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RESEARCH PAPER

Market integration for Chilean wheat prices using Vector Error Correction Models (VECM), a cointegration analysis

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Abstract

R. Valdés, S. von Cramon-Taubadel, and J. Díaz. 2011. Market integration for Chilean wheat prices using vector error correction models (VECM), a cointegration analysis. Cien. Inv. Agr. 38(1): 5-14. Historically Chile has been a wheat net importer country. This situation, added to the small size of its economy, causes that the domestic price of this cereal is highly influenced by import prices of substitute wheat. This research analyzed the integration level of the Chilean wheat market with respect to the USA and Argentinean markets using a vector error correction model (VECM), the impact of the band prices (D-BAND) and the change of the band mechanism introduced in 2004 (D-MECH) by the inclusion of two binary variables in the VECM. The results showed strong market integration among Argentina, Chile and USA, with USA leading the market. Additionally, the price of the Chilean wheat was influenced by the USA and Argentina prices. The binary variables, included in the models, showed that this system had been useful to protect the domestic market by reducing the fluctuations of the wheat prices (D-BAND), and the new mechanism performs as a protection over the international fluctuations (D-MECH). Both coefficients presented non-significative values, probably due to the difference among the input cost and the domestic price support mechanism, the sub-valuated commodities markets, increment on cereal price levels, inflationary scenarios and low number of observations.

Key words: Cointegration analysis, price band, wheat, cereal prices, international market of commodities, vector error correction model.

Introduction

The condition of being a net importer, in addition to being a small market, exposes the Chilean domestic wheat prices to fluctuations of international markets. In addition, according to Baffes and Gardner (2003), Chile is the country in which the prices are transmitted in the highest degree in Latin America. The authors found that, in the case of wheat, a 53% of the domestic wheat price oscillation was explained by the variations in the world prices with long run elasticity close to one. To reduce the volatility of wheat prices and to diminish farmer uncertainty, the government implemented in 1977, and modified in 1984, a price band. The impact of the band over the domestic market has been studied in the past, concluding that, in general, it was performed as a protective measure, increasing the wheat domes-

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tic prices (Engler and Nahuelhual, 2006; Morales and Foster, 2004, Venturelli, 2003). Moreover, Morales and Foster (2004) concluded that for the period 1984-2000, the band system showed an increase of 18.7% in the wheat domestic price, generating an increase of 8.2% in the demand by the Chilean wheat milling industry.

The price band is yearly calculated based on historical international prices of a reference market. Those markets were the Hard Red Winter Nº2 FOB price in the Gulf of Mexico from 1984 to 2003, and from December 2003 to now, the Argentinean PAN wheat FOB price for the first semester and the Soft Red Winter Nº2 wheat FOB price, in the Gulf of Mexico, for the second semester. The price band is calculated by ODEPA (Chilean Office for Agricultural Policies) and published in the Chilean official newspaper at the beginning of the agricultural season, prior the sowing period. Previous researches focused on considering the impact surplus transfers and their impact on the wheat demand. Nevertheless, they did not study in depth the dynamics among the different markets that interact with the domestic wheat market in Chile. Rather, this research focuses on identifying the forces affecting the domestic wheat market and the impact of the price band using a spatial price transmission framework to model the Chilean wheat price, arguing that different markets share the same traded commodity and the same long run information (Acosta and Ortega, 2006).

With this background, the objectives of this research were 1) To analyze the market integration of the regional wheat market with respect to USA, Argentina and Chile using a VECM approach; 2) To consider the impact of the price band over the Chilean domestic wheat price; and 3) To estimate the effect of the new price band mechanism over the Chilean domestic wheat price from 2003 to now.

Materials and methods

The data was analyzed using the econometric software Jmulti Version 4.22, available on www.jmulti.de.

The time series for real prices were analyzed since December, 1986 to December, 2007 and it generated a total of 253 observations. Table 1 presents a description of the variables used in this research.

The domestic prices and the FOB prices for PAN and Hard Red Winter wheat were expressed in real terms in US$/ton. All values were acquired from the Chilean Office for Agricultural Policies (ODEPA).

In order to carry out an analysis of the spatial price transmission dynamics over time in the international market for the Chilean wheat, a Vector Error Correction Model (VECM) was estimated using the domestic wheat price, a weighted price of the USA and Argentinean wheat (equation 1) and two binary variables representing the price band. The weighted price variable was created with the purpose to prevent both stability and residual problems by reducing statistical problems derived from the intervened Chilean market, isolating factors associated to price intervention policies in the geographically integrated market (Balcombe *et al.,* 2007).

Weighted Price = HRW_USA*(Imports from USA/
Total Imports) + PAN_ARG*(Imports from Argentina/
Total Imports (1)

Note: the total imports consider volumes from USA and Argentina.

To estimate the effects of the price band on the Chilean wheat market, the binary variable (D_BAND) was included. This value was 1 during the months in which tariff reductions (import prices over the ceiling price) or specific rights (import prices under the baseline price) were applied, and 0 when the band was not applied. Also, to estimate the effect of the new price band mechanism implemented in December 2003, the binary variable (D_MECH) was included. The value was 1 beginning in January, 2004 and 0 for the previous observations. According to Banerjee (1993), the VECM allows for a link between the short and long term dynamics, as it provides a methodology for modeling both in levels and in differences. Consequently, the VECM models simultaneously

Table 1. Description of the time series variables of the research.

Type	Variable description	Variable description	Measure unit
Real Prices	DOM_CH	Natural logarithm of Chilean wheat price	Price in USA dollars per ton
Real Prices	HRW_USA	Natural logarithm of Hard Red Winter N. 2 (FOB price)	Price in USA dollars per ton
Real Prices	PAN_ARG	Natural logarithm of Argentinean PAN (FOB price)	Price in USA dollars per ton
Weighted Real Prices	WGHT_PRICE	HRW_USA and PAN_AR corrected by imports in logarithm terms	Price in USA dollars per ton
Binary Variable	D_BAND	Binary variable for the Chilean price band application	0= without the application of specific rights or tariff reductions 1= with the application of specific rights or tariff reductions
Binary Variable	D_MECH	Binary variable for the change in the price band mechanism	0= January 1984 to December 2003 1= January 2004 to December 2007

Source: prepared by the authors (2008).

predict the short-term dynamics of adjustment (variations) and the long term (levels). The order of integration of the variables was determined with the Augmented Dickey Fuller (ADF) test in accordance with Dickey and Fuller (1979) while critical values for the joint tests are from Dickey and Fuller (1981). In this paper, the cointegration test, using the Johansen cointegration test according to Johansen and Juselius (1990), sought to detect long-term relationship among the variables, and Granger's causality tests, in accordance to Granger (1969), were used to verify the causality direction among the variables. Unit root testing requires choosing the number of lags in each test to eliminate autocorrelation in the residuals. The optimal lag p was chosen carefully by the Bayeasian of Akaike, Final Prediction Error, Hannan-Quinn and Schwarz Criterium. All was considered assuming a constant.

The following procedure was applied in order to analyze the models:

a) Perform the Augmented Dickey-Fuller Test (ADF) to determine the non-stationary character and the same degree of integration for the series, a fundamental requirement to apply the VECM (Enders, 1995).

b) Perform the Johansen test to analyze cointegration using all the variables and the suggested order process by the order criterions. This test must show evidence of cointegration among the time series, in order to follow to the next step.

c) Perform a Vector Error Correction Model (VECM) analysis.

d) Perform the Model Stability test (Bootstrap Chow test) and estimate if structural breaks are presents in the model.

e) Perform the Granger and Instant Causality test.

f) Apply a residual analysis of the VECM for possible shortcomings.

Results

The ADF test was executed to begin the analysis, which showed the unit root at all significant levels for both price series. These results are presented in the Table 2.

The purpose of the next analysis was to realize the cointegration test by using the Johansen approach. The results suggested one degree of cointegration for all series with a 10% of confidence, which enables the application of a VECM (Table 3).

The next step was to perform the stability analysis (Bootstrap Chow test). The null hypothesis states stability (H_0= No structural brakes) to search for a break point where it must be rejected. The results are presented on the Figure 1.

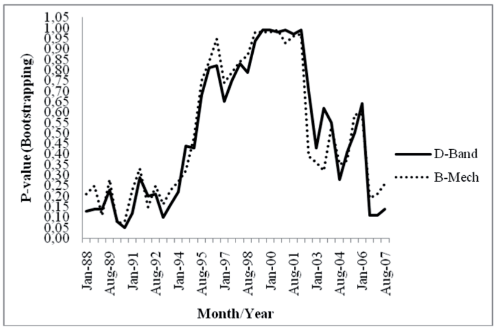

Figure 1. Results of stability test for break points (Chow test) for the models. Source: prepared by the authors (2008).

The Bootstrap Chow test showed few rejections for the stability hypothesis across the time series with critical values of 5, 10 and even 1%.

Table 2. Results from the augmented Dickey-Fuller test for each variable, with intercept.

Variables	Augmented Dickey Fuller Test	Asymptotic Critical Values		
	Test Statistic	1%	5%	10%
DOM_CH	0.9434	(-) 2.56	(-) 1.94	(-) 1.62
WGHT_PRICE	0.9678	(-) 2.56	(-) 1.94	(-) 1.62

Source: prepared by the authors (2008).

Table 3. Johansen cointegration test results.

Variables Included	Rank	LR Statistic	p-value	Critical Values 90%	95%	99%
DOM_CH, WGHT_ PRICE	r=0	23.50	0.0076	22.66	25.01	29.82
D_MECH	r=1	9.35	0.1819	10.40	12.25	16.24
DOM_CH, WGHT_PRICE	r=0	19.51	0.0620	17.98	20.16	24.69
D_BAND	r=1	4.02	0.4216	7.60	9.14	12.53

Source: prepared by the authors (2008).

First, for the model with D-BAND, the null hypothesis was rejected at a 10% level only for the period Jan-90 to Jan-91, and in all the others periods the stability hypothesis was accepted. On the other hand, for the model with D-MECH, the stability hypothesis was rejected at a 10% level for the period Jan-October 90. The VECM for both models were estimated using one lagged variable as suggested by the Akaike, Hannan Quinn and Schwarz Criteria (Table 4).

The binary variable D_BAND showed a positive and not significant value of 0.015 (t-value of 0.169). Although the parameter is not significant, the positive coefficient suggests that, in average terms, the band affected positively the Chilean wheat price during the research period, which is consistent with the band history of interventions. For research purposes, the analysis was focused on the long-run side of the model. For the remaining parameters, significant coefficients at almost 10% level were founded.

For the second model with D_MECH, all parameters on the long run side were significant at a 10% level, with the exception of the constant and the binary variables.

The next step was to execute the Granger and Instant Causality tests. The results are presented on the Table 5.

According to these results, variations on the weighted prices cause variation on the domestic prices, but the domestic prices do not cause variations on the weighted variable. Again, as expected, the international price of wheat influences the price of this commodity in Chile,

Table 4. Model estimation results.

	MODEL A				MODEL B			
	Equation DOM_CH		Equation WGHT_PRICE		Equation DOM_CH		Equation WGHT_PRICE	
Variables	Estimate	t-value	Estimate	t-value	Estimate	t-value	Estimate	t-value
ect model A	-0.049	-2.645	0.043	1.940	--	--	--	--
ect model B	--	--	--	--	-0.041	- 2.386	0.048	2.285
Δ DOM_CH$_{t-1}$	--	--	--	--	--	--	--	--
ΔWGHT_PRICE$_{t-1}$	-0.799	-4.023	- 0.799	- 0.799	-0.902	- 4.710	-0.902	-4.710
D_BAND	0.015	0.169	0.015	0.169	--	--	--	--
D_MECH	--	--	--	--	0.074	6.684	0.074	0.684

Source: prepared by the authors (2008).

Table 5. Results of the Granger and Instant causality tests.

Variables Included	Ho	Granger p-value	Instant p-value
DOM_CH, WGHT_PRICE,D_MECH	WGHT_PRICE do not cause DOM_CH	0.0018	0.0024
	DOM_CH do not cause WGHT_PRICE	0.1553	0.0024
DOM_CH, WGHT_PRICE,D_BAND	WGHT_PRICE do not cause DOM_CH	0.0006	0.0013
	DOM_CH do not cause WGHT_PRICE	0.1030	0.0013

Source: prepared by the authors (2008).

meaning the direction of causality is unidirectional. This result is in line with several studies that evaluated this price relationship.

The last step was to analyze the residuals by testing for autocorrelation (LM test for autocorrelation), heterocedasticity (VARCH-LM test) and normality (Jarque-Bera), considering five lags. The results are presented on the Table 6 and the null hypothesis were:

- Autocorrelation, Ho=No autocorrelation.
- Heterocedasticity, Ho=No heterocedasticity.
- Normality, Ho=Normality.

The analysis for both models presents the rejection of normality for the residuals hypothesis. The heterocedasticity and autocorrelation were not presented in both equations. These results make the weighted models suitable for a cointegration analysis among the markets involved in this paper. Furthermore, the models obtained from the J-Multi were rewritten in function of DOM_CH, WGHT_PRICE and the error correction term (ECT_{t-1}).

The following was obtained from Table 4:

a.1. $DOM\_CH(t) = -0.049\times(ECT_{t-1}) + 0.015\times D\_BAND_{(t-1)} - 1.275\times Const$ (2)

b.1. $WGHT\_PRICE(t) = 0.043\times(ECT_{t-1}) + 0.015\times D\_BAND_{(t-1)} - 1.275\times Const$ (3)

c.1. $ECT_{t-1} = DOM\_CH_{t-1} - 0.799\times WGHT\_PRICE_{t-1}$ (4)

a.2 $DOM\_CH(t) = -0.041\times(ECT_{t-1}) + 0.074\times D\_MECH_{(t-1)} - 0.767\times Const$ (5)

b.2 $WGHT\_PRICE(t) = 0.048\times(ECT_{t-1}) + 0.074\times D\_MECH_{(t-1)} - 0.767\times Const$ (6)

c.2 $ECT_{t-1} = DOM\_CH_{t-1} - 0.902\times WGHT\_PRICE_{t-1}$ (7)

Discussion

Discussion on the loading parameters

First, the loading parameters for the domestic prices, obtained from the equations (2) and (5), showed values of (-) 0.049 and (-) 0.041. These loading factors can be interpreted as the speed of the adjustments for the long run term; nevertheless, they must be analyzed jointly with the error correction term for a complete interpretation. On the one hand, these coefficients were significant at all levels as well as negative; in other words, the Chilean market adjusts to the Argentinean and USA markets.

Table 6. Residual analysis for both models.

Variables Included	Test	p-value
DOM_CH, WGHT_PRICE,D_MECH	LM-type for autocorrelation	0.3151
	VARCHLM	0.2983
	Jarque-Bera Test	0.0000 (u1)
		0.0391 (u2)
DOM_CH, WGHT_PRICE,D_BAND	LM-type for autocorrelation	0.3182
	VARCHLM	0.3122
	Jarque-Bera Test	0.0000 (u1)
		0.0000 (u2)

Source: prepared by the authors (2008).

These results are in line with the statements made by Engler and Nahuelhual (2006). According to the coefficient values, it is possible to infer that when the prices of Hard Red Winter and PAN wheat increase, the Chilean prices also increase to maintain the equilibrium, the magnitude of the coefficient indicate that each month, 4.9% of the divergence that could exist within this market, was eliminated. It can also be inferred that, after the new band mechanism was implemented, the coefficient decreased to 4.1% for the period.

Second, the loading parameters for the weighted prices were 0.043 and 0.048 with significant t-values of 1.940 and 2.285, as presented in Table 4. In order to explain these findings, it is useful to cite Baffes and Gardner (2003), whose work suggests that, in cases of concentrated producers and monopsony or oligopsony situations, the price transmission effect could be indirect through a small country to larger producer countries which are geographically separated. Additionally, the USA is the main world supplier of this commodity but with a relatively small speed of adjustment, mainly due to the fact that, besides being the largest producer and exporter, it has a significant domestic market, being a price maker with Argentina. These reasons lie behind the slow fade away of short term deviations in the United States, meaning that its prices are less sensitive to short term variations of international prices, relative to other markets (Machado and Margarido, 2004). Thus in the long run, these variations in the international price of wheat tend to be fully transmitted to prices in Chile, so that the elasticity of price transmission is unity. In economic terms this means that, for the markets involved in this paper, the Law of One Price holds, since variations in the international price are fully transmitted to domestic prices in Chile, having unity elasticity of transmission in line with the prediction of economic theory.

Finally, considering that many early empirical studies on market integration, associated to developing countries, appeal to the idea that prices in spatially linked markets are highly correlated (McNew, 1996; Ghoshray and Lloyd, 2003), a regression analysis among the domestic price as dependent variables with the weighted prices as independent variables was carried out; the results are presented in Table 7. These results confirm the hypotheses presented above in relation to the linked wheat markets in a spatial context.

Discussion on the binary variables

The binary variable D_BAND in Model A showed a positive and not significant value of 0.015 (t-value of 0.169). Although the parameter is not significant, the positive sign suggests that, in average, the band affected positively the Chilean wheat price during the research period, which is consistent with the history of interventions of the band. Analyzing the applications of reductions and rights over the last 15 years, it can be seen that tariff reductions were used approximately 7% of the total time, specific rights 71% and no-band application 21%, with respect of the remaining time (ODEPA, 2008).

Table 7. Regression statistics for DOM_CH with respect to WGHT_PRICE, HRW_USA and PAN_ARG.

	DOM_CH & WGHT_PRICE	DOM_CH & HRW_USA	DOM_CH & PAN_ARG
Multiple correlation index	0.79	0.78	0.76
R square	0.62	0.60	0.57
Adj. R square	0.62	0.60	0.56
Error	23.9	21.7	22.4
Observations	253	253	253

Source: prepared by the authors (2008).

The non-significant value for this coefficient can be approached by two ways. On the one hand, the years in which the band was applied corresponded to 47% with respect of the total period; this implies an equally distribution of the support resources associated to this policy, which is not in line with the 200% input price increases during the last 10 years. In this sense, the compensation from the point of view of the producers is clearly reduced, and the results of this instrument, as for example the income compensation, is diminished, producing a distortion on the domestic market which could infer in the significant level. Moreover, the world commodity markets are actually sub-valuated and the US$ Dollar/Chilean Peso exchange rate has been behaving irregularly, producing low incomes for wheat wholesalers and consequently inverse results with respect to the price increments derived from the band mechanism (ODEPA, 2008).

According to López *et al.* (2008), a positive influence of an agriculture policy tends to increase the producer gross income due mainly to the higher production levels and second to the existence of a minimum price. This represents important signals for a policy implementation. Moreover, a price support mechanism generally produces an increment in the consumer prices, when the wheat is oriented mainly to the milling industry in order to produce bread, in this sense; the negative effect of the price band received by the consumers is represented by higher prices of this product compared with a non band situation.

The binary variable D_MECH from the equations (5 and 6) showed values of 0.074 and a not significant t-value of 0.654. With these results, it is possible to conclude that the new mechanism acted as protection over international fluctuations, because the positive coefficient produced a price increment of nearly 7.4%. The non significant value could be produced by many situations. First, the low cost production strategy of Argentina, which produced several imperfections on the South American market, and second, the international wheat price increment since 2005, followed by the production problems presented by USA in 2007 and Argentina in the last season. Since harvesting seasons are counter seasonal for both countries, a shock in the Argentine price coming from international demand, early in the southern hemisphere harvesting season, implies a situation in which the international market sees a lack of supply, generating an imperfection of the international price markets and, consequently, in the Chilean price band estimation. The low number of observations available to the application of this new mechanism (48 observations) and the fact that responses from shocks in the United States are opposite to the response from shocks in Argentina, mainly because harvests in the two hemispheres occur in different periods, could also bias the estimation.

Finally, it is useful to conclude that a shock in Argentine and USA prices influences the Chilean price band in two steps. Chilean prices increase up immediately after the shock and then reverse downwards to the point where they stabilize. At first, the initial scarcity causes USA prices to follow Argentina's, raising the price levels and causing a market imperfection for the Chilean domestic wheat market. The second step, when quantities supplied by USA and Argentina tend to increase, Chilean prices head downwards to reach a minimum after the shock and stabilize there, producing an imperfection on the domestic market which is equivalent for the duration of this shock.

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Resumen

R. Valdés, S. von Cramon-Taubadel y J. Diaz. 2011. Integración espacial del mercado de trigo chileno, utilizando un Modelo de Corrección de Errores: análisis de cointegración. Cien. Inv. Agr. 38(1): 5-14. Chile ha sido históricamente un importador neto de trigo. Este escenario junto con el pequeño tamaño de su economía, permiten anticipar una gran influencia de los precios internacionales de este cereal sobre los precios domésticos. En este estudio, se realizó un análisis de integración de mercados para el trigo chileno, con respecto a Argentina y Estados Unidos, usando un modelo de corrección de errores (VECM). Asimismo, fue analizado el impacto de las bandas de precios (D-BAND) y el efecto del cambio en la metodologia de cálculo de este mecanismo implementado el año 2004 (D-MECH), incluyendo variables dicotómicas al modelo final. Se usaron series mensuales de precios mayoristas de trigo doméstico chileno desde diciembre de 1986 hasta diciembre de 2007, precios FOB de trigo argentino de variedad PAN y norteamericano de variedad Hard Red Winter Nr. 2. Los resultados mostraron una fuerte integración de mercados entre Chile, Argentina y Estados Unidos, siendo este último el líder de estos. Asimismo, el precio doméstico chileno fue influenciado por ambos mercados. Las variables dicotómicas arrojaron resultados que permitieron concluir que este sistema ha sido útil para reducir la fluctuación de los precios domésticos, causados por la variación de los precios internacionales. Estas presentaron valores no significativos, lo cual se debe principalmente a las diferencias entre los precios de insumos y aquellos fijados por esta política, el mercado sub-valorado de commodities, incrementos en el nivel de precios de cereales, escenarios inflacionarios y bajo número de observaciones.

Palabras clave: Análisis de cointegración, bandas de precios, trigo, precios de cereales, mercado internacional de *commodities*, modelo de corrección de errores.

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