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Intra- and international commodity market integration in the Atlantic economy, 1800–1913☆

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Abstract

In this paper, the course of intra- and international market integration in the nineteenth century Atlantic economy is investigated. The most fundamental contribution of the paper is in consistently sketching the course of commodity market integration over the long run. Additionally, this study suggests that the nineteenth century has been somewhat misread in terms of the development of markets as the evidence, especially on price convergence, points to dramatic improvements in intra- and international market integration in the years prior to the mid-century. A collective task for economic historians, then, is to link these developments with the revolutionary commercial and technological developments of the post-1850 period.

Keywords: Globalization; Commodity market integration; Wheat markets

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1. Introduction

What this paper sets as its task is to investigate the course of both intra- and international commodity market integration for a sample of 10 countries—namely Austria–Hungary, Belgium, France, Germany, Italy, Norway, Russia, Spain, the United Kingdom, and the United States—which participated in the Atlantic economy of the long nineteenth century from 1800 to 1913. Along the way, market integration is divided into two separate but related sub-processes, that of price convergence (roughly, the size of price differentials and their diminution over time) and price adjustment (roughly, the speed at which profitable price differential are arbitraged away). On this basis, a set of two criteria are formulated and then put to work as a means to assess the course of intra- and international market integration on a country-by-country basis.

The most fundamental contribution of the paper is in consistently sketching the course of commodity market integration over the long run. Additionally, this study suggests that the nineteenth century has been somewhat misread in terms of the development of markets as the evidence, especially on price convergence, points to dramatic improvements in intra- and international market integration in the years prior to the mid-century. A collective task for economic historians, then, is to link these developments with the revolutionary commercial and technological developments of the post-1850 period.

2. Motivation

As has been noted many times before, the process of market integration (generally explored under the aegis of the law of one price) has proven to be an area of abiding theoretical and empirical interest. Naturally, for the nineteenth century as well, no small number of scholarly works have been published in this vein which can be split into two distinct lines of inquiry: intra- and international.

In regards to the intranational line, there is an abundance of case studies to lead the way for us, the most informative of which are those for Austria–Hungary (Good, 1981; Szabad, 1961), the Benelux countries (Buyst et al., 2000; Dejongh et al., 2000; Griffiths, 1982), France (Chevet and Saint-Amour, 1991, 1992; Ejrnæs and Persson, 2000; Roehner, 1994), Germany (Fremdling and Hohorst, 1979; Gerhard and Engel, 2000; Kopsidis, 2002; Kuczynski, 1960), Norway (Hodne and Gjølberg, 1981), Italy (Sereni, 1947, 1966; Zamagni, 1983), Russia (Metzer, 1974, 1977; Milov, 1995), Spain (Barquín Gil, 1997; Gómez Mendoza, 1987; Peña and Sánchez-Albornoz, 1984), the United Kingdom (Chartres, 1995; Gourvish, 1970; Paterson and Shearer, 2001), and the United States (Coelho and Shepherd, 1974; Jue, 1999; Slaughter, 2001). However, while sharing a common unit of analysis—the nation-state—none of these studies presents comparable results, conclusions, or most importantly, methodologies. The primary contribution of this paper, then, is the application of a consistent set of criteria for commodity market arbitrage, in order to arrive at the most salient cross-country features of intranational market integration.

In regards to international markets, again, a relatively wide-ranging body of research exists (cf. Findlay and O'Rourke, 2001; Goodwin and Grennes, 1998; Hatton et al., 1994; Latham and Neal, 1983; Persson, 1999). And yet again, we are confronted with the same constraints as in the intranational studies—a lack of an overarching methodology in which to gauge relative performance on a country-by-country basis. Furthermore, those studies which are the fullest in terms of coverage and, thus, offer the most solid findings on the workings of international markets concentrate on developments in the second half of the nineteenth century and rely on grossly aggregated data, a situation which, as will be detailed below, has hopefully been resolved in this paper.

Finally, it is hoped that by proceeding from one level of analysis to another in step-wise fashion, this study should first uncover some hints as to what role the process of intranational integration played in the remarkable growth of the long nineteenth century and consequent convergence during this time. At the same time, the study will certainly shed more empirical light on the ongoing debates of the respective role of technology in market integration as well as the timing and evolution of the first wave of globalization.

3. Analytical framework

In the literature on historical and contemporary commodity markets, there have been numerous proposals for the correct measure of market integration. Drawing from these contenders, this paper takes market integration as a process of two separate but related developments, namely the articulation of a system of price convergence and adjustment.

On the issue of price convergence, it has been suggested that this is in fact the hallmark of market integration. The fundamental issue at hand is the formulation of an intra- and international division of labor—a process predicated, of course, upon the successful transmission of price signals across time and space. Undoubtedly, without the tendency for prices to converge, the concept of market integration becomes very hollow. However, it does not necessarily follow that price convergence is a sufficient condition for market integration as prices may be determined or influenced by processes outside of the realm of transaction and exchange (e.g., large-scale climatological events; on this point, see Post, 1977).

What is needed is some idea of the interrelationship among price systems (or series). Price adjustment can then be viewed as a supplementary element in the process of market integration. To this end, the simultaneous consideration of these two independent conditions, convergence and adjustment, is proposed as the proper approach to studies of market integration.

3.1. On the adjustment of prices

Recently, fairly dramatic developments have occurred in furthering our understanding of precisely how to model price adjustment in integrated markets. As has

been shown before (cf. Obstfeld and Taylor, 1997; Prakash, 1996; Prakash and Taylor, 1997), those studies of market integration based on the absolute law of one price (LOP) fail to compensate for the transportation and transaction costs associated with trade and, hence, proffer biased estimates of the speed of price adjustment.

In order to capture the effects of trade costs,[1] the model to be used incorporates a band equilibrium whereby prices in any market are allowed to be unresponsive to those in other markets for a given range of price differentials which are determined by trade costs. Thus, if prices are outside the band equilibrium they will adjust; but if prices are inside the band, price movements will be random. Further innovations to this model include asymmetric responses in the respective markets due to route-specific trade costs (Ejrnæs and Persson, 2000) and the modeling of storage strategies on the part of arbitrageurs (Coleman, 1995). In order to ease computational demands, however, only the former will be incorporated here.

To begin, the following two conditions describe the relation of prices in two locations in the presence of efficient goods-market arbitrage:

(1) $P_t^1 \leqslant P_t^2 + C_t^{21}$, or namely, that the price in the first location in time t (P_t^1) must be less than or equal to the price in the second location (P_t^2) plus the trade cost associated with physically transferring the identical good from the second to the first location (C_t^{21}). What condition (1) then implies is the following inequalities:

$$-C_t^{21} \leqslant P_t^2 - P_t^1, \tag{1a}$$

$$P_t^1 - P_t^2 \leqslant C_t^{21}. \tag{1b}$$

Likewise, if we reverse the order, we arrive at:

(2) $P_t^2 \leqslant P_t^1 + C_t^{12}$ which, in turn, implies the following inequalities:

$$-C_t^{12} \leqslant P_t^1 - P_t^2, \tag{2a}$$

$$P_t^2 - P_t^1 \leqslant C_t^{12}. \tag{2b}$$

We can define the price margins between the two locations as $P_t^1 - P_t^2 = M_t^{12}$ and $P_t^2 - P_t^1 = M_t^{21}$, noting that $M_t^{21} = -M_t^{12}$. What the conditions, 1a,1b,2a,2b, then imply are the following restrictions:

$$-C_t^{12} \leqslant M_t^{12} \leqslant C_t^{21}, \tag{3}$$

$$-C_t^{21} \leqslant M_t^{21} \leqslant C_t^{12}. \tag{4}$$

Or namely, that the price margin between two cities will simply be bounded by the set of trade costs prevailing between them.

[1] In what follows, we will remain agnostic as to the composition of the trade-cost terms. Certain elements can easily be included in the set of trade-cost determinants (i.e., transportation costs, brokerage and insurance costs, storage costs, tariffs, taxes, and spoilage) while there seems to be little consensus on how such things as exchange rate risk, prevailing interest rates, and/or the risk aversion of agents can be incorporated into the model. As such, "trade costs" will be interpreted as all the observed and unobserved costs of exchange.

To operationalize conditions (3) and (4), we can then state that for any pair of markets, the change in price in one market at time t, $(\Delta P_t^1 = P_t^1 - P_{t-1}^1)$, should be negatively related to the level of the margin between the two markets in the previous period $t-1$, $(M_{t-1}^{12} = P_{t-1}^1 - P_{t-1}^2)$, but only if the margin exceeds the band of trade costs, $(|C_{t-1}^{12}|, |C_{t-1}^{21}|)$. If the margin is less than the band of trade costs (i.e., the thresholds), the change in price is free to follow a random walk within the 'corridor' between the two bands. The asymmetric-threshold error-correction-mechanism (ATECM) is then given by:

$$\Delta P_t^1 = \begin{cases} \rho_1(M_{t-1}^{12} - C_{t-1}^{21}) + \eta_t^1 & \text{if } M_{t-1}^{12} > C_{t-1}^{21}, \\ \eta_t^1 & \text{if } -C_{t-1}^{12} \leqslant M_{t-1}^{12} \leqslant C_{t-1}^{21}, \\ \rho_1(M_{t-1}^{12} + C_{t-1}^{12}) + \eta_t^1 & \text{if } M_{t-1}^{12} < -C_{t-1}^{12}. \end{cases} \tag{5}$$

$$\Delta P_t^2 = \begin{cases} \rho_2(M_{t-1}^{21} - C_{t-1}^{12}) + \eta_t^2 & \text{if } M_{t-1}^{21} > C_{t-1}^{12}, \\ \eta_t^2 & \text{if } -C_{t-1}^{21} \leqslant M_{t-1}^{21} \leqslant C_{t-1}^{12}, \\ \rho_1(M_{t-1}^{21} + C_{t-1}^{21}) + \eta_t^2 & \text{if } M_{t-1}^{21} < -C_{t-1}^{21}, \end{cases} \tag{6}$$

where $(\eta_t^1, \eta_t^2) \sim Nid(0, \Omega)$. The sum of the ρ-coefficients (designated as the speed of price adjustment below) will equal zero in the case of no integration and negative one (or less) in the case of perfect integration; consequently, higher absolute values correspond to faster speeds of price adjustment.

With no closed form solution available due to the non-linearity introduced by the thresholds, estimation has to take place by maximizing the corresponding likelihood function. In this case, the likelihood function used follows that of the seemingly unrelated-regression (SUR) estimator,[2] or namely

$$\log L = -\frac{TM}{2}\log(2\pi) - \frac{T}{2}\log|\Omega| - \frac{1}{2}\sum_{t=1}^{T}\eta_t'\Omega^{-1}\eta_t, \tag{7}$$

where T is the number of observations and M is the number of equations (here, 2).

However, this approach seems to beg the question: all estimates of the speed of price adjustment (ρ) are contingent upon specified values of the trade-cost terms, $(|C_{t-1}^{12}|, |C_{t-1}^{21}|)$, and these, of course, are unknown. Estimation instead takes place by first observing the range of price margins between two cities for a given period of time (here, this will generally be 132 months). Assuming that these markets are at least weakly or (even indirectly) integrated, this range of price margins can then be used as the possible set of trade costs. The procedure that follows is straightforward albeit computationally intensive, namely calculate the value of the likelihood function for every possible combination of trade-cost terms and then identify the

[2] SUR refers to the fact that even in a system of linear equations that seem unrelated the estimated errors may, in fact, be correlated. Of course, in the model outlined above, the estimated errors are correlated by definition. Thus, SUR provides the ideal framework for capturing such contemporaneous cross-equation error correlation.

particular combination of trade-cost terms and associated values for the speed of price adjustment which maximizes the value of the likelihood function. These maximizing values are the estimates of trade costs and speeds of price adjustment used below.[3]

Fig. 1 attempts to roughly capture the procedure for a single city-pair, here London and Manchester in the years from 1800 to 1810. The main series is the difference in price (GBP/100 kg) of wheat in London and Manchester at monthly intervals. The minimum (−.43) and maximum (.21) are assumed to define the range of potential trade costs separating the markets. Implementing a grid search on all possible combinations of trade costs (both from London to Manchester and from Manchester to London) yields a maximum value for the likelihood function defined above. The associated speeds of price adjustment are −.1794 for London (with a t statistic of −1.97) and −.4185 for Manchester (with a t statistic of −2.53). The associated trade costs are .174 GBP/100 kg from London to Manchester (with a t statistic of 3.02) and .083 GBP/100 kg from Manchester to London (with a t statistic of 2.21) which are depicted in Fig. 1 as the two horizontal lines.[4] Thus, from 132 monthly observations on the price margin between two cities, the procedure generates one set of estimates of the trade costs and adjustment speed between them.

Naturally, this type of procedure does come at a cost, in terms of the need for high-frequency price data. Here, due to data constraints, all price data were collected at monthly frequencies. Add to this the wide-ranging geographic and temporal scale of the project and the data requirements become truly prodigious. In order not to compound the dimensionality of the project, the focus will be exclusively on the intra- and international markets for (constant-quality-adjusted) wheat. Motivating this choice of commodities is an easy task: throughout the nineteenth century (and well into the twentieth), the intra- and international markets for wheat can be taken as high watermarks for commodity market integration due to the large share of wheat in production, consumption, and commerce alike. Figs. 2 and 3 display the geographical range of cities considered while Appendix B summarizes the coverage and sources of the dataset.

3.2. The convergence of prices

We should now turn our attention to the means of assessing the degree of price convergence. As a starting point, it is suggested that use be made of the output generated from the ATECM model above. One of the chief attractions of the model is that it provides estimates of trade costs which are based on observed price differentials. Thus, if trade costs for any particular pair of cities are estimated to decline

[3] It should also be noted that the search procedure allows for bands of both zero and symmetric width. Thus, the model nests the more familiar ECM and TECM models used in other studies.

[4] The t statistics on the estimated speeds of price adjustment are calculated in the standard fashion. The procedure for generating the t statistics on the trade-cost estimates is detailed in Appendix A. Tables reporting the point estimates depicted in Figs. 4–7 as well as their associated standard errors are available at http://www.sfu.ca/~djacks/data/data.html.

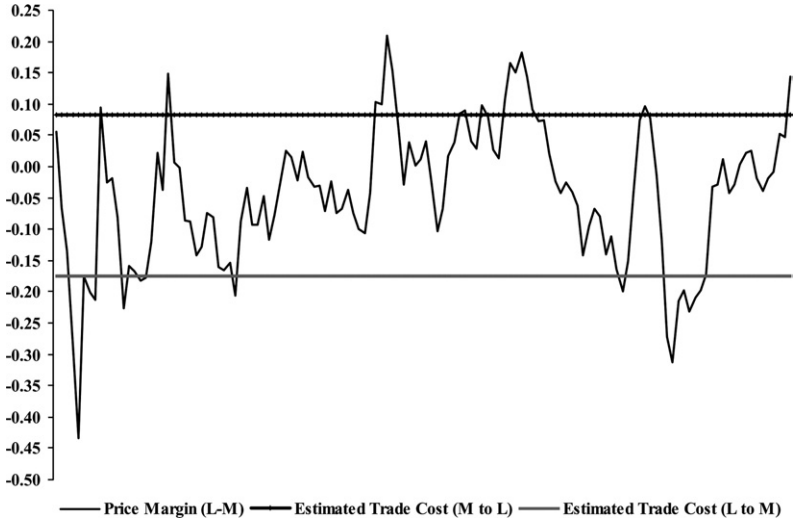

Fig. 1. London–Manchester price margin, 1800–1810 (GBP/100 kg).

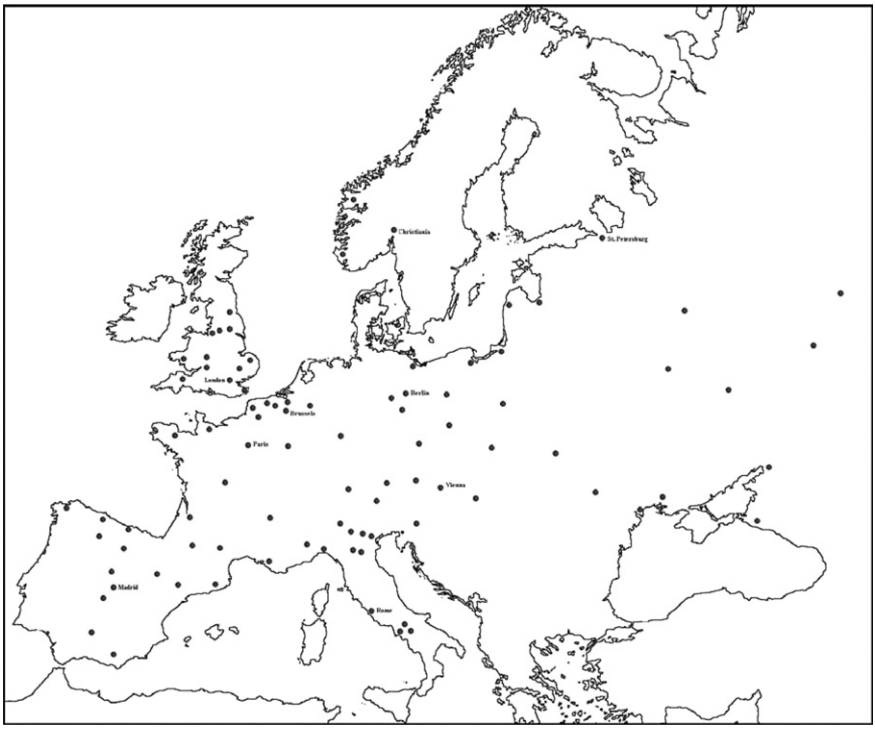

Fig. 2. European cities in sample.

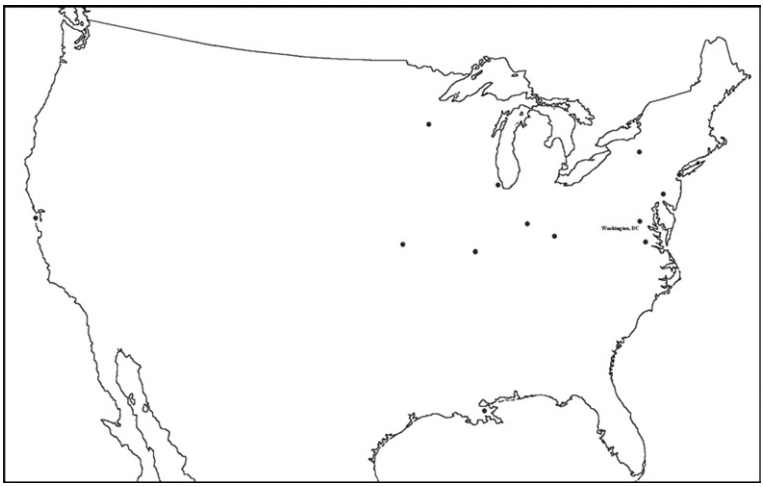

Fig. 3. U.S. cities in sample.

through time, it can be safely assumed that the level of the price differential between the two cities has fallen as well. Additionally, the estimates of the trade costs can be scaled by the average price for the corresponding city-pair and time horizon in order to arrive at a unit-less measure of price convergence (designated as relative trade costs below) appropriate for the type of cross-country comparisons one would like to make.[5]

In the preceding, the means for estimating trade costs and adjustment speeds at a given point in time and for a given city-pair was detailed. However, to address the evolution of commodity market integration, a panel of such observations on trade costs and adjustment speeds is needed. The following section describes the method for building up the panel used below.

3.3. A final note on data construction

To assess the intranational component of market integration, the first step was to construct a matrix of prices of dimension n (the number of cities; generally 12) by t (generally, 11 years, for 132 monthly observations) and to form all pair-wise

[5] A further measure of price convergence used extensively in the contemporary literature (cf. Engel and Rogers, 1995, 1996; Parsley and Wei, 2001a,b) is defined as the variance of the logged relative price over a given time horizon, or

$$V_{j,k,T} = \mathrm{Var}\left[\ln\left(\frac{P_{jT}}{P_{kT}}\right)\right].$$

This measure was also constructed and used in all regression specifications discussed below. Given the high degree of correlation between this variance term and the TCs/Price variable ($r > .90$), it will come as no surprise that the results added little further information on the process of price convergence and, therefore, are not reported here.

Table 1
Abbreviated data summary

Sample countries	Cities	Underlying price obs.	Resulting observations		
			Intranational	International	Total
Austria–Hungary	10	7,044	343	1536	1879
Belgium	4	4,104	68	1371	1439
France	12	16,416	1452	1962	3414
Germany	12	5,040	462	420	882
Italy	12	4,752	396	360	756
Norway	3	2,880	42	225	267
Russia	12	3,024	264	240	504
Spain	12	13,008	1124	1075	2199
United Kingdom	12	16,416	1452	1962	3414
United States	12	9,876	603	1665	2268
Full panel	101	82,560	6206	5408	11,614

combinations of cities in the set of prices in order to arrive at estimates of trade costs (divided by corresponding average prices) and adjustment speeds. The next step was to then record the average value of these estimated parameters. The final step was to iterate this procedure at 5-year steps for each country. Thus, for a country like the United Kingdom for which there is monthly price data for 114 years and 12 cities (or 66 unique city-pairs), estimation began in the period of 1800–1810 and ended in that of 1905–1913 with 20 intervening observations on the course of market integration (thus, $T = 22$).

As to the international component, the precedent set above on intranational market integration is followed. Here, instead of constructing the variables from observations formed from every pair-wise combination available in any given country, however, it was decided that the price data for each country should be matched with prices from a set of five cities (Bruges, London, Lwow, Marseilles, and New York City), all of which represent important markets for wheat in the international economy and for which data exist over the entire period.

Apart from this distinction, the methodology was identical to that identified previously: estimate the trade costs (divided by corresponding average prices) and adjustment speeds which can be inferred from the data; record the average values of these estimated parameters; and iterate this procedure at 5-year steps for each country. Table 1 gives a brief summary of the number of observations on the underlying price data as well as of the number of resulting estimates for both trade costs and adjustment speeds in the sample.

4. Intranational market integration

In what follows, the final results are presented for the exercises on price adjustment and convergence and a short country-by-country analysis is offered with reference to the existing literature on the topic of intranational market integration.

Figs. 4 and 5 depict the national averages for the speed of price adjustment and relative trade costs, respectively. In what follows, four countries will be examined in turn. These were chosen to represent the possible patterns of relative performance in intra- and international markets: namely Austria–Hungary (relatively strong intranational and relatively weak international performance), Spain (relatively weak intranational and international performance), the United Kingdom (relatively strong

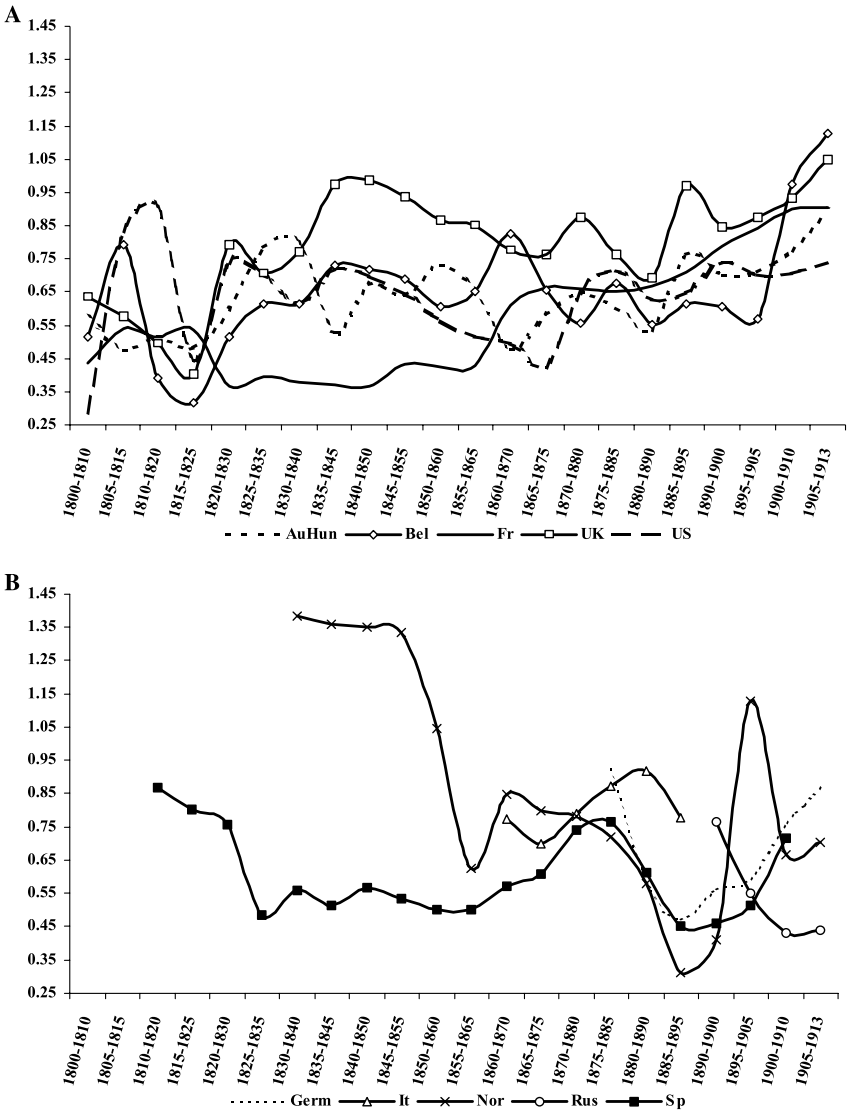

Fig. 4. Intranational price adjustment. (A) Average speeds of price adjustment. (B) Average speeds of price adjustment, cont.

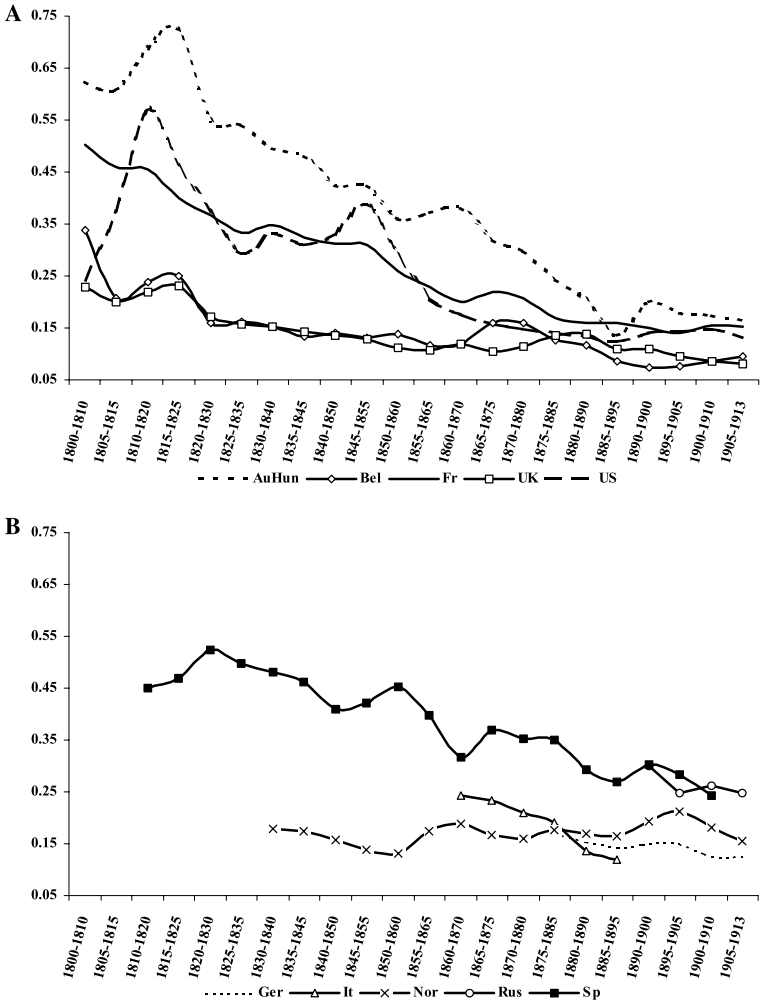

Fig. 5. Intranational price convergence. (A) Average relative trade costs. (B) Average relative trade costs, cont.

intranational and international performance), and the United States (relatively weak intranational and relatively strong international performance).[6]

4.1. Austria–Hungary, 1800–1913

The case of Austria–Hungary seems a suitable starting point as this country experienced radical change in the structure and performance of its internal markets in the

[6] The interested reader may refer to a longer version of this paper, Jacks (2004), which attempts to reconcile these results with the secondary literature for each sample country.

period as a whole; indeed, Austria–Hungary shares with France the distinction of having made the most improvement with respect to the two criteria for domestic market integration. Fig. 4A demonstrates that in terms of the speed of price adjustment Austria–Hungary experienced a significant improvement dating from the 1860 to 1880 period which may have been associated with active government support in the development of commercial facilities (Ville, 1990). Additionally, this timing is congruent with Komlos' story (1979, 1983) that the completion of the Customs Union of 1850 between Austria and Hungary contributed little stimulus to the internal market.

As to the evidence on price convergence, Fig. 5A shows the tremendous decline in relative trade costs in the Empire. The secondary literature gives us little reason to believe that this is not a true representation of economic conditions as the transport facilities of the Empire in the early nineteenth century, being chronically underfunded and subject only to decentralized control, were generally appalling (Blum, 1943), especially in outlying regions (Gasiorowski, 1950; Ville, 1990). Indeed, this situation was little improved in the late nineteenth century when shipping costs and times between Vienna and Buenos Aires via Hamburg—a trip comprising 742 km of ground transport plus 6151 km of ocean transport—were less than those between Vienna and Czernowitz in Bukovina—a trip comprising 721 km of ground transport (Milward and Saul, 1977). This evidence leads one to believe that the process of unifying the imperial market had its origins long before mid-century (cf. Good, 1981; Szabad, 1961) and might have been tied to changes in the transactions sector.

4.2. Spain, 1810–1910

In the past 30 years, few stones have remained unturned in furthering the discussion of internal markets in Spain in the nineteenth century. Indeed, the topic appears to be one of the dominant themes in the historiography of Spain. Hopefully, the analysis here will partially resolve some of the issues bearing on this theme: in a word, all the evidence presented here indicates that Spain made little progress in this century in forging a unified market for itself.

Indeed, the evidence in Fig. 4A lends ample support for that body of research which finds much to despair about in Spanish markets (Barquín Gil, 1997; García-Lombardero, 1987; Peña and Sánchez-Albornoz, 1983, 1984; Sánchez-Albornoz, 1974, 1975a,b; Simpson, 1995; Tortella, 2000) as there is virtually no trend in the measures of the speed of price adjustment. The series describing price convergence in Fig. 5A shows that Spain began and ended the period with the second highest levels of relative trade costs, being surpassed only by Austria–Hungary and Russia in each respective subperiod. While many accounts stress the progression of transport facilities from a highly seasonal, peasant trade based on mule carriage (Gómez Mendoza, 1983a, 1987; Ringrose, 1970) to a centralized and expansive rail network capable of melding the Ancien Regime's regional economies (Anes Alvarez, 1978; Die y Mas, 1900; Gómez Mendoza, 1982, 1983b, 1984), nothing in the timing or movement of the series lends much credence to this interpretation. While it is still possible that Spanish railways were hobbled due to their Madrid-centric radial design (Cordero

and Menéndez, 1978) or their implicit concentration on foreign—rather than Spanish—concerns (Ville, 1990), they seem to have played only a limited role in the process of Spanish market integration in the nineteenth century.

4.3. The United Kingdom, 1800–1913

In light of our evidence on the matter, Adam Smith's prognosis in 1776 that "the prices of bread and butchers' meat are generally the same, or very roughly the same throughout the greater part of the United Kingdom" (1970, p. 177) was an apt one. For after a period of disorder related to the Napoleonic Wars and their fallout (Fairlie, 1969; Galpin, 1925; Jacob, 1825), the internal market of the United Kingdom exhibited a remarkable ascent—with little tendency towards retrogression—in terms of the speed of price adjustment as demonstrated in Fig. 4A.

And even though the United Kingdom enjoyed the lowest level of relative trade costs at the beginning of the nineteenth century, this precociousness apparently in no way impeded the secular decline of these variables as seen in Fig. 5A. In many respects, we have little trouble in aligning our results with received wisdom which dates the emergence of a national market in wheat from the late seventeenth/early eighteenth centuries (Granger and Elliott, 1967; Schofield, 1983). While the literature on intranational integration in the nineteenth century is sparse, the story emerging from these studies suggests that the picture of a highly integrated economy at the dawn of this period adding strongly and surely to its successes appears to be the right one (Chartres, 1995; Gourvish, 1970; Paterson and Shearer, 2001).

4.4. The United States, 1800–1913

In many respects, the United States is an exceptional case study, chiefly because of the perpetual flux associated with its boundaries in the nineteenth century.[7] Fortunately, our proxy of wheat for commodities in general seems especially appropriate, at least if one agrees with the sentiments of the Superintendent of the 1860 Census who stated that "to trace [the] rise and progress [of the US grain trade] would be almost to complete a record of the development of this entire continent, for it has been the leading agent in the opening up of seven-eighths of our settled territory" (quoted in Schmidt, 1920, p. 98; see also Harley, 1978, 1980).

In regards to the actual story told by Fig. 4A, U.S. performance with respect to the speed of price adjustment was generally favorable and especially so after 1870.

[7] This flux need be acknowledged for only one other country in our sample, Austria–Hungary. But here, the problem of shifting borders is a limited one, for with the Treaty of Vienna (1815) Czernowitz, Ljubljana, and Trieste were formally incorporated into the Empire while the city of Krakow was given nominal status as a republic. It should also be made more explicit what the various series for the United States presented in Figs. 5A and 6A really are. As many cities in the sample in 1913 did not enter the historical price record in 1800, levels of price adjustment and convergence were chained backwards from 1913, correcting for any differences in the level of the statistics. For example, when Chicago price data became available, the statistics were calculated both including and excluding Chicago and then averaged. Deviations across series were never over the order of 5%, suggesting the final series is representative.

As to the process of price convergence, Fig. 5A suggests that while substantial progress was made in this arena most of the gains were made prior to 1870. Thus, there seems to be a split decision on the relative merits of arguments which find the antebellum period of canal and railroad construction as the key to intranational market integration (Clark, 1966; Fishlow, 1964; Schmidt, 1939; Slaughter, 2001) and those which find the key in a reunited and revivified U.S. pushing towards integration in the post-war period (Kim, 1995, 1998; O'Rourke and Williamson, 1999; Williamson, 1974).

4.5. General observations on intranational market integration

Having finished the review of country-by-country performance, it is now possible to offer some conclusions on the generalized character of intranational market integration. First, the countries in the sample can be broadly categorized based on their relative performance with respect to the two criteria of integration. In the first and highest group, one would have to place Belgium and the United Kingdom whose performance shows not only significant improvement over time but also high degrees of integration within these economies from the beginning of the nineteenth century. In an upper intermediate group, one might include Austria–Hungary, France, and the United States and in a lower intermediate group, Germany and Italy. Finally, registering the worst relative performance are Norway, Russia, and Spain. Thus, in large degree, this informal ranking conforms with many of our expectations, but also presents some clear exceptions, most notably of which are the relatively strong performances of Austria–Hungary and France and the relatively weak performances of Germany and Norway.

Second, the figures for internal price adjustment apparently demonstrate very little correspondence across countries[8] while those for price convergence certainly do. What this suggests, then, is that the former might be related to systematic differences in the level of general economic development in each country while the latter might be predicated upon international standards of commerce, communication, and transport. However, it also seems that the improvement in intranational market integration may not be associated solely with the development of railroads. Thus, Gerschenkron's early—but untested—misapprehensions about the capacity of railroads to integrate the national economy may yet be vindicated (Gerschenkron, 1962).

Third and finally, the dramatic developments of the late nineteenth century in the technology of transport and communications (e.g., railroads, steamships and telegraphs) have generally overshadowed the early part of the century with its more modest record of technological improvement (e.g., canals) and changes in internal commercial policy and domestic financial markets. Yet some indicators of commod-

[8] A notable exception here might be the period from 1875 to 1895 where the ρ-coefficients for a number of countries dip down appreciably. Potentially, this disruption of intranational market integration could be a response to the so-called grain invasion of the late nineteenth century (on the sources and consequences of the grain invasion, see Farnsworth, 1934; O'Rourke, 1997; Veblen, 1892).

ity market integration from this study point to dramatic improvements in intranational market integration dating from the first half of the nineteenth century. An obvious candidate in light of the existing literature (e.g., Harley, 1988; North, 1968) would then be the contribution of changes in the organization of trade vis-à-vis changes in technology; however, this will have to be left as a subject for future research.

5. International market integration

In assessing the degree and evolution of international market integration, the precedent set by the earlier section on intranational market integration will be followed: estimates of international market integration measured as performance with respect to international hub cities are aggregated for each country and the process is repeated on overlapping 11-year periods. The results of this exercise are depicted in Figs. 6 and 7; again, each country will be examined in turn, this time especially emphasizing differences in trade policy.

5.1. Austria–Hungary, 1800–1913

In contrast to its experience with its internal market, the place of Austria–Hungary in the international market was apparently a tenuous one. Fig. 6A presents the evidence concerning the speed of price adjustment for Austria–Hungary in international markets. It appears to mirror the country's engagement with the outside world relatively well as the institutional and natural trade barriers initially faced by Austria–Hungary were gradually overcome. This opening process found its culmination in the period of Austria–Hungary's brief flirtation with liberal trade policy (1850–1860) and was closed by the economic crisis of 1873 which brought with it a spate of protectionist measures (Eddie, 1977). From this time, Austria–Hungary continuously slipped back into autarky contributing to significant changes in sectoral employment and output (Pollard, 1981). This certainly added fuel to nationalistic—primarily Hungarian—fires which found Habsburg tariff policy to be a deliberate attempt to reinforce traditional patterns of development within the Empire and, thereby, to ensure the supremacy of the "hereditary" provinces of Austria and Bohemia (Gross, 1973).

In Fig. 7A one finds that relative trade costs fell appreciably through time for Austria–Hungary. After a rough patch at the beginning of the nineteenth century, prices in Austria–Hungary converged on those in international markets with appropriate shocks to the process in the 1860s, i.e., during the American Civil War, and the 1890s, a time of high exchange rate volatility associated with currency conversion (von Mises, 1909).

5.2. Spain, 1810–1910

Beginning with a look at the Spanish experience with price convergence in Fig. 7B, the early Spanish figures do not suggest any clearly aberrant behavior on its part.

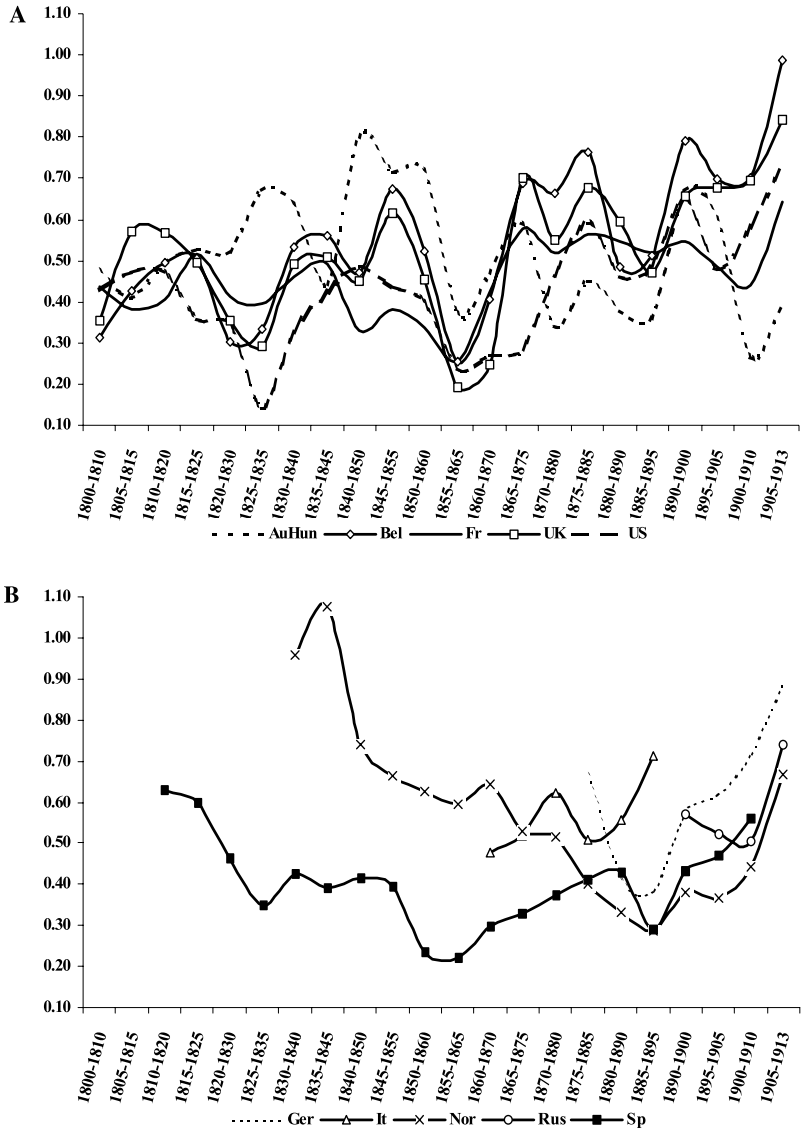

Fig. 6. International price adjustment. (A) Average speeds of price adjustment. (B) Average speeds of price adjustment, cont.

Indeed, it finds itself in league with the Belgium, France, and the United Kingdom. What is aberrant is that these measures of international trade costs remain so high throughout the century, and while some of this performance can be explained by uniquely disastrous events such as the crippling inflation and depreciation surrounding the Spanish American War (Tortella, 2000) as well as the three Carlist Wars, the

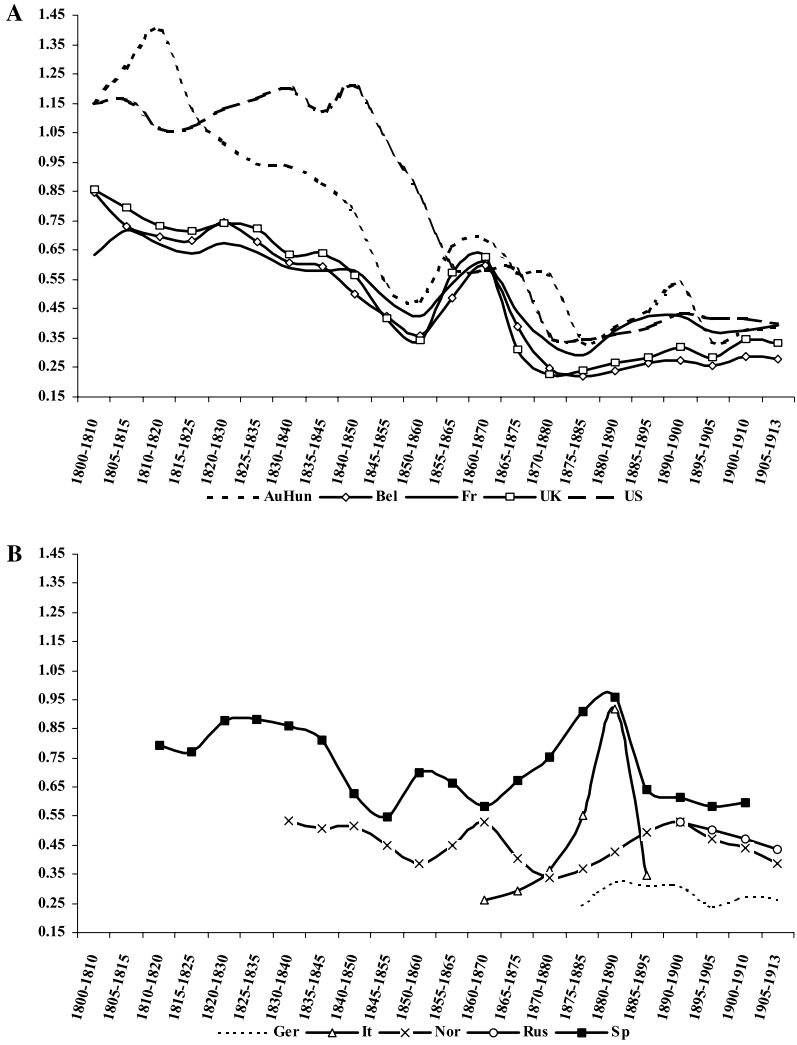

Fig. 7. International price convergence. (A) Average relative trade costs. (B) Average relative trade costs, cont.

brunt of the blame probably falls on the consistently prohibitive trade policies of the Spanish government (see Henderson, 1842).

Indeed, the figures on the speed of price adjustment in Fig. 6B shed some light on the subject, for it clearly shows a protracted Spanish withdrawal from international markets until c. 1850 when bans on all traffic in grains were finally lifted. The following period has already been identified as one of marked price divergence for a wide range of commodities (Sarda, 1947) as well as a retrenched and highly protective set of tariffs (Carreras, 1993), yet was associated with some improvement in the speed of

price adjustment. The combination of these trends was that, despite a climate and geography wholly unsuited for cereal cultivation (Tortella, 1994) as well as a comparative advantage in horticulture (Critz et al., 1999), Spanish agricultural output even in 1900 was seriously biased towards cereals (Simpson, 1995), representing tremendous misallocations of land, labor, and capital. Thus, even though certain sectors and regions were decidedly oriented to the outside world (García-Lombardero, 1987; Harvey and Taylor, 1987), it could still be maintained at the close of our period—just as one observer noted in the 1840s—that "local is everything, the Spaniard takes the goods that the gods provide him, just as they come to hand" (quoted in Simpson, 1995, p. 73).

5.3. The United Kingdom, 1800–1913

After the imbroglio of the Napoleonic Wars and reeling from the associated effects of the Continental System and conflagrations with America (on pre-War of 1812 hostilities, see Frankel, 1982), the United Kingdom performed relatively well with respect to the speed of price adjustment as seen in Fig. 6A. Its marks on the other criterion of price convergence were respectable, yet it suffered like the others from very high levels of relative trade costs. Therefore, the cause of international market integration in the United Kingdom could only improve, and improve it did, showing appreciable increases in the speed of price adjustment as well as appreciable decreases in relative trade costs. Given that by the end of the nineteenth century the United Kingdom was taking in over half of the world's wheat imports (Olson, 1974), these developments should come as no surprise.

As a closing note, attention should also be drawn to the fact that the repeal of the Corn Laws in 1846 appears to have been a decisive element in furthering the cause of international market integration, for the period around the mid-century represents an apex for the speed of price adjustment as well as a dramatic break-point for the measures of relative trade costs. Admittedly, these heights were soon lost (most likely due to the disruption surrounding the American Civil War), but recovery was made possible after 1860/5 with the signing of the Cobden-Chevalier (and subsequent) commercial treaties, thus, in part justifying the long-suffering British allegiance to free trade.

5.4. The United States, 1800–1913

The story of international market integration for the United States differs somewhat to the outline of that told for its internal development. Essentially, one can identify a long period of improving speeds of price adjustment and price convergence variously dating from sometime between 1820 and 1850 as seen in both Figs. 6A and 7A. On all counts significant progress was made, culminating in a high-water mark of integration in the period 1875–1885 when the Americans were in the full swing of "conducting the most stupendous bargain counter in the history of agriculture" (quoted in Saloutos, 1946, p. 180).

In explaining the nature and timing of this rise in price convergence and the speed of price adjustment, the deficiency of grain production in northwestern Europe dating from the mid-1830s (Fairlie, 1965) must be cited as well as tremendous increases in the commercial apparatus of the grain trade dating from the 1840s (Broomhall and Hubback, 1930; Farnsworth, 1934; Rothstein, 1960; Veblen, 1892). Although American dominance in the international wheat trade may have been a flash in the pan, as suggested by Pollard (1981), the fact remains that American engagement in that trade remained very high even after it had ceded its dominance to other producers such as Argentina, India, and Russia as the measures of international market integration recouped their losses associated with the Civil War and rose to new heights immediately prior to the First World War.

5.5. General observations on international market integration

Drawing out some of the points implicitly made throughout the section above allows for two important conclusions about the nature of international market integration. First, what the high degree of co-movement between the series in Figs. 6 and 7 suggests is that we can tentatively date the emergence of a truly international market for wheat from around 1835. To be sure, many countries took only a limited part in this growing international integration, but for no country is it possible to state that the state of affairs in 1913 was materially unchanged from that of 1800. This is especially true in relation to the convergence of prices as measured by relative trade costs. Thus, this analysis is consistent with the previously made point that parts of Europe had become grain deficient after 1836 (Fairlie, 1965) and with evidence pointing to the development of internationally responsive production and trade patterns roughly dating from 1830 (O'Rourke and Williamson, 2002).

Second, and very much related to this point, much of the action in price convergence seems to have taken place well before mid-century. This coincides with recent research which has demonstrated the reduction of global dispatch times (Kaukiainen, 2001), but it adds a new element, namely that the actual costs (and price differentials) associated with international trade were falling dramatically before 1870. Was this diminution simply a return to normalcy after a period of severe political disturbance[9] or perhaps the culmination of changes in not only the political environment but also commercial policy and the transaction sector? What is more, an interesting twist introduced by this analysis is that relative trade costs actually seemed to increase in the post-1870 era. However, whether this slight upswing in trade costs is the product of heightened protectionism in the face of cheap imports remains to be seen.[10]

[9] The author thanks one of the referees for raising this point.

[10] Notably, the price convergence figures for the sample's two free-trading importers of wheat, Belgium and the United Kingdom, were on the rise post-1870 as well.

6. Conclusion

This paper has attempted to present an overview of the course of intra- and international market integration in the long nineteenth century for a sample of 10 Atlantic economies. Admittedly, the constraints of space being what they are, the study probably does not do justice to the rich variety of experience of these countries, but one can feel certain that with few exceptions the figures presented here have accurately sketched the rough contours of their commercial advance, stagnation, and retrogression.

Additionally, the statistics for intra- and international market integration both suggest that the two criteria of price convergence and the speed of price adjustment are probably dependent on different combinations of causal factors. For while there seem to be some plausible stories to be told of the effect of railroads on the speed of price adjustment, it is less obvious that improvements in intra- and international price convergence can be solely associated with changes in transport technology.

Table 2
Preliminary regression results

Dependent variable	OLS		GLS	
	Coefficient	*p* value	Coefficient	*p* value
Trade costs as a share of price (mean = .416)				
Distance	**0.058**	**0.00**	**0.043**	**0.00**
Distance squared	**−0.002**	**0.00**	**−0.001**	**0.00**
Railroad connection	**−0.037**	**0.00**	**−0.036**	**0.00**
Interaction between railroad connection and distance	**0.011**	**0.00**	*0.001*	*0.77*
Canal connection	**−0.053**	**0.00**	**−0.055**	**0.00**
River connection	**−0.042**	**0.00**	**−0.021**	**0.00**
Port connection	**−0.030**	**0.00**	**−0.012**	**0.00**
Number of observations	11578		11578	
Prob > F	0.000		0.000	
Adjusted R^2	0.814		n/a	
Speeds of price adjustment (mean = .584)				
Distance	**−0.026**	**0.00**	**−0.018**	**0.00**
Distance squared	**0.001**	**0.00**	**0.001**	**0.00**
Railroad connection	**0.147**	**0.00**	**0.168**	**0.00**
Interaction between railroad connection and distance	**−0.025**	**0.00**	*−0.038*	*0.00*
Canal connection	**0.104**	**0.00**	**0.062**	**0.00**
River connection	**0.042**	**0.02**	**0.059**	**0.00**
Port connection	**0.017**	**0.08**	**0.015**	**0.08**
Number of observations:	11578		11578	
Prob > F	0.000		0.000	
Adjusted R^2	0.794		n/a	

N.B. OLS refers to ordinary-least-squares estimation with random effects; GLS refers to generalized-least-squares estimation with random effects, heteroskedastic panels, and panel-specific AR(1) processes. Time indicators have been suppressed in the interests of space; distance variables scaled in 1000 km units.

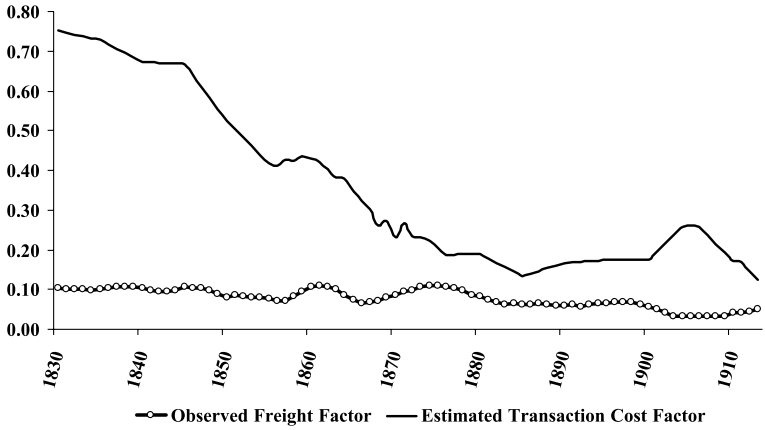

Fig. 8. Observed freight and estimated trade costs for 100 kg of wheat (as a share of average price), NYC-to-London.

Table 2 reports preliminary econometric results testing this hypothesis. The dependent variables in this case are one of the measures of market integration (relative trade costs or the speed of price convergence) generated from the estimation procedure described above. Rather than aggregated up to the country level as in Figs. 4–7 the measures have remained bilaterally defined by city-pairs (e.g., London–Manchester or London–Marseilles) and are regressed on controls for distance, the existence of shared river or oceanic connections, and the introduction of railroad and canal connections.[11] Here, the differential effects of transport technology on trade costs and speeds of price adjustment can clearly be seen. In reducing trade costs, the introduction of railroad connections ranks beneath both rivers and, most notably, the introduction of canals. In increasing the speed of price adjustment, the introduction of railroads garners pride of place. A natural question, then, is why such a small effect on trade costs?

A potential answer is that for much of the nineteenth century only a small portion of trade costs (computed from observed price differentials) was explained by transport charges. A hint of this is seen in Fig. 8 which for New York City and London compares estimates of trade costs as a share of final price against North's (1968) series for transport charges as a share of final price. What this suggests is that at the beginning of the period transport charges made up at most 15% of all trade costs while at the end of the period the corresponding figure was closer to 45%. Clearly, explaining this disparity between trade and transport costs as well as its evolution through time represents a potentially fruitful line for future

[11] Sources for these data are found in Appendix C.

research—one which has even been picked up by trade economists (Anderson and van Wincoop, 2004).[12]

Finally, the accrued evidence on price convergence in intra- and international markets may also lead one to rethink certain long-held beliefs about the nineteenth century, namely the typecasts of stagnation up to the mid-century with an accelerated and accelerating pace of integration up to the period immediately before the First World War. Thus, even though the point may be now belabored, it bears repeating: the processes of intra- and international commodity market integration seem to have had roots far back into the nineteenth century. A collective task for historians, then, is to link these developments with the revolutionary commercial and technological developments of the post-1870 period.

What remains as additional tasks for future research is to more fully explicate the interaction of intra- and international market integration as well as their simultaneous effects on economic growth and welfare. Furthermore, the role of transport technology in the integration process needs to be formally tested in light of recent work which suggests various roles for nominal exchange rate variability, monetary and customs unions, economic distances, and, of course, the much-touted border effect.

Appendix A. Diagnostic statistics and consistency checks

A.1. Diagnostic statistics

Hansen (1997) suggests a distribution theory for least-squares estimates of the threshold in a similar family of threshold autoregressive (TAR) models as well as a means of forming likelihood ratio statistics in order to gauge the relative performance of TAR models versus standard (linear) autoregressive models. The methodology developed by Hansen was adapted for use with our ATECM model. Specifically, the F statistic was formed as:

$$F_n = n\left(\frac{\hat{\sigma}_n^{*2} - \hat{\sigma}_n^2(\hat{\gamma})}{\hat{\sigma}_n^2(\hat{\gamma})}\right),$$

where the denominator equals the residual variance of the threshold model and the first term in the numerator equals the residual variance of a linear model; however, as γ (the threshold) is not identified, this F statistic does not take a χ^2 distribution. Thus, we approximate by using:

$$F_n^* = \sup_{\gamma \in F}\left[n\left(\frac{\tilde{\sigma}_n^{*2} - \tilde{\sigma}_n^{*2}(\gamma)}{\tilde{\sigma}_n^{*2}(\gamma)}\right)\right],$$

where the denominator equals the residual variance of a regression of n standard normals on the price margin (M^{12}) and the first term in the numerator equals the residual variance of a regression of n standard normals on the price margin less the estimated trade cost ($M^{12} - C^{21}$). The approximation converges weakly in probability to the null distribution of the F statistic, so the statistic is bootstraped (with 1000 replications) to approximate the asymptotic distribution, allowing one to calculate:

[12] What is more, Anderson and van Wincoop find evidence for very large (and non-transport-related) trade costs in highly integrated, present-day economies.

$$p - \text{value} = \frac{\text{count if } F_n^* > F_n}{1000}.$$

For the sampling distribution of the threshold estimate, we form:

$$LR_n(\gamma) = n\left(\frac{\hat{\sigma}_n^2(\gamma) - \hat{\sigma}_n^2(\hat{\gamma})}{\hat{\sigma}_n^2(\hat{\gamma})}\right),$$

for every set of γ used in the grid search. Using the critical values provided by Hansen for $C_\xi(\beta)$, minimum and maximum values of Γ were determined for which:

$$\hat{\Gamma} = \{\gamma : LR_n(\gamma) \leqslant C_\xi(\beta)\}.$$

This range of values for Γ provides confidence intervals from which the standard error was calculated as:

$$\frac{\text{abs}(\max \hat{\Gamma} - \min \hat{\Gamma})}{4.3125}.$$

An informal review of the standard errors and p values strongly suggests the applicability and significance of the ATECM specification.

A.2. Consistency checks: data horizons and estimated trade costs

In this space, we can also review evidence a few other causes of concern over the use of the ATECM model, namely the suitability of monthly data for the nineteenth century (i.e., given the radical transformations in communication and transportation technology, it might be expected that markets equilibrated in a time span not captured by monthly data), the model's use of untransformed price levels, and whether the estimation generates estimates of trade costs consistent with multi-lateral market integration.

Panel A of the table given below positively demonstrates that for even the end of the nineteenth century and even in the international market, the use of monthly data does not at all prejudice the results of the exercise as (after scaling for the different time horizons) the estimates of the speed of price adjustment are similar both in absolute and relative magnitude. What is more, the estimates of the threshold are remarkably similar.

The ATECM model, daily vs. monthly data, NYC–Paris–Berlin, 1896–1905 (t statistics reported in brackets)

City 1	City 2	Adjustment speed		Threshold from 2 to 1	Threshold from 1 to 2	p value	Obs.
		For city 1	For city 2				
(A) Estimation via price levels							
Daily							
Paris	New York	**−0.0172**	**−0.0232**	**6.98**	**−3.02**	0.0490	2940
		[−230.74]	**[−240.66]**	**[6.54]**	**[−2.96]**		
Paris	Berlin	**−0.0224**	**−0.0028**	**2.83**	*0.11*	0.0390	2866
		[−195.62]	**[−63.90]**	**[3.81]**	*[0.13]*		
Berlin	New York	**−0.0120**	**−0.0069**	**4.68**	**−2.55**	0.0411	3012
		[−690.69]	**[−117.70]**	**[7.74]**	**[−4.58]**		
Monthly							
Paris	New York	**−0.0303**	**−0.5223**	**6.66**	**−3.23**	0.0739	119
		[−2.13]	**[−8.45]**	**[2.43]**	**[−2.79]**		
Paris	Berlin	**−0.0876**	**−0.1666**	**2.47**	*−0.02*	0.0987	119
		[−2.38]	**[−7.52]**	**[3.56]**	*[−0.15]*		
Berlin	New York	**−0.0340**	**−0.2161**	**4.73**	**−2.73**	0.0972	119
		[−2.60]	**[−4.09]**	**[2.04]**	**[−3.92]**		

(*continued on next page*)

Appendix A (*continued*)

City 1	City 2	Adjustment speed		Threshold from 2 to 1	Threshold from 1 to 2	p value	Obs.
		For city 1	For city 2				
(B) Estimation via logged prices							
Daily							
Paris	New York	**−0.0132**	**−0.0138**	**0.19**	**−0.09**	0.0478	2940
		[−282.23]	**[−169.23]**	**[6.38]**	**[−4.01]**		
Paris	Berlin	**−0.0237**	**−0.0053**	**0.06**	*0.00*	0.0413	2866
		[−270.27]	**[−145.31]**	**[4.17]**	*[.06]*		
Berlin	New York	**−0.0074**	**−0.0070**	**0.14**	**−0.08**	0.0433	3012
		[−720.73]	**[−161.94]**	**[6.86]**	**[−4.12]**		
Monthly							
Paris	New York	**−0.0286**	**−0.3880**	**0.44**	**−0.23**	0.1330	119
		[−1.55]	**[−7.21]**	**[6.36]**	**[−4.54]**		
Paris	Berlin	**−0.1643**	**−0.1266**	**0.14**	*0.00*	0.1272	119
		[−3.96]	**[−5.06]**	**[3.67]**	*[0.09]*		
Berlin	New York	**−0.0086**	**−0.2271**	**0.33**	**−0.18**	0.1044	119
		[−1.04]	**[−5.43]**	**[6.01]**	**[−3.64]**		

Panel B of the above table also raises the issue of data transformation. Although it may seem undue (or at least, unstated) assumptions are being made about the structure of errors by using the price level, we can see that, if anything, the use of logged prices is not as desirable as our original specification. This is seen primarily in the closer adherence of the estimated thresholds in daily versus monthly data in the non-logged specification.

Finally, the table given below demonstrates that for the sample considered we see no violations of arbitrage potentials across multiple cities, i.e., $C_t^{12} + C_t^{23} \geqslant C_t^{13}$.

Trilateral goods movement, 1850–1860 (transaction costs in dollars per 100 kg of wheat)

Origin (1)	Transit point (2)	Destination (3)	(1) to (3) via (2)	(1) to (3) direct
Cincinnati	Philadelphia	New York	1.71	1.59
New Orleans	Alexandria	New York	1.88	1.32
Chicago	Cincinnati	New York	2.99	2.94
Indianapolis	Cincinnati	New York	3.08	2.75
San Francisco	New Orleans	New York	3.17	2.56
Cincinnati	Ithaca	Philadelphia	2.30	1.56
New Orleans	Alexandria	Philadelphia	1.88	1.32
Chicago	Cincinnati	Philadelphia	2.96	2.68
Indianapolis	Cincinnati	Philadelphia	3.05	2.90
San Francisco	New Orleans	Philadelphia	3.56	2.39
Cincinnati	Ithaca	Alexandria	2.54	1.44
New Orleans	Richmond	Alexandria	1.95	1.39
Chicago	Cincinnati	Alexandria	2.84	2.46
Indianapolis	Cincinnati	Alexandria	2.93	2.44
San Francisco	New Orleans	Alexandria	3.24	2.32
Cincinnati	Alexandria	Richmond	2.26	1.78
New Orleans	Alexandria	Richmond	2.21	1.72
Chicago	Cincinnati	Richmond	3.18	2.86
Indianapolis	Cincinnati	Richmond	3.21	2.70
San Francisco	New Orleans	Richmond	3.57	2.52

Appendix B. Data coverage and sources

N.B. All data listed below and employed in this study were taken as monthly observations. In the case of multiple series for one city, basic hedonic regressions using time and series dummies were the basis of estimating quality-adjusted price series. Unless otherwise indicated, prices were assumed to refer to the price of the locality's average grade of grain; thus, inter-market and inter-temporal differences in quality are 'soaked' up in the estimates of trade cost as detailed above, assuming a constant price mark-up exists (or can be approximated) for different grades of wheat over short periods of time. In the case of missing observations, these were predicted from a regression of the price series with gaps on the average price in all (domestic) markets in the 5 years immediately prior. All exchange rate data used in transforming the prices into American dollars (or cents) were derived from the Global Financial Dataset by Brian Taylor.

Austria–Hungary

Krakow, 1800–1913; Gorkiewicz, M., 1950. Ceny W Krakowie w Latach 1796–1914. Nakladem Poznanskiego Towarzystwa Przyjaciol Nauk, Poznan.

Ljubljana, 1800–1913; Valenčič, V., 1977. Žitna Trgovina na Kranjskem in Ljubljanske Žitne Cene od Srede 17. Stoletja do Prve Svetovne Vojne. Slovenska Akademija Znanosti in Umetnosti, Ljubljana.

Lwow, 1800–1913; Hoszowski, S., 1934. Ceny we Lwowie w Latach 1701–1914. Sklad Glowny, Lwow.

Vienna, 1800–1913; Pribram, A.F., 1938. Materialien zur Geschichte der Preise und Löhne in Österreich, Band I. Carl Ueberbeuters Verlag, Wien.

Budapest, 1873–1913; Vierteljahrshefte zur Statistik des Deutschen Reichs. Verlag von Puttkammer & Mühlbrecht, Berlin, various years; Annuaire Statistique Hongrois, Budapest, various years.

Czernowitz, Innsbruck, Linz, Prague, Trieste, 1894–1911; Vierteljahreshefte zur Statistik, various years.

Belgium

Brugge, Ghent, 1800–1913; Verlinden, C. et al., 1972. Dokumenten voor de Geschiedenis van Prijzen en Lonen in Vlaanderen en Brabant, vols. III and IV. De Tempel, Brugge.

Brussels, 1800–1895; Verlinden, C. et al., Dokumenten voor de Geschiedenis, vol. III.

Antwerp, 1896–1913; Vierteljahrshefte zur Statistik, various years.

France

Arras, Barleduc, Bayeux, Bordeaux, Chateauroux, Lyon, Marseille, Mende, Pau, Saint-Brieuc, Toulouse, 1800–1913; Drame, P. et al., 1991. Un Siecle se Commerce du Ble en France 1825–1913. Economica, Paris; Labrousse, E. et al., 1970. Le Prix du Froment en France au Temps de la Monnaie Stable (1726–1913).S.E.V.P.E.N., Paris.

Paris, 1800–1913; Drame, P. et al.; Labrousse. E. et al.; NBER Macrohistory Database; and Vierteljahreshefte zur Statistik, various years.

Germany

Berlin, Breslau, Danzig, Frankfurt, Köln, Konigsberg, Leipzig, Mindau, Magdeburg, München Posen, Stettin, 1879–1913; Vierteljahreshefte zur Statistik, various years.

Italy

Avellino, Bergamo Brescia, Carmagnola, Genoa, Maddaloni, Modena, Naples, Padua, Parma, Rome, Verona, 1862–1894; Ministero dell'Interno—Direzione Generale di Statistica, Annuario Statistico Italiano. Tipografia Elzeviriana, Rome, various years; Ministero di Agricoltura, Industria e Commercio, Movimento dei Prezzi di Alcuni Generi Alimentari dal 1862 al 1885. Tipografia Eredi Botta, Rome, 1886; Ufficio di Statistica Agraria, Il Frumento in Italia. Tipografia Nazionale di G Bertero, Rome, 1914.

Norway

Bergen, 1830–1913; Wedervang Archives, Norges Handelshøyskole, W271 Christiania, 1830–1913; Wedervang Archives, Norges Handelshøyskole, W126, W137, W213, W258, W382, W387.

Stavanger, 1842–1913; Wedervang Archives, Norges Handelshøyskole, W132, W392, W394.

Russia

Ieletz, Libau, Moscow, Nicolaief, Novorisslisk, Odessa, Riga, Rostov, Samara, Saratof, St. Petersburg, Warsaw, 1893–1913; Svod Tovarnykh Tsien na Glavnykh Rynkakh Rossil. St. Petersburg, various years.

Spain

Burgos, Cordoba, Coruña, Gerona, Granada, Lerida, Oviedo, Segovia, Zaragoza, 1814–1907; Barquin Gil, R., 1999. El precio del trigo en Espana (1814–1883). Historia Agraria 17, 177–217; Grupo de Estudios de Historia Rural, 1980. Los Precios del Trigo y la Cebada en España, 1891–1907. Banco de Espana, Madrid; Sanchez-Alborboz, N., 1975. Los precios agricolas durante la segunda mitad del siglo XIX.Servicio de Estudios del Banco de España, Madrid.

Santander, 1821–1907; Ibid. Lón, 1829–1907; Ibid. Toledo, 1836–1907; Ibid.

The United Kingdom

Carmarthen, Cambridge, Dover, Exeter, Gloucester, Leeds, Liverpool, London, Manchester, Newcastle, Norwich, Worcester, 1800–1913; London Gazette, various years; Public Record Office MAF 10/74–107, 223–253.

The United States

New York City, 1800–1913; Cole, A.H., 1938. Wholesale Commodity Prices in the United States, 1700–1861: Statistical Supplement. Harvard University Press, Cambridge; Rubinow, I.M., 1908. Russian Wheat and Wheat Flour in European Markets. USDA Bureau of Statistics Bulletin No. 66, Washington: GPO; Vierteljahrshefte zur Statistik, various years.

Philadelphia, 1800–1896; Bezanson, A. et al., 1937. Wholesale Prices in Philadelphia, 1784–1861, Part II. University of Pennsylvania Press, Philadelphia; Bezanson, A. et al., 1954. Wholesale Prices in Philadelphia 1852–1896. University of Pennsylvania Press, Philadelphia; and Cole, A.H., 1938. Wholesale Commodity Prices in the United States, 1700–1861: Statistical Supplement. Harvard University Press, Cambridge.

Alexandria, 1801–1913; Peterson, A.G., 1929. Historical Study of Prices Received by Producers of Farm Products in Virginia, 1801–1927. Technical Bulletin of the Virginia Polytechnic Institute.

Cincinnati, 1816–1913; Berry, T.S., 1943. Western Prices Before 1861: A Study of the Cincinnati Market. Harvard University Press, Cambridge; Cincinnati Price Current, various years; Cole, A.H., 1938. Wholesale Commodity Prices in the United States, 1700–1861: Statistical Supplement. Harvard University Press, Cambridge; and White, H.E., 1935. An Economic Study of Wholesale Prices at Cincinnati, 1844–1914. Cornell University, Ph.D. dissertation.

Chicago, 1841–1913; NBER Macrohistory Database.

Indianapolis, 1841–1913; Houk, H.J., 1942. A Century of Indiana Farm Prices, 1841 to 1941. Purdue University, Ph.D. dissertation.

Ithaca, 1841–1913; Ronk, S.E., 1935. Prices of Farm Products in New York State, 1841 to 1935. Cornell University Agricultural Experiment Station, Ithaca.

San Francisco, 1852–1913; Annual Report of the Chamber of Commerce of San Francisco. Neal Publishing Company. San Francisco, various years; Annual Report of the San Francisco Merchants Exchange. Commercial News Publishing, San Francisco, various years; Annual Report of the San Francisco Produce Exchange.Commercial Publishing Company, San Francisco, various years; Berry, T.S., 1984. Early California: Gold, Prices, Trade.The Bostwick Press, Richmond; Davis, H., 1894. Appendix I: Tables Relating to California Breadstuffs, The Journal of Political Economy, 2 (4) 600–612; Sacramento Union, various years; Transactions of the California State Agricultural Society. O.M. Clayes, Sacramento, various years.

Kansas City, Minneapolis, St. Louis, 1899–1913; USDA Agriculture Yearbook. GPO, Washington, various years.

Appendix C. Explanatory variable sources

Canal indicators: The following sources were used to construct route maps of canal. Please note that cities were coded as being connected by canals whenever the possibility of an all-water route arises, rather than by a direct inter-city service being established.

Belgium
Buyst, E., Dercon, S., van Campenhout, B., 2000. Road Expansion and Market Integration in the Austrian Low Countries during the Second Half of the 18th Century. Center for Economic Studies, University of Leuven.

France
Geiger, R.G., 1994. Planning the French Canals. University of Delaware Press, Newark.

Germany
Kunz, A., 1994. Transnational Traffic Flows on Central European Inland Waterways in the late 19th and early 20th Centuries. In: European Networks, 19–20th Century. Universita Bocconi, Milan, pp. 105–118; Kunz, A., 1996. Statistik der Binnenschiffahrt in Deutschland 1835–1989. St. Katharinen, Berlin.

The United Kingdom
Crompton, G., 1996. Canals and Inland Navigation. Scolar, Aldershot; and Rolt, L.T.C., 1971. Navigable Waterways. Longman, London.

The United States
Fogel, W.F., 1964. Railroads and American Economic Growth. Johns Hopkins University Press, Baltimore; and Goodrich, C., 1961. Canals and American Economic Development.: Cambridge University Press, New York.

Distance: Intranationally calculated as the linear distance between two cities using ESRI ArcView; internationally calculated as the sum of the linear distance to the nearest port and the trade-route-specific (non-linear) distance between departure ports taken from Philip, G., 1935. Philip's Centenary Mercantile Marine Atlas. Philip George & Son, London.

Port indicators: Equal to one if both cities in the city-pair are oceanic ports.

Railroad indicators: The following sources were used to construct route maps of railroads. Please note that cities were coded as being connected by railroads whenever the possibility of an all-rail route arises, rather than by a direct inter-city service being established (e.g., Marseilles and Bordeaux were coded as connected in 1855 with the completion of the Marseilles-Paris line, as the Bordeaux-Paris line was established in 1853).

Austria–Hungary
Gasiorowski, Z.J., 1950. The System of Transportation in Poland. University of California-Berkeley, Ph.D. dissertation; Komlos, J., 1983. The Habsburg Monarchy as a Customs Union.Princeton University Press, Princeton; Milward, A.S., Saul, S.B., 1977. The Development of the Economies of Continental Europe, 1850–1914. George Allen & Unwin, London; Plaschka, R.G., Drabek, A.M., Zaar, B., 1993. Eisenbahnbau und Kapitalinteressen in der Beziehung der Österreichischen mit der Südslawischen Ländern. Verlag der Österreichischen Akademic der Wissenshaften, Vienna; Szabad, G., 1961. Das Anwachsen der Ausgleichstendenz der Produktenpreise im Habsburgerreich um die Mitte des 19. Jahrhunderts. In: Sándor, V., Hanák, P. (Eds.), Studien zur Geschichte der Österreichisch-Ungarischen Monarchie. Akadémiai Kiadò, Budapest, pp. 213–235.

Belgium
Laffut, M., 1983. Belgium. In: O'Brien, P. (Ed.), Railways and the Economic Development of Western Europe, 1830–1914.MacMillan Press, London, pp. 203–226; Ville, S.P., 1990. Transport and the Development of the European Economy, 1750–1918. MacMillan Press, London.

France
The primary source was Joanne, A., 1858. Atlas Historique et Statistique des Chemins de Fer Francais. Librairie de L. Hachette, Paris. Supplementary data from Leclercq, Y., 1987. Le Reseau Impossible. Librairie Droz, Geneva; Milward, A.S., Saul, S.B., 1973. The Economic Development of Continental Eur-

ope 1780–1870. George Allen & Unwin, London; Mitchell, A., 2000. The Great Train Race: Railways and the Franco-German Rivalry, 1815–1914. Berghahn Books, New York; and Price, R., 1983. The Modernization of France. Hutchinson, London.

Germany
Gasiorowski, Z.J., 1950. The System of Transportation in Poland; Mitchell, A., 2000. The Great Train Race.

Italy
The primary source was Ferrovie dello Stato, 1940. Il Centenario delle Ferrovie Italiane, 1839–1939. Istituto Geografico de Agostini, Rome. Supplementary data from the Board of Trade, 1910. Railways in Belgium, France, and Italy. Darling & Son, London; Fenoaltea, S., 1983. Italy. In: O'Brien, P. (Ed.), Railways and the Economic Development of Western Europe, 1830–1914. MacMillan Press, London, pp. 49–120; and Ville, S.P., 1990. Transport and the Development of the European Economy.

Norway
Milward, A.S., Saul, S.B., 1973. The Economic Development of Continental Europe.

Russia
The primary source was Section de Statistique et de Cartogrpahie du Ministere de voies de communication, 1900. Aperçu Statistique des Chemins de Fer et des Voies Navigables de la Russie. Imprimerie du Ministere des voies de communication, St Petersburg. Supplementary data from Gasiorowski, Z.J., 1950. The System of Transportation in Poland; and Milward, A.S., Saul, S.B., 1977. The Development of the Economies of Continental Europe.

Spain
The primary source was Cordero, R., Merendez, F., 1978. El sistema ferroviario español. In: Artola, M. (Ed.), Los ferrocarriles en España, 1844–1943, vol. I. Banco de España, Madrid, pp. 163–340. Supplementary data came from Milward, A.S., Saul, S.B., 1977. The Development of the Economies of Continental Europe.

The United Kingdom
Acworth, W.M., 1889. The Railways of England.John Murray, London; and Simmons, J., Biddle, G. (Eds.), The Oxford Companion to British Railway History from 1603 to the 1990s. Oxford University Press, New York.

The United States
Martin, A., 1992. Railroads Triumphant. Oxford University Press, New York; Stover, J.F., 1961. American Railroads. University of Chicago Press, Chicago; Stover, J.F., 1999. The Routledge Historical Atlas of the American Railroads. Routledge, New York; Taylor, G.R., Neu, I.D., 1956. The American Railroad Network. Harvard University Press, Cambridge.

River indicators: Equal to one if both cities in the city-pair are connected by a navigable river system

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Blum, J., 1943. Transportation and industry in Austria, 1815–1848. The Journal of Modern History 15 (1), 24–38.

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