Market integration for agricultural output markets in Peru: the role of public infrastructure

Javier Escobal D'Angelo [1]
Grupo de Análisis para el Desarrollo (GRADE), Lima, Perú

Arturo Vásquez Cordano
OSINERG, Lima, Perú

Abstract

This paper shows the impact that investment in infrastructure may have on the efficiency of agricultural products markets. Using daily price series for the most important agricultural crop in Peru (potato), in 10 cities from 1995 to 2001, we show that there is enough evidence to conclude that agricultural markets are spatially integrated. However we also show that there is short term disequilibria that affect the efficiency with which price information is transmitted across markets. A Threshold Cointegration Model is used to asses the speed of adjustment towards the equilibrium, the presence of transaction costs and the probabilities of successful and failed arbitrage between spatially distributed markets. As was expected, the paper shows that distance and geographic differences are important factors affecting spatial integration and efficiency between markets. However, other elements susceptible of government intervention, such as availability of information (access to local media and telecommunications facilities), road density or access to wholesale markets, are key factors for the reduction of transaction costs and the improvement of spatial integration between markets.

JEL: R12, D23, H54, Q11, Q13

1. Introduction

The Enke-Samuelson model Roehmer (1995) which is a generalization of an arbitrage model, has been widely used to explain price differences between spatially separated markets. This model predicts that if transportation costs decrease, price differences and dispersion between cities reduces while traded volumes increase. Similarly, if transaction costs between two or more cities increase, then price differences increase and correlation decreases rapidly. Nevertheless, the application of this model to agricultural markets has been constrained by the lack of information about this type of costs. In view of the difficulty of estimating transaction costs, many specialized studies have used a modified definition of integration (analyzing the variations on price differentials). Following this approach, two markets are said to be integrated if price variations observed in one market are generated by variations in the other one. If these markets are geographically separated, these markets can be defined as spatially integrated.

[1] Corresponding author: jescobal@grade.org.pe

Many studies have shown that domestic agriculture markets have some degree of spatial integration. The degree of market integration has been measured through various methodologies, from the usage of correlation analysis to the use of autoregressive models, causality tests or cointegration techniques[2]. After reviewing the more recent literature on this topic, this chapter seeks to measure market integration in Peruvian agriculture using as a case study the Peruvian potato market. Further, after estimating the speed of adjustment of interrelated markets facing an external shock, the chapter proceeds and shows the impact of infrastructure investment on agricultural market integration. Using daily price series of one of the most important crops in Peru – potato- collected from 10 cities during the period January 1995 through May 2001, these chapters presents some evidence supporting the hypothesis of long-run spatial integration of Peruvian agricultural markets. Nevertheless, there exist transitory disequilibria that affect the efficiency in the transmission of information across those markets. An error correction model is used to estimate causality relations between spatially distributed markets as well as their speed of adjustment towards the equilibrium. Distance between markets as well as geographical differences restrict and distort spatial integration and efficiency between markets. However, other elements susceptible of government intervention, such as telecommunication facilities, road density or access to wholesale markets, are also important to improve efficiency and integration between markets.

The chapter is divided into five major sections. The second section presents a brief literature review on agricultural market integration showing how this literature has deal with the presence of transaction costs and potentially asymmetric price behavior. The third section presents a simple Threshold Cointegration Model that will be used to asses the speed of adjustment towards the equilibrium, the presence of transaction costs and the probabilities of successful and failed arbitrage between spatially distributed markets. Section four described the basic characteristics of the potato market in Peru, which is used here as a case study to evaluate spatial market integration in Peruvian Agriculture. After calculating the speed of adjustment of spatially distributed potato markets, we asses the importance of infrastructure in the reduction of transaction costs and the improvement of spatial integration between potato markets in Peru. Finally, section five summarizes the results and discusses some new lines of research that can be pursued.

2. Agricultural market integration and arbitrage relations: a brief literature review

The specialized literature has used alternative ways to define and measure the spatial integration of markets. On the one hand, it has been established that a set of markets is integrated if there are enough agents who, through arbitrage, act in such a way that prices reflect all the available information, without the presence of systematical extraordinary profits in any of those markets. Alternatively, the degree of integration has been identified as the difference between market prices. From this view, a significant difference of prices between two markets would reveal a low degree of integration

[2]See Goletti, et al. (1993).

(probably due to the existence of significant arbitrage costs), while a small difference would be a sign of a higher degree of integration.

Following Barrett and Li (2000), from a more formal approach, integration may be defined as *tradability* or *contestability* between markets. This would imply the transfer of *Walrasian demand excess* for goods from one market to the other, the transmission of shocks in prices between markets, or both. From this approach, an actual physical transfer of goods does not need to be observed to assure that markets are spatially integrated.

According to Sexton, et al. (1991) and Lutz, et al. (1995), two factors may explain the lack of spatial integration of markets. First, physical barriers for trading, incomplete information, risk adverse agents, among others, may be obstacles for an efficient arbitrage. Second, imperfect competition structures in the markets under analysis may constitute barriers to entry that would prevent price arbitrage. Moreover, if the transaction costs were higher than price differentials between localities, the arbitrage process between regions would be blocked causing markets segmentation.

In absence of simultaneous information about prices and trade flows, the correlation analysis of prices between different pairs of regions has been traditionally used as the appropriate framework to analyze spatial integration of markets [Fafchamps and Gavian (1996); Alexander and Wyeth (1994)]. Within this framework, a higher (lower) correlation is understood as a higher (lower) degree of spatial integration, whereas the sign of the correlation is taken as indicator of direction of the effects. A criticism this approach has received is that within this framework it is impossible to establish which region, among those being analyzed, is the main central market (if there exists one). On the other hand, if the impact of changes in prices over the different regions were not contemporaneous but lagged, the correlation analysis would indicate a low degree of integration even if there is actually market integration although it is not instantaneous[3].

Considering these limitations, several efforts have been made to introduce a dynamic framework, with the purpose of verifying the existence of integration in the short run and long run. Ravallion (1986) developed the distributed lags model that incorporates a dynamic component[4]. His proposal consists on evaluating separately spatial market integration allowing for long run integration as well as short run integration (that is, allowing for a lags structure that accounts for integration delay). In mathematical terms, this model can be presented as follows:

$$\begin{aligned} P_{it} &= a_i P_{it} + b_{io} + b_{i1} R_{t-1} + c_i X_i + \varepsilon_{it} \\ R_t &= \alpha \ R_{t-1} + \sum_{i=1}^{N} \beta_{io} P_{it} + \sum_{i=1}^{N} \beta_{i1} P_{it-1} + c X_t + \nu_t \end{aligned} \tag{1}$$

where, P_i (i = 1...N) represents the price in each local market, R is the central market price, X_i represents other exogenous variables that influence these markets' dynamics, and (ε_t, ν_t) are random error terms. Estimating and contrasting the parameters allow testing three important hypotheses: (1) spatial market segmentation: there is no influence of one particular market over the others [$b_{i0} = b_{i1} = 0$], (2) long run integration: despite

[3] Yet another criticism is supported on time series theory. If the series are non-stationary, the trend that leads them (either deterministic or stochastic) could be the cause of a high degree of correlation. In this case, the observed linkages would be based not on economic relations, but on spurious correlations.

[4] This model is also known as Radial Model. See Lutz, et al. (1995).

delays in the impact over other markets, full transmission is finally achieved [$a_i + b_{i0} + b_{i1} = 1$], and (3) short run integration: the adjustment of prices to shocks is instantaneous [$b_i = 0$, $b_{i1} = a_{i\,0} = 0$]. Additionally, we must consider that this model assumes a specific structure of integration relationship. It imposes, *a priori*, a restriction according to which there exists a central market; that is, a market that behaves as an articulating axis around which there are peripheral or satellite markets.

Silvapulle and Jayasuriya (1994) have indicated the main limitations of the radial model. First, the assumption of a central dominant market (i.e., the assumption that any link between cities is necessarily established through a central market) might not be an accurate way to model the dynamics of spatial integration between markets. Even in the case a central market actually exists, it is preferable testing the hypothesis of existence rather than imposing it *a priori*.

Subsequently, the radial model has been extended by using the vector autoregressive (VAR) technique, allowing for testing the existence of a central market. Despite this improvement, two problems become apparent. First, price series are typically non-stationary, so it is possible that spurious correlations arise. Second, spatial integration between agricultural markets has been studied from a one-way directional perspective, that is, the verification of the radial model hypothesis has been done by analyzing market pairs, assuming within each pair case the existence of a central market.

In the first case, the cointegration analysis enhances the study of long run behavior of the series, even when these are non-stationary. However, little literature on the second problem has been developed until now. Silvapulle and Jayasuriya (1994) as well as Gil and Sanjuan (2001), use the multivariate cointegration methodology to solve the second problem. In this sense, testing the hypothesis established by Ravallion's model is still the aim, but now within a framework where no *a priori* restriction is imposed. In the following section we present briefly the links between multivariate cointegration analysis and spatial integration of markets.

The first studies that introduced the cointegration techniques into the study of market integration, such as Palaskas and Harriss-White (1993) and Badiane and Shively (1996), assumed the existence of central agricultural markets as well as symmetric and "smooth" price responses. Under these assumptions, a shock in the central market may cause the same answer in all peripheral markets, independently of whether there is an increase or a decrease in prices, and independently of the magnitude of the shock.

Multivariate cointegration studies, as for example those carried out by Alexander and Alexander and Wyeth (1994), Silvapulle and Jayasuriya (1994) and Gil and Sanjuan (2001), expanded this type of analysis to a multimarket context, assuming the existence of a common trend that moves prices of regional markets towards their long run equilibrium levels after facing an exogenous shock. Nevertheless, this mechanism may not work in all periods if there are factors (as the arbitrage costs or information failures, for example) that hinder the adjustment mechanism. In such cases, only when deviations from equilibrium surpass a critical threshold, the profits due to adjustment exceed the costs, so the economic agents react to the shock and, consequently, the system returns to the equilibrium level. On the other hand, all these studies also assume that prices respond to exogenous shocks in a symmetric way and that transaction costs do not generate either asymmetries or discontinuities in such response. However, certain characteristics particular to agricultural product markets may in fact generate discontinuities or asymmetries in the responses of prices to shocks, reducing the robustness of these results.

2.1 Discontinuity and asymmetry in the price mechanisms of adjustment in regional agricultural markets

In the absence of exit and entry barriers for traders, the degree of arbitrage and integration will depend on both, prices differential and transaction costs (Abdulai (2000). However, some characteristics of the agricultural production, commercialization, and consumption, such as inappropriate transportation infrastructure, entry barriers and information failures, may turn the arbitrage process into a less smooth process than assumed by traditional models of market integration.

A source of asymmetry in the prices response to shocks that is commonly mentioned is the market power Scherer and Ross (1990). For example, the oligopolistic intermediaries in an agricultural market may react collusively in a faster way to shocks reducing their profit margins than they would react to shocks that increase them, generating as a result asymmetries in the transmission of those shocks to other segments of the market. Because of this, an increase in the central market prices would be spread to the regional markets in a faster way than would a decrease in such prices.

On the other hand, the role of inventory accumulation as a source of discontinuities in the adjustment of prices between markets has been documented Blinder (1982). According to this argument, variations in prices send signals to inventory holders that lead them to accumulate or reduce stocks. The expected increase in the dominant market's price in the next periods constitutes an incentive for traders to increase inventory holdings, thus buying big quantities of a certain agricultural product in the present. But the increase in local market stocks pushes prices down, so the actual increase is not as high as originally expected. If, on the other hand, it was expected that the dominant market prices decrease, there would be an incentive for traders to reduce their inventory stocks, response that would moderate the magnitude of the prices fall in the next periods. Under the argument of inventory holdings, regional market prices would not fully adjust to changes in the dominant market prices.

Other argument that explains the presence of discontinuous or asymmetric price responses is the existence of menu costs, understood as those costs that result from the repricing and information process that consumers face in the presence of exogenous variations Mankiw and Ball (1994). If variations in the costs of the agricultural product were perceived by the agents as temporary, the menu costs might constitute an incentive not to adjust prices even when a decrease in the product costs has actually occurred.

Finally, we should mention that the presence of search costs on imperfect regional agricultural markets has also been quoted by many researchers as a source of asymmetry or discontinuities in the prices adjustment process that occurs as response to exogenous shocks Blinder, et al. (1998). In many regions, some firms can exercise local market power, due to the absence of other firms located in spatial proximity that could compete with them. The consumers that face these dominant firms face high search costs to get all the information about prices offered by other firms. Under these conditions, dominant firms may raise their prices quickly when the dominant market's prices increase, whereas they could reduce them little or nothing when prices in the central market decrease.

For Baulch (1997), there are three factors that affect the degree of market integration and generate discontinuities in the price responses to exogenous shocks. The first one is the presence of high transaction costs relative to the price differential between two regions that determines the existence of autarkic markets. The second factor is the presence of barriers to entry, risk aversion and information failures. Finally, the existence of imperfect competition in relevant segments of the markets may cause high price differentials between markets that cannot be attributed to the transaction costs.

2.2 Alternative frameworks for the analysis of market integration in the presence of transaction costs

Taking into consideration the possible sources of discontinuity and asymmetry in the responses of agricultural market prices, researchers have used alternative frameworks to carry out studies about spatial integration of agricultural markets that introduce transaction costs as elements that affect arbitrage relations between different regions. As we will discuss later, the different techniques relate to concepts implicit in the dynamic model proposed by Ravallion (1986), reconsidered in terms of the cointegration method and error correction model [Silvapulle and Jayasuriya (1994); Palaskas and Harriss-White (1993)], as well as with notions from the parity-bounds model formulated by Sexton, et al. (1993) and Baulch (1997). A similarity between all of these models is that they study arbitrage relations between two regions by using, mainly, nominal price series of a particular product.

The analysis framework that almost all of these research works have used is the law of one price adjusted by transaction costs, described as follows. C_{ijt} is the transaction cost of trading an agricultural product from the market i to j and P_{it} is the price of the agricultural product in the market i. The efficient spatial arbitrage requires that no extraordinary profits could be generated by trading between regions i and j. In other words, it is necessary that the law of one price, adjusted by transaction costs, is fulfilled. The law is described in the following expression:

$$| P_{it} - P_{jt} | \leq C_{ijt} \qquad (2)$$

Under efficient arbitrage, null trade flows imply equation (2) holds with equality (binds). Also, the relation might determine bilateral trade flows from i to j or from j to i, depending on the market conditions in each city. When (2) holds with equality (binds), the prices are said to be in the parity threshold, whereas when the margin is bigger than the threshold, extraordinary profits from trade might be generated. A strict inequality in (2) would require non-null trade flows. Specialized literature involves different approaches to modeling arbitrage relations between two regions by using (2), furthermore, such approaches allow for estimations of transaction costs. In first place, linear models stand out[5]. This formulation seeks to explain linearly the price formation in two cities, defining (only) one market equilibrium. The basic equation of the model is:

$$P_{1t} = C_{12} + \alpha * time + \beta * P_{2t} + \mu_t \qquad (3)$$

where "time" is a linear trend and μ_t is a random error term. With prices measured in levels, the intercept C_{12} in the equation (3) shows the fixed transaction cost and the beta coefficient measures the proportional mark-up or the cost of trading between markets 1 and 2. Although equation (2) is informative, it is still incomplete since it does not introduce dynamic aspects on its specification. Another problem, of methodological

[5] See Badiane and Shively (1996).

nature, is the presence of unit roots in the price series, which causes spurious estimations of the equation (3) if the error term μ_t is non-stationary.

As Palaskas and Harriss-White (1993) sustain, if (2) was valid and μ_t was stationary, then we would say that both spatially separated markets are integrated and the expression (3) would be a cointegrating equation, which establishes the existence of a long run relation between price series. Therefore, the weak form of the spatial integration condition is defined. This condition establishes that if (2) was valid, the spatial integration might occur in the long run with temporary short run deviations[6]. It is worth to note that, in order to assure that the model is consistent with an efficient arbitrage situation, this framework is implicitly assuming that trade between the two cities is continuous and that there is no reversion in the direction that trade flows take. In this context, the fixed arbitrage cost is estimated independently of the patterns and continuity of trade. Nevertheless, empirically, only in few cases condition (2) is satisfied, so the model excludes situations in which no profitable trade carries on as well as those in which market conditions in different regions vary enough so as to generate reversions in the trade flows. In this sense, the existence of cointegration between price series is not enough to determine the existence of efficient arbitrage, and it will be necessary, in order to evaluate whether market relations are actually efficient, to compare transaction costs in (3) with observed costs or any other information about markets.

In second place, an alternative framework to study the integration relations between markets is the Parity Bounds Model[7] that assumes that transaction costs have a constant mean C_{12t} and a random component V_{ct} which is normally distributed with zero mean and constant variance. These costs constitute thresholds for a band of possible equilibrium, with respect to which the prices from both markets can be situated. The price differential $|P_{1t} - P_{2t}|$, in this context, may define two possible regimes. If this differential is inside the band, it means $|P_{1t} - P_{2t}| = C_{12t} - v'_{ct}$, an efficient arbitrage takes place where there is trade without the presence of extraordinary profits. On the other hand, if the differential is outside the band, it means $|P_{1t} - P_{2t}| = C_{12t} - v^0{}_{ct}$, little trade takes place and extraordinary profits come out to be exploited through arbitrage. In this setting, arbitrage failures or reversions of trade flows may occur.

If v'_{ct} and v_{ct}^0 were assumed to be independently distributed it is easy to formulate the likelihood function for the two regimes and, by maximizing this function, we could estimate the probability of successful or failed arbitrage, as well as the transaction costs. However, this model has some limitations. First, the model identification depends on the assumptions about the distribution of v'_{ct} and v_{ct}^0 (normality is usually assumed). On the other hand, the assumption of independence of the error terms does not seem to be reasonable since it would imply that all the information contained in the errors in one period would be completely lost in the future and, hence, it would not allow for the existence of a mechanism of adjustment that corrects the distortions in the arbitrage process. Other limitation of the Parity Bounds Model is that it does not include the dynamic component in the transaction costs analysis and, as a consequence, it does not allow us to infer anything about the speed of the price

[6] See Ravallion (1986) and Alexander and Wyeth (1994).
[7] See Baulch (1997) and Park, et al. (2002).

adjustment when there exists profitable trade opportunities (in other words, when the price differential is above the equilibrium band). Finally, to get conclusive results it is necessary to have additional information about trade flows and arbitrage costs between cities in order to carry out comparisons with the probabilities of occurrence of the possible regimes and with the estimated transaction costs.

In the presence of the limitations of the described analysis frameworks, the challenge, hence, is to develop a dynamic model that considers the presence of transaction costs, discontinuity and reversion in the trade patterns (or direction), and also that allows to make inference about the speed of price adjustment to equilibrium levels. In that sense, the bivariate cointegration techniques with threshold as well as the Band-TAR models constitute an analysis framework to overcome some of the limitations mentioned earlier. In this document, we use this type of approach with the purpose of analyzing market integration in presence of transaction costs for the Peruvian potato market case. The formal presentation of the technical details of the model will be described in the third section.

2.3 Structural determinants of the integration relations and the arbitrage costs

The last topic to discuss in this section is the structural determinants of the spatial integration of markets. Even though literature shows a special emphasis on the study of the existence of some type of market integration, the identification of the structural determinants of such integration has not received much attention. The identification of these factors is needed for the implementation of investment policies oriented to develop agricultural markets. Following this concern, the first step in the analysis consists on identifying an indicator of market integration. Literature has pointed out some indicators: a) the simple correlation coefficients between city pairs, b) the cointegration coefficients (which capture the existence of a long run linear relation between prices), and c) the parameters representing the speed of adjustment of prices from different regional markets to their equilibrium. In this chapter, we use the third indicator as a *proxy* of the degree of market integration since it gathers the dynamic aspects of the relationships between cities (Ejrnaes and Persson (2000)).

The second step in the analysis is oriented to identify the factors that explain the degree of market integration. It is worth to note that the research work that has been done on this topic is scarce. Goletti, et al. (1995) have developed one of these studies, they sustain that the degree of market integration is a result of the trade action itself as well as the operational environment, which is determined by the availability of transportation and telecommunication infrastructure and by the policies that affect the price transmission mechanism. Using a regression that links a market integration indicator with infrastructure variables, these authors find that for the rice market in Bangladesh, the main factors that determine the market integration were the transportation (mainly paved roads) and telecommunication infrastructure, distance between localities and price variability. Nevertheless, most of research on this issue does not come across the identification of structural determinants of the degree of market integration in presence of arbitrage costs, restraining their attention to the analysis of market integration.

In contrast with previous studies, the contribution of this chapter is that it tries to explain the degree of spatial market integration in presence of arbitrage costs by the existence of public assets in the cities under analysis, not only emphasizing on the transportation infrastructure as a determinant of integration between markets, but also taking into account other factors such as electrical energy and telecommunication infrastructure and the presence of public works. Furthermore, this study takes into account other determinants such as the existence of wholesaler commercialization centers in the localities under study and the presence of geographical differences between regions, by using regression analysis with the purpose of evaluating the factors that may influence in the determination of market integration. Once we have discussed the main contributions in the specialized literature, we proceed to present the model used in this research.

3. A simple threshold cointegration model

3.1 The model

In this section, we present a dynamic model that incorporates the existence of transaction costs and the reversion of trade flows patterns in the analysis of the series of agricultural products prices. In addition, it allows us to make inference about the speed of prices adjustment to their equilibrium levels and other parameters of interest by using the threshold cointegration method.

The model[8] explains the behavior of price differentials between two cities where an agricultural product is traded. Let X_{1t} be the logarithm of the output in the city 1 whose price in logarithms is p_{1t}. The first part of the model consists on specifying the demand function that, for simplicity, is assumed to be linear and symmetric for both cities:

$$p_{1t} = a_1 - n_1 X_{1t} + u_{1t} \qquad (4)$$

In this equation, a_1 and $n_1>0$ (price elasticity of demand) are parameters and u_{1t} is a random variable that represents the demand shocks. The equation establishes that an increase in X_{1t} in the first city leads to a decrease in its market price. u_{1t} is probably non-stationary in the long run, and this may be a sign of the existence of permanent demand shocks. Moreover, if the price series is daily, it would be sensible to think that u_{1t} will show serial autocorrelation. Following Ejrnaes and Persson (2000), the spatial arbitrage condition is given by:

$$p_{1t} \geq p_{2At} + C_t^{12} \qquad (5)$$

From equation (5) we may infer that city 1 will import from city 2 if the autarkic price in city 2 plus the arbitrage costs are less than or equal to the price in city 1. If the price p_{1t} differs from the autarkic price (p_{1At}), profits from trade would be available as long as such profits exceed the arbitrage costs. In both directions, the product importation (exportation) will imply that: $\Delta X_{1t} = \Delta F_t$, where ΔF_t is the product inflow from city 2 to city 1 (or vice versa, when the analyzed case is city 2). To complete the model it is necessary to define a specification for the arbitrage costs. Here, to simplify, following Prakash and Taylor (1997), we describe a logarithmic symmetric costs function by using a quadratic specification:

$$C_t^{12} = d + c_{12} \mid \Delta F_t \mid + 1/2\, b \mid \Delta F_t \mid^2 \qquad (6)$$

[8] See Prakash and Taylor (1997) for an application of this model to the *Gold Standard* case during the last century.

Thus, there is efficient arbitrage when the marginal income (MgI) is equal to the marginal cost (MgC). If $MgI = (p_{1t-1} - p_{2t-1})$ and $MgC = c_{12} + b\Delta F_t$, making equal both expressions we have that:

$$(p_{1t-1} - p_{2t-1}) = C_{12} + b\Delta F_t \tag{7}$$

Solving for ΔF_t from (7) and taking into account that $\Delta X_{1t} = \Delta F_t$ we find:

$$\Delta X_t = \begin{cases} -(1/b)[(p_{1t-1} - p_{1t-2}) - c_{12}] & if\ |\ p_{1t-1} - p_{1t-2}\ | \langle c_{12} \\ 0 & if\ |\ p_{1t-1} - p_{1t-2}\ | \leq c_{12} \\ (1/b)[(p_{1t-1} - p_{1t-2}) - c_{12}] & if\ |\ p_{1t-1} - p_{1t-2}\ | \rangle c_{12} \end{cases} \tag{8}$$

From (4), $p_{1t-1} - p_{1t-2} = a_1 - n_1 X_{1t} + u_t - a_1 + n_1 X_{1t-1} - u_{t-1} = -n_1 \Delta X_{t1} + e_{1t}$, where $e_{t1} = u_t - u_{t-1} \sim N(0, \sigma_1^2)$ is white noise. Replacing the previous result in (8) we get the following system:

$$\Delta p_{1t} = \begin{cases} (n_1/b)[(p_{1t-1} - p_{1t-2}) - c_{12}] + e_{1t} & if\quad p_{1t-1} - p_{1t-2} \langle c_{12} \\ 0 & if\ |\ p_{1t-1} - p_{1t-2}\ | \leq c_{12} \\ -(n_1/b)[(p_{1t-1} - p_{1t-2}) - c_{12}] + e_{1t} & if\ |\ p_{1t-1} - p_{1t-2}\ | \rangle c_{12} \end{cases} \tag{9}$$

Since a similar expression is obtained for Δp_{2t}, we may find a simple error correction model with symmetric thresholds (TVECM). This model takes into account the spatial price margin by differentiating $\Delta p_{1t} - \Delta p_{2t} = \Delta m_t$:

$$\Delta p_{1t} = \begin{cases} \alpha[m_{t-1} - c_{12}] + \varepsilon_t & if\quad p_{1t-1} - p_{1t-2} \langle c_{12} \\ 0 & if\ |\ p_{1t-1} - p_{1t-2}\ | \leq c_{12} \\ \alpha[m_{t-1} + c_{12}] + \varepsilon_t & if\ |\ p_{1t-1} - p_{1t-2}\ | \rangle - c_{12} \end{cases} \tag{10}$$

In (10) we have that $\alpha = (n_1 + n_2)/b$, which is the parameter of adjustment to an equilibrium band determined by certain thresholds, which are the symmetric marginal costs of arbitrage in each direction of trade, constant and equal c_{12}. This parameter of adjustment depends on the price elasticities of the demand functions of both cities. The prices of the agricultural product in the cities 1 and 2 (expressed in logarithms) are assumed to be non-stationary, being $m_{t-1} = p_{1t-1} - p_{2t-1}$ the price differential. The estimated value of α is expected to be within the interval]0,-1][9]. Finally, $\varepsilon_t = e_{1t} - e_{2t}$~ $N(0,\sigma^2)$.

A useful characteristic of this model is that it does not require empirical information about trade flows or transaction costs for its estimation. Moreover, from this specification we can distinguish three trade regimes: $m_t \rangle c_{12}$, $m_t \langle -c_{12}$ and, finally, $|m_t| \leq c_{12}$. The last regime corresponds to the condition for efficient spatial arbitrage, which is consistent with two situations: the first one, where trade occurs and arbitrage is efficient, and the other one, where no profitable trade occurs. In the first (second) regime, intermediaries do not exploit profitable trade opportunities by exchanging the agricultural product from 1 to 2 (2 to 1). If arbitrage takes place with lags, under these conditions, m_t will be pushed so as to adjust to the equilibrium band [$-c_{12}$, c_{12}]. This adjustment process will occur outside the band only until the threshold values of the band are reached.

The Threshold Error Correction Model (TECM), presented above, allows us to model the type of behavior described for m_t. Thus, if the price margin between cities is situated within the equilibrium band -that is when arbitrage is efficient- the error correction mechanism will not work, so the margin will not show a central trend but follow a random walk[10]. Otherwise, when the margin is outside the band, arbitrage takes place and the error correction mechanism will work adjusting the price differential towards the thresholds[11]. To build a more sophisticated version of this model that allows incorporating information about observable commercialization costs, we assume that arbitrage costs vary according to the innovations in fuel prices. This is convenient to control for the existence of transportation costs within the total arbitrage cost (which includes information costs, negotiation costs, etc). Moreover, we incorporate in first place a set of dummy variables to control for the inherent seasonality of high frequency price series (for example, daily prices), in second place a set of lags Δm_t to control for the possible presence of serial autocorrelation in the data and, finally, a lag of the price differential in the equation that describes the behavior inside the band in order to test the existence of non-stationary behavior within this regime[12]. With these innovations, the model to be estimated has the following form:

$$\Delta m_t = \begin{cases} \Delta c_{12t} + \alpha(m_{t-1} - \beta c_{12t} - \phi) + \sum_i d_i D_i + \sum_j \gamma_j \Delta m_{t-j} + \varepsilon_t^{out} & m_{t-1} > \beta c_{12t} + \phi \\ \lambda m_{t-1} + \Delta c_{12t} + \sum_i d_i D_i + \sum_j \gamma_j \Delta m_{t-j} \quad \varepsilon_t^{in} & si \; |m_{t-1}| \leq \beta c_{12t} + \phi \\ -\Delta c_{12t} + \alpha(m_{t-1} + \beta c_{12t} + \phi) - \sum_i d_i D_i - \sum_j \gamma_j \Delta m_{t-j} + \varepsilon_t^{out} & m_{t-1} < -\beta c_{12t} + \phi \end{cases} \quad (11)$$

Where β is the weight for the price of fuel (c_{12t}), d_i are the parameters of the seasonal dummies, γ_i are the coefficients of the lags of Δm_t. λ should be statistically equal to zero if, within the band defined by the thresholds, the price differential shows a

[9] α will be zero if C_{12} is sufficiently large so as to prevent arbitrage from occurring, if it is never possible to observe profitable arbitrage opportunities, or if the markets are not integrated because of the existence of market failures or high transportation costs. See Dercon and Van Campenhout (1999).

[10] Notice that, even when m_t is globally stationary, locally, within the band, it will show a non-stationary behavior. See Dercon and Van Campenhout (1999).

[11] The magnitude of the adjustment will be a percentage of the price margin deviation in each period.

[12] This last innovation in the basic model has been suggested by Dercon and Van Campenhout (1999).

non-stationary behavior[13]. Finally, ϕ is the transaction cost (which would represent the negotiation, information, enforcement costs, etc).

If the price of fuel is non-stationary, then as a first step it will be necessary to evaluate whether prices and this type of costs are cointegrated or not. If the existence of cointegration cannot be rejected, it will be possible to estimate the model without ambiguities. The estimation of ϕ (the implicit transaction cost) provides additional information about market performance. In particular, if ϕ is positive, there is evidence of market imperfections (entry barriers, incomplete information, etc)[14].

Under this specification of the model, within the equilibrium band, there is no dynamic relationship between the price variations in each market. Nevertheless, outside the band the error correction mechanism (controlling the seasonal factors and autocorrelated data) may be observed. The variations in one market are transmitted with errors to the other, but an adjustment process that will correct such errors in each period will work. Similarly to other conventional error correction models used in previous studies of market integration, a natural measure of spatial integration -for given transaction costs and an existing long run equilibrium band- is the speed of adjustment α: the closer the estimated parameter is to -1, the better the degree of integration.

The model presented here implicitly shows a clear relation between cointegration and efficient arbitrage. If an efficient arbitrage occurs, a non-stationary behavior must be observed in the margin m_t. Otherwise, that is only if imperfect arbitrage occurs, it will be possible to observe a cointegrating relation between prices and, hence, the formulation of an error correction approach will be valid.

Other useful estimators that may be obtained with this model are: the average time that prices take to adjust to the long run equilibrium, the percentage of cases in the sample where the efficient arbitrage condition is violated and the percentage of cases where the arbitrage condition is satisfied. These two last indicators are similar to the probabilities of a successful and failed arbitrage, which are estimated in the Parity Bounds Model.

In conclusion, the TECM is clearly consistent with the efficient spatial arbitrage models: it allows for discontinuities and reversion in trade flows, just as the parity bounds model. However, this model introduces more sensible assumptions about the probability distributions and explicitly incorporates dynamic elements by modeling the arbitrage process in a nonlinear error correction framework[15], so it results advantageous for this research.

3.2 Methodology

The research will take the Peruvian potato market as case of study, using the threshold bivariate cointegration methodology for the analysis. For the statistical tests

[13] It is necessary to use the Augmented Dickey Fuller (ADF) test or a similar test to test this hypothesis. See Chien Lo and Zivot (1999).

[14] However, as Balke and Fomby (1997) sustain, it is not possible to make statistical inference about the ϕ parameter by using the conventional techniques due to the non linearity of the model.

[15] The model just presented is a simple version of a large family of TECM models. Chien Lo and Zivot (1999) as well as Balke and Fomby (1997) present more complicated extensions in terms of more complicated lag's structure, different adjustment speed for each regime, etc.

we will use consumer price series of daily frequency, from the following cities: Lima, Huancayo, Arequipa, Puno, Trujillo, Ica, Piura, Huancavelica, Ayacucho and Cusco. Moreover, we will use daily data of the price of fuel Diesel 2 as a *proxy* variable to control for transportation costs. With the purpose of evaluating the dynamics of transmission of information between cities at regional level and, from that, the existence of threshold relations in prices, we have considered convenient to model these variables by using a nonlinear dynamic system (described on section 3.1) in which we explicitly incorporate long run relations between the prices of the set of pairs of cities and the transaction costs[16].

In first place, we will describe the characteristics of the Peruvian potato market analyzing the production and consumption behavior in order to verify empirically the existence of reversions in the regional trade patterns. These reversions might be explained by the threshold relations between prices caused by the transaction costs, as this document sustains. Secondly, we will proceed to evaluate whether the prices expressed in logarithms present unit roots by using the Augmented Dickey-Fuller test, this is important since the cointegration tests can be performed for series that show to be non-stationary of order I(1). Afterwards, we will evaluate the existence of long run relations between prices of pairs of cities and the price of diesel, using the Johansen and Juselius (1990) procedure as a prerequisite for the estimation of the price threshold model.

Once the existence of cointegration between the series under analysis is verified, we estimate the threshold error correction model described by the expression (11). From the estimation of this model, it will be possible to find the speed of adjustment towards the equilibrium, the transaction costs that constitute the equilibrium band thresholds of the prices, and the probabilities of successful and failed arbitrage at regional level, controlling for seasonality and autocorrelation of the daily frequency price series. Then we will perform the likelihood ratio tests in order to evaluate the significance of the estimated transaction costs by using the Prakash and Taylor (1997) methodology.

Finally, as a new feature of this document, we will explore whether there exists a relationship between (i) the degree of market integration of each city and the transaction costs and (ii) the assets endowments and public services infrastructure available in the cities (for example: roads, telecommunication services, electrical infrastructure, etc) by using regression techniques. The results of applying this methodology to the Peruvian potato market case are described in the next section.

4. Study of the Peruvian potato market

4.1 Brief description of the characteristics of the market under study

The potato market presents very special features since it has the largest cropping area[17], and hence the largest production, in Peru. The production of potato in Peru in the last years has been from 2.6 to 3.2 thousands of metric tons a year, proceeding from 234 to 285 thousand annually harvested hectares (Ministry of Agriculture of Peru, 2002).

[16] This type of approach presents a statistical model of the behavior of the variables rather than an economic structural model. The advantage of this type of approach is that it allows approaching the data without establishing a priori constraints.

[17] In 2001 according to FAO, Peru was the eleventh country with the biggest cropping area allocated to potato production, out of 152 countries (See http://faostat.fao.org/faostat/collections?version=ext&hasbulk=0&subset=agriculture)

The magnitude of the crop, which is harvested in all the departments of the *Sierra* as well as in several departments of the *Costa*, make that any deviation on its production or prices (caused by weather, harvested area, purchasing power, passability of roads, changes on returns, concentration of crops) constantly affects the market conditions for its commercialization and distribution.

In reference to the spatial distribution of the potato production in Peru, 9 out of the 19 departments that produce potato account for 75% of the total production, whereas 3 out of them contribute with 35%. Almost all of the potato production in Peru comes from the Mountains Region characterized by sharp seasonality. Hence, from 60% to 70% of the annual potato production is harvested between the months of March and June, and around 55% is harvested from April to June.

As mentioned before, the potato production is sharply affected by seasonality. This is so because the weather conditions determine the timing for the sowing season and consequently the harvest season. The variety of the climatic formations in this country makes it possible to sow during the whole year, although in different proportions. In some cases, sowing responds to programs for harvesting in low production seasons, so as to supply markets whose demand for fresh potato persists the entire year.

Because of its high concentration of population, good purchasing power, distance from the production areas and consumption tradition, Lima city is the largest permanent consumer market of potato in Peru (more than 1200 metric tons daily in average). Lima city has a wholesale commercialization market (*Mercado Mayorista*), where most of this tuber is consumed or sold to other markets to be commercialized. This market center keeps daily register of incoming production specifying information about origin and "varieties" (species) as well as of the wholesale corresponding prices.

Analyzing this market, it is worthwhile noting that in Peru, a high percentage of the potato production is destined to self-consumption and also to local or regional consumption. In addition, there exists a wide dispersion of small productive units (mainly in the department of Puno). The most important markets (such as the city of Lima, Trujillo, etc.) are supplied by the production shares destined to trade and by the variable surplus quantities left by another producers, strongly affected by relative prices. Only a small share of the total production is intended for international market.

4.2 The data

The previous step required to perform the statistical exercise described in Section 3, consisted on building an appropriate data base. In order to do this, we gathered daily information about wholesale nominal prices from a data base of daily prices compiled by INEI (Instituto Nacional de Estadística e Informática) to build the CPI (consumption price index). The period of analysis that was chosen is January 1995 through May 2001. Such data base was verified with information obtained from documents published by the Ministry of Agriculture (MINAG).

The cities selected for the analysis are: Lima, Arequipa, Huancayo, Ica, Ayacucho, Piura, Puno, Huancavelica, Trujillo and Cusco. They were chosen because their price series had the least number of missing observations[18], and also because they

[18] We used the random imputation method to solve the missing observations problem. In particular, we applied the procedure proposed by King et al. (2001). This procedure assumes that the data base follows a

have a significant share in the regional distribution of production (see Table 1). With the purpose of homogenizing the data, we considered five-day weeks since in the original data base there were too many missing observations for the weekends. We verified that excluding these weekend observations did not generate any bias. The final data base contains 1,540 observations for each city.

4.3 Model estimation and test of hypothesis

Using the data base described in the previous section, we proceeded to estimate the TECM presented in Section 3.1 in order to find the transaction costs and the speeds of adjustment for a total of 45 city pairs. Previously, we verified that all the price series were non-stationary in levels but stationary in first differences. Moreover, we verified that all the pairs of price series in logarithms for the analyzed cities cointegrated with the price of fuel, at least at a 10% significance level[19]. Generally, the estimations of the cointegration coefficients of prices were close to one, which is consistent with the presence of spatial market integration with constant real transaction costs. Subsequently, we estimated the TECM described in (11) from which we were able to estimate the transaction costs and the parameters of adjustment towards the equilibrium band. In order to carry out comparisons, we consecutively estimated an (auto regressive) AR (1) model in which we assumed there are no discontinuities or reversions in the trade flows. The estimation of this last model is useful to compare the goodness of fit of the TECM model using adjustment parameters; this coefficient is usually mentioned in studies of market integration. Table 2 shows, in addition to the described estimators, the average time that prices take to adjust towards the equilibrium band, the Dickey-Fuller test to evaluate the presence of non-stationarity within the equilibrium band (according to the description in the expression 7), the joint significance statistical tests of the price margin lags and the seasonal dummies, and the weight for the transportation cost.

The thresholds or transaction costs obtained here are estimators of the distortions in potato commercialization. Comparing them with observed transportation cost information may become a basis for future research about the efficiency of Peruvian agricultural markets. Unfortunately, given the currently available econometric techniques, it is not clear how to make statistical inference on these estimators since the parameters have a non standard limit distribution which depends on the sample moments (see Hansen 1997). Nevertheless, Chan (1993) and Chan and Tsay (1998) have proved that the threshold parameters are superconsistent[20], and that the other parameters of the TECM models are asymptotically distributed as a standard normal distribution with the typical formulas for the variance-covariance matrices, being independent of the threshold parameters. Hence, it is possible to evaluate the significance of the remaining parameters of the model using the traditional Wald test because the statistics are asymptotically distributed following a Chi-squared function [Chien Lo and Zivot (1999); Hansen 2001].

Despite it is not possible to make statistical inference about the transaction costs, the superconsistency of the thresholds guarantees that, for this research, these estimators

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multivariate normal distribution, and generates a set of random simulations from the original data base by using a distributed lags approach in order to complete the missing observations. The post-imputations results were consistent with the series data expressed in logarithms and showed to be superior to those obtained by the interpolation linear method.

[19] The results of the statistical tests are available upon request.

[20] According to Chan (1993), these parameters converge to T, which is the number of observations.

can be treated as the real transaction costs. Moreover, the existence of a considerable dispersion in the estimated costs[21] strengthen the previous argument because, despite it is possible that some thresholds show to be non-significant, it is unlikely that all the costs result non-significant given the important number of city pairs under study. Finally, it should be noticed that there exist other indirect ways to evaluate the importance of transaction costs in the arbitrage relations. A first alternative way consists on evaluating the significance of the adjustment parameter. This is a useful indicator since a coefficient statistically equal to zero would lead to reject the existence of a threshold error correction mechanism, and consequently, the existence of transaction costs. A second alternative consists on performing a likelihood ratio test to verify whether the proposed model with thresholds provides a better fit than alternative specifications without thresholds. In this context, validating the TECM model indirectly implies verifying the existence of transaction costs in the arbitrage relations. Following Prakash and Taylor (1997), we perform this test having as null hypothesis that the model specification is AR(1) without thresholds. Given that, as Chien Lo and Zivot (1999) point out, the distribution of the statistic is not standard, we used the Montecarlo Simulations method to find the critical values and approximate p-values.

4.3.1 Main Results

In Figure 1 we can observe the equilibrium band defined for prices differential in the city pair Lima-Huancayo. The estimation results suggest that the equilibrium band is defined by the thresholds 0.205, -0.205. As suggested by the figure, since prices differential is either above or within the band, most of the trade flows would be taking place in one direction (Huancayo-Lima), with a transaction cost of 20.5%.

According to Table 2, it is possible to verify the presence of an adjustment mechanism towards the equilibrium band, determined by the transaction costs, for all the city pairs under study. This is so, since the adjustment parameters are significantly different from zero. This result can be interpreted as evidence of intermediaries' prediction failures about prices differences between cities. For example, if an oversupply (undersupply) of potato takes place, negative (positive) profits will be obtained as a result of arbitrage, but they will tend to disappear as market adjusts to correct the disequilibrium.

In general, the estimated transaction costs are fairly reasonable for the city pairs under analysis. For example, in the case of the pair Ayacucho-Puno, the transaction costs are very high (79%), so chances of trade between both cities would be small. This result can be explained by two reasons; first, Puno is a region that consumes by itself its potato production, and second, there exists a considerable distance and geographical diversity between both cities. A similar explanation is valid for the pairs Huancavelica-Puno, Huancayo-Puno and Huancavelica-Cusco.

On the other hand, there exist intermediate cases such as Piura-Huancavelica, Arequipa-Ayacucho, Huancayo-Trujillo, Ayacucho-Trujillo, among others, where the transaction costs are not so high and the adjustment parameters indicate a higher adjustment speed towards the equilibrium. In these cases, the integration between markets takes place, as Erjnaes and Persson (2001) sustain, through medium cities that

[21] The variation coefficient of the transaction costs presented on Table 3 is 0.412.

are used as linkage for the commercialization and transportation of products. For example, the pair Huancayo-Trujillo is linked through Lima city, whereas the pair Puno-Huancavelica is integrated through the corridor Huancayo-Lima-Trujillo. The estimated thresholds, in these cases, can be interpreted as the differential transaction costs from one pair of markets to a third market, with which they are linked as suppliers or consumers. This interpretation is consistent with Ejrnaes and Persson (2000) arguments; these authors show that the equilibrium price differential between integrated markets that do not trade with each other is lower than the transportation cost between them.

Moreover, it is worth to emphasize the existence of city pairs where the adjustment towards the equilibrium is fast because transaction costs are low and, consequently, arbitrage opportunities do not persist for too long (less than 8 days for the adjustment towards the equilibrium). We may quote the cases of Lima-Huancayo, Ica-Lima, Arequipa-Ica, Huancayo-Huancavelica, Piura-Trujillo, among others. The closeness of the cities, the similarity of geographical conditions and the accessibility to paved roads, would facilitate the potato trade, as they do in the case of the pair Lima-Huancayo. An additional detail that should be mentioned is that, in general, the city pairs located in the Coast present lower transaction costs and higher speed of adjustment to the equilibrium, this is a sensible result since this region has better transportation facilities, especially in terms of the good condition of the roads.

Other important result is that, in most of the cases, the TECM model proves to be a suitable specification compared to a simple AR (1) model without thresholds. This is so because since, according to Table 3, in many of the market pairs under analysis the transaction costs are a significant source of trade distortion, estimating arbitrage relations without taking into account such costs would imply a specification mistake.

4.3.2 Identification of the different arbitrage regimes and their consistency with the potato consumption in Peru

In order to identify different arbitrage regimes, we show in Table 4 the percentage of cases in which the prices differential between markets falls either within or outside the equilibrium band. As observed in this table, most of the market pairs present potential reversion in trade patterns, although the percentage of implicated observations is little.

The market pairs are most frequently situated in the Regime II, where no arbitrage opportunities persist: the efficient arbitrage condition is satisfied in more than 70% of the cases. Only in few cases, we observe less than 60% of the observations from a particular pair of cities within the Regime II (for example, the case of Puno-Cusco, Lima-Huancayo). In other words, even if in some occasions the trade opportunities are not completely exploited, most of the markets are often in an efficient arbitrage situation.

It is possible to conclude that, even though the integration of markets exists in the long run, since arbitrage opportunities are present due to rigidities in the process of adjustment to the equilibrium, the markets do not prove to be integrated in the short run. However, for most market pairs the efficient arbitrage situation is satisfied in more than 70% of the observations.

We should mention that without further information about the observed transaction costs or about trade flows it is not possible to get robust conclusions either about efficiency in arbitrage relations or about reversions in the trade patterns. Nevertheless, some information pieces are available for this aim. Using information from the survey ENAHO – IV quarter 2001 performed by INEI, it is possible to estimate the consumption of potato by department for the last three months of the year 2001, in order to contrast this estimation with information on potato production so as to evaluate the occurrence of reversions in trade patterns. The results are shown in Table 5.

Given the large variety of climates and cropping zones in Peru, it is not surprising that the same crop is produced in different periods during the year. This diversity allows for the existence of trade opportunities between regions. As shown in Table 3, potato producing departments are "net exporters" in one period of the year but "net importers" in other period of the year. Thus, for example, the potato production in Junín exceeds by far its departmental consumption during the first six months of the year, whereas during the second semester Junín needs to buy potato from other departments to provide for its own consumption. Something similar is observed in Ayacucho, Cuzco, Huancavelica, or Ica where it is required to import potato at least during some months of the year. On the other hand, there are departments that always produce more than the output they actually consume, such as Arequipa and La Libertad, so they tend to be net exporters most of the year, while others, such as Lima and Piura, tend to be net importers during the whole year. With this evidence, it is possible to support the hypothesis of the existence of reversions in the trade patterns of the potato market, as it was pointed out from the results presented in Table 4.

Another way to test the existence of different arbitrage regimes as well as the reversion in the trade patterns is comparing the behavior of the prices differential with respect to the observed transportation costs. On the basis of information obtained from the MTC (Ministry de Transports) about the average freight per ton, it is possible to identify the presence of different arbitrage regimes. For example, as shown in Figure 2 for the case of the pair Lima-Huancayo[22], it is possible to identify that the trade direction goes from Huancayo to Lima between May and September because the prices in Lima are higher than the average freight cost. This result is consistent with the evolution of the potato production in the country, which is shown in Table 5. During these months, the central part of the *Sierra* enters the harvest period for this tuber, known as the main cropping season, having Lima city as its main destination market. The opportunities to trade from Huancayo towards Lima city increase in this period. However, during September and December when the complementary cropping season takes place, the production of the central part of the Mountains (Sierra Central) decreases, so the demand from Lima is satisfied by the department of Huanuco. In this period of the year, trade opportunities for Huancayo decrease because its prices are not competitive anymore when facing Lima city's market. Thus, the presence of reversion in the potato trade patterns between these cities becomes apparent, and as this study verifies the direction of trade is not unidirectional over the year.

4.4 Determinants of market integration in potato market

After estimating the transaction costs and the adjustment parameters as indicators of trade distortion and markets speed of convergence to equilibrium, respectively, we proceed to identify what are the determinants of these variables by evaluating the availability of public assets in the cities under analysis, such as telecommunications and local media infrastructure, electrical energy infrastructure, roads, among others. The identification of the determinants of the transaction costs existing between agricultural

[22] The data and graphics for the other city pairs are available upon request.

markets located in different cities will help to the implementation of policies oriented to improve efficiency and competitiveness in such markets.

The information used in these sections was obtained from the National Infrastructure Survey performed by INEI, this survey collected district data about different types of infrastructure: roads, electricity, telephones, schools, health centers, local market infrastructure, radio and television stations, among others, during the period 1997 to 1999.

Taking the transaction costs and the adjustment parameters as dependent variables, two types of regressions are estimated in this section. In the first place, we used the stepwise method for linear regressions to evaluate the relationship between transaction costs and public assets. As a starting point, we estimated a first equation to analyze the relationship between the estimated costs and the infrastructure endowment in 1999 for the districts that constitute the province where the cities under analysis are located. The independent variables in this regression are: 1) the percentage of districts of the province where the first (second) city of the pair under analysis is located that have access to more than 13 hours of electrical energy - Energy 1 and Energy 2 -, 2) the percentage of paved roads in the department where the first (second) city is located - Road 1 and Road 2 -, 3) the percentage of districts from the province where the first (second) city is located that has local radio stations - Radio 1 and Radio 2 -, 4) the percentage of telephone installations concentrated in the province where the first (second) city is located - Telecom 1 and Telecom 2 -, 5) the percentage of districts in the province where the first (second) city is located that has permanent market infrastructure - Market 1 and Market 2 -, and 6) the percentage of districts in the province where the first (second) city is located that has local fairs (Fair 1 and Fair 2).

The results for the Model 1 are shown in Table 6. It is possible to observe that there exists a negative relation (that is, estimated coefficients are negative and significant) between transaction costs (the dependent variable) and access to road infrastructure, electric infrastructure, and telecommunication means. On the other hand, given their respective coefficients are not significant, we would expect that accessing to local fairs and permanent market infrastructure does not have noticeable effects on transaction costs.

The next step consisted on estimating a truncated regression to evaluate the relationship between the markets' efficiency, which is approximated by the parameter of adjustment to the equilibrium. The selection of a truncated model was considered suitable since, in theory, the speed of adjustment can be seen as distributed in the interval [0,-1], where 0 would indicate that markets do not converge to the equilibrium and -1 would indicate a perfect adjustment to the equilibrium in presence of exogenous shocks. The results for Model 2 are shown in Table 6. As we can notice, the results are similar to those found with Model 1: public assets play a relevant role in the increase of markets efficiency by increasing the speed of adjustment to transitory disequilibria.

Finally, we proceeded to evaluate the relationships between transaction costs and adjustment parameters (as dependent variables) and changes in district infrastructure endowment (roads, electric energy, radio stations) in the cities under analysis between 1997 and 1999 (as independent variables). That is, taking the infrastructure endowment in 1997 as initial stock, the estimated regressions included as regressors the changes in infrastructure endowment observed between 1997 and 1999. As Table 7 shows, the increase or variation in the proportion of roads and electric infrastructure between 1997 and 1999 are significant variables that contribute to the reduction of transaction costs.

We find similar results for the estimation of the Model 2, although in this case the increase in the presence of local media is also relevant for the improvement of markets efficiency. However, this model is not conclusive about the effects of an increase of electric infrastructure.

5. Conclusion

This chapter has evaluated how infrastructure endowments may affect the speed of adjustment of spatially distributed agricultural markets. To our knowledge, this is the first time that the connection between infrastructure endowments and market integration has been empirically assessed in a multivariate setting. As we have described in the literature review section there is research that has explicitly connected key public infrastructure with bivariate measures of integration. However this has not been done yet in a multivariate cointegration framework.

We have shown that an increase in road and electrical energy infrastructure as well as a higher access to local media and telecommunication facilities in the cities under analysis will lead to reductions on transaction costs as well as on the average time that prices take to adjust to their equilibrium levels when facing an exogenous shock. Consequently, the degree of spatial integration of potato markets will increase in the long run. With these findings we can state that the road and electric infrastructure as well as the access to local media and telecommunications facilities are key factors for the reduction of transaction costs and the improvement of spatial integration between markets. Apparently, the public provision of such public services is crucial for generating conditions that improve the efficiency of the Peruvian agricultural markets.

We believe that this analysis can be improved by implementing some adjustments to the methodology proposed here, and thus remains an area for future research. First, we recognize that the regression equations proposed in this chapter are in some extent *ad hoc* and could be replaced in future research by equations derived from supply and demand equilibrium. Further, complementarities between different types of infrastructure services should be assessed, evaluating how they interact and further improve market integration.

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Figure 1 Estimated transaction costs: Lima vs. Huancayo

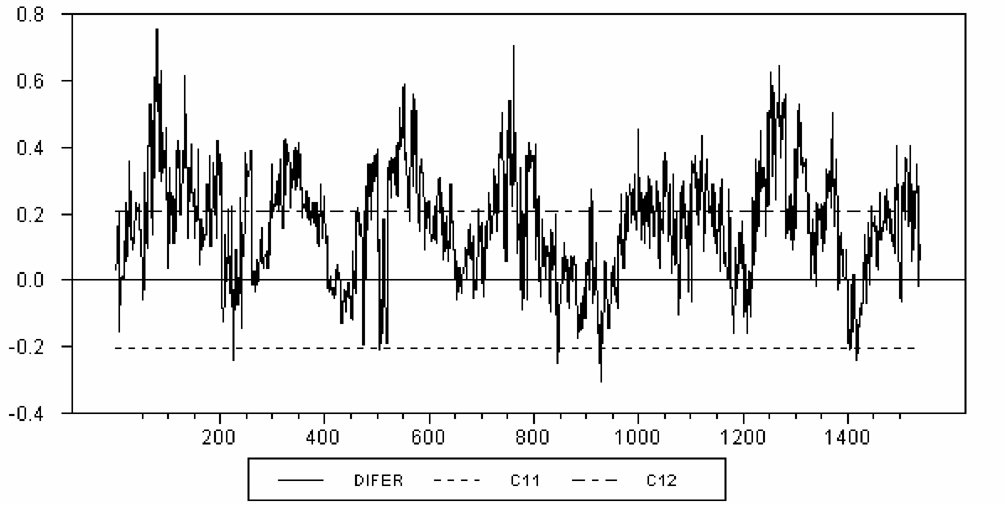

Table 1 Regional distribution of potato production in Peru   2001

Regions	Tons	Percentage
Lima	119236	3.77%
Ica	34306	1.08%
Arequipa	119257	3.77%
Ayacucho	140725	4.45%
Junín	421052	13.30%
Huancavelica	186675	5.90%
Cusco	178196	5.63%
Puno	397062	12.54%
Piura	10401	0.33%
La Libertad	318825	10.07%
Total national	1925735	60.84%

Source: Own estimates

Table 2 Transaction costs and speed of adjustment to the equilbrium of the Peruvian potato market

Market pairs	Threshold Error Correction Model								AR (1) Model without thresholds		
	Transaction costs	Speed of adjustment	Average period of adjustment (90% of equilibrium value)	ADF Test to evaluate the regime inside the band	Weight of the observable transaction cost	Nullity test fo the seasonal dummies	Nullity test for the lags	Number of lags	Speed of adjustment	Average period of adjustment (90% of equilibrium value)
Lima - Huancayo	0.205	-0.256 ***	7.802	-7.524	0.076 *	146.836 ***	142.417 ***	2	-0.173 ***	12.123
Lima - Piura	0.545	-0.191 ***	10.839	-2.586	-0.278 *	18.171 *	21.612 ***	6	-0.058 ***	38.639
Lima - Arequipa	0.239	-0.179 ***	11.684	-2.956	-0.154 ***	18.277 *	27.232 ***	4	-0.093 ***	23.509
Lima - Trujillo	0.296	-0.637 ***	2.275	-6.086	0.057	21.531 ***	65.793 ***	2	-0.103 ***	21.001
Ica - Lima	0.111	-0.512 ***	3.212	-1.912	-0.102 ***	47.138 ***	218.138 ***	5	-0.174 **	12.024
Lima - Ayacucho	0.204	-0.225 ***	9.033	-5.569	-0.101 ***	45.385 ***	21.971 ***	8	-0.081 ***	27.359
Lima - Huancavelica	0.526	-0.354 ***	5.273	-6.549	-0.123	37.003 ***	8.908 **	2	-0.078 ***	28.849
Lima - Cusco	0.314	-0.084 ***	26.189	-1.263	-0.122	8.576	13.367 ***	2	-0.034 ***	66.141
Huancayo - Huancavelica	0.245	-0.247 ***	8.116	-1.998	-0.098	19.680 ***	32.075 ***	6	-0.099 ***	21.944
Ayacucho - Huancayo	0.314	-0.229 ***	8.82	-6.22	-0.098	36.159 ***	70.518 ***	4	-0.096 ***	22.79
Huancayo - Cusco	0.414	-0.165 ***	12.804	0.512	-0.121	28.247 ***	12.791 ***	3	-0.048 ***	46.72
Huancayo - Ica	0.282	-0.277 ***	7.092	-7.932	0.028	64.405 ***	65.311 ***	2	-0.167 ***	12.578
Huancayo - Trujillo	0.404	-0.357 ***	5.208	-6.098	0.005	25.119 ***	137.046 ***	2	-0.107 ***	20.316
Piura - Trujillo	0.325	-0.239 ***	8.408	-3.437	0.009	30.925 ***	22.437 ***	2	-0.090 ***	24.388
Piura - Ica	0.413	-0.187 ***	11.099	-1.943	-0.213 **	17.437 *	79.659 ***	2	-0.075 ***	29.587
Arequipa - Piura	0.567	-0.196 ***	10.534	-2.204	-0.486 ***	85.406 ***	42.924 ***	2	-0.069 ***	32.044
Piura - Huancayo	0.453	-0.067 ***	32.961	-1.467	-0.403	17.520 ***	52.884 ***	2	-0.078 ***	28.377
Piura - Huancavelica	0.657	-0.256 ***	7.791	-5.762	-0.131	39.642 ***	21.279 ***	2	-0.1 ***	21.797
Piura - Ayacucho	0.576	-0.102 ***	21.364	-3.358	0.243	25.418 ***	222.204 ***	2	-0.064 ***	35.055
Arequipa - Ayacucho	0.562	-0.123 ***	17.711	-4.498	-0.056	45.522 ***	337.76 ***	3	-0.055 ***	40.859
Arequipa - Puno	0.396	-0.071 ***	31.511	-0.902	-0.669 ***	22.866 ***	16.529 ***	3	-0.037 ***	61.769
Arequipa - Trujillo	0.442	-0.739 ***	1.716	-6.309	-0.096 *	25.954 ***	137.777 ***	3	-0.086 ***	25.549
Arequipa - Ica	0.232	-0.205 ***	10.047	-1.009	-0.359 ***	60.79 ***	567.306 ***	3	-0.119 ***	18.035

Continued ...

Table 2 Transaction costs and speed of adjustment to the equilbrium of the Peruvian potato market

Market pairs	Threshold Error Correction Model								AR (1) Model without thresholds	
	Transaction costs	Speed of adjustment	Average period of adjustment (90% of equilibrium value)	ADF Test to evaluate the regime inside the band	Weight of the observable transaction cost	Nullity test fo the seasonal dummies	Nullity test for the lags	Number of lags	Speed of adjustment	Average period of adjustment (90% of equilibrium value)
Huancayo - Arequipa	0.553	-0.106 *	20.517	-7.262	0.046	60.202 ***	31.669 ***	2	-0.107 ***	20.338
Huancavelica - Arequipa	0.819	-0.373 **	4.93	-5.794	-0.257 ***	31.789 ***	49.504 ***	2	-0.065 ***	34.121
Puno - Trujillo	0.516	-0.261 ***	7.618	-2.246	-0.05	18.045 *	73.343 ***	2	-0.055 ***	40.436
Ayacucho - Puno	0.798	-0.456 ***	3.782	-4.644	0.566	35.863 ***	38.901	2	-0.031 ***	74.013
Puno - Ica	0.744	-0.199 ***	10.369	-0.856	-0.33 **	31.579 ***	202.342 ***	1	-0.039 ***	57.979
Huancayo - Puno	0.942	-0.267 ***	7.424	-5.958	-0.066	51.927 ***	15.786 ***	2	-0.039 ***	56.668
Huancavelica - Puno	0.769	-0.235 ***	8.614	-4.843	-0.121	42.328 ***	21.147 ***	2	-0.046 ***	49.314
Huancavelica - Trujillo	0.368	-0.461 ***	3.72	-6.987	0.127 *	32.890 ***	115.140 ***	2	-0.087 ***	25.429
Huancavelica - Cusco	0.714	-0.480 ***	3.519	-4.886	-0.222 **	2.026	25.521 ***	2	-0.056 ***	39.976
Trujillo - Ica	0.199	-0.197 ***	10.465	-5.54	-0.037	41.169 ***	32.525 ***	2	-0.104 ***	20.934
Trujillo - Cusco	0.68	-0.773 ***	1.554	-4.305	-0.033	11.04	104.812 ***	2	-0.045 ***	50.491
Ayacucho - Trujillo	0.557	-0.344 **	5.468	-5.449	0.135	25.523 ***	165.457 ***	2	-0.056 ***	40.194
Ayacucho - Huancavelica	0.298	-0.126 ***	17.047	-0.333	-0.236 ***	60.811 ***	47.033 ***	2	-0.089 ***	24.695
Huancavelica - Ica	0.377	-0.219 ***	9.303	-5.179	-0.053	40.329 ***	63.33 ***	2	-0.083 ***	26.448
Lima - Puno	0.343	-0.054 ***	41.458	-0.287	-0.099	17.979 *	9.603 ***	2	-0.031 ***	73.818
Piura - Puno	0.433	-0.135 ***	15.822	-2.484	-0.259 ***	18.176 *	13.873 ***	2	-0.069 ***	32.344
Puno - Cusco	0.371	-0.118 ***	18.379	-2.516	0.019	16.959 *	7.493 **	2	-0.047 ***	47.351
Ayacucho - Ica	0.421	-0.114 ***	19.007	-5.589	-0.027	48.006 ***	42.651 ***	2	-0.065 ***	34.001
Cusco - Ayacucho	0.483	-0.107 ***	20.297	-4.605	-0.029	12.346	84.999 ***	2	-0.049 ***	45.354
Ica - Cusco	0.437	-0.152 **	14.006	-1.431	-0.057	9.078	69.039 ***	2	-0.041 ***	55.105
Piura - Cusco	0.477	-0.120 ***	17.969	-3.779	-0.162 *	47.089 ***	69.399 ***	2	-0.069 ***	31.861
Cusco - Arequipa	0.415	-0.138 ***	15.56	-1.138	-0.064	26.068 ***	28.969 ***	2	-0.047 ***	47.986

*** significative at 1%, ** significative at 5%, significative at 10%
Source: own estimates.

Table 3 Likelihood ratio test.
(Ho: AR(1) vs H1: TVEC)

Market Pairs	Ratio	Probability
Lima - Huancayo	82.792 **	0.001
Lima - Piura	86.330 **	0.001
Lima - Arequipa	36.934 **	0.019
Lima Trujillo	90.284 **	0.000
Ica - Lima	468.421 **	0.000
Lima Ayacucho	12.864	0.136
Lima - Huancavelica	52.938 **	0.007
Lima - Cusco	16.819 *	0.096
Huancayo - Huancavelica	24.367 **	0.047
Ayacucho - Huancayo	26.123 **	0.041
Huancayo -- Cusco	12.426	0.140
Huancayo - Ica	8.199	0.208
Huancayo -Trujillo	14.626	0.124
Piura - Trujillo	49.484 **	0.010
Piura - Ica	24.438 **	0.046
Arequipa - Piura	148.204 **	0.000
Huancayo - Piura	36.216 **	0.021
Piura - Huancavelica	36.417 **	0.020
Piura - Ayacucho	3.662	0.295
Arequipa - Ayacucho	127.485 **	0.000
Arequipa - Puno	1450.225 **	0.000
Arequipa - Trujillo	28.841 **	0.033
Huancayo - Arequipa	13.149	0.135
Huancavelica - Arequipa	29.751 **	0.031
Puno - Trujillo	21.579 *	0.064
Ayacucho - Puno	10.212	0.171
Puno - Ica	71.099 **	0.002
Huancayo - Puno	9.514	0.179
Puno - Huancavelica	4.432	0.281
Huancavelica - Trujillo	18.627 *	0.080
Huancavelica - Cusco	11.911	0.150
Trujillo - Ica	55.196 **	0.008
Trujillo - Cusco	6.223	0.249
Ayacucho - Trujillo	18.022 *	0.086
Ayacucho - Huancavelica	102.857 **	0.000
Huancavelica - Ica	42.411 **	0.013
Lima - Puno	21.484 *	0.067
Piura - Puno	116.192 **	0.000
Puno - Cusco	22.199 *	0.059
Ayacucho - Ica	24.746 **	0.040
Cusco - Ayacucho	33.016 **	0.025
Piura - Cusco	53.261 **	0.007
Arequipa - Cusco	52.764 **	0.007

Critic Values: 6.195, 16.531, 23.695 and 49.360 at 25%, 10%, 5% and 1% of significance

The approximated p-value and the critic values have been found through 1000 MonteCarlo simulations.

* significative at 10%, ** significative at 5%

Source: Own estimates

Table 4 Probabilities of occurrence for the different kinds of arbitrage

City Pairs	Regime I Trade opportunities: profit for the first city	Regime II Efficient arbitrage (no profitable trade opportunities)	Regime III Trade opportunities: profit for the second city
Lima - Huancayo	0.7%	57.6%	41.7%
Lima - Piura	6.5%	93.3%	0.1%
Lima - Arequipa	12.7%	85.5%	1.9%
Lima - Trujillo	1.8%	87.0%	11.2%
Ica - Lima	10.7%	85.7%	3.5%
Lima - Ayacucho	2.9%	78.2%	18.9%
Lima - Huancavelica	0.0%	96.4%	3.5%
Lima - Cusco	8.4%	65.7%	25.8%
Huancayo - Huancavelica	12.5%	78.6%	9.0%
Ayacucho - Huancayo	11.5%	85.8%	2.7%
Huancayo - Cusco	11.8%	82.3%	5.9%
Huancayo - Ica	20%	79%	1%
Huancayo - Trujillo	9.8%	89.2%	1.0%
Piura - Trujillo	2.1%	62.6%	35.3%
Piura - Ica	1.1%	77.7%	21.2%
Arequipa - Piura	2.9%	95.9%	1.1%
Huancayo - Piura	0.9%	64.2%	34.8%
Piura - Huancavelica	0.0%	88.8%	11.2%
Piura - Ayacucho	0.0%	73.4%	26.6%
Arequipa - Ayacucho	0.0%	80.6%	19.0%
Arequipa - Puno	14.5%	82.5%	2.9%
Arequipa - Trujillo	0.3%	90.9%	8.8%
Arequipa - Ica	1.9%	77.5%	20.6%
Huancayo - Arequipa	10.3%	89.7%	0.0%
Huancavelica - Arequipa	0.6%	99.4%	0.0%
Puno - Trujillo	1%	81%	18%
Puno - Ayacucho	20.6%	79.4%	0.0%
Puno - Ica	1%	94%	5%
Huancayo - Puno	4.5%	95.5%	0.0%
Puno - Huancavelica	4.0%	96.0%	0.0%
Huancavelica - Trujillo	9.9%	88.9%	1.2%
Huancavelica - Cusco	0.13%	99.74%	0.13%
Trujillo - Ica	18.8%	70.1%	11.2%
Trujillo - Cusco	0.7%	97.9%	1.4%
Ayacucho - Trujillo	10.3%	89.0%	0.6%
Ayacucho - Huancavelica	2.6%	82.3%	15.1%
Huancavelica -Ica	9.2%	89.7%	1.0%
Lima - Puno	31.6%	65.3%	3.1%
Piura - Puno	6.5%	86.2%	7.3%
Puno - Cusco	0.5%	47.9%	51.6%
Ayacucho - Puno	18.1%	80.5%	1.5%
Cusco - Ayacucho	0.5%	87.3%	12.1%
Ica - Cusco	5.4%	81.8%	12.8%
Arequipa - Cusco	1.2%	71.0%	27.7%

Source: Own estimates

Table 5 Estimation of the average potato consumption in Peru by departments for the IV quarter of 2001

Departments	Estimated consumption (Tons)	Consumption confidence interval 95%		Production (February)	Production (June)	Production (August)	Production (October)	Estimated gap (Feb)	Estimated gap (Jun)	Estimated gap (Aug)	Estimated gap (Oct)
Arequipa	4464.46	3490.46	5438.46	17569	2531	13172	15417.00	13,105	-1,933	8,708	10,953
Ayacucho	3063.81	1786.30	4341.33	5590	21112	0	12.00	2,526	18,048	-3,064	-3,052
Cusco	4276.50	2864.79	5688.21	4536	46303	235	252.00	260	42,027	-4,041	-4,024
Huancavelica	3472.33	2181.78	4762.87	2480	17723	0	858.00	-992	14,251	-3,472	-2,614
Ica	2533.97	1673.06	3394.87	0	344	30084	7459.00	-2,534	-2,190	27,550	4,925
Junin	9014.24	6541.88	11486.59	31315	48738	6407	3771.00	22,301	39,724	-2,607	-5,243
La Libertad	6106.89	4646.68	7567.09	5758	53663	18779	14191.00	-349	47,556	12,672	8,084
Lima	44875.52	41847.53	47903.51	3022	1112	2500	25404.00	-41,854	-43,764	-42,376	-19,472
Piura	3301.32	2479.18	4123.46	1370	1004	546	437.00	-1,931	-2,297	-2,755	-2,864
Puno	5920.87	4447.51	7394.23	2259	38534	0	0	-3,662	32,613	-5,921	-5,921
Total Analizado	87029.89	82439.67	91620.10	73899.00	231064.00	71,723	67,801	-13,131	144,034	-15,307	-19,229
Resto del país	34986.92	31222.39	38751.45	83334.00	125073.00	38,516	55,954	48,347	90,086	3,529	20,967
Total Perú	122016.80	116818.60	127215.00	157233.00	356137.00	110,239	123,755	35,216	234,120	-11,778	1,738

Source: Own estimates

Table 6 Determinant factors in the reduction of the transaction costs and the increase of the speed of adjustment between markets

Independent Variables	Coefficients Model 1	Coefficients Model 2
Intercept	4.011 **	-0.901
	(2.51)	(2.19)
Energy1	-2.731 **	-0.458 **
	(2.12)	(2.73)
Energy2	-0.514	-1.343 **
	(0.41)	(3.25)
Roads1	-1.971 **	0.281
	(2.37)	(1.59)
Roads2	-1.865 **	-0.685 **
	(2.84)	(2.66)
Telecom1	-0.343 *	-0.182 **
	(1.63)	(2.70)
Telecom2	-0.045	-0.148 **
	(0.21)	(2.17)
Market1	0.249 *	0.111 **
	(1.87)	(1.91)
Market2	-0.136	0.217 **
	(0.59)	(3.16)
Radio1		-0.097
		(0.58)
Radio2	-0.044	-0.242 **
	(0.16)	(2.17)
Fair1	0.039	-0.076
	(0.2)	(0.80)
Fair2	0.352	0.299 **
	(1.18)	3.48
No. Of observations	45	45
Log - Likelihood	21.725	66.749
Maximum likelihood R2	0.348	0.846
BIC	-165.264	-187.917

Dependent Variable Model 1: Estimated Transaction Cost. Estimated through a linear regression. In model 2: Speed of Adjustment.Estimated through a censored regression.
In the first model, t - robust statistics in absolute value between parenthesis.
In the second model, z - robust statistics in absolute value between parenthesis.
** significative at 5%, * significative at 10%
Source: Own estimates

Table 7 Changes in the provision as factors that decrease the transaction costs and increase the speed of adjustment between markets

Independent Variables	Coefficients Model 1	Coefficients Model 2
Intercept	0.884	-0.798
	(0.95)	(0.79)
Energy1 (1997)	-0.624	0.221
	(0.81)	(0.32)
Energy2 (1997)	0.745	-1.557 *
	(1.45)	(1.88)
Roads1 (1997)		-0.357
		(1.64)
Roads2 (1997)	-1.285 **	-1.197 **
	(3.76)	(2.54)
Radio1 (1997)	0.662 *	-1.079 **
	(1.67)	(2.91)
Radio2 (1997)	-1.184 **	-1.229 **
	(2.05)	(2.09)
Δ Energy1 (1999 - 1997)	-1.165 *	0.479
	(1.62)	(0.75)
Δ Energy2 (1999 - 1997)	0.962 *	1.439 *
	(1.81)	(1.84)
Δ Roads1 (1999 -1997)	0.294	-0.582 **
	(1.27)	(2.62)
Δ Roads2 (1999 -1997)	-1.108 **	-0.971 **
	(2.79)	(1.98)
Δ Radio1 (1999 -1997)	0.226	-0.123
	(1.29)	(0.40)
Δ Radio2 (1999 -1997)	0.229	-0.169 *
	(1.00)	(1.61)
No. Of observations	45	45
Log - Likelihood	29.041	60.802
Maximum likelihood R2	0.529	0.377
BIC	-183.7	-192.131

Dependent Variable Model 1: Estimated Transaction Cost. Estimated through a linear regression. In model 2: Speed of Adjustment.Estimated through a censored regression.
In the first model, t - robust statistics in absolute value between parenthesis.
In the second model, z - robust statistics in absolute value between parenthesis.
** significative at 5%, * significative at 10%
Source: Own estimates

Figure 2 Price differential between Lima and Huancayo per ton of potato, 2000 - 2001