Presented at the 25th IAEE Conference in Aberdeen 2002 and published in the conference proceedings

MARKET INTEGRATION IN THE INTERNATIONAL COAL INDUSTRY: AN ERROR CORRECTION MODEL

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ABSTRACT

The coal market has recently experienced a higher degree of consolidation, through a number of mergers and acquisitions. This has raised the important question of whether companies can exert market power, and raise consumer prices. Since the degree of market integration is an essential part of the competitive impacts of mergers, this paper analyses market integration for internationally traded coal, using an error correction approach. Both the coking and steam coal markets show evidence of market integration, as demonstrated by the stable long-run cointegrating relationship between the price series in the different world regions. The degree of market integration is higher for steam coal than for coking coal, and the steam coal market has also experienced increased market integration over time, which is not the case for the coking coal market. One reason for this is likely the development of spot markets for steam coal, which has reduced transaction costs and arbitrage possibilities.

1. INTRODUCTION

During the last 30 years the international coal industry has undergone dramatic changes, which have fundamentally transformed the organization and the structure of the industry. In the 1970s isolated national producers dominated the coal industry, and in many cases these companies were state-owned, producing only for national usage. The oil crises in 1973 and 1979 forced a revision of this setting, and initiated the rapid development of the international coal market to its appearance today. World trade of seaborne coal increased substantially, and during recent years many analysts have considered the international coal market as an essentially unified global market (e.g. Ellerman, 1995; Humphreys and Welham, 2000).

The purpose of this paper is to test the hypothesis of the existence of a single economic market for the international coal industry, and to investigate whether the industry has experienced increased market integration over time. The general concept of the ‘Law of One Price’, stating that prices (expressed in the same currency) at geographically separated markets should be equal (with the exception of transaction costs), is used for defining the presence of a single economic market (Krugman and Obstfeld, 2000).

There are at least three motivations for this research. *First*, during the last decade the coal market has been characterized by a wave of mergers and acquisitions. This development has increased the consolidation of the market, since multinational corporations specializing in mining have replaced many of the local coal producers (Regibeau, 2000). The fear of these companies exercising market power, and driving prices higher, motivates an empirical analysis of market integration in the industry. The consolidation of markets through mergers and acquisitions is not something which is unique for the coal and energy markets. The structure of many markets has during the last years moved towards larger and more competitive global markets, a development which seems to imply larger companies, and as a consequence a more consolidated market. This raises the question whether the stronger market position of larger companies lead to an anticompetitive behavior in the market? When it comes to analyzing if a merger would result in higher prices to the consumer it is important to define the relevant market and its structure. Market integration tests are thus important for merger analysis, since it provides specific evidence as to the competitiveness of the markets, and the effectiveness of pricing.

Second, previous research on market integration in the international coal industry has not emphasized the different markets (end uses) for internationally traded coal products (see also section 2). The international coal market can be separated into coking coal and steam coal. Coking coal is primarily used as an input for the production of coke in the iron and steel industries, while steam coal is mainly used as an input in the power sector to produce electricity and heat. The use of steam coal in the electricity generating industry has developed rapidly during the last decades, while the use of coking coal as a chemical reductant in the steel making process has declined in the Western hemisphere due to the advent of new technologies for the production of steel. Given the situation of a more developed market for steam coal, most analysts have focused their

* Generous financial support from the Swedish Competition Authority is gratefully acknowledged, as are helpful comments from Patrik Söderholm, Bo Jonsson, Marian Radetzki, Mats Nilsson, John Tilton, and James Griffin.

research on this market, even though world demand for coking coal is still increasing. A *third* and final reason for this study is given by the relevance of geographic markets for a product such as coal. Coal is by nature a bulky product, and areas of production and consumption are separated. This implies that transportation costs tend to be important for both supply and demand decisions. One can thus argue that coal, both steam and coke, cannot be a perfectly integrated market, if for no other reason because of relatively high transportation costs.

Studying the relationship between prices at separated locations provides an indication of market integration. According to economic theory, two markets are integrated when their price levels are closely related (Stigler, 1969). The method for determining market integration in this paper is an error correction model, introduced by Engle and Granger (1987). The model examines movements in prices for goods located in different regions in order to test the hypothesis of a long-run cointegrating relationship.[1] It is however argued that a long-run cointegrating relationship alone is an insufficient indication of market integration, and should be complemented with error correction estimates (Gjolberg, et al., 1996). Error correction models have gained increased support for empirical estimations of market integration in energy industries during the last ten years (e.g., deVany and Walls, 1993; Sauer, 1994; Asche et al., 2001). This is mainly because the model extends the analysis by estimating a speed of adjustment parameter that measures how fast prices move back to the long-run equilibrium, as well as the short-run responses.

The data represents quarterly import prices in US Dollars/ton, separated for coking coal and steam coal, for the two dominant importers of coal, Europe and Japan. The time period examined stretches from 1980 until 2000, which includes coal prices ‘all time high’ in the beginning of the 1980s, when the security of supply issue dominated most political agendas, as well as the recent years when the contract standard is under development and multinational corporations specializing in mining are the dominant suppliers.

The paper proceeds as follows: section two examines the historical development of internationally traded steam and coking coal. Section three presents the model, and section four the empirical results, for both the steam and coking coal markets. Finally, in section five, some concluding remarks are made.

2. THE DEVELOPMENT OF THE INTERNATIONAL COAL MARKET

Globalization has been an important feature in the transformation of the international market for coal to its present form. Before the 1960s there was basically no such thing as an international market for coal, given that most export was land-based between neighboring countries. The exception was the US who exported some of their coal production to Europe as well as to Japan. A natural obstacle for the development of a world market for traded coal, compared with e.g. oil, is the relatively high transportation costs involved in shipping and handling coal (IEA, 1997). According to Lundgren (1996) freight rates for bulk products, such as coal, have decreased about 65-70 percent since the 1950s. This has created an opportunity for the development of a global market for seaborne trade.

2.1 Coking Coal

Coking coal is primarily used as a chemical reductant in iron and steel production. Growth in the coking coal market was most evident during the 1960s, something which can be ascribed to higher demand for coking coal primarily in Europe where production could not sustain the newly created demand. The higher demand for coking coal in the steel and iron making process in many European countries produced significant trade of seaborne coal, where previously there had been almost none. During the 1970s the demand for coking coal increased substantially in the newly industrializing countries, mainly in Asia and Latin America, which reinforced the development in the 1960s. During the 1980s growth in the coking coal market slowed down due to the slow growth in industry use for coking coal (mainly in Europe), and a new technical process that decreased the use of coke in the steel making process. (IEA, 1997)

In 1999 the total volume of export in coking coal was 188 million tons and the largest exporter, Australia, represented 49 percent of the market. The US was the second largest exporter with a share of 16 percent. The quarterly price levels for import of coking coal in the two dominant regions, Europe and Japan, was in 1999 US$49.17/ton and US$42.95/ton in average customs unit values, respectively. Figure 2.1 presents coking coal price levels for Europe and Japan from 1980 until 2000. It is evident from the figure that the prices in these geographical markets tend to be closely correlated. Notably is though that the price level in Japan, from 1994 and onwards, is slightly lower than the price level in Europe. This development can to some extent be explained by the growth in demand for coking coal in Asia, while at the same time in Europe many heavy industries was shut down. This can primarily be credited to the globalization process, when many heavy industries moved from the higher cost production in the US and Europe to the Asian-Pacific region (IEA, 2000). Interestingly, the price difference between the geographically separated markets has increased during the last years. This might be an indication that the market for coking coal is becoming less integrated; contradicting the notion of a unified market for internationally traded coking coal. This development shows the need for an empirical analysis of the current market situation for coking coal.

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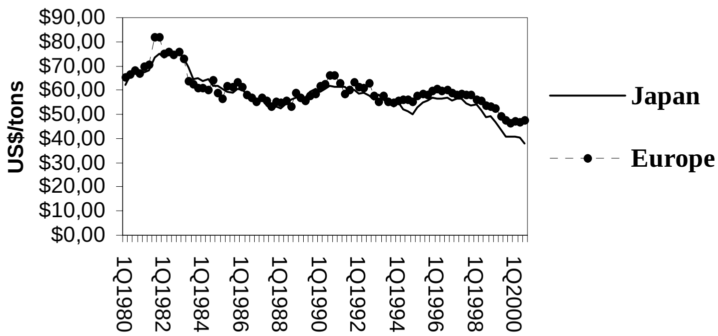
[1] Critique against price tests for identifying the possibility of market power, is discussed in Werden and Froeb (1993).

Figure 2.1: Import Prices for Coking Coal



Source: IEA (quarterly)

The prices for coking coal are generally settled by long-term contracts (more than five years), through negotiations between suppliers and consumers. During the last 5-6 years spot markets for coal have developed, but these are still limited in scope since the demand for coking coal is to a large extent fixed in the short-run. There is though evidence that the spot prices have an affect on the contract prices settlements, especially in the European market (IEA, 1997). Despite the existence of long-term contracts, the prices for coking coal are considered to be relatively flexible. Annual renegotiations, allowing the prices to change, are the norm. The timing of the negotiations has an impact on the prices, and for the coking coal market the price settlements with the Japanese Steel Mills are the most influential. These settlements are made before the negotiations for European and South African steel makers (IEA, 1997).

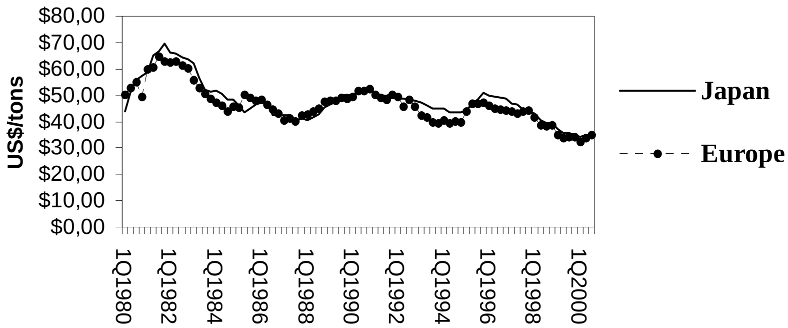
2.2 Steam Coal

Steam coal is primarily used for electricity generation, and it represents more than 60 percent of all traded coal. Compared to the coking coal market it has grown considerably faster during the last 20 years, which is mainly explained by the substantial increase in electricity demand during this period (IEA, 2000). The oil crises in 1973 and 1979 were the two individual events that have had the most impact on the creation of a world market for seaborne steam coal trade. The high oil prices enforced by the OPEC cartel increased the demand for internationally traded coal as a whole, but especially for steam coal. Transportation costs and storing costs for steam coal seemed no longer to be an overwhelming obstacle, especially since ‘security of supply’ became a political issue that appeared as important as a cost driven perspective (Söderholm, 1998).

In 1999 the total volume of export in steam coal was 333 million tons, and Australia was the largest exporter with a 24 percent share of the market. South Africa represented the second largest exporter, with 19 percent of the total export in steam coal (IEA, 2000). The price levels for imported steam coal in the two dominating regions, Europe and Japan, were in 1999 US$34.33/tons and US$35.87/tons, respectively, measured in average customs unit values. Figure 2.2 presents the quarterly steam coal prices for Europe and Japan from 1980 until 2000. The prices in these geographically separated markets are highly correlated, even more so than the price levels for coking coal. It is worth noting that the trend for steam coal is opposite to the one for coking coal, in that the prices for steam coal has been converging significantly, especially since 1997. This trend can be seen as an indication of a more integrated market for steam coal. Given this, a proper econometric test seems motivated.

The contractual arrangements for steam coal are by large the same as those for coking coal. So far, long-term contracts are dominating the market, but spot markets are becoming increasingly more common in the price formation process. The spot purchasing practice is more developed for steam coal than for coking coal, which is mainly due to the greater number of supply alternatives in the steam coal market, as well as reduced concern among major electric utility companies over secure supply alternatives. Spot markets are most frequent and developed in the Asian market, where spot sales are functioning as indicators for the long-term contract negotiations. The prices in the Asian market are also influenced by the prices set in the European market, since prices in the European market are mostly set one quarter ahead of the prices in Asia (IEA, 1997).

Figure 2.2: Import Prices for Steam Coal



Source: IEA (quarterly)

2.3 Is there a Single Economic Market for Internationally Traded Coal?

One aspect of the international coal market, which contradicts the notion of a unified global *economic* market, is the domination of two *geographical* markets, the European and the Asian-Pacific market. This is primarily sustained by the relatively high transportation costs and freight rates, and implies that countries, which are geographically closer to each other, are the primary exporters/importers. This situation, and the relatively strong relationship between coal prices as is illustrated in Figures 2.1-2.2, tend to support the notion of a unified market for internationally traded coal (see also Ellerman, 1995).

Still, even if the prices tend to follow the same path in the long-run, responses to price deviations in the short-run can provide useful information on the degree of market integration. In addition, the recent development of more consolidated coal suppliers may be an issue of concern, since the prospect of these companies exercising market power increases substantially when there are fewer, more dominant, players operating in the market (IEA, 2000). Additional reasons supporting the chosen topic are that previous research has to a large extent focused on the steam coal market, but the assumption about a single economic market has been made for the international coal market as a whole (IEA, 1997). The markets for steam coal and coking coal should not be treated jointly, due to the different developments and uses for these products. In addition, several studies on market integration, using cointegration and error correction techniques, have been conducted on both the gas and oil markets (e.g., Sauer, 1994; Asche, et al., 2000; deVany and Walls, 1993), but this kind of sophisticated econometric analysis has not been applied to the coal market. The above motivates a thorough empirical investigation for both steam and coking coal in order to test the hypothesis of a single economic market for traded coal.

3. COINTEGRATION AND ERROR CORRECTION MODELS

Stigler formulated a theory of price correlation, as he defined a market as "the area within which the price of a good tends to uniformity, allowances being made for transportation costs" (1969, p. 85). Stigler and Sherwin (1985) linked the statistical tests for price correlations to market integration, when they proposed examining price correlation as a test for market integration. The use of cointegration tests as a tool for analyzing market integration was proposed by e.g. deVany and Walls (1993). They argue that the long-run equilibrium level that is present when prices are cointegrated indicates that the examined market is integrated. When long-term cointegrating vectors are present in the model, these relationships are integrated into error correction models, which can be used to explore the dynamics of the short-run price adjustment process.

The first step in finding evidence of cointegration relationships among price series is to test for unit roots. This procedure identifies non-stationarity among price series, which is a necessary condition for cointegration. Price series can be tested for unit root by performing the augmented Dickey-Fuller (1979) test, where the first differences of the price series are regressed on the lagged price series. After establishing the presence of non-stationary price series, tests for cointegration can be performed. Consider two price series, p_i and p_j, that by themselves are non-stationary and must be differenced once to generate stationarity. A linear transformation of these can though result in a series ε_t that is stationary, $I(1)$:[2]

$$p_{j,t} - \alpha - \beta p_{i,t} = \varepsilon_t \qquad (1)$$

If this linear transformation exists between p_i and p_j, the time series are considered as cointegrated (Engle and Granger, 1987) since the regression indicates that the difference between the time series, $p_{j,t}$ - $\beta p_{j,t}$, is varying at random around a fixed level. When this is the case, it is possible to distinguish between a long-run and a short-run relationship between p_i and p_j. The long-run relationship captures the cointegration relationship, in which the series moves together around a fixed level. The

[2] This is only true if p_i and p_j are integrated of the same order, in this case integrated of order one (Greene, 1993).

short-run relationship describes deviations of p_i and p_j from their long-run trends. The vector [1, - β] in equation (1) captures the cointegration relationship between the two price series.

The model that differentiates between a long-run and short-run relationship for time series analysis has been widely known as the error correction mechanism (ECM) model (Engle and Granger, 1987). When non-stationary variables in a model are verified as cointegrated, the following ECM model can be derived:

$$\Delta p_{j,t} = \alpha + \beta_j \Delta p_{j,t-k} + \beta_i \Delta p_{i,t-k} + \delta EC_{t-1} + \varepsilon_t, \qquad (2)$$

where k represents the lag length and the error-correction term is represented by EC_{t-1}, which adopts the following form:

$$EC_{t-1} = p_{j,t-1} - \alpha - \beta p_{i,t-1}, \qquad (3)$$

This term captures the deviation from long-run equilibrium, and the coefficient δ in equation (2) measures the speed of adjustment, which indicates how long it takes for the time series to move back to the equilibrium level in case of e.g. a price shock in one region. The coefficients β_i and β_j represents the short-run counterparts to the long-run solution in equation (3). These parameters can only be estimated given a lag length of at least two. When testing for cointegration there are two tests that are usually employed in the literature, the Engle and Granger test (Engle and Granger, 1987) and the Johansen test (Johansen, 1988; 1991). Here the Johansen cointegration test will be employed, mainly because it makes it possible to draw inferences of the parameters included in the cointegrating vector.

4. RESULTS FOR THE INTERNATIONAL COAL INDUSTRY 1980-2000

The data used for this study represent quarterly import prices for coking and steam coal from the first quarter in 1980 to the third quarter in 2000, for the two dominating geographical markets for internationally traded coal, Europe and Japan. It has been collected from the International Energy Agency's (IEAs) quarterly publication *Energy Prices and Taxes*, and represents import costs in US Dollars/ton. Monthly or weekly data would have been preferred given that short-run responses provide finer results when using closer observations, but since coal prices are in many cases set in long-term contracts (adjusted every year) quarterly data should be sufficient for recognizing the short-run adjustment process. The econometric model outlined in section 3 will be employed in logarithmic form.[3] The results for steam coal and coking coal are presented separately in this section, mainly due to the hypothesis that the differences between these markets will yield different results and possibly different conclusions. The section ends by investigating changes over time in both markets.

The first step in finding evidence of cointegration relationships among price series is to test for unit roots. This procedure identifies non-stationarity among price series, which is a necessary condition for cointegration. The tests for coking coal and steam coal shows that it is not possible to reject the hypothesis of unit root in levels, in either Europe or Japan, but for first differencing. Tests for cointegration can therefore be conducted both for coking coal and steam coal.

4.1 Cointegration Results for Coking Coal

The test for cointegration first requires an estimation of an unrestricted vector autoregressive (VAR) model, in order to select the number of lags for the VAR. Table 4.1 reports the test statistics and choice criteria for selecting the order of the VAR model. Test statistics for two different tests, the Akaike Information Criterion (AIC) and the Schwartz Bayesian Criterion (SBC) is presented. The test concludes that the model with the highest numbers selects the order of the VAR. As the results in Table 4.1 show, the outcome is indecisive. The AIC test selects two lags, while the SBC test selects one lag. A VAR of order one does, however, remove the short-run responses for the price series, except for the speed of adjustment parameter. I have therefore chosen to continue the estimations using a VAR with two lags, suggested by the AIC test.

Table 4.1: Selecting the order of the VAR model

# of Lags	*AIC*	*SBC*
0	178.12	175.74
1	317.76	**310.61**
2	**318.21***	306.30
3	315.22	298.54

* Bold numbers indicates the highest value

The next step in the market integration approach is to test for the number of cointegrating vectors present in the error correction model, using the Johansen cointegration test. Given two possible cointegrating variables, at most one cointegrating vector (r) can be found (Maddala and Kim, 1998). Since the price series represent import prices for the two different regions,

[3] Logarithmic form prevents that growth rates depend on the levels of the price series (Hendry and Juselius, 2001). The coefficients also become easier to interpret, since they are scale-invariant. A problem with log-form is, though, that the prices are not quoted as they are in arithmetic form. However, the arithmetic form assumes either perfectly integrated markets or no market integration at all. The most likely outcome is something in between, which the log-linear form accounts for.

it is reasonable to believe that differences in transportation costs and quality between regions are incorporated in the intercept parameter. The cointegration test is therefore based on a model with restricted intercept and no trends, which is also suggested when testing whether to include an intercept in the VAR. Table 4.2 reports the result of the cointegration test based on the maximum eigenvalue statistics, which tests the null hypothesis of number of cointegrating vectors against the hypothesis of the number of cointegrating vectors plus one, that is $H_0(r)$ against $H_1(r+1)$. The test is carried out sequentially, starting from the null of no cointegrating vector, $H_0(0)$, until the test fails to reject the null hypothesis.

Table 4.2: Johansen Cointegration test

Maximum Eigenvalue	*95% Critical Value**	*90% Critical Value**	$H_0(r)$	$H_1(r+1)$
16.41**	15.87	13.81	0	1
2.72	9.16	7.53	1	2

* Critical values are calculated using the statistical software Microfit 4.0.

** Bold numbers indicate a rejection of the null hypothesis

Table 4.2 shows that the test rejects the null hypothesis of no cointegrating vector, but fail to reject the null hypothesis of one cointegrating vector. This indicates that there exists a long-run relationship between prices in Europe and Japan, concerning coking coal. Given this outcome, it is possible to estimate the long and short-run responses using the error correction technique. The long-run response is represented by the error correction term that includes the cointegrating vector. Equation (4) shows the result of the cointegration test for coking coal prices in Europe and Japan. The cointegration relations for variable Europe, normalized on Europe, have the following representation:[4]

$$P_E = 1.4089 + 0.66275 P_J \qquad (4)$$
$$(-4.4129) \quad (-8.4656)$$

Equation (4) indicates that when the price in Japan rises by one percent, the corresponding long-run increase in the European price level is 0.66 percent. The values in the parentheses represent the t-statistics, which indicate that the coefficients for the intercept and prices in Japan are statistically significant. An economic interpretation of the intercept term is that it represents the price differences between the time series in the long-run, which in the case of coal incorporates transportation costs and quality differences. The sign indicates that the price level in Japan is lower than the price level in Europe, as is also evident when looking at Figure 2.1.

The response in Europe to a price increase in Japan indicates that there exists a long-run relationship between these markets. How strong this relationship is can be tested by imposing an over-identifying restriction that $\beta_J = 1$. This restriction would imply a perfect relationship between the price series, which in turn means that the markets are completely integrated. This test has been carried out using the Johansen procedure. The null hypothesis of $\beta' = (1, -1)'$ is rejected, given the log-likelihood ratio statistic CHSQ(1) = 12.33, which is statistically significant. Given this result it is possible to conclude that the prices in Europe and Japan do not show evidence of a perfect relationship. In order to provide a more comprehensive conclusion for the price correlation, estimations for the short-run responses have also been conducted.

The error correction model used is given in equation (5). The equation shows that the lag length of the model is two. The dependent variable used is Europe, but estimations using Japan as the dependent variable has also been performed.

$$\Delta P_{E,t} = b_E \Delta P_{E,t-1} + b_J \Delta P_{J,t-1} + \delta EC_{t-1}\,, \qquad (5)$$

where b_J and b_E is the estimated short-run counterparts to the long-run solution in equation (4), and δ represents the speed of adjustment parameter, which indicates how fast the prices moves back towards long-run equilibrium in case of a deviation in the previous time period. Table 4.3 presents the estimated values of these parameters, using both prices in Europe and Japan as the dependent variable.

Table 4.3: Error Correction Estimates

	EUROPE			JAPAN		
Coefficients	b_E	b_J	δ_E	b_J	b_E	δ_J
Estimate	0.016	**0.469***	**-0.342**	0.197	0.069	0.084
t-values	(0.129)	(2.993)	(3.167)	(1.675)	(0.746)	(1.041)

* Bold numbers indicate that the corresponding coefficients are statistically significant.

The results using prices in Europe as the dependent variable indicate that a one percent increase of prices in Japan the preceding period, yields a 0.469 percent increase of the price level in Europe the present time period. This result is statistically significant, and suggests that the prices in Europe are reacting to price changes in Japan the previous time period.

[4] Pesharan and Smith (1999) discuss the necessity of an identifying restriction that normalizes the coefficient of one variable to equal one.

The result of a price change in the own region the preceding time period is 0.016, an effect which is not statistically significant. The speed of adjustment parameter is statistically significant and implies that a deviation from the long-run equilibrium in Japan the preceding time period, is adjusted for by 34 percent in Europe the following quarter. Turning the attention to the results when using Japanese prices as the dependent variable we can see that none of the short-term response parameters are statistically significant. In the case of cointegration there should be Granger-causation in at least one direction (Mehra, 1994). Since the adjustment parameter, δ_J, is not statistically different from zero, but δ_E is, the results are consistent with the presence of Granger-causality. The direction of the causality is that prices in Japan Granger-causes prices in Europe. This result indicates that Japan acts as a price leader and Europe acts as a price follower in the coking coal market.

When summarizing the results for coking coal, it is evident that the prices in Europe and Japan are cointegrated, and therefore follow a long-run relationship. This result supports the hypothesis of an integrated world market for coking coal. When examining the short-run responses to the long-run equilibrium, the conclusions about the degree of market integration are indecisive. The results are consistently pointing towards the Japanese market as a price leader, since their price does not adjust to changes in the European price level. This result is consistent with the fact that prices in Asia generally are set before the prices in Europe, as discussed in section 2.

4.2 Cointegration results for Steam Coal

Tests for cointegration and error correction for the steam coal market follow the same general procedure as for coking coal. The conclusion for the unit root test is once again indecisive; the AIC test selects a VAR of order two, while the SBC test selects a VAR of order one. As in the coking coal market, the model chosen is therefore a VAR of order two, which is suggested by the AIC test. The next step is to test for the number of cointegrating vectors present in the error correction model. The cointegration test is based on a model without an intercept and time trend. The reason for this choice is because an estimation of the VAR suggests that the intercept should not be included, and a test of excluding the intercept term could not be rejected. For economic intuition it seems somewhat peculiar not to include an intercept, given that it incorporates the differences in transportation costs between the world regions. This does however not imply that there does not exist any transportation costs, only that the differences in transportation costs to Europe (from e.g. Poland and USA) cannot be significantly separated from transportation costs to Japan (mainly from Australia).

Table 4.5 reports the result of the cointegration test based on the maximum eigenvalue statistics, testing the null hypothesis of the number of cointegrating vectors against the hypothesis of the number of cointegrating vectors plus one. It shows that the test rejects the null hypothesis of no cointegrating vector, but fail to reject the null hypothesis of one cointegrating vector. This indicates that there exists a long-run cointegrating relationship between prices in Europe and Japan, concerning steam coal. Given this outcome, it is possible to estimate the long and short-run responses, as well as the speed of adjustment parameter.

Table 4.5: Johansen Cointegration test

Maximum Eigenvalue	*95% Critical Value**	*90% Critical Value**	*$H_0(r)$*	*$H_1(r+1)$*
11.28**	11.03	9.28	0	1
1.26	4.16	3.04	1	2

* Critical values are calculated using the statistical software Microfit 4.0.
** Bold numbers indicates a rejection of the null hypothesis

Equation (6) shows the results of the cointegration test for Europe and Japan. The cointegration relationship for variable Europe, normalized on Europe, have the following presentation:

$$P_E = \underset{(268.99)}{0.99290} P_J \qquad (6)$$

This indicates that when the prices in Japan rise by one percent, the corresponding increase in Europe in the long-run is 0.99 percent. This result indicates a strong and stable long-run relationship between the prices in Europe and Japan. Compared to the coking coal market, it is evident that the price series concerning steam coal is more closely related. A one percent increase in the Japanese price level imply, in the case of coking coal, a 0.66 percent increase in the European price level, compared to a 0.99 percent increase considering steam coal. The value in the bracket represents the t-statistics, which indicate that the effect of a prices change in Japan is highly statistically significant. In order to test if the price levels are perfectly related an over identifying restriction, $\beta_J = 1$, has been imposed. The null hypothesis of $\beta' = (1, -1)'$ are though rejected, given the log-likelihood ratio statistic CHSQ(1) = 2.54 (0.111) which is statistically significant. It is however noteworthy that the log-likelihood ratio is accepted at an 89.9 percent significance level, indicating that at a confidence level of 89.9 percent the hypothesis of perfectly related price series cannot be rejected.

The error correction model, which produces estimates for the speed of adjustment parameter and short-run responses, is performed as outlined in equation (5). Table 4.6 presents the estimated values of these parameters, using both Europe and Japan as the dependent variable.

Table 4.6: Error Correction Estimates

	EUROPE			JAPAN		
Coefficients	b_E	b_J	δ_E	b_J	b_E	δ_J
Estimate	0.003	0.240	-0.111	**0.243***	**0.200**	**0.174**
t-values	(0.021)	(1.719)	(-1.006)	(2.689)	(2.229)	(2.447)

* Bold numbers indicate statistical significance.

The results using Europe as the dependent variable show that none of the short-run response parameters are statistically significant. The effect of a one percent increase of the price level in Japan the preceding period does indicate that the price level in Europe increases by 0.24 percent the present quarter. The result using Japan as the dependent variable indicates that a one percent increase of prices in Europe the preceding period, yields a 0.2 percent increase of the price level in Japan the present time period. This result is statistically significant, and suggests that the prices in Japan are reacting to price changes in Europe the preceding time period. The result of a price change in the own region the preceding time period is 0.243, which also is statistically significant. The speed of adjustment parameter is 0.174 when using Japan as the dependent variable, which also is statistically significant. This means that a deviation from the long-run equilibrium level in Europe the preceding time period, is adjusted for by 17.4 percent in Japan the following time period. Since only one of the speed of adjustment parameters is statistically significant, there is again evidence of Granger-causality. The results for the steam coal market imply that prices in Europe Granger-cause prices in Japan. This result might be an indication that it is Europe that acts as a price leader in the steam coal market, and not Japan as in the coking coal market.

The results from the cointegraiton and error correction models, considering steam coal, indicate that the market integration between the European market and the Japanese market is strong. The prices follow a stable long-run relationship, which almost point towards a perfect relationship between prices in Europe and Japan. When examining the short-run response, given by the adjustment towards the long-run equilibrium, the results are consistent with the conclusion that European prices Granger-causes Japanese prices. This result may be explained by the timing of price negotiations, since steam coal prices in Europe normally are settled before the prices in Japan (see section 2).

4.3 Market Integration Over Time

In order to investigate whether the coal markets have experienced increased market integration over time, the price series have been separated into two time periods. The first period represents price data from quarter one 1980 to quarter four 1989, and the second time period represents prices from quarter one 1990 until quarter three 2000. The cointegration results indicate a long-run equilibrium relationship, for both coking and steam coal for the two time periods. It is noteworthy, however, that for steam coal prices during the 1990s, a cointegrating relationship could only be confirmed given a ten percent significance level.

Given cointegration, it is possible to estimate the long-run and short-run cointegrating relationship, as well as the speed of adjustment parameter. Only the long-run relationship will be presented here, mainly due to the difficulty of analyzing the short-run results given different lag lengths of the different price series. Before these estimations are presented it is however of interest to determine whether it is at all statistically motivated to run the error correction models when dividing the price series into two time periods. In order to determine this, a Chow test was conducted. This test verifies if the improvement in the fit due to the break up of the sample is statistically significant or not (Dougherty, 1992). The F-statistic is 6.03 for steam coal and –1.87 for coking coal. Given a critical value of 3.15, these results imply that separating the price series into two time periods are motivated concerning steam coal but not for coking coal. Thus, only for steam coal the Chow test rejected the null hypothesis that the two sub-samples could be combined into one single error correction model. As a consequence, the following estimations of the error correction model can only be motivated for the steam coal market.

The long-run relationships of the cointegrating vector for steam coal are presented in Table 4.7, separated in two time periods. Since the results are normalized on Europe, the estimate for Europe will equal one. When analyzing the cointegrating results for steam coal it is evident that the price series have become more integrated over time. In the long-run, a price increase in Japan was adjusted in Europe by 78 percent during 1980-1989, and by 99 percent during 1990-2000. The intercept term during the 1980s show that if the price in Japan were zero, the price in Europe would be 0.85. It is noteworthy that an intercept term, according to the statistics, should be included for the 1980s but not for the 1990s. A likely explanation is that when the markets become more integrated, the price levels also converge and the price differential decreases.

Table 4.7: The Long-run Cointegration Results, Normalized on Europe

	1980Q1-1989Q4		**1990Q1-2000Q3**	
STEAM COAL	**Japan**	**Intercept**	**Japan**	**Intercept**
Estimate	0.77990	0.84637	0.99560	-
t-values	15.40	4.27	155.26	-

Tests to establish whether the price levels are perfectly related have also been performed. For the time period 1980-1989 the null hypothesis of β' = (1, -1)' are rejected, given the log-likelihood ratio statistic CHSQ(1) = 8.21 which is statistically significant. For the period 1990-2000 the null hypothesis could not be rejected, given the log-likelihood ratio statistic CHSQ(1) = 0.31 which is also statistically significant. This result implies that the price levels in Europe and Japan for steam coal are perfectly related for the time period 1990-2000. This is in line with the theory about a single world market for steam coal.

The results from the cointegration and error correction models, concerning market integration over time, indicate that the development for steam coal and coking coal has been dissimilar. The hypothesis of a world market for steam coal is supported given the results over time as well. The market for steam coal has clearly become more integrated during the 1990s, a conclusion which does not hold for the coking coal market. A likely explanation for the more integrated market for steam coal is the development of spot markets during the 1990s, which has reduced the transaction costs (i.e., arbitrage) for buyers and sellers for steam coal. This has decreased the possibility of arbitrage profits since the integrated market has become more transparent.

5. CONCLUDING REMARKS

The results in this study are consistent with the conclusion that the international market for traded steam coal is more integrated than the market for coking coal. This outcome is given both when examining the entire time period for the separate markets, as well as when examining whether any of the markets has experienced more market integration over time. The results for the entire time period show that both the coking and steam coal markets indicate some level of market integration, as demonstrated by the stable long-run cointegrating relationship. The degree of market integration is however higher for steam coal than for coking coal; a one percent increase in the Japanese price level imply, in the case of steam coal, a 0.99 percent increase in the European price level, while for coking coal the corresponding increase is 0.66 percent. Noteworthy are also that, for both coking and steam coal, the short-run price adjustments are only significant from one direction. In the coking coal market, the results are consistent with Japan as a price leader, and in the steam coal market, Europe acts as a price leader. This result may be explained by the timing of price negotiations, where the Japanese prices are normally settled before the European prices concerning coking coal, and vice versa for steam coal.

In order to test for market integration over time, the price series data are separated into two time periods, 1980-1989 and 1990-2000. The results from this investigation show that the steam coal market has experienced increased market integration over time, which is not the case for the coking coal market. The structural break in 1990 is confirmed for steam coal when using a Chow test, indicating a higher degree of market integration during the latter decade. It is reasonable to believe that the establishment of spot markets has been important for the above result. In the coking coal market the Chow test does not support the separation of the price series into two time periods, and neither does the price series indicate any increased market integration over time. When comparing the price series of coking and steam coal by the eye (perhaps not the most statistically approved method, but still highly intuitive for economic analysis) it is evident that the prices for steam coal converges in the end of the period, while the prices for coking coal diverges. This is consistent with the results for coking coal and it may imply a non-competitive behavior in the coking coal market. As mentioned earlier, this result is not statistically approved by the Chow test. It would therefore be of interest to see if future research would come to the same conclusion. But even if this result cannot be supported statistically, it is of interest to ask why the coking coal market has not experienced higher market integration over time? A possible explanation might be that the steel making process has fewer substitutes, than the electricity generating industry. A further reason is likely that the technical development in the steel making process has decreased demand for coking coal.

A policy implication of the finding that the steam coal market has become an integrated global market in the 1990s is that a merger or acquisition that occurred during this period would not add as much to the merged companies market power, as the same activity during the 1980s. This implies that in a larger market a merger will weigh less. This conclusion is also given by the lower transaction costs and arbitrage possibilities for a more integrated market. In the coking coal market the situation is somewhat different. There do not appear seem to be any tendencies towards greater integration, and the possibility that a given merger would result in non-competitive pricing has therefore not decreased during the 1990s.

An important caveat of the error correction model is that it is sensitive to the different specifications that are necessary for estimating the relevant coefficients. As an example, the method chooses the number of lags involved and the results are dependent upon this specification, even if economic theory might indicate another level. Because of this all results should be treated cautiously, and reliant upon the specified levels and orders. It is therefore important to note that the results produced in this paper needs to be reinforced by the use of other methods in order to provide a more comprehensive analysis of market integration in the international coal market. The error correction model produces necessary conditions for market integration, but these are not sufficient for concluding that the market is fully integrated. It is therefore important to undertake further research concerning market integration, preferably using alternative research methods which, for instance, focus more explicitly on arbitrage costs.

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