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Electronic version

URL: <https://journals.openedition.org/histoiremesure/1542>

DOI: 10.4000/histoiremesure.1542

ISSN: 1957-7745

Publisher

Éditions de l'EHESS

Printed version

Date of publication: 15 June 2006

Number of pages: 185-219

ISBN: 978-2-7132-2094-4

ISSN: 0982-1783

Electronic reference

Erik Buyst, Stefan Dercon and Bjorn Van Campenhout, "Road Expansion and Market Integration in the Austrian Low Countries during the Second Half of the 18th Century", *Histoire & mesure* [Online], XXI - 1 | 2006, Online since 01 June 2009, connection on 23 April 2022. URL: <http://journals.openedition.org/histoiremesure/1542> ; DOI: <https://doi.org/10.4000/histoiremesure.1542>

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Abstract. We analyse the integration of wheat markets across 18 towns in the Austrian Low Countries during the second half of the 18th century and their relationship to the rapidly expanding paved-road network during this period. Through the use of a switching regression approach (threshold cointegration), we study the long-term and short-term integration of these markets using monthly wheat prices. We find that throughout this period, markets were spatially interconnected. However, price margins responded slowly to local shocks. We also find that transaction costs were relatively high. The results suggest a complex market with regular trade flow reversals and periods of unprofitable trade between key markets. It is widely accepted in Belgian historiography that the construction of a paved road network caused a substantial reduction in transaction costs. Our research, however, indicates that distance, fixed costs or links by rivers and canals influenced transaction costs more than the expansion of a paved road network.

Résumé. Expansion du réseau routier et intégration des marchés dans les Pays-Bas autrichiens de la seconde moitié du XVIII^e siècle. L'article analyse l'intégration des marchés du blé entre 18 villes des Pays-Bas autrichiens, dans la seconde moitié du XVIII^e siècle. Il s'intéresse en particulier au rôle qu'aurait joué la rapide expansion du réseau de routes pavées dans cette intégration. Un *threshold cointegration* est utilisé pour évaluer l'intégration à court et à long terme entre ces marchés, à partir de données mensuelles sur les prix du blé. Il apparaît que, tout au long de la période étudiée, les marchés étaient bien interconnectés. Mais l'ajustement aux chocs locaux ne se faisait qu'assez lentement. En outre, les coûts de transaction s'avèrent relativement élevés. Ces résultats donnent l'image d'un marché complexe, avec des inversions régulières des flux et des périodes où le commerce entre des marchés-clés ne dégagait pas de profits. L'historiographie belge considère en général que la construction d'un réseau de routes pavées a réduit les coûts de transaction de façon substantielle. La présente recherche, elle, indique que ces derniers étaient surtout influencés par la distance, les coûts fixes et l'existence de rivières et canaux, plutôt que par le réseau routier.

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It is widely argued that improvements in transport and information technology increased the opportunities for trade and arbitrage, and therefore stimulated market integration ¹. In this paper, we use the Austrian Low Countries as a test case. During the 18th century, an impressive network of paved roads was built in this economically advanced area, linking most cities to each other. Many authors have suggested that this caused a substantial reduction in transaction costs ².

The absence of transport prices impedes us to quantify directly the beneficial effects of road construction on trade, but Blondé advances the following *qualitative* arguments to stress their importance. A first advantage is that fewer horses could transport heavier freights over longer distances. This generated serious cost reductions as the maintenance of horses accounted for approximately half of total transport costs. Second, the reliability of transport services improved substantially since it became less dependent on weather conditions. Rainfall and light snow slowed down transport on paved roads, but usually did not make it impossible anymore, as was often the case on dirt roads. Consequently, overland transport could more or less continue during winter, so that the sector's heavy fixed costs — maintenance of horses and carriages — could be distributed over more rides. Third, road transport became faster, despite the appearance of many tollhouses along paved roads.

Due to lack of data, it is impossible to test these arguments directly. Therefore, we use an indirect approach. Using price data of an important commodity traded in many cities, e.g. wheat, we ask whether the development of paved roads contributed to the creation of a national market, i.e. a system of spatially interlinked markets across the territory. Do we observe a decline in transaction costs when moving wheat around the country during the second half of the 18th century? Was there a change in the speed of arbitrage among wheat markets?

In analysing the issue of market integration, we apply recent econometric techniques from the booming literature on spatial price analysis in e.g. agricultural economics. In particular, we build on recent time series techniques for the analysis of co-movement of non-stationary series (cointegration) and the implied dynamic adjustment processes (error-correction). However, the standard way of applying these techniques to commodity markets assumes conti-

1. EJRNAES, M. & PERSSON, K. G., 1997; GOODWIN, B. & GRENNES, T. J., 1998; PERSSON, K. G., 1999.

2. For a detailed discussion, see B. BLONDÉ, 1999.

nuous, unidirectional trade. This is unlikely to be realistic in a relatively small area with several important markets, which may be supplied by a variety of sources from different directions. As a consequence, there may be regular periods of absent trade on certain routes. Depending on local conditions, trade flows may change as well. A standard, single-equation dynamic error-correction model cannot handle this phenomenon. To implement this analysis, we use a switching error-correction regression approach using threshold cointegration ³.

1. Sources

To answer the questions mentioned above, it is clear that we need detailed and accurate price data that reflect real market conditions. Since the late Middle Ages, many city governments in the Southern Low Countries collected price data to monitor the local food situation. Most of these figures have been published as annual averages. Since we want to measure the speed at which markets responded to each other, we need at least *monthly* data. Unfortunately, the number of cities for which monthly price data have been published is fairly limited. Moreover, the way these price series were constructed varied strongly from researcher to researcher. For some cities, the author noted down the price observed during the first market day of the month. In other instances, a monthly average was calculated after leaving out the highest and lowest value registered during that month. In still other cases, the opposite procedure was followed: the author took the average of the highest and lowest price observed during that month. Sometimes we just do not know what procedure was used ⁴. Given the volatile character of food prices, comparing such figures can lead to highly misleading results.

Fortunately, there is a source available that circumvents most of these problems. Its emergence is related to a fundamental change in the economic policy of the Austrian Low Countries' central government. Until the mid-18th century, the central government's food policy was dominated by *ad hoc* crisis management in the case of acute shortages ⁵. Influenced by mercantilist ideas, it was replaced in the late 1750s by a constant concern of organising efficient food supplies ⁶. In addition, the central government aimed at

3. OBSTFELD, M. & TAYLOR, A. M., 1997; PRAKASH, G. & TAYLOR, A. L., 1997; EJRNAES, M. & PERSSON, K. G., 2000.

4. From another point of view, Van der Wee was also very dissatisfied of the quality of the series published. See H. VAN DER WEE, 1961.

5. For a general assessment in a European context, see K. G. PERSSON, 1996 and 1999.

pursuing a more differentiated grain policy. Until the mid-18th century, export prohibitions had a general character. Thereafter, they became restricted to certain grain products and to certain areas ⁷. All this necessitated a close monitoring of fluctuations in local grain prices. Therefore, the central government decided to establish its own information network.

From 1765 to 1794, customs officials registered market prices in a standardised way in more than twenty cities. Specialised civil servants supervised the whole operation and compared the obtained figures with the weekly price lists collected by the city governments. As the various city administrations used their own local measurement systems, these specialised civil servants had to convert the price data in a common measurement unit, e.g. in Brabantine *stuivers* per *razier* from Brussels ⁸. Finally, these data were used as an input to produce detailed reports on the Austrian Low Countries' food situation ⁹ published a considerable part of these data ¹⁰. For various agricultural products he noted down the prices observed during the first market day of the month. Therefore, the time of price registration was the same for all markets under consideration.

We limit our research to wheat prices, as this commodity was by far the most traded grain product in the Austrian Low Countries ¹¹. Moreover, wheat has a higher value/weight ratio than rye, so that the profits from arbitrage are likely to be substantial. We selected eighteen markets for which close to all 360 monthly observations are available (see Table 1). A comparison with early 19th-century turnover data tells us that the eighteen recorded cities compose a representative sample of all large and medium-sized grain markets in the Austrian Low Countries. The only drawback is that Limburg and Luxembourg are not represented in the sample. Agriculture in these regions was not well developed, so that subsistence farming dominated the picture ¹². Absence of important wheat markets was the obvious result.

6. MATERNÉ, J., 1994.

7. VANDENBROEKE, C., 1967.

8. A *razier* from Brussels is 49 litres.

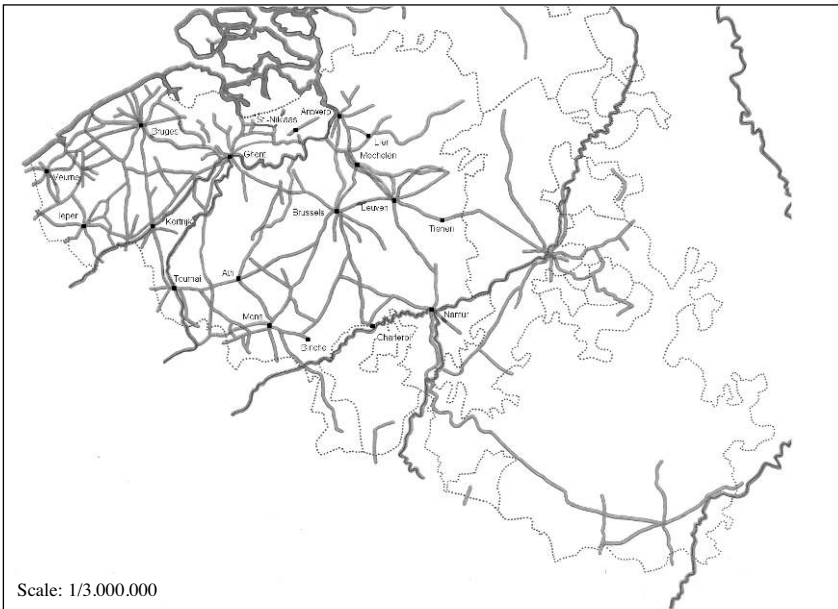
9. MATERNÉ, J., 1994.

10. VANDENBROEKE, C., 1973.

11. We do not know the sales volumes of grain during the second half of the 18th century. In 1813, the sales volume of wheat on « Belgian » markets amounted to 731,000 hectolitres, compared to 492,000 hectolitres for rye. We have no reasons to believe that these proportions were substantially different in the preceding decades. (We thank Dr. M. Goossens for providing us these data which are based on Archives Nationales, Paris, F¹¹ 843).

12. DEJONGH, G., 2000.

Map 1. *The Austrian Low Countries and their transport infrastructure (canals and roads) by the end of the 18th century*



Note: We thank Dr. Michael-W. Serruys for kindly providing us this map.

2. General context

Table 1 provides details on the size of these markets. Even though the data are from 1813, it seems unlikely that the order and relative importance had changed dramatically since the late 18th century. Leuven was undoubtedly the most important wheat market of the Austrian Low Countries. It was located in the middle of rich agricultural areas that were linked to the city by a network of canals and paved roads. Moreover, Leuven was an important centre of beer breweries consuming large quantities of grain. Charleroi, in second position, benefited from its location on the edges of the rich farmlands of Hainaut and Walloon Brabant. Moreover, the strong expansion of coal mining and iron making in the area created a large demand for wheat. The Brussels wheat market occupied a strong third position. Being the capital of the Austrian Low Countries, the city counted many high-income earners, e.g. top civil servants, lawyers, and traders.

Looking at the evolution of wheat prices between 1765 and 1794, we notice a remarkable stability (for Brussels, see Figure 1). During most of the period, the Austrian Low Countries produced an export surplus which

explains the relative absence of price hikes ¹³. The only real exception is 1789, as a result of crop failure and mounting political tensions. Both elements would eventually lead to the so-called Brabantine Revolution, which gave large parts of the Austrian Low Countries a short-lived independence (October 1789-October 1790). The turmoil clearly resulted in an increased volatility of wheat prices. Another, but much smaller blip in wheat prices is registered in the early 1770s, due to poor harvests.

Table 1. *Relative importance of markets: yearly turnover of wheat in 1813*

<i>Market</i>	<i>Hectolitres</i>
Leuven	99,436
Charleroi	87,355
Brussels	70,039
Tournai	36,675
Ghent	36,463
Bruges	30,218
Veurne	28,441
St. Niklaas	26,369
Namur	24,055
Tienen	23,655
Ieper	18,166
Mechelen	17,769
Mons	14,999
Antwerp	13,831
Lier	10,729
Kortrijk	7,555
Ath	1,888
Binche	1,500

Source: Data from the Archives Nationales, Paris, F^{II} 843 (see footnote 11).

To introduce price differences between markets, we focus on two large ones located close to each other, Leuven and Brussels. The latter being a centre of high income earners, it is not surprising that wheat prices were somewhat higher in the capital of the Austrian Low Countries than in Leuven. Figure 2 shows that the price relationship between the two cities was relatively stable in the long run, which suggests that arbitrage between these well-established markets may have taken place. Stability is clearly interrupted in the early 1790s and the series afterwards may well be too small to check the persistence of the earlier patterns.

13. For the same reason, urban regulations on the wheat trade only had a nuisance value. Markets such as Tournai and Kortrijk were situated close to important French cities, so that it is not impossible that some French wheat was also traded there.

Figure 1. *Wheat prices in Brussels, 1765-1794 (in Brabantine stuivers per razier from Brussels)*

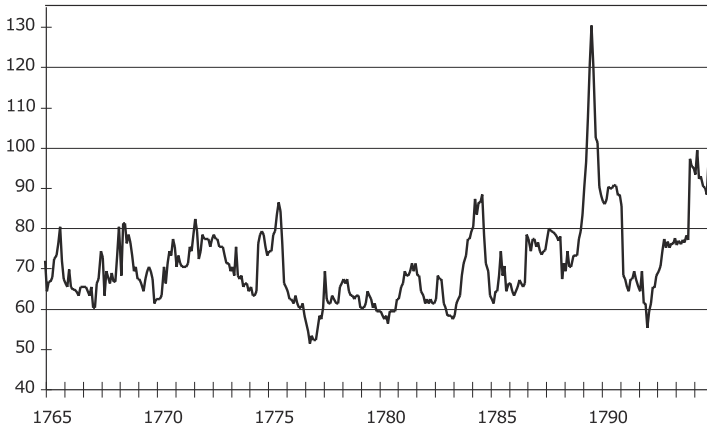
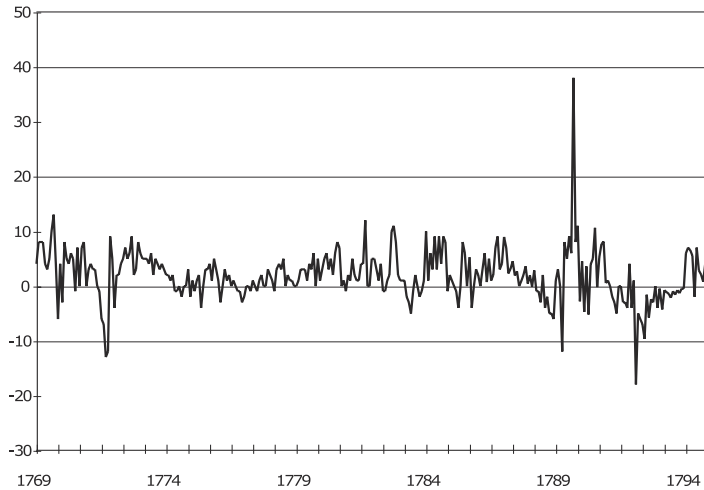
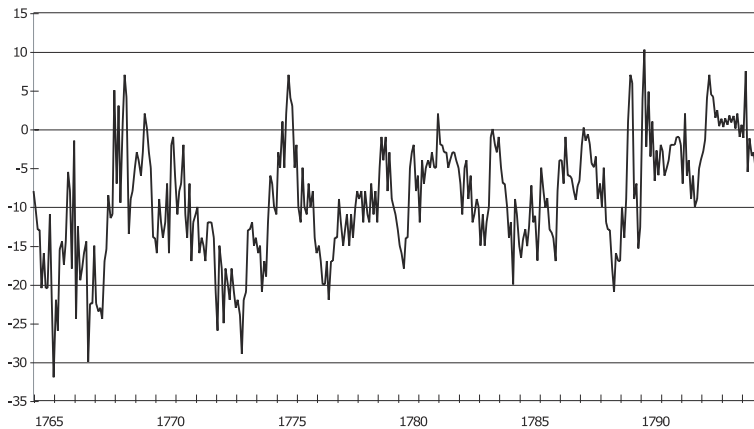


Figure 2. *Brussels wheat prices minus Leuven wheat prices, 1769-1794*



An important feature is that at times the margins between these two markets become close to zero or even negative. This suggests that in certain seasons, no profitable trade was possible from Leuven to Brussels or even that trade flows, if present, would have been from Brussels to Leuven. This is a feature that complicates the econometric analysis of market integration, as will be discussed below.

Figure 3. *Brussels wheat prices minus Ghent wheat prices, 1765-1794*



Other markets display similar features. For example, Figure 3 gives the price differential between Brussels and Ghent. As Ghent was located in a typically rye producing era, wheat prices in Ghent were higher than in the capital of the Austrian Low Countries ¹⁴. Therefore, grain was usually flowing from Brussels to Ghent in this period. Margins appear to be fluctuating, but from the mid-1770s they seem to stabilise. Fluctuations sometimes result in very small or reverse margins, also suggesting the absence of profitable trade or possibly trade reversals.

As indicated before, various authors have stressed the importance of the construction of a network of paved roads as a crucial determinant of market integration in the Austrian Low Countries. How did this network develop in the 18th century? Before 1704, most paved roads remained limited to small and incoherent stretches around large cities. For strategic reasons, a systematic network of paved roads was built during the Spanish War of Succession that linked Brussels with other important cities, such as Antwerp, Ghent, Leuven and Mons. After the Peace of Utrecht (1713), the central government lost its interest in the construction of paved roads, but the initiative was soon taken over by regional and local authorities.

Around the middle of the 18th century the central government's interest in infrastructure revived again. Moreover, this policy was put into a much broader economic perspective: the Austrian Low Countries should take over

14. DEJONGH, G., 2000.

a part of Holland's profitable transit trade to Liège and the Rhineland. Investments in the port of Ostend and in the construction of an integrated network of waterways and paved roads played a key role in this plan. By 1763, the road network connected most of the main towns and a decade later the east-west project was realised ¹⁵. Blondé has demonstrated that it proved to be a highly successful strategy in attracting transit trade. Of course, domestic trade also benefited substantially from the improved infrastructure network ¹⁶. By the early 1790s, provincial roads had expanded too, so that the Austrian Low Countries obtained the highest paved road density in Europe ¹⁷.

3. Data analysis method

In the analysis, we can only rely on price data and on information about the extension of the paved road network. First, we will try to use the price information to address two questions. (1) Can we detect evidence that markets are integrated? (2) How fast is this adjustment occurring? Then, we will try to link the results from the econometric analysis to the road network evolution in the 18th century. In particular, we will investigate whether the presence and development of paved roads can explain our estimates of transaction costs and of arbitrage speed between markets.

The fact that only price information is available limits the methodological possibilities to analyse market integration. In line with other studies, statistical properties of the relationship between prices in different markets can tentatively be interpreted as evidence of actual linkages between these markets. Under certain conditions, the existence of a long-run relationship between prices of different markets can be tested, providing evidence of integration between these markets in the long run. Furthermore, dynamic equations can then be derived, specifying the dynamic processes leading from short-run disequilibria to the long-run equilibrium. Applying this model to the situation described above in 18th-century wheat markets is problematic. The reason is the recurrence of very low or even negative margins. This suggests that at times, no profitable trade was possible or trade flows were reversed. Consequently, we need an approach that can handle this situation.

15. For more details, see e.g. G. THEWES, 1994; GENICOT, L., 1939 and 1946; URBAIN, Y., 1939.

16. BLONDÉ, B., 1999.

17. GENICOT, 1946.

Formally, let C_t^{ij} be the transaction cost of moving grain between markets i and j in period t . Let P_t^i be the price of grain in market i and P_t^j the price in market j . Efficient spatial arbitrage¹⁸ requires then that there are unexploited profits from trade between markets i and j unless transaction costs exceed potential margins, or:

$$|P_t^i - P_t^j| \leq C_t^{ij} \quad (1)$$

Non-zero trade flows under efficient arbitrage would imply equality of both sides in (1). Efficient arbitrage could imply flows from i to j or from j to i , depending on market conditions in i and j . When (1) is valid with equality, prices are said to be at the parity bound. If margins are larger than the parity bounds, profitable trade could take place. Strict inequality of (1) would require zero trade flows. As in Ravallion, if (1) is valid, then the two spatially separated markets will be referred to as integrated¹⁹. A weaker form of market integration could be defined as requiring (1) only to be valid in the long run: deviations could occur in the short run, but arbitrage would in due course return the market to satisfy (1).

There have been different approaches to develop this into a statistical model of market integration²⁰. Cointegration models only use price data and test whether there is a particular stable relationship between prices in i and j , in the long run. Note that for these models to be consistent with the efficient arbitrage model, they require continuous trade and no flow reversal. The model tested is:

$$P_t^j = \alpha + \beta \cdot P_t^i + \eta_t \quad (2)$$

Stationarity of η_t implies the existence of a long-run relationship between prices: they move together. It is implicit in the model that trade is taking place continuously and in one direction only. Errors are made, however, and they are corrected over some period of time. The Engle-Granger results imply the existence of an error-correction representation that models this correction process over time. Testing restrictions on this error-correction model allows inference about the speed of adjustment to this long-run relationship²¹. However, it is clearly only a limiting case of the efficient arbitrage condition

18. TAKAYAMA, T. & JUDGE, G. G., 1971.

19. RAVALLION, M., 1986.

20. The readers who are not familiar with cointegration models (or time series in general) should refer to the Annex below before reading this part of the paper. It presents the method and gives intuitive definitions of technical terms and parameters.

in (1), excluding situations in which no profitable trade can take place and markets in which conditions change sufficiently to allow a reversal of the trade flow. In recent years, threshold cointegration models have been developed to deal with these situations and applied to market integration ²².

Suppose that, as is usually the case, (real) prices in market *i* and *j* are non-stationary. Suppose further that real transfer costs to move grain between markets *i* and *j* are equal to C^{ij} in each direction, and constant over time. To derive an alternative model that could address some of the shortcomings of other approaches, let us define the margin between the prices in *i* and *j* as:

$$m_t = P_t^i - P_t^j \quad (3)$$

Suppose that for the time being we have no information about trade flows nor about transaction costs. We can distinguish three regimes, depending on the difference between margin and transaction costs: $m_t > C^{ij}$, $m_t < -C^{ij}$ and $|m_t| \leq C^{ij}$. The last regime corresponds to (1), the condition for efficient spatial arbitrage, and consists of both situations in which trade occurs and arbitrage is efficient, and situations in which no profitable trade occurs. In the first (resp. second) regime, market traders have not exploited profitable trade opportunities, in moving grain from *i* to *j* (resp. *j* to *i*).

If arbitrage takes place, however slowly, then m_t would in the long run be a process returning to a band $[-C^{ij}, C^{ij}]$. Arbitrage will only happen outside this band until the threshold values of the band are reached. Even though m_t does not return to a particular equilibrium level but to a band, m_t is a stationary process. A threshold cointegration model and in particular the Band-Threshold Autoregression Model (Band-TAR) provides a reasonable way to characterise the behaviour of the actual margin m_t ²³. A version of the model can be specified as follows. Inside the parity bounds, when arbitrage is efficient, there is no arbitrage and the price gap shows no central tendency. When outside the parity bounds, arbitrage takes place and, just as in Purchasing Power Parities or error-correction models, there will be some non-linear autoregressive process to return to the long run band, and the size of the adjustment will be a percentage of the deviation in each period.

21. PALASKAS, T. B. & HARRISS-WHITE, B., 1993; ALEXANDER, C. & WYETH, J., 1994; GOODWIN, B. & SCHROEDER, T., 1987.

22. BALKE, N. & FOMBY, T. B., 1997; PRAKASH, G. & TAYLOR, A. M., 1997; OBSTFELD, M. & TAYLOR, A. M., 1997; GOODWIN, B. & GRENNES, T. J., 1998.

23. PRAKASH, G. & TAYLOR, A. M., 1997; OBSTFELD, M. & TAYLOR, A. M., 1997; BALKE, N. S. & FOMBY, T. B., 1997.

Formally, defining $\Delta m_t = m_t - m_{t-1}$, we can write this process as:

$$\Delta m_t = \begin{cases} \rho, (m_{t-1} - C^{ij}) + \eta_t^{out} & m_{t-1} > C^{ij} \\ \eta_t^{in} & \text{if } |m_{t-1}| \leq C^{ij} \\ \rho, (m_{t-1} + C^{ij}) + \eta_t^{out} & m_{t-1} < -C^{ij} \end{cases} \quad (4)$$

where ρ is the speed of adjustment of m_t towards the band $[-C^{ij}, C^{ij}]$ ²⁴. The value of ρ is expected to be in the half open interval $]0, -1]$ ²⁵. In equation (4), the errors are white noise, i.e. η_t^{out} is i.i.d.(0, σ_{out}^2) and η_t^{in} is i.i.d.(0, σ_{in}^2). Inside the band $[-C^{ij}, C^{ij}]$, there is no adjustment: the margin follows a random walk. Note that in this model, even though m_t is globally stationary, locally, i.e. inside the band, it displays unit root behaviour.

The link with error-correction models can be seen very clearly if we re-write (4) using (3):

$$\begin{cases} \Delta P_t^i = \Delta P_t^j + \rho, (P_{t-1}^i - P_{t-1}^j - C^{ij}) + \eta_t^{out} & P_t^i - P_t^j > C^{ij} \\ \Delta P_t^i = \Delta P_t^j + \eta_t^{in} & \text{if } |P_t^i - P_t^j| \leq C^{ij} \\ \Delta P_t^j = \Delta P_t^i + \rho, (P_{t-1}^j - P_{t-1}^i - C^{ij}) + \eta_t^{out} & P_t^j - P_t^i > C^{ij} \end{cases} \quad (5)$$

Inside the band (when $[P_t^i - P_t^j] \leq C^{ij}$), there is no systematic dynamic relationship between changes in prices in each market. However, outside the band, error-correction behaviours can be observed (they are described by the part of the equation involving the ρ parameter). Changes in one market are only passed on with error to the other market, but there is a process of correction: in each period, part of the error is corrected. Like in previous error-correction model based analysis for market integration, a natural measure of how well markets are integrated for given transfer costs and given the existence of a long-run (band) equilibrium is the speed of adjustment ρ : the closer to minus one, the better markets are integrated.

Equations (4) and (5) also show very clearly the subtle relationship between cointegration and spatial price arbitrage. If spatial arbitrage takes place, unit root behaviour in price margins should be observed. This regime

24. The model could be easily generalised by allowing for further lags in m and by allowing ρ and η^{out} to be different depending on whether $m_{t-1} > C^{ij}$ or $m_{t-1} < -C^{ij}$. The estimation technique remains unchanged.

25. ρ is expected to be zero if C^{ij} is sufficiently large not to allow ever any trade to take place or if never any scope for profitable arbitrage can be observed. In general, if the markets are not connected for whatever reason (market imperfections or high transfer costs), then ρ is expected to be zero.

includes margins up to and including the parity bound; only when imperfect arbitrage takes place will we observe cointegration and the error-correction formulation to be correct. The model given is a simple version of the Band-TAR model. Balke and Fomby give extensions in terms of a more complicated lag-structure, different adjustment speeds depending on the side of the price band, different threshold structure and other market equilibria ²⁶.

Even though the margin in this model is locally non-stationary, it is overall stationary, provided α is non-zero. Of course, stationarity needs to be tested. Balke and Fomby use Monte Carlo simulations to investigate the power of a large number of tests and find that standard tests for cointegration, such as the ADF or the Phillips-Perron tests, still have reasonably high power, even if the true model is a TAR ²⁷. Stationarity of the margin is evidence of interconnectedness: at least in the long-run, the markets are integrated.

Once stationarity of the margin is established, one can proceed with the estimation of the Band-TAR model. The strategy is to estimate the model using a grid search over different possible values for the threshold. The basic tool is an arranged autoregression. In our application, this orders the data according to the values of Dm_t rather than by time. Note, however, that the dynamic relationship between m_t and its lags is retained; only the order of the observations is different. The sample is then partitioned in two sub-samples, one with all the observations inside the band and one with all the observations outside the band. Next, one has to choose a criterion, either to maximise the likelihood function of the TAR model ²⁸, or to maximise the sum of the residual sum of squared errors in each of the sub-samples ²⁹. Given the piecewise linearity of the model outside the band and the unit root behaviour inside the band, either method is efficient and equivalent. These procedures return (super-consistent) estimates of the threshold (C^{ij}) and the adjustment speed α ³⁰.

26. BALKE, N. S. & FOMBY, T. B., 1997.

27. The superconsistency results related to estimates of the cointegrating vector can be shown to apply as well. Even though no inference is possible on these estimates, in this stage the assumption of constant additive (i.e. non-proportional) transfer costs as assumed in the model could be looked into, by checking whether the coefficient on the other price in the cointegrating relationship is close to one (PALASKAS, T. B. & HARRISS-WHITE, B., 1993; DERCON, S., 1995).

28. As in G. PRAKASH & A. M. TAYLOR, 1997 and M. OBSTFELD & A. M. TAYLOR, 1997.

29. BALKE, N. S. & FOMBY, T. B., 1997.

30. CHAN, K. S., 1993.

The estimated threshold provides an estimate of the margin used in trade. Its significance and confidence interval are not straightforwardly derived, since the parameter space is truncated at zero (i.e. the threshold is not defined for non-positive values). Non-standard distributions could be derived using Monte Carlo simulations. Measures of the degree of market integration are straightforwardly derived from the analysis. The estimated value of the adjustment speed τ gives the speed with which arbitrage restores equilibrium when profitable trade opportunities exist. The closer τ to minus one, the faster the adjustment. If the estimate is statistically not different from minus one, integration can be said to occur in the short run. Since both the estimated thresholds and the arbitrage speed are estimated for a large number of market pairs, we can further use these estimates to look for the determinants of transactions costs and arbitrage speed across markets, and more specifically for the role of roads and distances.

4. Empirical Results

To put the empirical results in perspective, Table 2 gives an overview of some of the key market relations, mainly neighbouring markets or links between the larger towns³¹. We include information on the development of paved roads during the survey period as well as on whether there is a river or canal network providing a direct link between the towns³².

Table 2 shows average margins (in absolute values) between 3 and 10 *stuivers* per *razier* from Brussels over the period. Distances are typically relatively low, but at the beginning of the 18th century, many of these key market-pairs were not connected by a paved road: about half were connected in 1718, while the network had expanded to about 63 percent in 1763 and 78 percent by 1793. Direct links by water are important but many towns are not connected in this way.

To conduct the threshold cointegration analysis on the price series of these market pairs, we first need to apply non-stationarity tests on the series. In Annex 2, Table 1, we find that the series are non-stationary in levels, but

31. In Annex 2 we provide further results of (potentially) more indirectly connected markets.

32. In this period, rivers and canals connected directly the following towns: Charleroi-Namur (Samber), Brussels-Antwerp (canal), Lier-Antwerp (Nete), Leuven-Mechelen (canal), Ath-Tournai (Dender), Tournai-Gent-Antwerp (Scheldt), Bruges-Ghent (canal), Kortrijk-Ghent (Leie), Veurne-Bruges (canal), Ieper-Veurne (canal), Lier-Mechelen (Nete), Mechelen-Antwerp (Rupel).

Table 2. *Main characteristics of key markets*

<i>Market Pairs:</i>		<i>Mean Margin*</i>	<i>Distance (km)</i>	<i>Road in 1718</i>	<i>Road in 1763</i>	<i>Road in 1793</i>	<i>River or canal 1783</i>
Ath	Tournai	7,1	29	No	Yes	Yes	Yes
Ghent	Tournai	9,0	71	No	Yes	Yes	Yes
Kortrijk	Tournai	6,4	26	No	Yes	Yes	No
Binche	Mons	4,5	15	No	Yes	Yes	No
Ath	Mons	5,9	19	No	Yes	Yes	No
Brussels	Mons	6,1	52	Yes	Yes	Yes	No
Charleroi	Binche	6,8	19	No	No	No	No
Brussels	Ath	5,8	43	No	No	Yes	No
Namur	Charleroi	4,0	39	No	No	Yes	Yes
Brussels	Charleroi	5,3	59	No	Yes	Yes	No
Brussels	Namur	5,3	50	No	Yes	Yes	No
Tienen	Namur	5,9	45	No	No	No	No
Leuven	Namur	4,6	47	No	Yes	Yes	No
Mechelen	Brussels	4,3	23	Yes	Yes	Yes	Yes
Ghent	Brussels	9,8	51	Yes	Yes	Yes	No
Leuven	Brussels	3,6	26	Yes	Yes	Yes	No
Leuven	Tienen	6,8	20	Yes	Yes	Yes	No
Antwerp	Mechelen	4,6	24	Yes	Yes	Yes	Yes
Leuven	Mechelen	5,9	24	No	Yes	Yes	Yes
Lier	Antwerp	7,0	13	Yes	Yes	Yes	Yes
St Niklaas	Antwerp	5,0	25	No	No	No	No
Ghent	Antwerp	8,9	98	No	No	No	Yes
Bruges	Antwerp	7,4	160	No	No	No	Yes
Ghent	St Niklaas	9,1	30	No	No	No	No
Bruges	Ghent	6,9	62	No	No	No	Yes
Kortrijk	Ghent	8,9	45	No	Yes	Yes	Yes
Veurne	Bruges	9,5	45	No	No	Yes	Yes
Ieper	Bruges	7,7	48	No	No	Yes	No
Kortrijk	Bruges	8,3	46	No	Yes	Yes	No
Kortrijk	Ieper	6,2	25	No	Yes	Yes	No

* *Stuiver per razier* from Brussels.

stationary in first differences, as expected. Cointegration tests were then conducted, as a test for long-run co-movement of the price series. The result of these tests (Dickey Fuller and Augmented Dickey Fuller tests with 12 lags) are reported in Table 3. We find that the null of no cointegration is rejected at 1 percent for all but two market pairs tested, where it is rejected at 5 percent ³². In short, cointegration is present, so that in the long-run all

32. The null states that there is unit root behaviour in the error term of the cointegrating relationship, or equivalently, that there is no cointegration. If the null is rejected, we have cointegration. Here, we reject the null of no cointegration for all market pairs on a 1 percent level, except for two pairs, where we can reject « only » at 5 percent.

these markets are connected. Note that this is the case despite the absence of roads for a number of market pairs. If we extend the analysis to other markets, which are only indirectly linked, we find the same result. Indeed, for 99 percent of all possible combinations of price differentials, we find stationary errors in the cointegrating relationship. In Annex 2, Table 2, we give some of the results. An alternative test involves looking at the stationarity of the difference between prices in different markets. Implicitly, this is imposing the restriction on the cointegrating vector that the coefficient on the price at the right hand side is equal to one. Annex 3, Table 3 gives the results for the key markets. Virtually all margins are stationary at least at 10 percent.

Table 3. *Cointegration tests as tests for long-run market integration*

		DF	ADF(12)
Ath	Tournai	-7,69 **	-3,17 **
Ghent	Tournai	-9,15 **	-3,65 **
Kortrijk	Tournai	-9,97 **	-4,57 **
Binche	Mons	-9,70 **	-2,82 **
Ath	Mons	-7,76 **	-2,36 *
Brussels	Mons	-8,70 **	-4,37 **
Charleroi	Binche	-11,45 **	-3,80 **
Brussels	Ath	-8,07 **	-4,64 **
Namur	Charleroi	-11,65 **	-3,81 **
Brussels	Charleroi	-11,75 **	-5,74 **
Brussels	Namur	-10,56 **	-4,73 **
Tienen	Namur	-8,76 **	-4,29 **
Leuven	Namur	-10,85 **	-3,73 **
Mechelen	Brussels	-9,30 **	-4,80 **
Ghent	Brussels	-7,12 **	-3,54 **
Leuven	Brussels	-11,40 **	-4,22 **
Leuven	Tienen	-10,43 **	-4,30 **
Antwerp	Mechelen	-7,63 **	-4,21 **
Leuven	Mechelen	-9,80 **	-4,31 **
Lier	Antwerp	-6,67 **	-3,43 **
St Niklaas	Antwerp	-7,27 **	-3,83 **
Ghent	Antwerp	-9,04 **	-3,55 **
Bruges	Antwerp	-6,12 **	-2,59 *
Ghent	St Niklaas	-7,88 **	-3,63 **
Bruges	Ghent	-7,02 **	-2,62 **
Kortrijk	Ghent	-7,95 **	-4,19 **
Veurne	Bruges	-8,07 **	-3,61 **
Ieper	Bruges	-5,56 **	-3,59 **
Kortrijk	Bruges	-6,47 **	-2,94 **
Kortrijk	Ieper	-7,60 **	-3,64 **

Note: 1 percent critical value is -2.60 (**), 5 percent critical value is -1.95.

The fact that the significance of the test-statistic is typically lower than the one obtained using an unrestricted cointegrating vector may suggest that in some cases, the coefficient on prices is not equal to one. Inference on the cointegrating vector is not possible, but in most cases we find the coefficient on the market price on the right hand side to be relatively close to one, justifying the specification of a dynamic model in margins as in (5). Given the possibility of regular trade reversals, we present a threshold cointegration model, using the margins as the cointegrating relationship in Table 4. We give the estimated threshold, which is our best estimate of transaction costs, and the coefficient on the error-correction term (lagged margin in (5)), which gives an indicator of the adjustment speed to long-run equilibrium. Recall that a fast and immediate correction would require a coefficient of minus one, i.e. all errors are immediately corrected and ‘short-run integration’ is present. We include therefore a test on the null hypothesis of short-run integration. For comparison, we also give the results of a simple error-correction model (in particular an AR(1) model on the margins), which would be the true model if thresholds did not matter, i.e. if we did not worry about trade reversal and the absence of trade in some periods.

Inference on the thresholds is complicated since non-positive values are not defined, so that test-statistics follow non-standard distributions. However, we can immediately test the null of short-run integration. It appears that despite typically higher adjustment speeds than if we misspecified the model to exclude periods of non-profitable trade or trade reversal, only in two market pairs do we find that the null of short-run integration cannot be rejected (Ath-Tournai and Brussels-Charleroi). In short, even though the data are only monthly, they do not support a hypothesis of fast and immediate corrections (within one month) to deviations from the long-run equilibrium. In other words, adjustment is sluggish. Considering other market pairs, which are only indirectly linked, confirms these estimates (Annex 2, Table 3). Virtually no markets can be found with immediate adjustment of deviations from the long-run margins, i.e. short-run integration is not present.

Table 5 illustrates this further. For these key markets, we give the half-life implied by the estimates, i.e. the time that is needed for a variable to return to half its initial value — a measure of how fast errors are corrected ³⁴.

34. A half-life is the solution for T in $x(t+T)=x(t)/2$. It can be shown that $T = \ln(1/2) / \ln(b)$, with $b = 1 + \Delta x(t) / x(t-1)$, or in our case, $b = 1 + \pi$. If π is -0.5 , then T is one, so it takes one month to correct half the shock. In the limit, when π approaches -1 , any error in $t-1$ is fully corrected in t .

Typically, half-lives are relatively substantial. On average about 1.4 months (i.e. about 42 days) are needed to correct half the error, although the range is up to 4 months, according to our point estimates.

Table 4. *Dynamic adjustment model and short run integration*

Threshold cointegration model (5)						AR(1) (simple error-correction)		
		Estimated	Adjustment	t value	Short run	model		
		Threshold	speed	adjustm.	integrat.	Adjustment	t value	Short run
						speed	adjustm.	integrat.
Ath	Tournai	10,70	-1,01	-8,30**	-0,08	-0,29	-7,82**	19,23**
Ghent	Tournai	4,00	-0,42	-7,93**	10,95**	-0,29	-7,79**	19,09**
Kortrijk	Tournai	1,40	-0,51	-10,18**	9,78**	-0,45	-10,19**	12,43**
Binche	Mons	1,20	-0,46	-9,00**	10,57**	-0,40	-9,41**	14,31**
Ath	Mons	3,20	-0,37	-7,24**	12,33**	-0,25	-7,21**	21,22**
Brussels	Mons	8,50	-0,51	-5,67**	5,4**	-0,20	-6,23**	24,41**
Charleroi	Binche	5,30	-0,60	-9,31**	6,21**	-0,29	-7,79**	19,01**
Brussels	Ath	2,60	-0,34	-7,01**	13,61**	-0,25	-7,08**	21,79**
Namur	Charleroi	0,51	-0,57	-11,05**	8,34**	-0,53	-11,39**	9,95**
Brussels	Charleroi	5,90	-1,05	-12,43**	-0,59	-0,40	-9,51**	14,53**
Brussels	Namur	5,10	-0,67	-7,87**	3,88**	-0,28	-7,82**	19,86**
Tienen	Namur	2,00	-0,23	-5,90**	19,75**	-0,19	-6,10**	26,41**
Leuven	Namur	3,60	-0,76	-9,43**	2,98**	-0,46	-9,62**	11,28**
Mechelen	Brussels	0,50	-0,37	-8,51**	14,49**	-0,34	-8,63**	16,53**
Ghent	Brussels	13,00	-0,37	-4,81**	8,19**	-0,09	-4,21**	40,61**
Leuven	Brussels	2,91	-0,83	-10,29**	2,11*	-0,52	-10,44**	9,49**
Leuven	Tienen	7,19	-0,59	-7,01**	4,87**	-0,23	-6,26**	21,28**
Antwerp	Mechelen	1,00	-0,31	-7,22**	16,07**	-0,28	-7,55**	19,79**
Leuven	Mechelen	3,50	-0,54	-7,65**	6,52**	-0,33	-7,80**	15,90**
Lier	Antwerp	4,53	-0,29	-5,74**	14,05**	-0,16	-5,53**	29,40**
St Niklaas	Antwerp	1,00	-0,30	-6,94**	16,19**	-0,27	-7,41**	20,39**
Ghent	Antwerp	7,72	-0,38	-6,52**	10,64**	-0,16	-5,56**	30,00**
Bruges	Antwerp	1,00	-0,15	-4,90**	27,77**	-0,14	-5,17**	31,88**
Ghent	St Niklaas	5,60	-0,24	-5,37**	17,01**	-0,15	-5,43**	30,27**
Bruges	Ghent	8,00	-0,57	-7,06**	5,33**	-0,23	-6,84**	22,92**
Kortrijk	Ghent	4,60	-0,27	-6,25**	16,90**	-0,18	-6,03**	26,72**
Veurne	Bruges	7,91	-0,34	-6,14**	11,92**	-0,15	-5,21**	30,57**
Ieper	Bruges	2,30	-0,18	-5,24**	23,87**	-0,14	-5,24**	31,10**
Kortrijk	Bruges	9,10	-0,48	-7,85**	8,50**	-0,19	-6,11**	26,27**
Kortrijk	Ieper	1,00	-0,32	-7,86**	16,70**	-0,29	-7,85**	18,81**

**= significant at 1 percent. *=significant at 5 percent

The analysis also generated information on trade opportunities that are left unexploited to some extent in each period. In particular, we have estimated how often a market pair is located in one of the three regimes specified in equation (5): (a) no trade possible due to margins below transactions costs, (b) potential trade from the first market to the other, since the current

price margins appear to be exceeding current transactions costs, and (c) the reverse situation expressing unexploited profits via a trade reversal, since profitable trade could take place from the second to the first market (margins larger than transactions costs).

*Table 5. Half-life implied by the estimated adjustment speed
(half-lives in months)*

		<i>Half-life</i>
Ath	Tournai	0,00
Ghent	Tournai	1,27
Kortrijk	Tournai	0,97
Binche	Mons	1,12
Ath	Mons	1,50
Brussels	Mons	0,97
Charleroi	Binche	0,76
Brussels	Ath	1,67
Namur	Charleroi	0,82
Brussels	Charleroi	0,00
Brussels	Namur	0,63
Tienen	Namur	2,65
Leuven	Namur	0,49
Mechelen	Brussels	1,50
Ghent	Brussels	1,50
Leuven	Brussels	0,39
Leuven	Tienen	0,78
Antwerp	Mechelen	1,87
Leuven	Mechelen	0,89
Lier	Antwerp	2,02
St Niklaas	Antwerp	1,94
Ghent	Antwerp	1,45
Bruges	Antwerp	4,27
Ghent	St Niklaas	2,53
Bruges	Ghent	0,82
Kortrijk	Ghent	2,20
Veurne	Bruges	1,67
Ieper	Bruges	3,49
Kortrijk	Bruges	1,06
Kortrijk	Ieper	1,80

Table 6 reports the estimated situation in the wheat markets of the Austrian Low Countries in this period. First note that many markets incentives appear to have existed for trade flow reversals, i.e. potential trade has occurred in both directions at different times in this period. For very few markets the direction of trade remained unchanged most of the time. This is evidence of a complex and probably quite active grain market in this area, despite the fact that immediate adjustment to long-run margins does not take place. In

Table 6. *Direction of trade opportunities implied by regressions*

<i>Market (1)</i>	<i>Market (2)</i>	<i>Potential trade from (1) to (2)</i>	<i>Inside the transactions cost band 'no trade'</i>	<i>Potential trade from (2) to (1)</i>
Ath	Tournai	14	73	13
Ghent	Tournai	15	28	57
Kortrijk	Tournai	46	16	38
Binche	Mons	43	22	35
Ath	Mons	35	36	30
Brussels	Mons	24	75	2
Charleroi	Binche	52	44	4
Brussels	Ath	52	27	20
Namur	Charleroi	51	12	37
Brussels	Charleroi	8	57	35
Brussels	Namur	3	58	39
Tienen	Namur	67	26	6
Leuven	Namur	11	47	41
Mechelen	Brussels	34	11	55
Gent	Brussels	0	69	31
Leuven	Brussels	39	45	15
Leuven	Tienen	1	63	36
Antwerp	Mechelen	49	18	34
Leuven	Mechelen	53	31	16
Lier	Antwerp	14	32	54
St Niklaas	Antwerp	41	22	37
Ghent	Antwerp	1	45	54
Bruges	Antwerp	22	14	64
Ghent	St Niklaas	2	40	59
Bruges	Ghent	31	59	9
Kortrijk	Ghent	60	30	10
Veurne	Bruges	55	43	2
Ieper	Bruges	59	18	23
Kortrijk	Bruges	30	63	7
Kortrijk	Ieper	51	13	36

Note: Figures are percentages of observations in the regime.

addition, transactions costs appear at times too high for trade between the markets, presumably because supplies from other areas make the trade relationship not profitable; for some markets, this is quite regularly the case. Unfortunately, one would need trade flow data, which are currently unavailable, to be able to confirm this interpretation. Nevertheless, in the Austrian Low Countries, there is a long history of fairly intense grain trade between different towns at least since medieval times, with small or larger quantities being moved around ³⁵. At the same time, wheat is a bulky, relatively low value commodity. Therefore, transactions costs in moving grain are relatively high in relation to its value, so that large margins will be needed to induce trade.

To conclude, we find evidence of an integrated market, at least in the long run. Arbitrage to bring margins in line with long-run levels is relatively slow, which is in line with the findings for France ³⁵. Nevertheless, the evidence suggests a complex market with periods of changing trade flows of wheat, resulting in some trading routes losing profitability from time to time.

We now turn to the final part of the analysis: to what extent has the presence and development of a road network contributed to this degree of market integration? Can our fairly complicated modelling strategy provide any insight on this issue? To study this question, we took the estimated thresholds and the estimated adjustment speeds of all markets. We then regressed them onto the actual distances via the existing road network, the squared distances (to allow for non-linear changes in costs and adjustment speed), a dummy describing whether a paved road existed in the beginning of the period under consideration and a dummy to control for the fact that some towns have links by water, yielding cost or other advantages in trade. Recall that the threshold is our best approximation for transaction costs in wheat markets. The adjustment speed measures the speed with which the margins return to long-run equilibrium, presumably due to arbitrage in the market, when the margins become larger than transaction costs. To show the added-value of the switching regression model, which allows for no trade or trade reversals, we also did these regressions on the simple (absolute value of the) margin and the adjustment speed implied by a simple error-correction model. Since we expect the latter to be misspecified — an expectation based on, among others, a visual inspection of the data series —, we can check whether this misspecification would have caused an erroneous interpretation of the evidence. We conducted the regression on the ‘key markets’ identified before and on the entire possible data set. Since in our relatively small area virtually all markets seem cointegrated, this would seem methodologically acceptable.

Tables 7 and 8 first give the evidence on respectively the margins and the adjustment speed α from the basic error-correction model. In other words, these regressions give the results based on probably inappropriately taking into account the role of trade flow reversals and unprofitable trade. We find that margins are significantly affected by distances, especially for long-distance trade. This is unsurprising since variable transaction costs presumably increase with distance. We cannot detect any effect of the presence of paved

35. VAN DER WEE, H., 1963.

36. O’GRADA, C. & CHEVET, J.-M., 2002.

roads or links by rivers or canals. About the adjustment speed in Table 8, we notice that for larger distances, adjustment speed is affected by distance, albeit in a non-linear way (a decreasing marginal effect for larger distances). However, using transaction costs and adjustment speed estimates from our threshold cointegration model, we find some different results. In Table 9, we notice that estimated transaction costs increase with distance in a non-linear way, even for the small sample of key markets. Again, the presence of roads does not affect transaction costs. The effect of links by water is also insignificant, although in some, more restricted formulations, its effect is, as expected, negative ³⁷. However, in terms of adjustment speed, Table 10 shows that roads do matter and distances are non-significant. Rivers and canals have no effect on the adjustment speed ³⁸. Roads increase the speed of adjustment to long-run equilibrium, suggesting faster spatial market arbitrage. The contribution seems especially large on relatively short distance trade (key markets). In short, our evidence suggests that paved roads in the 18th century did not change the long-run marketing margins between markets, i.e. they do not appear to cut costs significantly. However, they encouraged faster market arbitrage: they cut the length of time needed to erode any short-run deviations from the long-run margins via spatial trade.

Table 7. Margins in the basic error-correction model

	<i>Key markets</i>		<i>All market pairs</i>	
	<i>Coef</i>	<i>t-value</i>	<i>Coef</i>	<i>t-value</i>
Constant	4.691	3.919 **	4.295	5.703 **
Road in 1765?	-0.292	-0.427	0.179	0.497
Distance in km	0.062	1.784 +	0.071	4.968 **
Distance*distance	-0.000	-1.374	-0.000	-3.734 **
River or canal link?	0.467	0.707	-0.393	-0.761
Joint F	1.53		12.38**	
N	29		152	

36. For the full sample, the effect is negative and significant at 20 percent. If we drop the (insignificant) road variable and the squared distance variable, the effect of rivers and canals becomes significant at 10 percent. Since transport by inland water ways is especially useful for bulky commodities, this effect is in line with expectations. If we drop the link-by-water variable, the road variable remains insignificant. In short, some (cost-reducing) effect of the presence of canals and rivers can be detected, but no effect from paved roads, independent of the exact specification.

37. The effect of rivers and canals remains insignificant in all possible formulations attempted. Dropping insignificant variables does not change the size and significance of the coefficient of the roads variable. This is not a surprise: transport by rivers and canals is typically slow.

Table 8. *Adjustment speed in basic error-correction model*

	<i>Key markets</i>			<i>All market pairs</i>		
	<i>Coef</i>	<i>t-value</i>		<i>Coef</i>	<i>t-value</i>	
Constant	-0.296	-3.382	**	-0.344	-12.334	**
Road in 1765?	-0.047	-1.008		-0.025	-1.751	+
Distance in km	0.001	0.561		0.003	5.102	**
Distance*distance	-0.000	-0.117		-0.000	-3.854	**
River or canal link	-0.009	-0.021		-0.072	-1.476	
Joint F	1.026			13.564**		
N	29			152		

Table 9. *Estimated thresholds*

	<i>Key markets</i>			<i>All market pairs</i>		
	<i>Coef</i>	<i>t-value</i>		<i>Coef</i>	<i>t-value</i>	
Constant	-0.919	-0.414		2.345	1.191	
Road in 1765?	1.279	1.009		1.065	1.134	
Distance in km	0.166	2.607	*	0.068	1.825	+
Distance*distance	-0.000	-2.458	*	-0.000	-1.430	
River or canal link?	0.008	0.065		-1.907	-1.412	
Joint F	1.81			2.51*		
N	29			152		

Table 10. *Adjustment speed in threshold cointegration model*

	<i>Key markets</i>			<i>All market pairs</i>		
	<i>Coef</i>	<i>t-value</i>		<i>Coef</i>	<i>t-value</i>	
Constant	-0.233	-1.532		-0.529	-5.388	**
Road in 1765?	-0.176	-2.036	*	-0.080	-1.711	+
Distance in km	-0.005	-1.225		0.002	1.219	
Distance*distance	0.000	1.340		-0.000	-0.612	
River or canal link?	0.027	0.318		0.070	1.037	
Joint F	1.73			2.94*		
N	29			152		

5. Sensitivity Analysis

To convince ourselves about the robustness of our results, we performed a further series of regressions. First, from a visual inspection of Figures 1, 2 and 3 and the other underlying data series, it is clear that at the end of the period considered, the data become unstable. Indeed, it was a period of substantial political and social instability, with the Brabantine Revolution (1789-1790) against the Austrian authorities, followed by the consequences of the French Revolution spilling over into the Austrian Low Countries from

1792. This instability in the relationships between markets has been documented in earlier analysis ³⁸. While the post-1788 period is too short to perform a full comparable analysis, we repeated the entire econometric analysis excluding the data until 1788. In this period, we continue to find systematic long-run integration (*via* cointegration tests) for all market pairs, while the lack of systematic fast or short-run integration remains the other main finding. Inspecting the thresholds, we find a few changes upwards or downwards, but they generally remain the same. Repeating the regressions in Tables 7 to 10 does not change our conclusions either. Coefficients remain very similar and one of the core findings the fact, that road building does not appear to have changed the transactions costs, as measured *via* the threshold, is still valid.

Secondly, our results appear robust to outliers in the left-hand side variables in Tables 9 and 10. Since the core results from these tables are determinants of estimated variables, it is possible that poor predictions result in large outliers. To control for this, very small and very large values were dropped to retain only about 80 percent of the observations. No change in the significance of the results or their interpretation could be detected. Thirdly, we tried a few other specifications, including one with interaction terms between roads and distance, but F-tests on restrictions suggested that the formulation in Tables 9 and 10 could not be rejected ($F(2,146) = 1.83$ for the thresholds and $F(2,146) = 1.37$ for the adjustment speed).

7. Interpretation

How can we interpret these findings? In particular, why did transaction costs not decrease as a result of paved road construction? Several points can be raised. High margins can be caused by many different factors. They could be a reflection of market power of traders. Indeed, if market power is sufficiently large, so that entry is practically impossible, new infrastructure will not necessarily have a large impact on the profits made by traders. This is not a very plausible explanation for this period. There is no evidence that a few large traders and their families dominated 18th-century grain trade in the Austrian Low Countries. Instead, most records suggest a relatively large number of medium-sized enterprises. Consequently, it is unlikely that this large number of traders could effectively control markets without any risk of being undercut by competitors ³⁹.

38. BUYST, E., DERCON, S. & VAN CAMPENHOUT, B., 1998.

A more plausible explanation for the sticky nature of transaction costs is the price structure of the tolls levied on paved roads. As the tolls varied according to the number of harnessed horses, bulk transport was discouraged. Consequently, the use of paved roads remained an expensive affair for wheat traders. Farmers were in very much the same position. In some instances, they even refused to use paved roads and returned to the old dirt roads. In those cases, the advantage of faster and cheaper transport was apparently more than offset by the cost of the tolls. Therefore, the toll issue remained a matter of heated debate during the whole period under consideration ⁴⁰.

Discouraging bulk transport by levying toll on paved roads according to the number of harnessed horses had at least two important economic effects. First, it contributed to the continuing high level of fixed costs relative to variable costs in transport ⁴¹. Second, it favoured trade in high-value commodities, more specifically the move of luxury goods from the ports at the coast towards East into Liège and the Rhineland. The intention was to try to capture some of the high profits Dutch traders were making by this trade ⁴². Incentives were therefore created to invest in transport and trade of high-value commodities. Consequently, traders were not likely to invest at first in trade and transport of bulky commodities such as wheat. Furthermore, there was little scope for back-loading as well: on the way back from the East, traders would move other high value goods back, such as wine, rather than cereals. Consequently, we do not have any evidence of a large corresponding increase in new private transport capacity for inter-city cereal trade to capitalise on the better road infrastructure that could have resulted in cost or margin cutting.

The finding that adjustment speeds nevertheless increased is also interesting. While moving grain may not have become cheaper and long-run margins remained unaffected by roads, we observe that the adjustment speed of prices increased significantly. In other words, the main consequence of the road network expansion in the 18th century was a faster integration of markets: information flew faster and the threat that wheat could be shipped increased.

39. VAN HOUTTE, H., 1920.

40. See B. BLONDÉ & R. VAN UYTYEN, 1999.

41. The non-linear relationship in costs means that for relatively large distances, costs are coming down (Table 9). However, the coefficient on the quadratic term is relatively small, so that the reduction is limited.

42. DE VRIES, J. & VAN DER WOUDE, A., 1997.

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We analysed the integration of wheat markets across 18 towns in the Austrian Low Countries in the second half of the 18th-century and its relationship with the expansion of the paved road network in this period. During this century, the paved road network expanded fast, resulting in paved road connections between most towns by 1800. An inspection of data on wheat prices suggests fairly complicated trading patterns, with periods of either no trade or trade reversals. Consequently, we use a switching regression approach (threshold cointegration) to study long-run and short-run integration of these markets. We find that throughout this period, markets were spatially interconnected, presumably through arbitrage. However, adjusting price margins after local shocks to long-term levels was relatively slow and took about 42 days on average. We also find relatively high thresholds, suggesting relatively high transaction costs. The implication is also that in many periods, no trade took place between certain towns, while trade flows were likely to have switched regularly in response to local conditions.

It is widely accepted in Belgian historiography that the construction of a paved road network caused a substantial reduction in transaction costs. Our research, however, indicates that transaction costs were mainly influenced by distance and fixed costs, not by the expansion of a paved road network. However, adjustment speeds in markets were affected by the existence of paved roads. The evidence is consistent with a fairly complex but integrated grain market. The price structure of tolls levied on paved roads discouraged bulk transport. Therefore, the expansion of a paved road network mainly favoured high-value trade, attempting to capture rents from trade with the Rhineland in neighbouring countries. New private investment in inter-city grain trade that may have led to the cutting of price margins and trading costs typically appears not to have happened in this period. Nevertheless, better communication and transport facilities due to the road network resulted in faster arbitrage.

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Annex 1

Principle, Aim and Limits of the Cointegration Approach

Two markets are said to be integrated if they are connected through a process of arbitrage. If markets are integrated, this will manifest itself in the price movements of a single homogenous good in the two markets. Price movements in one market will be transmitted to the other market, hence studies that try to assess market integration rely heavily on the correlation or co-movement of prices.

The first attempts to assess the degree of market integration relied on simple bivariate correlation coefficients between price levels in the two markets⁴³ or between changes in the price levels in the two markets⁴⁴. However, this approach was limited in terms of modeling the dynamics underlying arbitrage. The first study to explicitly acknowledge that trade between two markets takes time, and hence prices can react with a lag, was written by Ravallion⁴⁵. He proposed an Autoregressive Distributed Lag model that can distinguish unrelated markets from short-run integrated markets and long-run integrated markets. He also showed that, when there is evidence of long-run market integration, the model belongs to the class of error-correction models.

The main issue with the Ravallion approach is the time series properties of the price data. Generally, price series are non-stationary in nature, meaning that the mean and variance are not constant over time. Loosely speaking, prices tend to wander about with no tendency to revert to a fixed mean. Granger and Newbold showed that regressions involving the levels of such data produce misleading results⁴⁶. However, there is not only bad news. If there exists a linear combination of two non-stationary time series that results in a stationary residual, the two price series are said to be cointegrated. This means that the two series are, as it were, drifting together at roughly the same rate. In this case, it is possible to distinguish between the long-run equilibrium (i.e. the manner in which the two variables co-move over time), and the short-run dynamics (i.e. the deviations of the two variables from their long-run trend). The first can be done by looking at the cointegrating vector, while the latter can be studied using the error-correction representation⁴⁷.

More specifically, let P_t^i denote the price of a homogenous good at time t in market i . If a researcher wants to use cointegration analysis to assess the degree of market integration between two markets (say markets 1 and 2), he will start by testing the stationarity of the price series. This involves a standard unit root test for the

43. BLYN, G., 1973; RICHARDSON, D. J., 1978.

44. STIGLER, G. J. & SHERWIN, R. A., 1985.

45. RAVALLION, M., 1986.

46. GRANGER, C. W. J. & NEWSOLD, P., 1974.

47. ENGLE, R. F. & GRANGER, C. W. J., 1987.

price series of each market, for instance the following test, proposed by Dickey and Fuller ⁴⁸:

$$\Delta P_t^j = \gamma P_t^j + \varepsilon_t$$

where $\Delta P_t^j = P_t^j - P_{t-1}^j$ is the change in the price of the good over time, ε_t are mean zero white noise innovations and γ is the parameter to be tested. The null of this test is that γ equals zero (in which case the process is non-stationary) against the alternative that it is less than zero (in which case the series is stationary). Hence, the standard t-ratio would provide the test statistic. The time series properties, however, render the standard critical values of the t-test invalid, so that inference has to be based on the Dickey-Fuller critical values that were obtained using Monte Carlo simulations. These critical values can be found in most econometrics handbooks.

If the series appears to be non stationary, it has to be first differenced, and the test has to be carried out again. If it is stationary after first differencing, it is said to be integrated of order one, denoted as I(1). Most economic time series are integrated of order 1.

Next, one has to test for cointegration between the two series. This can be done

$$P_t^1 = \alpha + \beta P_t^2 + \varepsilon_t$$

by running a
s t a n d a r d
Ordinary Least

Squares regression of the form:

$$\Delta \varepsilon_t = \delta \varepsilon_{t-1} + v_t$$

and saving the residuals. Next, a third unit root test has to be performed, this time on the saved residuals. Hence:

where v_t is again a zero mean residual and δ is tested to be significantly smaller than zero using the Dickey-Fuller critical values. If this turns out to be the case, then the prices are said to be cointegrated. The constant α in the cointegrating regression can then be interpreted as the constant margin between the two markets (roughly speaking, the transaction cost),

$$\Delta P_t^1 = \Phi \Delta P_{t-1}^2 = \lambda (P_{t-1}^1 - \alpha - \beta P_{t-1}^2) + \omega_t$$

king, the trans-
action cost),

while the β can be interpreted as a proportional transaction cost ⁴⁹. Given that a long-run relationship between the prices in the two markets has been established, the short-run dynamics can be investigated by re-estimating the process as an error-cor-

48. DICKEY, D. A. & FULLER, W. A., 1979.

49. DERCON, S., 1995.

rection specification following the Granger representation theorem. In its simplest form, an error-correction representation would look like this:

where w_t is again an error term and F and l are parameters to be estimated by an Ordinary Least Squares regression. This process describes how the prices in the two markets behave in the short run, consistent with a long-run cointegrating relationship. Indeed, if the prices in both markets can both wander about, but they tend to wander together in the long run, there must be some force that keeps them from wandering apart indefinitely. This is exactly what the l in the error correction specification does. Hence, this parameter will be estimated negative: if there is a deviation from the cointegrating relationship, this will have to be corrected sooner or later. Therefore, it is an indicator of the speed at which the prices adjust back to their long-run equilibrium after a prior disequilibrium. A more intuitive way to interpret this parameter is to express it in terms of half-lives, which gives the time that is needed for an initial shock to the long-run equilibrium to return to half of its initial value. For instance, if the parameter is estimated to be -1 , this means that any error is completely corrected within one time period, and hence the half-life will be zero. Generally, the lower the absolute value of l , the more sluggish the price adjustment will be.

The major problem with cointegration analysis in the context of market integration studies is that it does not adequately model the non-linearities that are caused by the existence of transaction costs⁵⁰. In theory, if the price difference between two markets falls short of the transaction cost of moving the goods between the two, a rational trader will stop trading, and the prices in each market will be determined by local demand and local supply. In other words, within the band created by the transaction cost, one expects no adjustment. Obviously, this will influence the time series properties of the price series: the existence of this band will lead to a higher probability of rejecting cointegration.

As we saw above, cointegration methods estimate a long run relationship between two markets with a constant transaction cost, and deviations from this relationship, be they positive or negative, are corrected at the same speed l . Hence, cointegration methods are only valid in a specific market setup where one market is indisputably a net exporter and the other is a net importer. These two markets are connected by a continuous trade flow, and reversal of trade flows is not allowed. In this setting, a positive deviation from the long-run relationship can be seen as too little arbitrage, while a negative deviation from the long-run relationship is interpreted as too much arbitrage. These 'errors' will be corrected in subsequent periods, when traders adjust their behavior by shipping more or less goods. However, even in this case it is likely that adjustment will be asymmetric, in that negative errors

50. McNew, K. & FACKER, P., 1997.

will be corrected at a different speed than positive errors.

If we acknowledge that transaction costs result in a band where no arbitrage takes place, the cointegration approach becomes less attractive. In situations where markets are not logically linked by a continuous flow of goods in one direction and where a reversal of trade flows is possible, one has to search for alternative methods that incorporate the non-linear adjustment process. For goods that are both a major cash crop and a main staple food with a high volume of trade, reversal of trade flows should not simply be ruled out. Situations where the price in the importing market occasionally drops below the price in the exporting market (as is frequently the case in our sample) can be seen as an indication of the possibility of trade flow reversals.

The approach used in the main part of the paper accommodates these issues. It allows for a range of differences between market prices in which there is no trade, and hence no price adjustment. Furthermore, it also allows for trade flow reversals, thereby providing a significant improvement on standard cointegration and error-correction methods used to model price dynamics. However, the approach in this paper has its limitations, too. It has been criticized on the grounds that it assumes constant transaction costs. In a world where most economic series (like our price series) are found to be non-stationary, this may indeed seem like a very strong assumption. Furthermore, the way in which the thresholds are estimated does not provide us with standard errors for the estimates and hence it is impossible to say something about how precisely the transaction costs are estimated. A last reservation is that this method restricts itself to the analysis of the link between two mar-

	<i>Levels</i>		<i>First differences</i>	
	<i>DF</i>	<i>ADF(12)</i>	<i>DF</i>	<i>ADF(12)</i>
Tournai	-0,66	-0,09	-22,75	-5,98
Mons	-0,21	0,14	-9,39	-2,98
Binche	-0,27	0,21	-9,00	-3,06
Ath	-0,29	0,24	-9,25	-3,08
Charleroi	-0,41	0,07	-8,14	-2,34
Namur	-0,32	0	-6,70	-2,22
Brussels	-0,32	-0,01	-8,24	-3,08
Tienen	-0,5	0,12	-5,10	-1,76
Mechelen	-0,49	-0,01	-9,29	-3,50
Antwerp	-0,25	-0,1	-9,44	-3,40
Lier	-0,46	0,17	-7,96	-3,50
St Niklaas	-0,51	-0,31	-7,80	-3,04
Ghent	-0,51	-0,31	-7,82	-2,81
Bruges	-0,38	-0,13	-8,51	-2,82
Veurne	-0,69	-0,38	-8,28	-2,42
Ieper	-0,54	-0,38	-9,98	-2,26
Kortrijk	-0,54	-0,27	-10,93	-4,13
Leuven	-0,41	0,19	-25,33	-5,10

kets at a time. However, markets typically form part of a wider market system, where arbitrage from one market to another market often proceeds via several other

markets. Hence, a more multivariate approach would be interesting, but the empirical

dif-

cal

			DF	ADF(12)
Mons	Tournai	-8,89	**	-3,24 **
Brussels	Tournai	-8,86	**	-3,74 **
Ieper	Tournai	-8,41	**	-3,79 **
Charleroi	Mons	-10,10	**	-4,02 **
Namur	Mons	-8,33	**	-3,90 **
Mechelen	Mons	-8,30	**	-3,76 **
Antwerp	Mons	-7,81	**	-3,75 **
Ghent	Mons	-6,66	**	-3,41 **
Ath	Binche	-9,06	**	-3,00 **
Namur	Binche	-8,50	**	-4,21 **
Brussels	Binche	-9,08	**	-4,12 **
Charleroi	Ath	-9,17	**	-3,55 **
Namur	Ath	-8,29	**	-3,87 **
Kortrijk	Ath	-5,89	**	-3,18 **
Leuven	Charleroi	-13,94	**	-4,05 **
Tienen	Brussels	-9,09	**	-3,75 **
Antwerpen	Brussels	-8,41	**	-4,57 **
Bruges	Brussels	-5,97	**	-3,37 **
Mechelen	Tienen	-8,42	**	-3,74 **
Lier	Mechelen	-9,61	**	-3,78 **
Leuven	Antwerp	-9,80	**	-3,78 **
Leuven	Lier	-6,73	**	-3,66 **
Bruges	St Niklaas	-7,02	**	-4,07 **
Veurne	Ghent	-6,97	**	-4,46 **
Leuven	Ghent	-7,08	**	-2,78 **
Ieper	Veurne	-9,55	**	-4,58 **
Kortrijk	Veurne	-8,35	**	-4,07 **

Annex 2

Table 1 *Results of stationarity tests*

H0 of unit root 5% critical value is -1.95^{51} . Results imply that all markets are non stationary in levels, but stationary in differences (except for Tienen).

Table 2. *Cointegration tests in indirectly linked markets*

Note: 1% critical value is -2.60 (**) 5% critical value is -1.95 (*)

10% critical value is -1.61 (+)

Results imply that all market pairs reported are integrated in the long run.

51. FULLER, W. A., 1976.

<i>Market pairs</i>		<i>DF</i>	<i>sig</i>	<i>ADF(12)</i>	<i>sig</i>
Ath	Tournai	-7.82	**	-2.92	**
Ghent	Tournai	-7.79	**	-3.09	**
Kortrijk	Tournai	-10.19	**	-4.49	**
Binche	Mons	-9.41	**	-2.37	*
Ath	Mons	-7.21	**	-2.17	*
Brussels	Mons	-6.23	**	-1.72	+
Charleroi	Binche	-7.79	**	-1.65	+
Brussels	Ath	-7.08	**	-2.89	**
Namur	Charleroi	-11.39	**	-2.34	*
Brussels	Charleroi	-9.51	**	-3.18	**
Brussels	Namur	-7.82	**	-2.68	**
Tienen	Namur	-6.10	**	-2.34	*
Leuven	Namur	-9.65	**	-2.94	**
Mechelen	Brussels	-8.63	**	-4.34	**
Gent	Brussels	-4.21	**	-2.25	*
Leuven	Brussels	-10.56	**	-3.39	**
Leuven	Tienen	-6.22	**	-1.65	+
Antwerp	Mechelen	-7.55	**	-3.99	**
Leuven	Mechelen	-7.84	**	-3.15	**
Lier	Antwerp	-5.53	**	-2.42	*
St Niklaas	Antwerp	-7.41	**	-3.23	**
Gent	Antwerp	-5.56	**	-1.94	+
Bruges	Antwerp	-5.17	**	-1.91	+
Ghent	St Niklaas	-5.43	**	-1.6	
Bruges	Ghent	-6.84	**	-2.37	*
Kortrijk	Ghent	-6.03	**	-3.01	**
Veurne	Bruges	-5.21	**	-1.68	+
Ieper	Bruges	-5.23	**	-2.85	**
Kortrijk	Bruges	-6.11	**	-2.47	*
Kortrijk	Ieper	-7.85	**	-2.96	**

Table 3. *Stationarity of margins of key market pairs*

Note: 1% critical value is -2.58 (**) 5% critical value is -1.95 (*)
10% critical value is -1.62 (+)

Virtually all the key market pairs seem to have stationary margins — another way of looking at long-run integration (i.e. imposing a coefficient of one on the price in the cointegrating vector) — at least at 10 percent. A model defined in margins appears plausible.

		<i>Threshold</i>	<i>Rho out</i>	<i>t rho out</i>	<i>Short run integration</i>	<i>sig</i>	<i>ARI</i>	<i>tARI</i>	<i>Short run integration</i>	<i>sig</i>
Mons	Tournai	2,80	-0,46	-8,68 **	10,19 **		-0,35	-8,63 **	16,40 **	
Brussels	Tournai	15,00	-1,54	-7,41 **	-2,60		-0,29	-7,81 **	18,77 **	
Ieper	Tournai	0,50	-0,34	-8,01 **	15,55 **		-0,33	-8,33 **	17,10 **	
Charlero	Mons	6,30	-0,42	-7,29 **	10,07 **		-0,21	-6,49 **	24,05 **	
Namur	Mons	4,80	-0,19	-4,88 **	20,80 **		-0,13	-4,87 **	32,97 **	
Mechelen	Mons	5,50	-0,37	-6,43 **	10,95 **		-0,21	-6,31 **	24,03 **	
Antwerp	Mons	3,90	-0,30	-6,01 **	14,02 **		-0,21	-6,40 **	24,22 **	
Ghent	Mons	13,00	-0,41	-4,72 **	6,79 **		-0,12	-4,84 **	34,35 **	
Ath	Binche	2,28	-0,50	-8,56 **	8,56 **		-0,38	-9,14 **	15,00 **	
Namur	Binche	5,80	-0,33	-6,02 **	12,22 **		-0,17	-5,80 **	27,54 **	
Brussels	Binche	2,50	-0,38	-7,65 **	12,48 **		-0,29	-7,77 **	19,44 **	
Charlero	Ath	10,00	-0,64	-6,66 **	3,75 **		-0,24	-6,90 **	22,37 **	
Namur	Ath	6,50	-0,33	-5,97 **	12,12 **		-0,16	-5,45 **	29,47 **	
Kortrijk	Ath	3,00	-0,24	-6,45 **	20,43 **		-0,19	-6,25 **	25,96 **	
Leuven	Charlero	2,96	-0,91	-12,36 **	1,22		-0,58	-11,19 **	8,22 **	
Tienen	Brussels	17,30	-0,94	-6,26 **	0,40		-0,12	-4,97 **	36,01 **	
Antwerp	Brussels	1,00	-0,37	-7,90 **	13,45 **		-0,32	-8,30 **	17,47 **	
Bruges	Brussels	3,00	-0,15	-4,62 **	26,18 **		-0,12	-4,66 **	35,60 **	
Mechelen	Tienen	20,01	-1,39	-6,74 **	-1,89		-0,10	-4,32 **	40,96 **	
Lier	Mechelen	1,21	-0,36	-7,86 **	13,97 **		-0,31	-8,05 **	18,20 **	
Leuven	Antwerp	1,73	-0,56	-9,57 **	7,52 **		-0,43	-9,18 **	12,37 **	
Leuven	Lier	6,01	-0,31	-6,08 **	13,53 **		-0,15	-4,91 **	29,00 **	
Bruges	St Niklaas	1,00	-0,18	-5,76 **	26,24 **		-0,16	-5,59 **	28,69 **	
Veurne	Ghent	3,01	-0,13	-4,64 **	31,05 **		-0,10	-4,45 **	38,48 **	
Leuven	Ghent	8,00	-0,24	-5,47 **	17,32 **		-0,12	-4,38 **	33,60 **	
Ieper	Veurne	1,00	-0,27	-6,97 **	18,84 **		-0,25	-7,07 **	21,74 **	
Kortrijk	Veurne	2,50	-0,34	-7,47 **	14,50 **		-0,26	-7,31 **	20,60 **	

Table 4. *Results of threshold models and tests for short-run integration*

Results indicate that only four market pairs appear integrated in the short run.