What Drove Nineteenth Century Commodity Market Integration?[*]

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I. Introduction

For a number of years, the process of commodity market integration has proven to be an area of abiding theoretical and empirical interest. Long-standing deviations from the law of one price have been documented for a remarkably wide range of geographic areas and time periods. The literature on the topic has recently been reoriented, primarily due to the work of Engel and Rogers (1995, 1996) and McCallum (1995). The shared hypothesis of these two lines of research is that there is a marked effect of national borders, both in terms of heightened commodity price variation and diminished commodity flows, which is registered in the data even after controlling for such things as distance and exchange rate volatility. Although very recent work has called into question the extent of the border effect in relation to the impediment of the flow of goods (Anderson and van Wincoop, 2003), the ubiquity of a border effect in the determination of relative price volatility seems inescapable (cf. Engel and Rogers, 2001; O'Connell and Wei, 2002; and Parsley and Wei, 1996, 2001a,b).

The common strand linking this literature is the attempt to explain the degree of commodity market integration at a given point in time through the use of a handful of explanatory variables. A few questions have remained unasked, and therefore unanswered, in the literature. Namely, are the forces at work identified in the contemporary literature indicative of commodity market integration in other periods? More importantly, what can we take as the proximate causes of the evolution of commodity market integration?

[*] In the interests of space, all appendices have been removed from this version of the paper. For those interested, the full version is available at www.econ.ucdavis.edu/graduate/dsjacks/papers .

To answer these questions, this paper proposes to broaden the temporal scope of the existing literature by considering another period of nascent globalization, namely the long nineteenth century. In the past decade, the nineteenth century has received a new wave of interest as researchers have repositioned the period as one of so-called early globalization. Thus, the corpus of work by O'Rourke, Williamson, and others has directed the attention of economic historians and economists alike back to this time of unprecedented—and in many respects, unsurpassed— integration of global commodity, capital, and labor markets (O'Rourke and Williamson, 1999).

What this paper will attempt to do then is serve as a bridge between the contemporary trade literature and the economic history of the nineteenth century. Furthermore, the paper also has non-trivial implications for the economic development. If well-functioning markets do indeed allow for gains from the division of labor and/or increasing returns, then the determination of which factors contribute most directly to the process of market integration becomes crucial.

The first fundamental result is that the findings presented below not only can be aligned with the contemporary trade literature but also allow for the identification of further variables which have been relatively underrepresented: technological change; enduring, trade-enhancing geographical features associated with navigable waterways; the choice of monetary regime and commercial policy; and intra- and inter-state conflict.

Second, when commodity market integration is split into the sub-processes of price adjustment and convergence, the results point to the fact that two different sets of causal factors predominate in each case. Most surprisingly, variables associated with the choice of commercial policy and monetary regime—and not technological change—dominate price convergence. And while a more balanced set of factors is at play in price adjustment, the role of technological change is much more muted than previously supposed.

II. Motivation

In confronting the economic history literature, there are certain themes which seem to dominate the narrative of the nineteenth century. Although diplomatic, commercial, and financial advances are given some credit, the prevailing view seems to be that the main drivers of commodity market integration in this period were fundamental changes in the technology of communication and transport.

When only considering the record of transport costs in the nineteenth century, this view seems somewhat vindicated. Figure 1 below depicts North's (1958) series on the course of freight costs (as a share of final price) for wheat from NYC to London in the period from 1830 to 1913. It is immediately apparent from the figure that even though there was a secular decline in freight costs throughout the nineteenth century, the most impressive declines took place in the post-1875 period. Thus, the movements in freight costs correspond nicely with the timing of the introduction and eventual domination of steam over sail on this route. Such improvements in observed freight costs can been demonstrated for railroads as well.

However, for much of the nineteenth century only a small portion of trade costs (estimated from observed price differentials and detailed below) was explained by transport charges. A hint of this is seen in Figure 2 which compares estimates of trade costs for New York City and London as against North's (1958) 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 research—one which has recently been picked up by trade economists (Anderson and van Wincoop, 2004).[1]

Thus, what this paper seeks to do is to use estimates of trade costs and of speeds of price adjustment in wheat markets, in order to determine the drivers of commodity market integration in the nineteenth century. Specifically, these estimates will be related to cross-sectional and temporal variations in geography, technology, institutions, and warfare.

III. 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 underlying issue at hand is the formulation of an intra- and inter-national division of labor—a process predicated, of course, upon the successful transmission of price signals across time and space. Without the tendency for prices to converge, the process of market integration becomes a hollow concept. However, it does not necessarily follow that price convergence is a sufficient condition for (economically significant) market integration as prices may be determined or influenced by processes outside of the realm of commercial exchange (e.g. large-scale climatological events; on this point, see Post, 1977).

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

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.

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; and Prakash and Taylor, 1997), those studies of market integration based on the absolute law of one price (LOP) fail to compensate for the very real elements of 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,[2] 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 transportation and transaction 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.

[2] 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,

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

1.) $P_t^1 \leq P_t^2 + C_t^{21}$, 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 transaction 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:

1a.) $-C_t^{21} \leq P_t^2 - P_t^1$

1b.) $P_t^1 - P_t^2 \leq C_t^{21}$

Likewise, if we reverse the order, we arrive at

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

2a.) $-C_t^{12} \leq P_t^1 - P_t^2$

2b.) $P_t^2 - P_t^1 \leq C_t^{12}$

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

3.) $-C_t^{12} \leq M_t^{12} \leq C_t^{21}$

4.) $-C_t^{21} \leq M_t^{21} \leq C_t^{12}$

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

prevailing interest rates, and/or the risk aversion of agents can be incorporated into the model. As such, "trade

To operationalize conditions 3.)-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*, $(M_{t-1}^{12} = P_{t-1}^1 - P_{t-1}^2)$, 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:

$$5.)\ \Delta P_t^1 = \begin{cases} r_1(M_{t-1}^{12} - C_{t-1}^{21}) + h_t^1 & if\ M_{t-1}^{12} > C_{t-1}^{21} \\ h_t^1 & if\ -C_{t-1}^{12} \le M_{t-1}^{12} \le C_{t-1}^{21} \\ r_1(M_{t-1}^{12} + C_{t-1}^{12}) + h_t^1 & if\ M_{t-1}^{12} < -C_{t-1}^{12} \end{cases}$$

$$6.)\ \Delta P_t^2 = \begin{cases} r_2(M_{t-1}^{21} - C_{t-1}^{12}) + h_t^2 & if\ M_{t-1}^{21} > C_{t-1}^{12} \\ h_t^2 & if\ -C_{t-1}^{21} \le M_{t-1}^{21} \le C_{t-1}^{12} \\ r_2(M_{t-1}^{21} + C_{t-1}^{21}) + h_t^2 & if\ M_{t-1}^{21} < -C_{t-1}^{21} \end{cases}$$

where $(h_t^1, h_t^2) \sim Nid(0, \Omega)$. The sum of the r-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 is analogous to that of the SUR estimator, or namely

$$7.)\ \log L = -\frac{TM}{2}\log(2p) - \frac{T}{2}\log|\Omega| - \frac{1}{2}\sum_{t=1}^{T} h_t^{'}\Omega^{-1}h_t\ ,$$

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

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costs" will be interpreted as all the observed and unobserved costs of exchange.

Of course, this approach seems to beg the question: all estimates of the speed of price adjustment (r) are contingent upon specified values of the trade-cost terms, $(|C^{12}_{t-1}|, |C^{21}_{t-1}|)$, 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 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 adjustment speeds used below.[3]

Figure 3 below 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] It should also be noted that the search procedure allows for a band of zero width. Thus, the model nests the more familiar ECM model traditionally used in other studies and allows for the construction of diagnostic statistics as detailed in Appendix II.

3.02) and .083 GBP/100 kg. from Manchester to London (with a t-statistic of 2.21) which are depicted in Figure 3 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, partly due to data constraints, all price data was 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 inter-national 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 inter-national 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. Figures 4 and 5 display the geographical range of cities considered while Appendix I below summarizes the coverage and sources of the dataset.

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 for any particular pair of cities the estimated trade costs are observed to decline through time, it can be assumed that the

[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 the second appendix to this chapter.

level of the price differential between the two cities has fallen as well. Additionally, coupled with information on the general level of prices, 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 *TCs/Price* 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.

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 twelve) by *t* (generally, 11 years, for 132 monthly observations) and to form all pair-wise 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 value of the 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 (66 unique city-pairs), estimation began in the period of 1800-1810 and

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

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

ended in that of 1905-1913 with 20 intervening observations on the course of market integration (thus, T=22).

As to the international component, in large part 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, it was decided that the price data for each country should be matched with prices from a set of 5 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 exists 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 values of these estimated parameters; and iterate this procedure at 5-year steps for each country.

IV. Empirical Results

To weigh the determinants of nineteenth century commodity market integration, this section takes an unabashedly empirical approach. The variables of interest will be the (scaled) trade cost and price adjustment estimates described above. The measures remain bilaterally defined by city-pairs (e.g., London-Manchester or London-Marseilles) and are presently regressed on a large number of independent variables which seem likely contenders in driving commodity market integration.

The first step will be to consider a benchmark case inspired by the work of Engel and Rogers (1995, 1996) and Parsley and Wei (1996, 2001a). Along the way, further explanatory

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This measure was also constructed 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 variables will be introduced; this approach serves two purposes. First, it allows the analysis to be tied to the existing trade and economic history literatures. Second, it also demonstrates the consistency of estimates across specifications.

Table 1 below summarizes the coverage of the underlying price data as well as the resultant observations on trade costs and speeds of price adjustment while Table 2 provides summary statistics on all dependent and independent variables employed below. Finally, a correlation matrix for all independent variables is reproduced in Table 3.

Benchmark Analysis

Researchers looking into the forces affecting market integration for the late twentieth century have generally used a modified gravity-model. Typically, a regression of the following type, taken from Engel and Rogers' seminal work (1996), is estimated:

$$9.)\quad V(P_{j,k}) = b_1 r_{j,k} + b_2 B_{j,k} + \sum_{m=1}^{n} g_m D_m + u_{j,k},$$

where the dependent variable equals the variance of the logged price ratio in cities j and k, $r_{j,k}$ is the distance between cities, $B_{j,k}$ indicates a border between the two cities (i.e., an indicator variable for trade across national borders), and D_m is an indicator variable for each city in the sample. Additions to this model have included trade barriers and regional indicators (Engel and Rogers, 1995), lagged dependent variables (Parsley and Wei, 1996), the difference of the changes in the logged prices as the dependent variable (Parsley and Wei, 2001b), and a squared distance term (Engel and Rogers, 2001).

Here the same exercise will be followed in broad form, but with a view towards more explicitly modeling the structure of errors. Typically, estimation of equation 9.) has taken place

added little further information on the process of price convergence and, therefore, are not reported here.

within the framework of ordinary-least-squares estimation with no or limited controls for heteroscedasticity or serial correlation. What is currently proposed is the use of GLS estimation,[6] explicitly incorporating group-wise, cross-sectionally correlated heteroskedasticity (based on country-pairs) and serial correlation[7] into the structure of the variance-covariance matrix. Thus, our baseline results come from the following regression:

$$10.)\quad Integration_{j,k,T} = b_1 dist_{j,k} + b_2 distsq_{j,k} + b_3 evol_{j,k,T} + b_4 border_{j,k} + \sum_{T=1}^{22} g_T D_T + u_{j,k,T},$$

where the dependent variable is time-specific and is defined as one of the measures of market integration between city-pairs over a period (i.e., either the estimated trade cost term, *TCs/Price*, or the speed of price adjustment. The first two terms on the right-hand side, $dist_{j,k}$ and $distsq_{j,k}$, refer to the distances and squared distances separating cities j and k; $evol_{j,k,T}$ is the variance of the logged nominal exchange rate between the currencies of j and k over the period, T; $border_{j,k}$ denotes the existence of a border between j and k; and D_T is a set of time dummies for each of the twenty-two periods considered.

Furthermore, a suitable weighting matrix for the dependent variables needs to be specified in order to implement the GLS estimator with group-wise and serially-correlated disturbance terms. In all results reported below, the weights used were the number of observations on prices underlying estimation of each city-pair's trade costs and speed of price adjustment. Given the behavior of the related class of threshold-auto-regression estimators in simulations (Blake and Fomby, 1997; Chan, 1993; and Hansen, 1997), it is assumed that the

[6] GLS also has the desirable property of controlling for the fact that the dependent variables are themselves estimated variables. Given a properly defined set of weights on observations, the GLS estimator is consistent and unbiased (see Saxonhouse, 1976).

[7] As a further corrective for the possibility of serial correlation, regressions on non-overlapping observations were also estimated. In this case, the results were not fundamentally altered, although this approach entailed a general loss of power. Consequently, it was opted to use all available data and correct for serial correlation as described above; Appendix I reports the results of this exercise.

number of observations will be inversely proportional to the asymptotic variance of the resultant estimates. It should also be noted that the results presented are highly invariant to any set of plausible weights selected, such as the value of summed squared errors, log-likelihood values, F-test values, or p-values.

The results from this initial regression are reported in column 1 of Table 4 below. The patterns look sensible. Trade costs increase with distance, nominal exchange rate volatility, and the border (alternatively, one can say the price convergence is decreasing in the same variables). The speed of price adjustment decreases as these same variables rise. Thus, this initial exercise nicely illustrates the broad pattern one would expect from all of the following results, namely that coefficients on trade costs should have the opposite sign of those on the speed of price adjustment. What remains to be seen, however, is if there are any noticeable differences in the relative strength of regressors on trade costs and adjustment speeds.

Technology Variables

One of the most noticeable gaps in the existing trade literature is any consideration of technological change. Understandably, this gap is primarily a function of the time horizons considered (generally, only the 1990s) in which one would reasonably expect no fundamental shifts in the technology of communication, transport, and/or transactions. Here, an attempt is made to integrate technological change into the analysis.

As even the most cursory review will reveal, the historical literature on the nineteenth century seems to be dominated by certain key themes, namely the development of intra- and inter-national communication and transport networks. In this account, the dynamic twins of the railroad and telegraph take pride of place in creating economically and socially unified polities.

In order to assess the validity of the various untested claims made about the efficacy of railroads, in particular, in forming coherent national and international markets, a series of variables was constructed which capture the historical development of American and European rail networks.[8] These variables switch "on" with the completion of an intercity rail connection. However, since estimates of trade costs and adjustment speeds are generated over eleven-year periods, it was decided not to code these variables as being discrete. Rather, they are continuously defined, capturing the portion of a time period in which a railroad connection existed. For instance, a railroad link between Marseilles and Bordeaux was introduced in 1855. In this case, the railroad variable would have been coded as 0 for the period of 1840-50, .09 for the period of 1845-55, .55 for the period of 1850-60, and 1 for the period 1855-65. This coding technique was also employed for many of the other variables considered below. Appendix II below provides definitions as well as sources for all independent variables.

The effects of including the railroad variable along with an interaction term with distance (*railroad-distance*) on the initial results are reported in column 2 of Table 4 below. The motivation for including our interaction term, railroad-distance, is that a railroad between Maddaloni and Naples (the shortest rail route at 30 km.) may have had a very different impact than that between Samara and Brugges (the longest route at 8080 km.). The railroad variable proves to be significant in the case of both trade costs and adjustment speeds although the magnitude of the effect is telling—railroads were associated with only a 7.4% reduction in trade costs but a 25% increase in adjustment speeds when evaluated at their means. Notably, the

[8] Unfortunately, the data for constructing a separate variable capturing the introduction of the telegraph do not exist. However, all indications from the secondary literature point to the fact that telegraphs were almost universally introduced at the same time as railroads. Accordingly, the *railroad* variable most likely captures the effects of both railroads and telegraphs.

results indicate no significant interaction term between railroad and distance for trade costs while it does appear that distance had a muting effect on adjustment speeds.

A further issue to be addressed is one touched off forty years ago by Fogel (1964). Briefly, the debate revolves around the question of what was the incremental contribution of railroads over and beyond that of canals. Given the extensive and expandable canal network in the United States prior to the establishment of railroads, it was Fogel's argument that this incremental contribution of railroads was small. The results presented here are surprising in that they confirm Fogel's skepticism, albeit in a way not addressed in the original debate. Whereas the original argument was framed in terms of the contribution of railroads to economic growth via investment demand and social savings via lower transportation costs, what the second column of Table 4 implies is that while canals' contribution to adjustment speeds was definitely overshadowed by that of railroads, canals were associated with equivalent reductions in trade costs.[9]

Finally, to assess technological change in maritime shipping, exploratory regressions were run on the variables included in our final specification (see below) along with an interaction term between time and an indicator variable on port city-pairs (*port*). The results of these exercises are depicted in Figures 6 and 7 which plot the sum of the coefficients attached to this interaction term along with those associated with the original set of time indicator variables. Broadly, they offer an interesting story of the integration of ports through time: if there were any advantages associated with ports in terms of trade costs or adjustment speeds, these were dissipated sometime around 1870. However, the post-1870 period is precisely when one would

[9] In a preliminary exercise, an interaction term between *canal* and *distance* was employed. The estimated coefficients were highly insignificant for both dependent variables. This was a pattern repeated with other potentially distance-related variables, i.e. rivers and ports. Throughout, it is only the railroad-distance interaction which performs relatively well. Consequently, interaction terms for the other variables have been suppressed.

expect the advantages of ports to mount as steam overtook sail's pride of place in maritime shipping. Thus, these results imply that technological change in the maritime industry (read steamships) may have had far more muted effects than previously supposed. Until the diffusion of maritime technology can be more explicitly captured, however, these results will remain only suggestive.

Geography Variables

Much of the recent literature on long-term growth patterns has tried to assess the implications of geography for economic activity, interaction, and evolution—some finding a critical role (Sachs, 2000, 2001) and others a negligible one (Acemoglu et al., 2002). Without pushing the parallel too far, it can be fairly said that one of the issues central to this debate is the degree to which geography shapes patterns and terms of trade. Surprisingly little work in the literature on market integration has explicitly tried to incorporate the potential contribution of geographic features, beyond the inclusion of distance or border variables.

As a slight remedy to this situation, indicator variables on the existence of port facilities on both sides of our city-pairs (*port*) and of a shared navigable river system (*river*) were introduced to the estimating equation. As can be seen in column 3 of Table 4, the inclusion of these variables adds to the explanatory power of the regressions on trade costs (with the expected negative signs confirmed) and adjustment speeds (with the expected positive signs confirmed). Interestingly, the coefficients on *river* do not stray very far from those on *canal*—a nice result if one considers a canal to be an artificial river—while the small magnitude of the *port* coefficients is consistent with the analysis above on the role of maritime technology.

Monetary Regime Variables

The choice of monetary regime as an independent variable may strike some as an odd one. After all, in standard models of arbitrage, the only role for monetary regimes would seem to be in the amelioration of nominal exchange rate volatility, and this is being controlled for already. The motivation for including the choice of monetary regime then comes from the mounting empirical evidence that it is indeed a strong determinant (or at least, correlated with other unobserved determinants) of the directions and dimensions of the volume of trade.[10]

The effects of two potentially key variables—the emergence of the classical gold standard and the existence of monetary unions—on the process of market integration are explored presently. Column 4 of Table 4 clearly indicates that the former variable consistently and significantly contributes to the process of market integration. The nearly equal but opposite coefficients respectively associated with *border* and *gold standard* in the regressions on trade costs and adjustment speeds allow for a very tantalizing interpretation: namely, the adoption of the gold standard resulted in the effective extension of a country's borders to include other nations in the gold standard club. Furthermore, as exchange rate volatility is already controlled for, the adoption of the gold standard must be symptomatic of deeper integrative forces at work (Bordo and Flandreau, 2003).

Less dramatic results are forthcoming when the monetary union variable is considered. Although correctly signed, monetary union fails to be significant in either the trade cost or adjustment speed regressions. However, given the peculiar history of monetary unions in the nineteenth century (as well as limitations imposed by the sample), these results may not be surprising. From the sample countries, it was possible to effectively code only one monetary union from 1800-1913. This was the Latin Monetary Union which saw Belgium, France, Italy, and Switzerland united under a single monetary standard based on the silver 5-franc piece. Its year of inauguration, 1865, was an inauspicious one as the dollar price of silver plummeted in the next decade, forcing the Latin Monetary Union countries onto a *de facto*, then *de jure* gold standard (Flandreau, 1996). Thus, the effectiveness of the Latin Monetary Union is probably conflated with that of the gold standard variable. In what follows, therefore, the monetary union variable is omitted from the regressions.

Commercial Variables

The variables included in this section explore two different facets of commercial interaction, trade-enhancing networks and trade-diminishing policy. As to the former, a substantial body of empirical and theoretical work attests to the role of networks in overcoming incomplete information and fostering commercial linkages between nations (Casella and Rauch, 2003; Greif 1993, 2000; Rauch 2001; Rauch and Trindale, 2002). The basic idea is that shared social or ethnic backgrounds facilitate the transmission of information on market conditions and, thus, greater integration of markets as individuals exploit any potential arbitrage opportunities. Here, it is proposed that the use of common language variable be used to roughly capture such shared social backgrounds which might be expected to reduce trade costs while increasing adjustment speeds.

As to the latter, the course of commercial policy in the nineteenth century Atlantic economy is a familiar one in the economic history literature. Following the disruptions of the Napoleonic Wars, commercial policy in the early nineteenth century was still formulated in near-

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[10] For an indication of the work on historical monetary standards see López-Córdova and Meissner (2003); on contemporary currency unions, see Frankel and Rose (2002), Glick and Rose (2002), and Rose and van Wincoop

mercantilist terms until Britain's repeal of the Corn Laws in 1846. This date marked the beginning of a liberal interlude for much of the Atlantic economy dating from mid-century until the 1880s when a 'grain invasion' by newly settled regions provoked a new round of appeals for agricultural—and industrial—protection (O'Rourke, 1997). Accordingly, variables capturing ad valorem tariff rates on wheat and prohibitions on wheat importation were coded as *ad valorem* and *prohibition*, respectively.

Column 5 of Table 4 presents the results of including the aforementioned commercial variables. A significant, though somewhat weak pro-integration effect can be seen for the common language variable, both in terms of trade costs and adjustment speeds. On the other hand, the commercial policy variables are related with very large effects on trade costs and somewhat smaller effects on adjustment speeds. It should also be noted that with the inclusion of the commercial variables the coefficients on the border were effectively halved when compared to the results in column 4. Thus, with a more precise set of variables, it may be possible in future research to diminish the border effect even further.

Conflict Variables

With respect to this last category, the contemporary trade literature has focused on observational units which are relatively free from incidences of war and insurrection, so it might be instructive to give them full consideration for the nineteenth century—a relatively peaceful century, but one to which the depredations of war were not unknown. Using data collected under the auspices of the Correlates of War project, it was possible to construct suitable variables for the occurrence of interstate warfare. These were designed to represent one country's neutrality in the face of a time of war for a trading partner (*neutral*), open conflict between trading partners

(2001).

and a common enemy (*allies*), and open conflict between trading partners (*At war (external)*). A final element added was the *At war (internal)* variable seeks to capture the effects on intranational integration when a country is war with another.

In a similar vein, further variables included are those which capture the effects of civil wars on international and intranational integration. These are designated as *Civil war (external)* and *Civil war (internal)*, respectively.

The results of the exercise incorporating the conflict variables are reported in column 6 of Table 4. The signs on the coefficients are consistent with reasonable expectations. Participation in warfare in any form simultaneously raises trade costs and lowers adjustment speeds. Interestingly, the insignificance of the *neutral* variable suggests that, at least for the nineteenth century, the adverse effects of warfare on integration were limited to those actively engaged in conflict. The magnitude of the coefficients, furthermore, make it clear that both trade costs and adjustment speeds seem to be highly sensitive to the outbreak of open conflict. This may seem an obvious point, but only limited attempts have been made by economists and historians in explicitly quantifying the effects of conflict on trade.

A Ranking of Independent Variables in the Final Specification

Rounding things out, Table 5 below summarizes the final specification into a more easily digestible format. The point of the exercise is to simply decompose the effects of like increases in the values of the independent variables on the various measures of market integration. A few conclusions are clearly forthcoming with regard to the relative contributions of technology, monetary regimes, commercial policy, and conflict. First, the overwhelming effect of open conflict on trade costs and adjustment speeds is easily recognized. Indeed, the possibility remains that the decline in frequency and intensity of warfare throughout the nineteenth century was one of the primary driver of commodity market integration. Of course, until the direction of causality linking these two developments is made clear, this will remain a speculative claim.

Second, even if the conflict variables are considered somehow exogenous to the process of market integration, this exercise still provides strong results. Namely, in considering the other potential drivers of integration, it is apparent that many non-technological developments had powerful effects in the nineteenth century. This is particularly so in the case of trade costs in which commercial policy and the gold standard trumped all of the technology variables considered.

V. Conclusion

Building on the insights provided by the contemporary literature on the determinants of the degree of commodity market integration at a single point in time, this paper has attempted to lay a foundation for assessing the determinants of the evolution of commodity market integration.

First, a number of variables have been determined which undoubtedly figured heavily in determining the pace of market integration. Among these were variables recognizable from the contemporary literature such as controls for distance, exchange rate volatility, common languages, and the border effect. Interestingly, the results verify the commonality of commodity market integration in the nineteenth and twentieth centuries. Additionally, further variables were identified which to date have been unrepresented in the trade literature: the establishment of inter-city transport linkages; enduring, trade-enhancing geographical features associated with navigable waterways; the choice of monetary regime; commercial linkages and policy; and the effects of intra- and inter-state conflict.

Second, the decision to split commodity market integration into the sub-processes of price convergence and price adjustment has been justified as two different sets of causal factors predominate in each case. Price convergence—as reflected in the results on trade costs—seems to be more responsive to changes in the choice of monetary regimes and commercial policy than changes in the underlying technology of trade. Running somewhat counter to this finding, price adjustment—as reflected in the results on adjustment speeds—represents a more balanced account as technological, monetary, and commercial variables all seem to play a part. In any case, explanations of market integration in terms of exogenous, technological change have probably and unduly diverted our attention from analyzing the more important elements of the organization of trade and its institutional apparatus.

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Figure 1: NYC-to-London Observed Freight Costs for 100 kg. of wheat (as a share of average price)

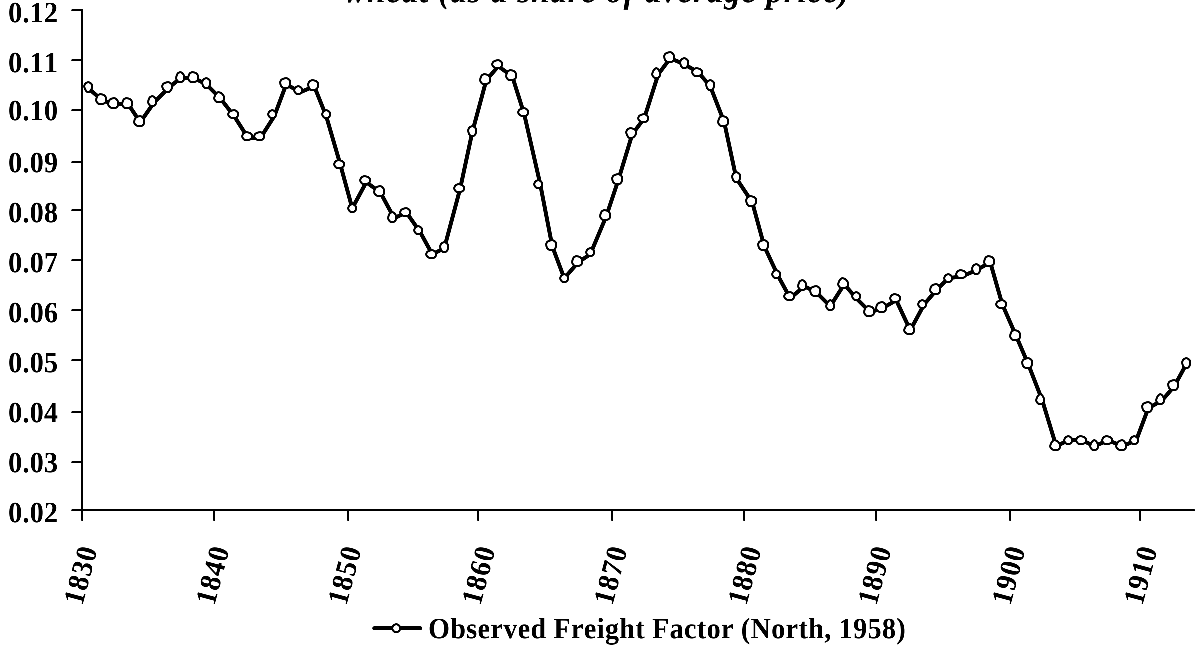

Figure 2: NYC-to-London Observed Freight & Estimated Trade Costs for 100 kg. of wheat (as a share of average price)

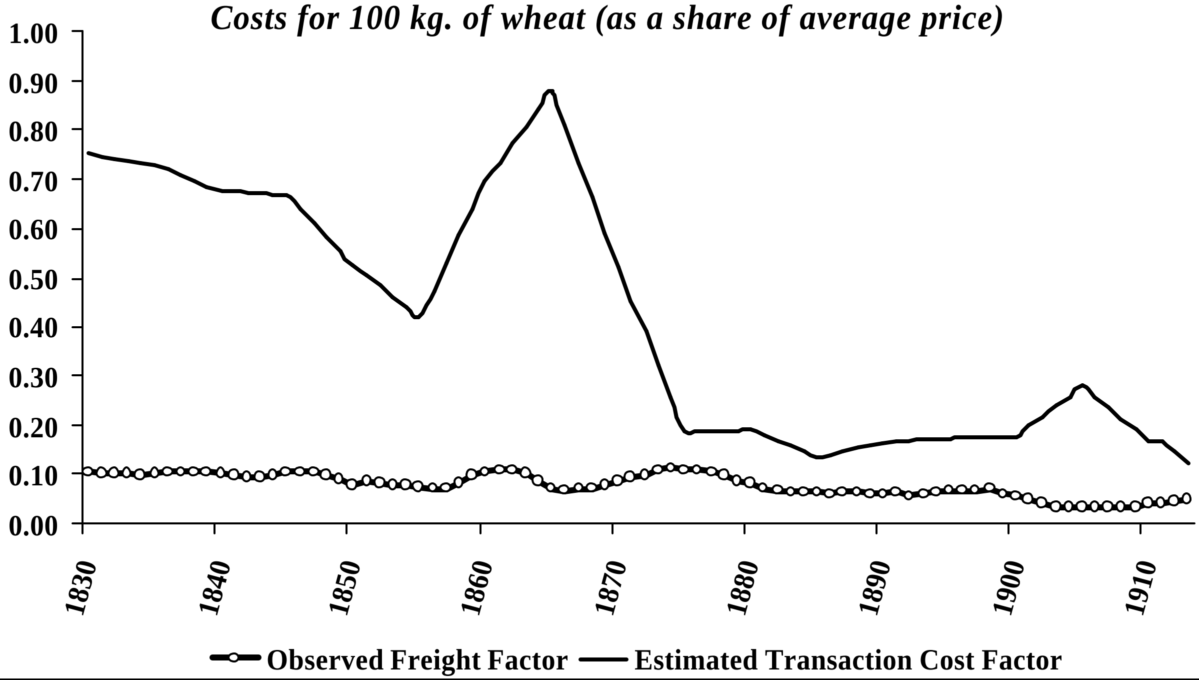

Figure 3: London-Manchester Price Margin, 1800-10 (GBP/100 kg.)

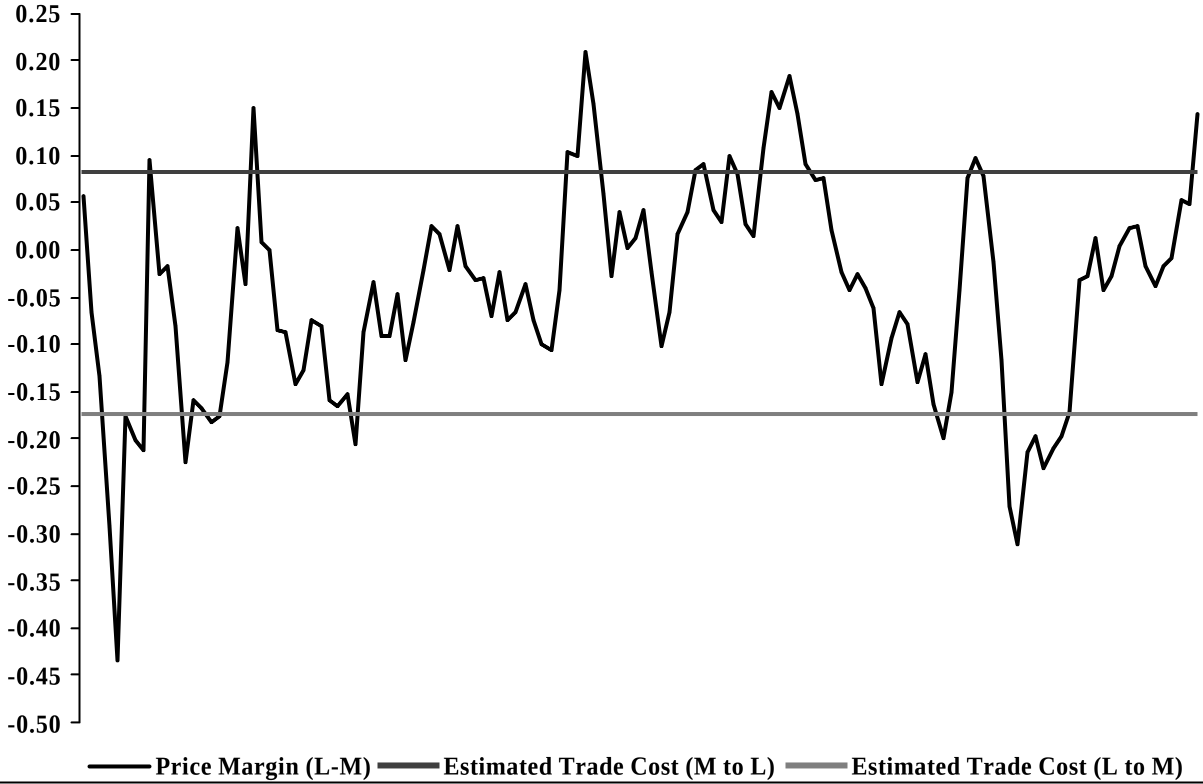

Figure 4: European Cities in Sample

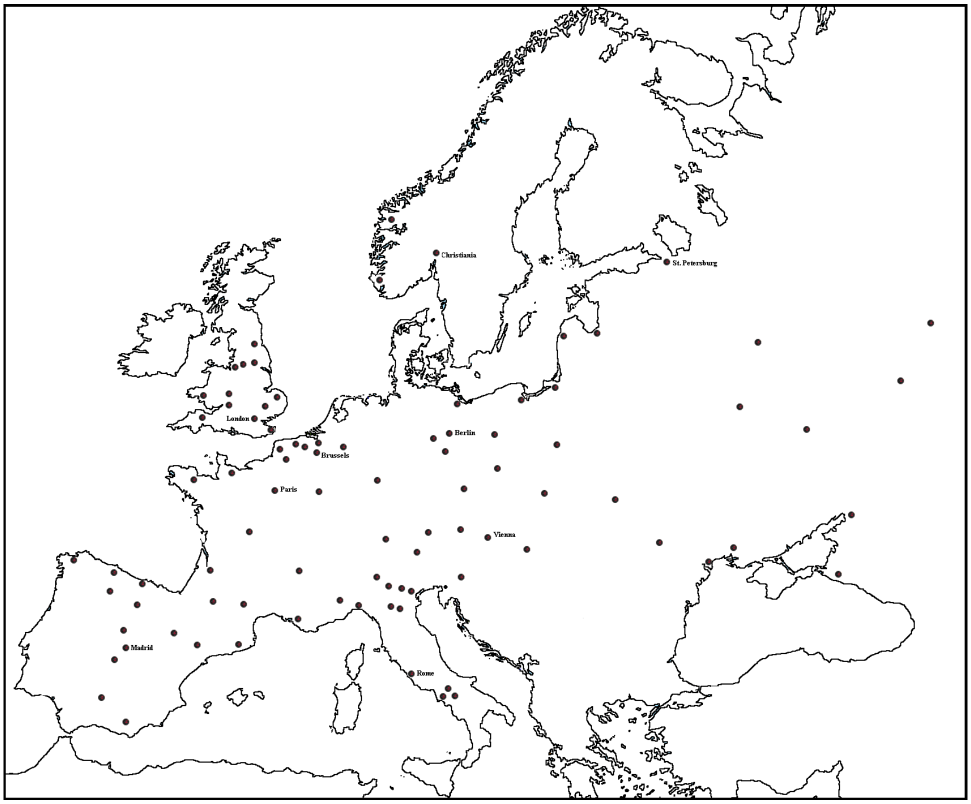

Figure 5: U.S. Cities in Sample

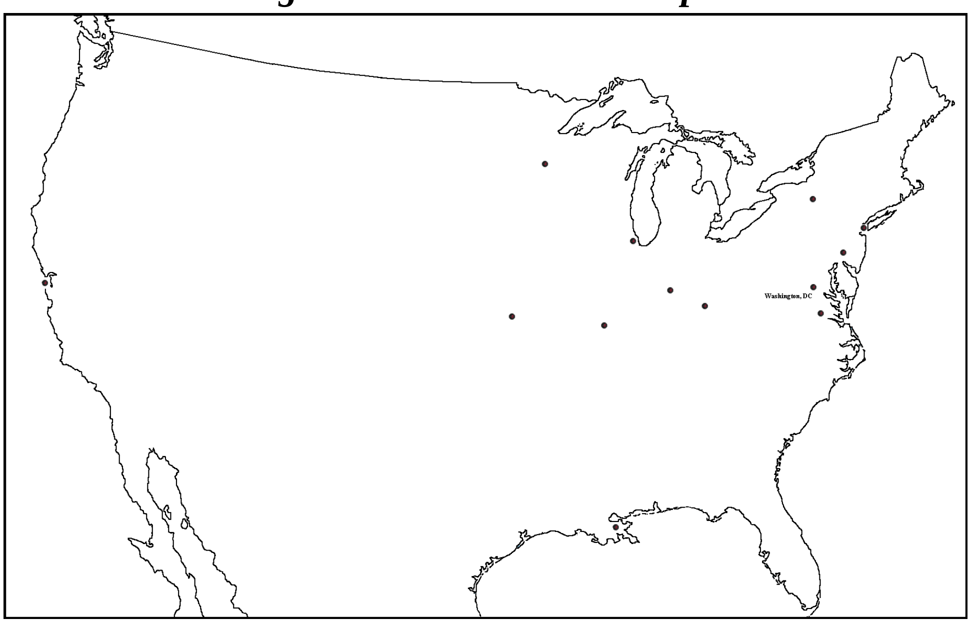

Table 1: Abbreviated Data Summary

		Underlying	Resulting Observations		
SAMPLE COUNTRIE	Cities	Price Obs.	Intra-national	Inter-national	TOTAL
Austria-Hungary	10	7044	343	1536	1879
Belgium	4	4104	68	1371	1439
France	12	16416	1452	1962	3414
Germany	12	5040	462	420	882
Italy	12	4752	396	360	756
Norway	3	2880	42	225	267
Russia	12	3024	264	240	504
Spain	12	13008	1124	1075	2199
United Kingdom	12	16416	1452	1962	3414
United States	12	9876	603	1665	2268
Full Panel	101	82560	6206	5408	11614

Table 2: Data Summary

	Description	N	Mean	Standard Deviation	Minimum	Maximum
		Dependent Variables				
TCs/Price	Sum of estimated trade costs over average price	11578	0.384	0.267	0.009	1.954
Adjustment Speed	Sum of estimated asymmetric speed-of-price-adjustment parameters	11578	0.585	0.333	-1.432	0.364
		Weights				
Observations	Number of underlying price observations used in estimation of datapoint	11578	123	20.045	23	132
		Independent Variables				
Distance	Sum of land (linear) and sea (non-linear) distance	11578	2531	3232	30	27270
Distance squared	Distance squared (km.)	11578	16800000	48500000	900	744000000
Exchange rate volatility	Variance of logged nominal exchange rate	11540	0.005	0.019	0	0.156
Border	Indicator of trade across national borders	11578	0.466	0.499	0	1
Railroad	Portion of time in a period in which a railroad connection existed	11578	0.440	0.485	0	1
Railroad-distance	Interaction term between Railroad and Distance	11578	571	1342	0	8079
Canal	Portion of time in a period in which a canal connection existed	11578	0.050	0.218	0	1
River	Indicator of a shared river system (bilaterally defined)	11578	0.028	0.166	0	1
Port	Indicator of ports (bilaterally defined)	11578	0.099	0.299	0	1
Gold standard	Portion of time in a period under gold standard adherence (bilaterally defined)	11578	0.111	0.302	0	1
Monetary union	Portion of time in a period under a monetary union (bilaterally defined)	11578	0.021	0.142	0	1
Common language	Indicator of a common language	11578	0.065	0.247	0	1
Ad valorem	Average ad valorem tariff on wheat between two countries	11578	0.070	0.158	0	0.983
Prohibition	Average portion of time in a period in which countries banned wheat imports	11578	0.073	0.197	0	1
Neutral	Portion of time in a period in which only one trade partner is at war	11578	0.026	0.093	0	1
Allies	Portion of time in a period in which two trade partner's are allied in war	11578	0.008	0.077	0	1
At war (external)	Portion of time in a period in which two trade partner's are at war	11578	0.014	0.102	0	1
At war (internal)	Portion of time in a period in which a country is at war times (1-Border)	11578	0.051	0.167	0	1
Civil war (external)	Portion of time in a period in which a country is in civil war times Border	11578	0.019	0.081	0	0.621
Civil war (internal)	Portion of time in a period in which a country is in civil war times (1-Border)	11578	0.021	0.086	0	0.621

Table 3: Correlation Matrix for Independent Variables

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
(1)	Distance	1.00																			
(2)	Distance squared	0.83	1.00																		
(3)	Exchange rate volatility	0.24	0.13	1.00																	
(4)	Border	0.67	0.36	0.26	1.00																
(5)	Railroad	-0.34	-0.22	-0.04	-0.40	1.00															
(6)	Railroad-distance	0.17	0.03	0.20	0.20	0.47	1.00														
(7)	Canal	-0.16	-0.08	-0.06	-0.21	0.14	-0.07	1.00													
(8)	River	-0.12	-0.06	-0.04	-0.16	0.08	-0.05	0.13	1.00												
(9)	Port	0.06	0.00	-0.03	0.12	-0.10	-0.04	-0.02	-0.06	1.00											
(10)	Gold standard	0.25	0.16	-0.09	0.40	-0.12	0.08	-0.09	-0.06	0.17	1.00										
(11)	Monetary union	-0.01	-0.02	-0.03	0.16	0.13	0.16	-0.03	-0.02	-0.02	0.19	1.00									
(12)	Common language	0.21	0.12	0.00	0.28	-0.07	0.10	-0.06	-0.05	0.02	0.16	0.25	1.00								
(13)	Ad valorem	0.22	0.08	0.06	0.47	-0.18	0.12	-0.10	-0.08	0.08	0.08	0.02	0.15	1.00							
(14)	Prohibition	0.21	0.07	0.12	0.40	-0.32	-0.14	-0.08	-0.06	-0.02	-0.14	-0.05	0.04	0.20	1.00						
(15)	Neutral	0.29	0.15	0.07	0.30	-0.18	-0.02	-0.07	-0.05	0.07	-0.02	0.00	0.13	0.12	0.18	1.00					
(16)	Allies	0.03	0.01	0.16	0.11	-0.09	-0.04	-0.02	-0.02	-0.01	-0.04	-0.01	0.14	0.03	0.28	0.03	1.00				
(17)	At war	0.02	-0.01	0.15	0.14	-0.11	-0.05	-0.03	-0.02	0.01	-0.05	-0.02	-0.01	-0.03	0.33	0.00	-0.01	1.00			
(18)	Intra-war	-0.19	-0.10	-0.07	-0.28	-0.13	-0.10	0.06	0.04	-0.03	-0.11	-0.04	-0.08	-0.13	-0.11	-0.09	-0.03	-0.04	1.00		
(19)	Intra-civil	0.20	0.12	0.03	0.27	-0.17	-0.03	-0.06	-0.04	0.02	-0.05	-0.04	0.00	0.07	0.33	0.05	-0.02	-0.03	-0.08	1.00	
(20)	Inter-civil	-0.13	-0.08	-0.06	-0.21	-0.07	-0.06	-0.04	0.03	-0.05	-0.08	-0.03	-0.06	-0.10	-0.08	-0.07	-0.02	-0.03	0.02	-0.06	1.00

|r|=(.66, 1.00)
|r|=(.33, .65)
|r|=(0, .32)

NB: r between TCs/Price and Speed of Adjustment = -0.3913

Table 4: GLS Regression Results

	(1) **Benchmark**		*(2)* **Technology**		*(3)* **Geography**		*(4)* **Monetary Regime**		*(5)* **Commerce**		*(6)* **Conflict**	
	Trade costs/ average price	*Adjustment Speed*	*Trade costs/ average price*	*Adjustment Speed*	*Trade costs/ average price*	*Adjustment Speed*	*Trade costs/ average price*	*Adjustment Speed*	*Trade costs/ average price*	*Adjustment Speed*	*Trade costs/ average price*	*Adjustment Speed*
Distance	**0.0296**	**-0.0206**	**0.0285**	**-0.0098**	**0.0263**	**-0.0089**	**0.0212**	**-0.0039**	**0.0243**	**-0.0045**	**0.0245**	**-0.0057**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.010)	(0.000)	(0.063)	(0.000)	(0.020)
Distance squared	**-0.0007**	**0.0006**	**-0.0007**	**0.0003**	**-0.0006**	**0.0002**	**-0.0004**	*0.0001*	**-0.0005**	*0.0000*	**-0.0005**	*0.0001*
	(0.000)	(0.000)	(0.000)	(0.007)	(0.000)	(0.033)	(0.000)	*(0.680)*	(0.000)	(0.787)	(0.000)	(0.452)
Exchange rate volatility	**1.2908**	**-0.8473**	**1.3643**	**-0.7429**	**1.3052**	**-0.7340**	**0.9329**	**-0.7605**	**1.2422**	**-0.3046**	**0.9939**	**-0.4505**
	(0.000)	(0.010)	(0.000)	(0.000)	(0.000)	(0.010)	(0.000)	(0.096)	(0.000)	(0.096)	(0.000)	(0.016)
Border	**0.1303**	**-0.0944**	**0.1192**	**-0.0610**	**0.1278**	**-0.0630**	**0.1960**	**-0.1048**	**0.1056**	**-0.0525**	**0.1258**	**-0.0558**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Railroad			**-0.0263**	**0.1516**	**-0.0289**	**0.1514**	**-0.0417**	**0.1718**	**-0.0592**	**0.2070**	**-0.0474**	**0.2012**
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Railroad-distance			*0.0023*	**-0.0340**	*-0.0010*	**-0.0335**	*0.0254*	**-0.0364**	**0.0066**	**-0.0410**	**0.0028**	**-0.0398**
			(0.269)	(0.000)	(0.629)	(0.000)	(0.157)	(0.000)	(0.001)	(0.000)	(0.014)	(0.000)
Canal			**-0.0240**	**0.0680**	**-0.0236**	**0.0559**	**-0.0276**	**0.0631**	**-0.0237**	**0.0607**	**-0.0285**	**0.0587**
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
River					**-0.0366**	**0.0571**	**-0.0367**	**0.0575**	**-0.0360**	**0.0540**	**-0.0321**	**0.0513**
					(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)
Port					**-0.0131**	**0.0186**	**-0.0120**	**0.0156**	**-0.0090**	**0.0139**	**-0.0140**	**0.0096**
					(0.000)	(0.023)	(0.000)	(0.061)	(0.004)	(0.091)	(0.004)	(0.024)
Gold standard							**-0.1557**	**0.1324**	**-0.0927**	**0.1214**	**-0.1009**	**0.1284**
							(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Monetary union							*-0.0915*	*0.0807*				
							(0.457)	(0.361)				
Common language									**-0.0309**	**0.0283**	**-0.0302**	*0.0089*
									(0.026)	(0.052)	(0.027)	(0.536)
Ad valorem									**0.6047**	**-0.0667**	**0.6187**	**-0.0886**
									(0.004)	(0.007)	(0.002)	(0.000)
Prohibition									**0.3130**	**-0.1393**	**0.2691**	**-0.1427**
									(0.000)	(0.000)	(0.000)	(0.000)
Neutral											*0.0429*	*-0.1188*
											(0.271)	(0.536)
Allies											**0.0994**	**-0.0367**
											(0.045)	(0.019)
At war (external)											**0.1809**	**-0.1855**
											(0.000)	(0.002)
At war (internal)											**0.1741**	**-0.2304**
											(0.000)	(0.000)
Civil war (external)											**0.3747**	**-0.1895**
											(0.000)	(0.000)
Civil war (internal)											**0.4607**	**-0.1695**
											(0.000)	(0.000)
N:	11540	11540	11540	11540	11540	11540	11540	11540	11540	11540	11540	11540
Weighted by:	Obs	Obs	Obs	Obs	Obs	Obs	Obs	Obs	Obs	Obs	Obs	Obs
Wald χ-squared:	24720.29	26506.36	24207.09	28103.19	25647.99	28614.95	26646.96	30371.21	28185.47	29065.69	32267.22	31472.17
Prob > χ-squared:	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

NB: Year dummies suppressed; distance coefficients scaled to 1000 km; p-values reported in parantheses.

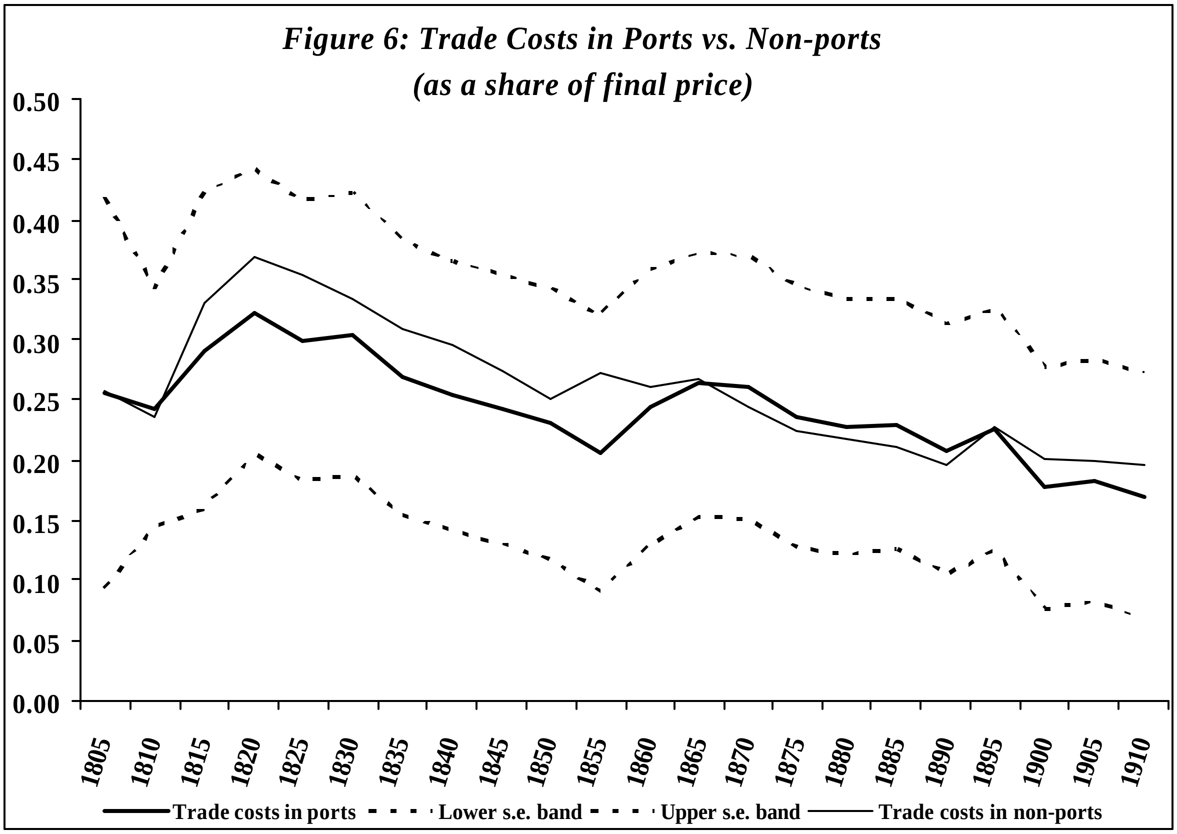
Figure 6: Trade Costs in Ports vs. Non-ports
(as a share of final price)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1805 1810 1815 1820 1825 1830 1835 1840 1845 1850 1855 1860 1865 1870 1875 1880 1885 1890 1895 1900 1905 1910
Trade costs in ports
Lower s.e. band
Upper s.e. band
Trade costs in non-ports

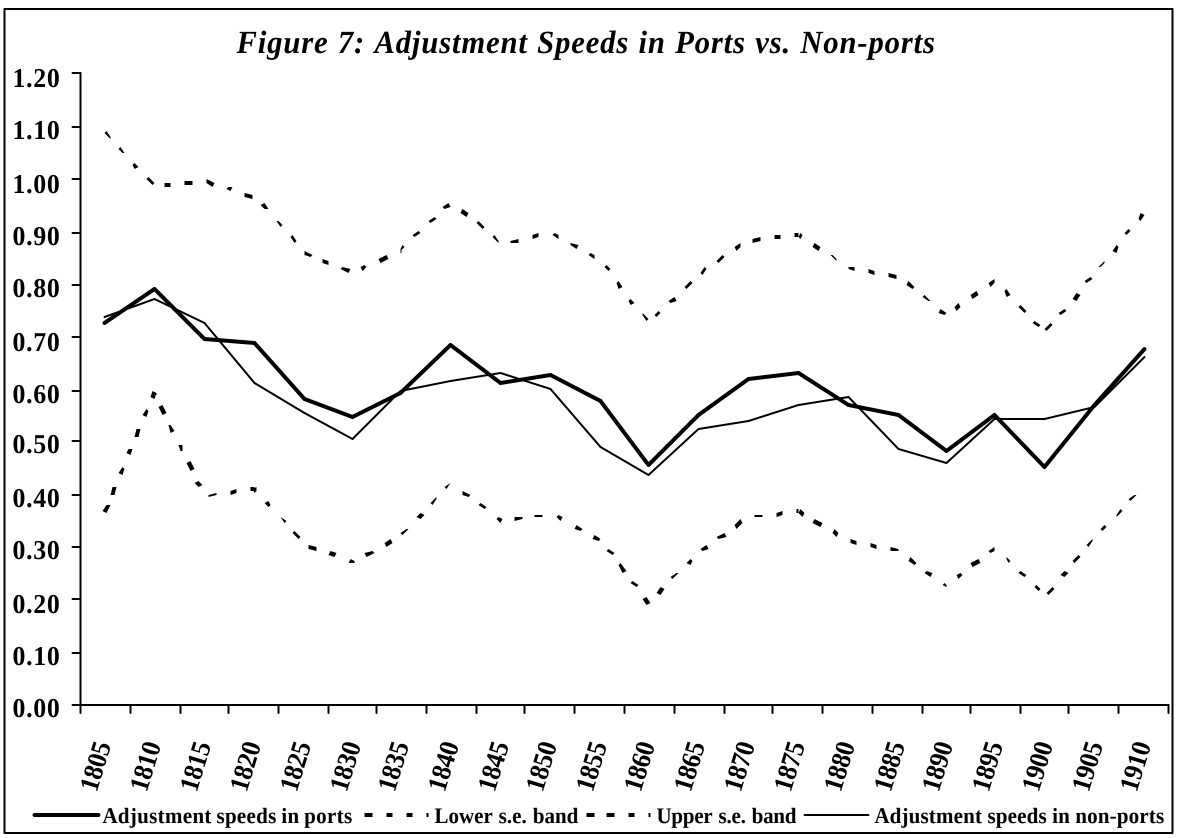
Figure 7: Adjustment Speeds in Ports vs. Non-ports
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1805 1810 1815 1820 1825 1830 1835 1840 1845 1850 1855 1860 1865 1870 1875 1880 1885 1890 1895 1900 1905 1910
Adjustment speeds in ports
Lower s.e. band
Upper s.e. band
Adjustment speeds in non-ports

Table 5: Ranking of Independent Variables

Change in dependent variable (expressed in terms of standard deviations) brought on by a:

	TCs/Price	*Adjustment Speed*	
a.) One standard deviation increase in independent variable*			
Ad valorem	**0.366**	**-0.160**	Railroad-distance
Distance	**0.297**	**-0.055**	Distance
Exchange rate volatility	**0.071**	**-0.042**	Ad valorem
Distance squared	**-0.021**	**-0.026**	Exchange rate volatility
Railroad-distance	**0.014**	*0.002*	Distance squared
b.) Discrete change from 0 to 1 in indicator variable			
Civil war (internal)	**1.725**	**-0.692**	At war (internal)
Civil war (external)	**1.403**	**0.604**	Railroad
Prohibition	**1.008**	**-0.569**	Civil war (external)
At war (external)	**0.677**	**-0.557**	At war (external)
At war (internal)	**0.652**	**-0.509**	Civil war (internal)
Border	**0.471**	**-0.428**	Prohibition
Gold standard	**-0.378**	**0.386**	Gold standard
Allies	**0.372**	**0.176**	Canal
Railroad	**-0.178**	**-0.168**	Border
River	**-0.120**	**0.154**	River
Common language	**-0.113**	**-0.110**	Allies
Canal	**-0.107**	**0.029**	Port
Port	**-0.053**	*-0.357*	Neutral
Neutral	*0.161*	*0.027*	Common language

* Change in "distsq" taken as the square of a standard deviation of the "dist" variable.

NB: Figures in bold represent variables with coefficients at least 5% significance.