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Road Expansion and Market Integration in the Austrian Low Countries during the Second Half of the 18th Century.

by

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Development Economics

Center for Economic Studies
Discussions Paper Series (DPS) 00.10
http://www.econ.kuleuven.be/ces/discussionpapers/default.htm

March 2000

DISCUSSION
PAPER

Road expansion and market integration in the Austrian Low Countries during the Second Half of the 18th Century

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We analyse the integration of wheat markets across 18 towns in the Austrian Low Countries during the second half of the 18th century and the relationship with the rapidly expanding paved road network in this period. We use a switching regression approach (threshold cointegration) to study long-run and short-run integration of these markets, using monthly wheat prices. We find that throughout this period, markets were spatially interconnected. However, price margins adjust only slowly to long-term levels in response to local shocks. We also find that transaction costs are 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 mainly influenced transaction costs, not the expansion of a paved road network. Two factors can account for this. First, the toll structure on paved roads discouraged bulk trade. Secondly, new private investment in inter-city grain trade that may have led to cuts in the trading costs, typically appeared to be absent in this period. However, adjustment speeds in markets are significantly affected by the existence of paved roads. Better communication and faster transport due to the road network resulted in faster arbitrage.

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1. INTRODUCTION

The integration of commodity markets has become a hot topic in the economic history literature of the 1990s. Therefore, it comes as no surprise that the Twelfth International Economic History Congress, organised in Madrid in 1998, devoted a separate session to the subject (Nunez (1998))[1]. Especially the integration of food markets attracts a lot of attention from researchers. It is easy to understand why. As a local market becomes more closely linked with its neighbours, the potential food supply zone of that local market will increase substantially. Consequently, local harvest conditions will exert less influence on local prices in an integrated market system. A local harvest failure, for instance, will lead to less upward pressure on local prices, as the price differential with neighbouring markets will soon trigger off an inflow of food from these markets. It is precisely the possibility for high-price areas to import food from low-price areas that reduces price volatility in well-integrated markets (Gibson and Smout (1995)). As such, the process of market integration diminishes the risk of local or regional famines. More in general, it reduces uncertainty for both consumers and producers of food, which improves the quality of life and favours economic development.

Not only the important positive effects of market integration explains the current attention for the subject. Since the 1980s the methods to analyse the behaviour of markets have changed dramatically. Financial theory gave the initial impetus by developing a new framework to investigate the performance of stock markets. Soon, however, it became clear that these techniques could also be used to scrutinise commodity markets. In conjunction with the spectacular breakthroughs in computing power, cliometricians did not hesitate to apply these new tools to economic history[2].

Initially, Belgian historiography remained untouched by these developments[3], but in the late 1990s things started to change. Especially the second half of the 18th century received much attention (Buyst, Dercon and Van Campenhout (1998), Dercon and Van Campenhout (1998), Van Campenhout (1998)). Why?

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[1] The various contributions to this book also provide a rich bibliography.

[2] Examples are Ejrnaes and Persson (1997) and Grennes and Goodwin (1998).

[3] Of course, we do not claim that research on market integration in the Austrian Low Countries only started in the late 1990s. We refer e.g. to Van der Wee (1963) and Vandenbroeke (1972). We merely argue that their analysis did not go beyond the use of correlation coefficients. As we know today, the use of correlation coefficients can generate highly misleading results.

The second half of the 18th century is a crucial period of change in the development of the economy in the Austrian Low Countries. Population growth soared and per capita income did gradually increase, causing a steep rise in domestic food demand. Nevertheless, the Austrian Low Countries managed to export grain during most of the period under consideration. This indicates that grain production expanded rapidly in the second half of the 18th century. Crop yields reached top levels compared with other continental European areas when improved techniques allowed fallow to disappear in the crop rotation system (Vandenbroeke (1975), Van Zanden (1993)). Second, an impressive network of paved roads was built in the Austrian Low Countries during the 18th century. It has been suggested that this caused a substantial reduction in transaction costs.

The absence of transport prices impedes us to quantify the beneficial effects of road construction on trade, but Blondé (1995) 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 transportation 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 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 methodological considerations and econometric techniques from the booming literature on spatial price analysis in agricultural economics. For an overview see Fackler and Goodwin (1999). 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 continuous, 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 (Taylor and Obstfeld (1998), Taylor and Prakash (1998)). In section 2 we give the data sources and in section 3 we present the general context. Section 4 explains the econometric methodology and section 5 gives the results. Section 6 presents some sensitivity analysis and section 7 gives the interpretation of our findings.

2. 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

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[4] From another point of view, Van der Wee was also very dissatisfied of the quality of the series published. See his book review of C. Verlinden (1959), in *Belgisch Tijdschrift voor Filologie en Geschiedenis*, vol. 39 (1961), pp. 942-944.

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 (Materne (1994)). In addition, the central government aimed at 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 (Vandenbroeke (1967)). 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 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[6]. Finally, these data were used as an input to produce detailed reports on the Austrian Low Countries' food situation (Materne (1994)). Vandenbroeke (1973) published a considerable part of these data. For various agricultural products he noted down the prices observed during the first market day of the month. So, 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[7]. 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 (Dejongh (2000)). Absence of important wheat markets was the obvious result.

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[5] For a general assessment in a European context, see Persson (1996, 1999).

[6] A *razier* from Brussels is 49 litres.

[7] 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, F^{11}843).

3. 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.

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

Market	Hectolitre
Leuven	99,436
Charleroi	87,355
Brussels	70,039
Doornik	36,675
Ghent	36,463
Brugge	30,218
Veurne	28,441
St. Niklaas	26,369
Namen	24,055
Tienen	23,655
Ieper	18,166
Mechelen	17,769
Bergen	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^{11}843 (see footnote 8)

Looking at the evolution of wheat prices between 1765 and 1794 we notice a remarkable stability (for Brussels, see Figure I). The only real exception is 1789 a result of crop failure and mounting political tensions. Both elements would eventually lead to the socalled 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.

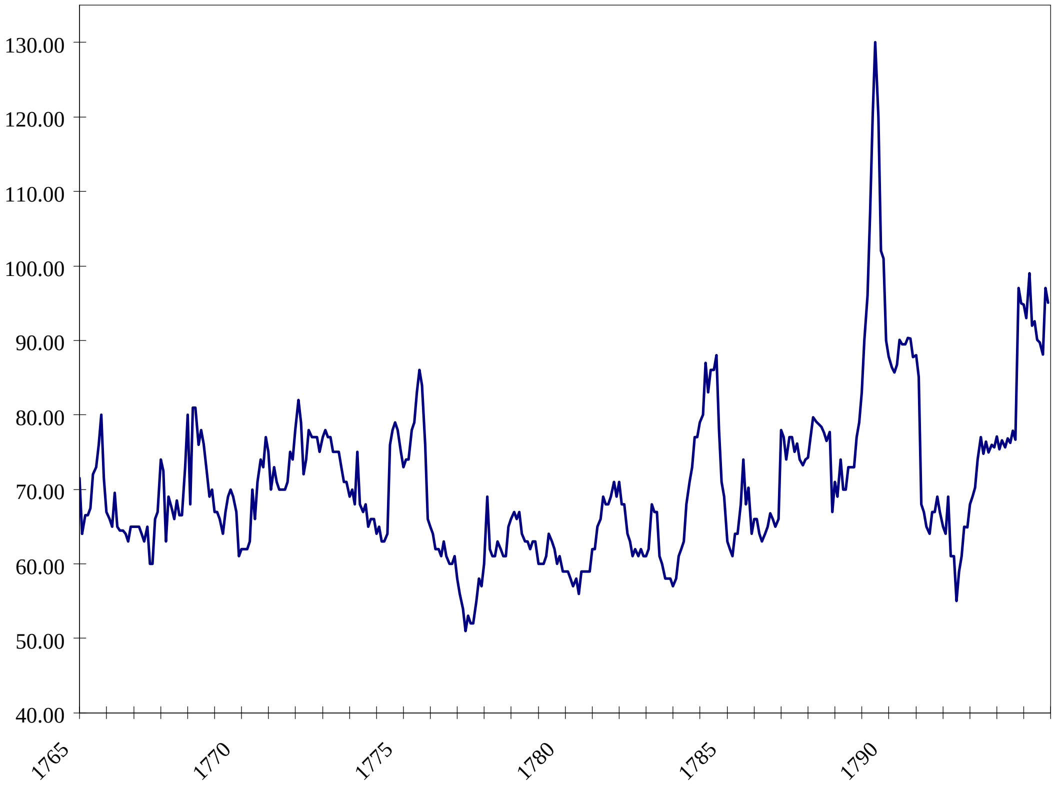

Figure I: Wheat prices in Brussels, 1765-1794 (in Brabantine stuivers per razier from Brussels)

To introduce price differences between markets, we focus on two large markets 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 II 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 be too small to check the persistence of the earlier patterns.

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.

Other markets display similar features. For example, Figure III 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 (Dejongh (2000)). So, grain is usually flowing from Brussels to Ghent in this period. Margins appear to be fluctuating, but from the mid-1770s they settle on some more persistent level. Fluctuations sometimes result in very small or negative margins, also suggesting the absence of profitable trade or possibly trade reversals.

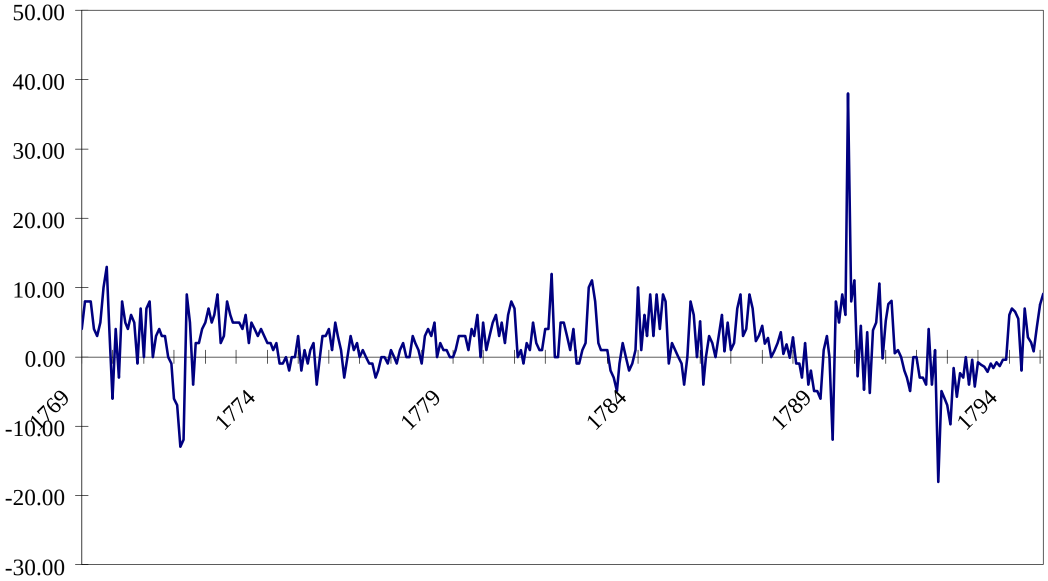

Figure II: First differences of wheat prices in Brussels and Leuven, 1769-1794

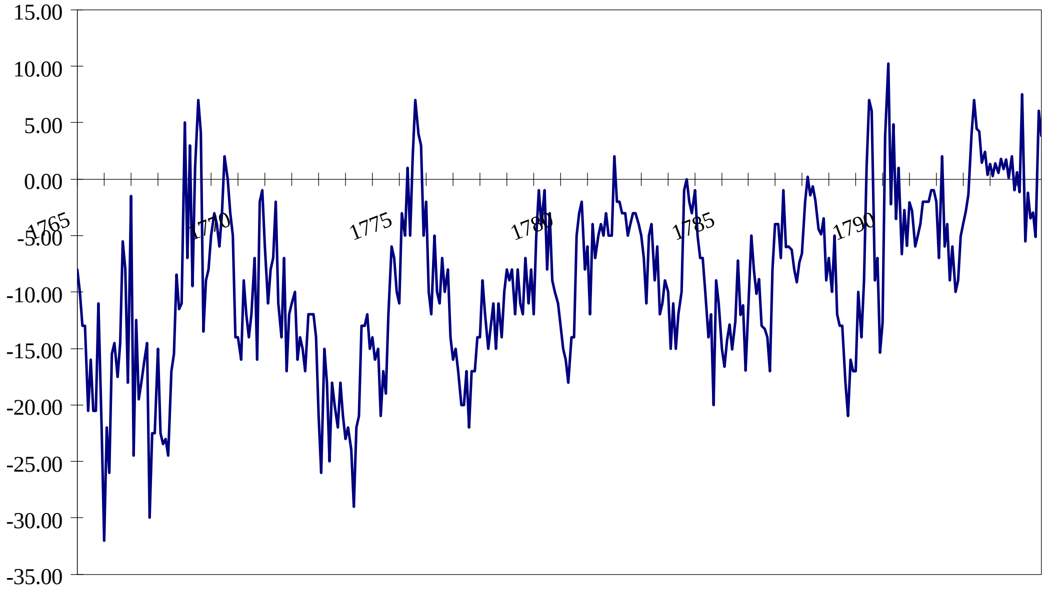

Figure III: First differences of wheat prices in Brussels and Ghent, 1765-1794

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 the 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 Bergen (Map 1). 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 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 (see map 2) and a decade later the east-west project was realised[8]. Blondé (1995) 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. By the end of the period (1793, map 3) provincial roads expanded, so that the Austrian Low Countries had obtained the highest paved road density in Europe (Genicot (1946)).

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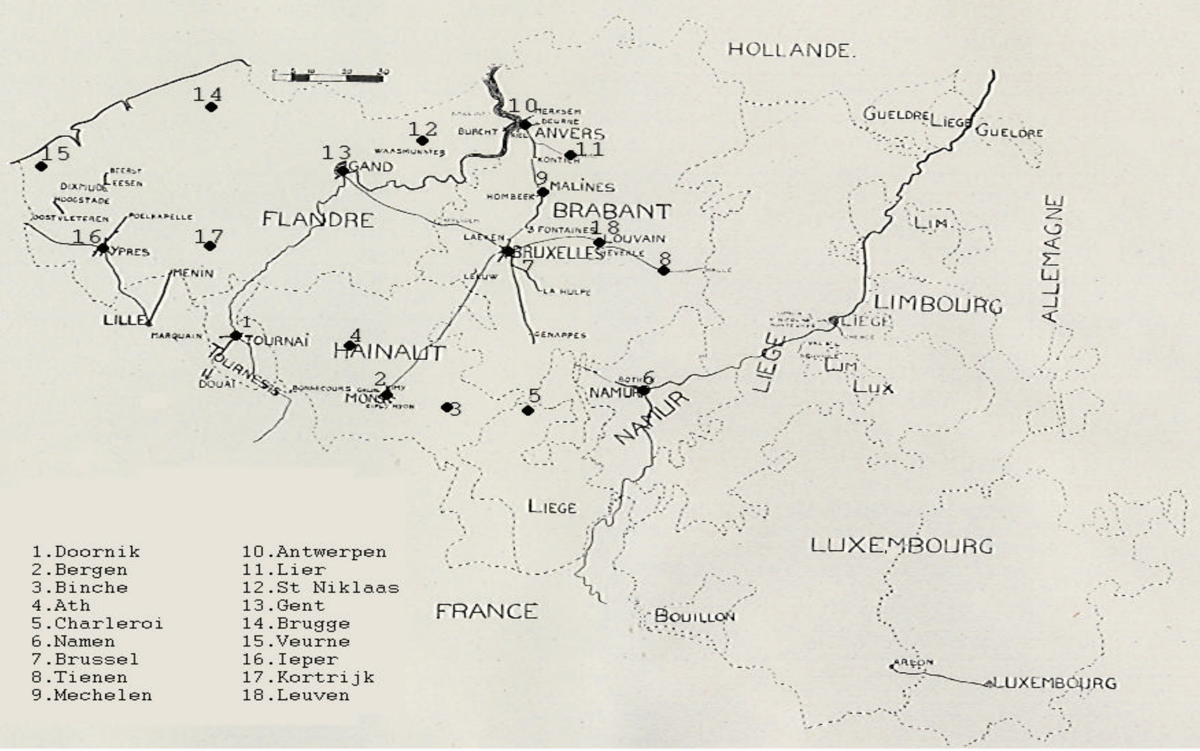
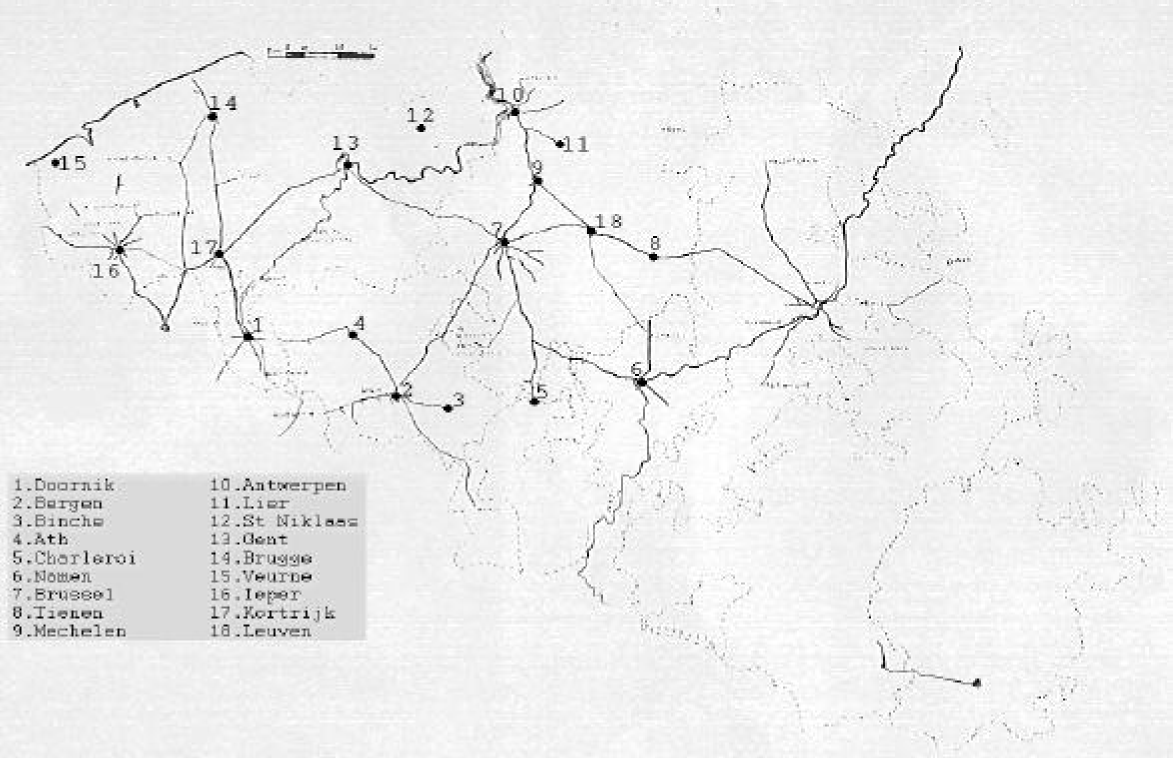
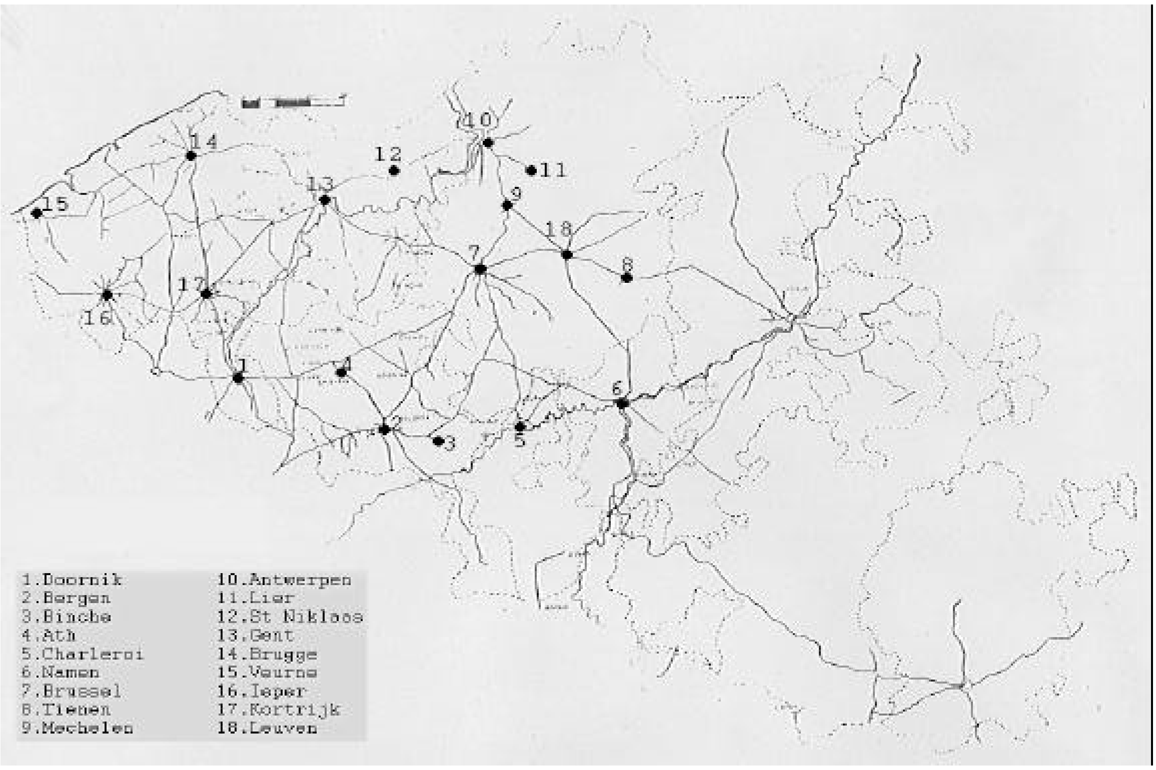
[8] For more details, see, e.g., Thewes (1994), Genicot (1939 and 1946), Urbain (1939).



Map 1: Paved road network in 1718



Map 2: Paved Road Network in 1763



Map 3: Paved Road Network in 1793

4. DATA ANALYSIS METHOD

In the analysis, we can only rely on price data and on some information about the extension of the paved road network. First, we will try to exploit 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 then 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 is possible or trade flows are reversed. Consequently, we need an approach that can handle this situation.

Formally, let C_t^{ij} be the transactions cost of moving grain between markets i and j in period t. Let P_t^i be the p rice of grain in market i. Efficient spatial arbitrage (Takayama and Judge (1971)) requires then that there are unexploited profits from trade between market i and j unless:

$$\left| P_t^i - P_t^j \right| \leq C_t^{ij} \tag{1}$$

Non-zero trade flows under efficient arbitrage would imply equality of both sides in (1). Efficient arbitrage could imply flows from i to j and 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 (1987), if (1) is valid, then the two spatially separated markets will be referred to as integrated. 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 integration. Cointegration models only use price data and test whether in the long run there is a particular stable relationship between prices in i and j. 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:

$$P_t^i = \alpha + \beta . P_t^j + \eta_t \tag{2}$$

Stationarity of η_t implies the existence of a long-run relationship between prices: they move together. Implicit in the model, 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 relationship (Palaskas and Harriss-White (1993), Alexander and Wyeth (1994), Goodwin and Schroeder (1987)). However, it is clearly only a limiting case of the efficient arbitrage condition 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 (Balke and Fomby (1997), Prakash and Taylor (1997), Obstfeld and Taylor (1997), Goodwin and Grennes (1998)).

Suppose that, as is usually the case, (real) prices in market j and i 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 price in i and j as:

$$m_t = P_t^i - P_t^j \tag{3}$$

Suppose that for the time being we have no information about trade flows nor about transaction costs. We can distinguish three regimes: $m_t > C^{ij}$, $m_t < -C^{ij}$ 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 (second) regime, market traders have not exploited profitable trade opportunities, in moving grain from i to j (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 on the band are reached. Even though m_t does not return to a particular equilibrium level but a to a band, m_t is a stationary process (Balke and Fomby (1997)). 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 (Prakash and Taylor (1997), Obstfeld and Taylor (1997), Balke and Fomby (1997)). 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 PPP 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 is a percentage of the deviation in each period. Formally, defining $\Delta m_t = m_t - m_{t-1}$, we can write this process as:

$$\Delta m_t = \begin{cases} r\,.\left(m_{t-1} - C^{ij}\right) + h_t^{out} & m_{t-1} > C^{ij} \\ h_t^{in} \qquad\qquad if & \left|m_{t-1}\right| \le C^{ij} \\ r\,.\left(m_{t-1} + C^{ij}\right) + h_t^{out} & m_{t-1} < -C^{ij} \end{cases} \tag{4}$$

where the errors are white noise, i.e. n_t^{out} is i.i.d. $\left(0,\sigma_{out}^2\right)$ and η_t^{in} and η_t^{in} is i.i.d. $\left(0,\sigma_{in}^2\right)$; ρ is the speed of adjustment of m_t towards the band $\left[-C^{ij},C^{ij}\right]$[9]. The value of ρ is expected to be in the half open interval]0, -1][10]. Inside the band, 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):

$$\begin{cases} \Delta P_t^i = \Delta P_t^j + r\,.\left(P_{t-1}^i - P_{t-1}^j - C^{ij}\right) + h_t^{out} & P_t^i - P_t^j > C^{ij} \\ \Delta P_t^i = \Delta P_t^j + h_t^{in} \qquad\qquad \text{if} & \left|P_t^i - P_t^j\right| \le C^{ij} \\ \Delta P_t^j = \Delta P_t^i + r\,.\left(P_{t-1}^j - P_{t-1}^i - C^{ij}\right) + h_t^{out} & P_t^j - P_t^i > C^{ij} \end{cases} \tag{5}$$

Inside the band, there is no systematic dynamic relationship between changes in prices in each market. However, outside the band, error-correction behaviour can be observed. 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. Similar to 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 includes margins up to and including the parity

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[9] 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.

[10] 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.

bound; only when imperfect arbitrage takes place, we will 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 (1997) 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.

Even though locally the margin in this model is non-stationary, overall it is stationary, provided ρ is non-zero. Of course, stationarity will need to be tested. Balke and Fomby (1997) use Monte Carlo simulations to investigate the power of a large number of tests and find that standard tests for cointegration, such the ADF or the Phillips-Perron tests still have reasonably high power, even if the true model is a TAR[11]. 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 Δm_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 is two sub-samples, one with all 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 (as in Prakash (1996), in Prakash and Taylor (1997) and in Obstfeld and Taylor (1997)), or to maximise the sum of the residual sum of squared errors in each of the sub-samples (Balke and Fomby (1997)). Given the piece-wise 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}) (Chan (1993)) and the adjustment speed.

The estimated threshold provides an estimate of the margin used in trade. Its significance and a confidence interval is 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

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[11] 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 and Harriss-White (1994), Dercon (1995)).

the adjustment speed ρ gives the speed with which arbitrage restores equilibrium when profitable trade opportunities exist. The closer ρ 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 use these estimates further to look for the determinants of transactions costs and arbitrage speed across markets, more specifically the role of roads and distances.

5. 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 towns[12]. 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 towns[13].

Table 2 shows average margins (in absolute values) between 3 and 10 *stuivers* per *razier* from Brussels over the period. Distances are typically relative 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.

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[12] In annex we also provide further results of (potentially) more indirectly connected markets.

[13] In this period, rivers and canals connected directly the following towns: Charleroi-Namen (Samber), Brussels-Antwerp (canal), Lier-Antwerp (Nete), Leuven-Mechelen (canal), Ath-Doornik (Dender), Doornik-Gent-Antwerp (Scheldt), Brugge-Ghent (canal), Kortrijk-Ghent (Leie), Veurne-Brugge (canal), Ieper-Veurne (canal), Lier-Mechelen (Nete), Mechelen-Antwerp (Rupel).

Table 2: Main characteristics of key markets

Market Pairs:		Mean Margin*	Distance (km)	Road in 1718	Road in 1763	Road in 1793	River or canal 1763
Ath	Doornik	7.1	29	No	Yes	Yes	Yes
Ghent	Doornik	9.0	71	No	Yes	Yes	Yes
Kortrijk	Doornik	6.4	26	No	Yes	Yes	No
Binche	Bergen	4.5	15	No	Yes	Yes	No
Ath	Bergen	5.9	19	No	Yes	Yes	No
Brussels	Bergen	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
Namen	Charleroi	4.0	39	No	No	Yes	Yes
Brussels	Charleroi	5.3	59	No	Yes	Yes	No
Brussels	Namen	5.3	50	No	Yes	Yes	No
Tienen	Namen	5.9	45	No	No	No	No
Leuven	Namen	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
Brugge	Antwerp	7.4	160	No	No	No	Yes
Ghent	St Niklaas	9.1	30	No	No	No	No
Brugge	Ghent	6.9	62	No	No	No	Yes
Kortrijk	Ghent	8.9	45	No	Yes	Yes	Yes
Veurne	Brugge	9.5	45	No	No	Yes	Yes
Ieper	Brugge	7.7	48	No	No	Yes	No
Kortrijk	Brugge	8.3	46	No	Yes	Yes	No
Kortrijk	Ieper	6.2	25	No	Yes	Yes	No

* *stuiver* per *razier* from Brussels

To conduct the threshold cointegration analysis on the price series of these market pairs, we need to conduct first non-stationarity tests on the series. In Annex Table 1, we find that the series are non-stationary in levels, but stationary in first differences, as expected. Cointegration tests were conducted, as test for long-run co-movement of the price series. These tests (Dickey Fuller and Augmented Dickey Fuller tests with 12 lags) are reported in Table 3. We find that for all market pairs tested, the null of no cointegration is rejected at 1 percent for all but two markets, were it is rejected at 5 percent[14]. In short, cointegration

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[14] The null states that there is unit root behaviour in the error term of the cointegrating relationship, or equivalently, there is no cointegration. If the null is rejected, we have cointegration. So, 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.

is present, so that in the long-run all these markets are connected. Note that this is the case despite the absence of roads for a number of market pairs. When extending 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 stationarity of the errors in the cointegrating relationship. In Annex Table 2, we give some of the results. An alternative test involves looking at 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 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

Market Pairs:		DF	ADF(12)
Ath	Doornik	-7.69 **	-3.17 **
Ghent	Doornik	-9.15 **	-3.65 **
Kortrijk	Doornik	-9.97 **	-4.57 **
Binche	Bergen	-9.70 **	-2.82 **
Ath	Bergen	-7.76 **	-2.36 *
Brussels	Bergen	-8.70 **	-4.37 **
Charleroi	Binche	-11.45 **	-3.80 **
Brussels	Ath	-8.07 **	-4.64 **
Namen	Charleroi	-11.65 **	-3.81 **
Brussels	Charleroi	-11.75 **	-5.74 **
Brussels	Namen	-10.56 **	-4.73 **
Tienen	Namen	-8.76 **	-4.29 **
Leuven	Namen	-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 **
Brugge	Antwerp	-6.12 **	-2.59 *
Ghent	St Niklaas	-7.88 **	-3.63 **
Brugge	Ghent	-7.02 **	-2.62 **
Kortrijk	Ghent	-7.95 **	-4.19 **
Veurne	Brugge	-8.07 **	-3.61 **
Ieper	Brugge	-5.56 **	-3.59 **
Kortrijk	Brugge	-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 a 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 a 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 on 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 markets do we find that the null of short-run integration cannot be rejected (Ath-Doornik and Brussels-Charleroi). In short, even though the data are only monthly, the data 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 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 4: Dynamic adjustment model and short run integration

Market Pairs:		Threshold cointegration model (5)				AR(1) (simple error-correction) model		
		Estimated Threshold	Adjustment speed	t value adjustm.	Short run integration	Adjust-ment speed	t value adjust-ment	Short run s integration
Ath	Doornik	10.70	-1.01	-8.30 **	-0.08	-0.29	-7.82 **	19.23 **
Ghent	Doornik	4.00	-0.42	-7.93 **	10.95 **	-0.29	-7.79 **	19.09 **
Kortrijk	Doornik	1.40	-0.51	-10.18 **	9.78 **	-0.45	-10.19 **	12.43 **
Binche	Bergen	1.20	-0.46	-9.00 **	10.57 **	-0.40	-9.41 **	14.31 **
Ath	Bergen	3.20	-0.37	-7.24 **	12.33 **	-0.25	-7.21 **	21.22 **
Brussels	Bergen	8.50	-0.51	-5.67 **	5.45 **	-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 **
Namen	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	Namen	5.10	-0.67	-7.87 **	3.88 **	-0.28	-7.82 **	19.86 **
Tienen	Namen	2.00	-0.23	-5.90 **	19.75 **	-0.19	-6.10 **	26.41 **
Leuven	Namen	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 **
Brugge	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 **
Brugge	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	Brugge	7.91	-0.34	-6.14 **	11.92 **	-0.15	-5.21 **	30.57 **
Ieper	Brugge	2.30	-0.18	-5.24 **	23.87 **	-0.14	-5.24 **	31.10 **
Kortrijk	Brugge	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

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[15]. For comparison, we also give the half-life implied by the simple error-correction model. 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 5: Half life implied by the estimated adjustment speed (half lives in months)

Market Pairs:		Half-life
Ath	Doornik	0.00
Ghent	Doornik	1.27
Kortrijk	Doornik	0.97
Binche	Bergen	1.12
Ath	Bergen	1.50
Brussels	Bergen	0.97
Charleroi	Binche	0.76
Brussels	Ath	1.67
Namen	Charleroi	0.82
Brussels	Charleroi	0.00
Brussels	Namen	0.63
Tienen	Namen	2.65
Leuven	Namen	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
Brugge	Antwerp	4.27
Ghent	St Niklaas	2.53
Brugge	Ghent	0.82
Kortrijk	Ghent	2.20
Veurne	Brugge	1.67
Ieper	Brugge	3.49
Kortrijk	Brugge	1.06
Kortrijk	Ieper	1.80

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+Δx(t)/x(t-1), or in our case, b=1+ρ. If ρ is -0.5, then T is one, so it takes one month to correct half the shock. In the limit, when ρ approaches -1, any error in t-1 is fully corrected in t.

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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 appears 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 6 reports the estimated situation in the wheat markets of the Austrian Low Countries in this period. First note, that for 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. Also, 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 so. Unfortunately, one would need trade flow data to be able to confirm this interpretation, which are currently unavailable. 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 (Van der Wee (1963)). At the same time, wheat is a bulky, relatively low value commodity, so 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. 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.

Table 6: Direction of trade opportunities implied by regressions

Market (1)	Market (2)	Potential trade from (1) to (2)	Inside the transactions cost band 'no trade'	Potential trade from (2) to (1)
Ath	Doornik	14	73	13
Ghent	Doornik	15	28	57
Kortrijk	Doornik	46	16	38
Binche	Bergen	43	22	35
Ath	Bergen	35	36	30
Brussels	Bergen	24	75	2
Charleroi	Binche	52	44	4
Brussels	Ath	52	27	20
Namen	Charleroi	51	12	37
Brussels	Charleroi	8	57	35
Brussels	Namen	3	58	39
Tienen	Namen	67	26	6
Leuven	Namen	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
Brugge	Antwerp	22	14	64
Ghent	St Niklaas	2	40	59
Brugge	Ghent	31	59	9
Kortrijk	Ghent	60	30	10
Veurne	Brugge	55	43	2
Ieper	Brugge	59	18	23
Kortrijk	Brugge	30	63	7
Kortrijk	Ieper	51	13	36

Note: Figures are percentages of observations in the regime.

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 extent 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 value-added of modelling the markets as a switching regression model, allowing for no trade or trade reversals, we also did these regressions on the simple (absolute value of the) margin en 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 appear cointegrated, this would appear methodologically acceptable.

Tables 7 and 8 first give the evidence on respectively the margins and on the adjustment speed ρ 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 large distance trade. This is unsurprising since variable transaction costs presumably increase with distance. We cannot detect an effect of the presence of paved roads or links by rivers or canals. On the adjustment speed in Table 8, we notice that for larger distances, adjustment speed is affected by the 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 in 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[16]. 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

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[16] 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 waterways 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.

adjustment speed[17]. 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 did 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

	Key markets			All market pairs		
	coef	t-value		coef	t-value	
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		

Table 8 Adjustment speed in basic error-correction model

	Key markets			All market pairs		
	coef	t-value		coef.	t-value	
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		

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[17] The effect on rivers and canals remains insignificant in all possible formulations attempted. Dropping insignificant variables does not reduce 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 9 Estimated thresholds

	Key markets			All market pairs		
	coef	t-value		coef	t-value	
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

	Key markets			All market pairs		
	coef	t-value		coef	t-value	
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		

6. 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 I, II and III and the other underlying data series, it is clear that at the end of the period considered, the data become unstable. Indeed, it is a period of substantial political and social instability, first 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. Indeed, in earlier analysis (Buyst, Dercon and Van Campenhout (1998)), this instability in the relationships between markets has been documented. While the period post-1788 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 generally they remain the same. Repeating the regressions in Tables 7 to 10 also does not change the conclusions in this paper. Coefficients remain very similar and one of the core findings, that road building does not appear to have changed the transactions costs, measured via the threshold, is still valid.

Secondly, the 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 and 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 quite 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 sufficiently without risk of being undercut by competitors (Van Houtte (1920)).

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 farmers 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 (see e.g. Blondé and Van Uytven (1999)).

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[18]. Second, it favoured trade in high-value commodities, more specifically the move of luxury goods from the ports at the coast towards the 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 (De Vries and Van der Woude (1997)). Incentives were therefore created to invest in transport and trade of high-value commodities. So, 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 increased nevertheless is then interesting. While moving grain may not have become cheaper and long-run margins remain unaffected by roads, we observe that the adjustment speed increased significantly. In other words, the main consequence of the road network expansion in the 18th century was a faster integration of markets: information and goods flew faster, simple because communication and transport could use better infrastructure.

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[18] The non-linear relationship in costs means that at relatively large distance, costs are coming down (table 9). However, the coefficient on the quadratic term is relatively small, so the reduction is limited.

8. CONCLUSION

We analyse the integration of wheat markets across 18 towns in the Austrian Low Countries in the second half of the 18th century and the relationship with the expansion of a 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 is relatively slow and takes about 42 days on average. We also find relatively high thresholds, suggesting relatively high transaction costs. The implication is that in many periods, no trade takes place between certain towns, while trade flows are 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 are mainly influenced by distance and fixed costs, not by the expansion of a paved road network. The price structure of tolls explains to a large extent the sticky nature of transaction costs. As the tolls on paved roads varied according to the number of harnessed horses, bulk transport was discouraged. Therefore, the expansion of a paved road network mainly favoured high-value trade, attempting to capture rents from Dutch trade with Liège and the Rhineland. 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. The main effect of paved road construction was that the adjustment speed between markets increased. Clearly, better communication and faster transport due to the paved road network resulted in faster arbitrage.

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ANNEX

Annex Table 1: Results of stationarity tests

Market	levels		First differences	
	DF	ADF(12)	DF	ADF(12)
Doornik	-0.66	-0.09	-22.75	-5.98
Bergen	-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
Namen	-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
Brugge	-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

H0 of unit root 5 % critical value is –1.95 (Fuller (1976)).

Results imply that all markets are non-stationary in levels, but stationary in differences (except for Tienen).

Annex Table 2: cointegration tests in indirectly linked markets

		DF		ADF(12)	
Bergen	Doornik	-8.89	**	-3.24	**
Brussels	Doornik	-8.86	**	-3.74	**
Ieper	Doornik	-8.41	**	-3.79	**
Charleroi	Bergen	-10.10	**	-4.02	**
Namen	Bergen	-8.33	**	-3.90	**
Mechelen	Bergen	-8.30	**	-3.76	**
Antwerp	Bergen	-7.81	**	-3.75	**
Ghent	Bergen	-6.66	**	-3.41	**
Ath	Binche	-9.06	**	-3.00	**
Namen	Binche	-8.50	**	-4.21	**
Brussels	Binche	-9.08	**	-4.12	**
Charleroi	Ath	-9.17	**	-3.55	**
Namen	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	**
Brugge	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	**
Brugge	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	**

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.

Annex Table 3 Stationarity of margins of key market pairs

Market Pairs:		DF	sig	ADF(12)	Sig
Ath	Doornik	-7.82	**	-2.92	**
Ghent	Doornik	-7.79	**	-3.09	**
Kortrijk	Doornik	-10.19	**	-4.49	**
Binche	Bergen	-9.41	**	-2.37	*
Ath	Bergen	-7.21	**	-2.17	*
Brussels	Bergen	-6.23	**	-1.72	+
Charleroi	Binche	-7.79	**	-1.65	+
Brussels	Ath	-7.08	**	-2.89	**
Namen	Charleroi	-11.39	**	-2.34	*
Brussels	Charleroi	-9.51	**	-3.18	**
Brussels	Namen	-7.82	**	-2.68	**
Tienen	Namen	-6.10	**	-2.34	*
Leuven	Namen	-9.65	**	-2.94	**
Mechelen	Brussels	-8.63	**	-4.34	**
Ghent	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	**
Ghent	Antwerp	-5.56	**	-1.94	+
Brugge	Antwerp	-5.17	**	-1.91	+
Ghent	St Niklaas	-5.43	**	-1.6	
Brugge	Ghent	-6.84	**	-2.37	*
Kortrijk	Ghent	-6.03	**	-3.01	**
Veurne	Brugge	-5.21	**	-1.68	+
Ieper	Brugge	-5.23	**	-2.85	**
Kortrijk	Brugge	-6.11	**	-2.47	*
Kortrijk	Ieper	-7.85	**	-2.96	**

Note: 1% critical value is –2.58 (**)

5% critical value is –1.95 (*)

10% critical value is –1.62 (+)

Virtually all the key markets 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.

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

		Threshold	Rho Out	t rho out		Short run integration	sig	AR1	tAR1		short run integration	sig
Bergen	Doornik	2.80	-0.46	-8.68	**	10.19	**	-0.35	-8.63	**	16.40	**
Brussels	Doornik	15.00	-1.54	-7.41	**	-2.60		-0.29	-7.81	**	18.77	**
Ieper	Doornik	0.50	-0.34	-8.01	**	15.55	**	-0.33	-8.33	**	17.10	**
Charlero	Bergen	6.30	-0.42	-7.29	**	10.07	**	-0.21	-6.49	**	24.05	**
Namen	Bergen	4.80	-0.19	-4.88	**	20.80	**	-0.13	-4.87	**	32.97	**
Mechelen	Bergen	5.50	-0.37	-6.43	**	10.95	**	-0.21	-6.31	**	24.03	**
Antwerp	Bergen	3.90	-0.30	-6.01	**	14.02	**	-0.21	-6.40	**	24.22	**
Ghent	Bergen	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	**
Namen	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	**
Namen	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	**
Brugge	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	**
Brugge	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	**

Results indicate that only four markets appear integrated in the short-run.