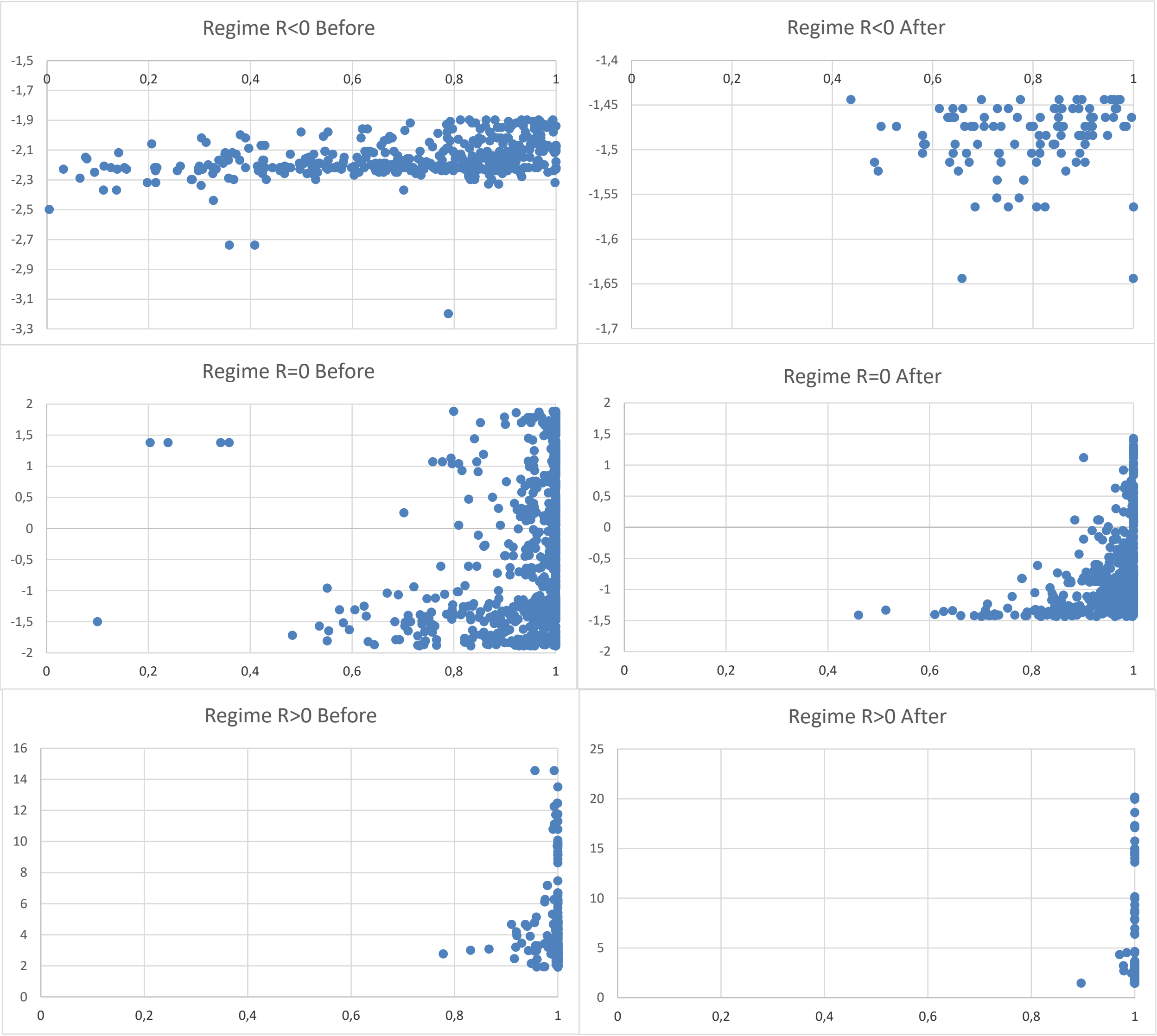
We estimate the parameters by maximizing the logarithm of the likelihood function subject to the constraint that the probabilities lie between zero and one and sum to one. The estimated parameters are presented in the following table:

Period	**Before zone merger**			**After zone merger**		
Parameters	**λ1**	**λ2**	**λ3**	**γ1**	**γ2**	**γ3**
Regime	R=0	R>0	R<0	R=0	R>0	R<0
Probability	0,51	0,20	0,30	0,72	0,12	0,16
Z statistics	26,89	14,44	18,07	30,20	7,29	8,57

Table 9. Estimated probabilities for the three regimes before and after the zone merger.

We can conclude that initial estimated probability of being in spatial integrated equilibrium regime, i.e. with zero marginal rent to spatial arbitrage, was about 50%. After the merger of the Southern gas trading zones it raises to 70%. That indicates the market became more spatially efficient. The probability of being in the regime of barriers to trade used to be about 20% and has been reduced after the policy implementation. We can infer that less unexploited arbitrage opportunities have been observed on the market with extended South zone. It demonstrates an improvement in the efficiency of the market. The decrease in probability to be in the autarchic regime can be interpreted as a decrease in trade when the trade is not profitable, that corresponds as well to an improvement in the market efficiency and is consistent with the spatial equilibrium theory.

Following Barrett and Li (2002) we use the estimates for the parameters to calculate for each observation empirical probability to be in one of the three regimes. In other words we attribute a particular regime to each observation. This clustering provides some insights about the relation between the regimes and the infrastructure load. It shows whether one of the three regimes is associated with some range of load rate. The following picture illustrates for each regime the values of the marginal rents to spatial arbitrage in EUR depending on the values of the load rate before and after the South zones merger.


Regime R<0 Before

Regime R<0 After

Regime R=0 Before

Regime R=0 After

Regime R>0 Before

Regime R>0 After

Graph 10. Marginal rents to spatial arbitrage (in EUR, Y axis) vs load rate (X axis) before and after the merger of trading zones.

Before the zone merger we observed different values of the infrastructure use for the autarchic and the spatial equilibrium regimes. We see that the pipeline is loaded up to 100% even being in the autarchic regime, where marginal rents are negative. This is not consistent with spatial equilibrium theory. Moreover, it is surprising to observe not fully loaded infrastructure in the third regime, with the highest arbitrage rents. This can be understood as the presence of eventual barriers to arbitrage.

Analysing the situation after the merging of the Southern zones, we find a higher loaded infrastructure for all regimes. Having less concentrated points around 100% load in the autarchic and more concentrated in the equilibrium regimes supports the idea about increased market efficiency. Comparing the equilibrium regimes, when the traders are indifferent to trade the gas or not, we see higher rates of the pipeline use after the zone merging. This can be interpreted as a sign of increased liquidity on the markets. The remarkable result is that in the third regime, which allows barriers to trade, the infrastructure is fully loaded. The observed high price spreads meaning the opportunities to arbitrage remain unexploited, are explained, as we see, by bottlenecks. We can infer that the inefficiency on the market, observed in this case, is explained by technical constraints that can be eliminated by additional infrastructure.

Summing up, the results show an improved market efficiency and increased market integration after the merging of the Southern gas trading zones. We also found that the infrastructure has been used more efficiently after the policy implementation. The market became more consistent with the spatial arbitrage equilibrium theory and observed inefficiencies are explained by the needs of additional infrastructure.

VI. Conclusion

The French example allowed us to infer about market integration and market efficiency estimated before and after policy measures targeting a more integrated gas market. We consider a merger of two Southern gas trading zones as an example of such policy and study its impact on price behavior and arbitrage activity with relatively new methodology applied to the gas markets.

We perform the integration analysis according to the empirical and the theoretical notions of integration. At first, we analyse the French gas market according to the empirical notion of integration. We detect changes in price behaviour through econometric modelling and state that the market became more integrated after the extension of the South trading region. We discover that the price spread depends on its previous value and the values of past shocks. Our estimates show that the North and the South prices are cointegrated, their spread is stationary and the market absorbs eventual shocks quicker after the policy implementation.

We further confirm the results about increased market integration by studying it regarding its theoretical notion. In particular, we complete our analysis by spatial equilibrium approach and build a parity bounds model. This model confirms increased market integration after the zone extension showing a higher probability to observe the spatial equilibrium regime. That also indicates an increase in market efficiency. Analysing the relation between the infrastructure use and the regime probabilities, we can find an improvement in market efficiency and in the efficiency of the infrastructure use after the merging of the Southern gas trading zones. We also note some indices of increase in liquidity in the South trading zone after the policy implementation.

If the first, econometric method gives us an empirical estimation of the market integration before and after policy measures, the second, theory based method, which has not been applied yet to the research dealing with gas market integration, confirms the results thanks to a parity bounds model. Such application of the spatial equilibrium theory can open a new page in the research dealing with gas market integration and assessment of policies. This will be useful taking into account European initiatives to create an integrated and liquid gas market.

VII. References

Asche, F., Misund, B., Sikveland, M. (2013). "The relationship between spot and contract gas prices in Europe." Energy Economics 38: 212–217.

Asche, F., Osmundsen, P., Tveterås, R. (2002). "European Market Integration for Gas? Volume Flexibility and Political Risk." Energy Economics 24(3): 249–265.

Aune, F. R., Rosendahl, K. E., & Sagen, E. L. (2009). "Globalisation of natural gas markets–effects on prices and trade patterns". The Energy Journal, 39-53.

Barrett, C.B., Li, J.R. (2002). "Distinguishing between Equilibrium and Integration in Spatial Price Analysis." American Journal of Agricultural Economics 84(2): 292–307.

Brown, S.P.A., Yücel, M.K. (2008). "Deliverability and regional pricing in U.S. natural gas markets." Energy Economics 30(5): 2441–2453.

Cuddington, J.T., Wang, Z. (2006). "Assessing the degree of spot market integration for US natural gas: evidence from daily price data." Journal of Regulatory Economics 29(2): 195–210.

De Vany, A., Walls, W.D. (1993). "Pipeline Access and Market Integration in the Natural Gas Industry: Evidence from Cointegration Tests." The Energy Journal 14(4): 1–19.

Doane, M.J., Spulber, D.F. (1994). "Open Access and the Evolution of the U. S. Spot Market for Natural Gas." Journal of Law and Economics 37(2): 477–517.

Engle, R.F., Granger, C.W.J. (1987). "Co-integration and error correction: Representation, estimation and testing". Econometrica. 55 (2): 251–276

Enke S. (1951). "Equilibrium among Spatially Separated Markets: Solution by Electric Analogue." Econometrica 19(1): 40–47.

Harker, P.T., (1986). "Alternative Models of Spatial Competition." Operations Research 34(3): 410–425.

King, M., Cuc M. (1996). "Price Convergence in North American Natural Gas Spot Markets." The Energy Journal 17(2): 17–42.

Kleit, A.N. (2001). "Are Regional Oil Markets Growing Closer Together? An Arbitrage Cost Approach." The Energy Journal 22(2): 1–15.

Massol, O., Banal-Estañol, A. (2016). "Market Power and Spatial Arbitrage between Interconnected Gas Hubs." Working Paper

Massol, O., Hache, W. (2016). "Sanctions against Iran: An assessment of their global impact through the lens of international methanol prices." Working Paper

Negassa, A., Myers, R.J. (2007). “Estimating Policy Effects on Spatial Market Efficiency: An Extension to the Parity Bounds Model.” American Journal of Agricultural Economics 89(2): 338–352.

Neumann, A. (2009). “Linking Natural Gas Markets--Is LNG Doing its Job?” Energy Journal.

Neumann, A., Siliverstovs, B., von Hirschhausen, C. (2006). “Convergence of European spot market prices for natural gas? A real-time analysis of market integration using the Kalman Filter.” Applied Economics Letters 13(11): 727–732.

Nick, S., & Thoenes, S. (2014). “What drives natural gas prices?—A structural VAR approach.” Energy Economics, 45, 517-527.

Olsen, K.K., Mjelde, J.W., Bessler, D.A. (2015). “Price formulation and the law of one price in internationally linked markets: an examination of the natural gas markets in the USA and Canada.” The Annals of Regional Science 54(1) 117–142.

Park, H., Mjelde, J.W., Bessler, D.A. (2008). “Price interactions and discovery among natural gas spot markets in North America.” Energy Policy 36(1): 290–302.

Renou-Maissant, P. (2012). “Toward the Integration of European Natural Gas Markets: A timevarying Approach.” Energy Policy 51: 779–790.

Ritz R. (2015). “Strategic Investment and International Spillovers in Natural Gas Markets” Communication at the Tenth Conference on The Economics of Energy and Climate Change, Toulouse, France, September 2015.

Samuelson, P.A. (1952). “Spatial Price Equilibrium and Linear Programming.” The American Economic Review 42(3): 283–303.

Schultz, E., & Swieringa, J. (2013). “Price discovery in European natural gas markets”. Energy Policy, 61, 628-634.

Serletis, A. (1997). “Is There an East-West Split in North American Natural Gas Markets?” The Energy Journal 18(1): 47–62.

Sexton, R., Kling, C., Carman, H. (1991). “Market Integration, Efficiency of Arbitrage and Imperfect Competition: Methodology and Application to U.S. Celery.” American Journal of Agricultural Economics 73(3): 568–580.

Siliverstovs, B., L'Hégaret, G., Neumann, A., von Hirschhausen, C. (2005). “International market integration for natural gas? A cointegration analysis of prices in Europe, North America and Japan.” Energy Economics 27(4): 603–615.

Spiller, P.T., Huang, C.J. (1986). “On the Extent of the Market: Wholesale Gasoline in the Northern United States.” Journal of Industrial Economics 35(2): 131–145.

Stigler, G.J., Sherwin, R.A. (1985). “The Extent of the Market.” Journal of Law and Economics 28(3): 55–585.

Takayama, T., Judge, G.C. (1971). “Spatial and Temporal Price and Allocation Models.” North- Holland: Amsterdam.

Carter, C. A., Hamilton, N.A. (1989) "Wheat Inputs and the Law of One Price." Agribus. 5 : 489-96.

Goodwin, B. K., Grennes, T. J, Wohlgenant, M. K. (1990) "A Revised Test of the Law of One Price Using Rational Price Expectations." American Journal of Agricultural Economics 72 : 682-93.