What Drove 19th Century 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 (LOP) have been documented for a remarkably wide range of geographic areas and time periods.

As of late, the literature on the topic has been reoriented, primarily due to the work of Engel and Rogers (1995, 1996) and McCallum (1995). The shared hypothesis of these two lines of work is that there is a pernicious and persistent border effect, both in terms of commodity price variation and 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 physical flows 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 through the use of a handful of geographic and institutional variables. A few questions have remained unasked, and therefore, unanswered, in the literature. Are the forces at work identified in the contemporary literature indicative of commodity market integration in other periods? More importantly, what may we take as the proximate causes of the *evolution* of commodity market integration?

To answer these questions, we propose to broaden the temporal scope of the existing literature by considering another period of nascent globalization, namely the long 19th Century. In the past decade, the 19th century has received a new wave of interest and inquiry 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). This paper takes as it aim to act as a bridge between the contemporary trade literature and the study of economic history.

The fundamental results are, first, we are able to not only align our results with the received wisdom but also identify further variables which have been relatively underrepresented in the literature: proxies for technological change; enduring, trade-enhancing geographical features associated with navigable waterways; and the choice of monetary regime.

Second, we find that splitting commodity market integration into the sub-processes of price convergence and synchronization is justified as all of our results confirm the fact that two different sets of causal factors predominant in each case. Most surprisingly, institutional and *not* technological variables dominate the former. And while a more balanced set of factors is at play in the latter case, the role of technological change is much more muted than previously supposed.

Finally, intertemporal analysis allows us to not only expound upon the most significant factors under consideration but also the rich variety of experience partially masked by our panel results. The sub-sample results are found to be consistent with our maintained thesis that traditional explanations of the evolution of market integration have been overly reliant on technological change as an explanatory variable, given the apparently more substantive role of the organization of trade.

By way of conclusion, we draw implications from these results which we find to be far from trivial. First, given that current disparities in economic development worldwide are best explained in terms of a dynamic process which extends far into the past, the degree to which institutions or technology matters in terms of "getting prices right" through market integration is essential, in the sense that the promotion of markets has long been a tacit, if not explicit, goal of many development agencies. Second, the recent work of Acemoglu et al. (2002a,b) proposes a path of causality stretching from (geographically-dependent) trade to institutional change to economic growth. The results proffered here suggest another line of thinking, namely that trade itself could potentially be a function of existing institutions. Thus, Acemoglu et al.'s explanation for the rise of Europe would necessarily be incomplete as the path of causality would again originate from institutions.

The rest of the paper is structured as follows. Section II positions the paper with respect to the context of commodity market integration as well as outlines the various measures and techniques employed throughout the study. Section III briefly details the construction of our data. Section IV presents and discusses our empirical results while section V concludes.

II. ANALYTICAL FRAMEWORK

Following the contemporary literature on the empirical irregularities of the Law of One Price, we split the concept of market integration into the related but distinct sub-processes of price convergence and price synchronicity.

Generally, it is suggested that price convergence is the *sine qua non* of market integration as the fundamental issue at hand is the formulation of an intra- and inter-national division of labor. Of course, this process is predicated upon the successful transmission of price signals to the constituent economies, i.e. with no tendency for prices to equalize, the process of market integration is a meaningless concept. However, it does not necessarily follow that the observation of price convergence alone can be taken as proof of economically significant market integration, as prices may be influenced by processes outside of the realm of economic transaction and exchange (e.g., climatological events).

What is needed is some idea of the interrelationship among price systems (or series), specifically how they dynamically adjust to shocks in other markets. Price synchronization can then be viewed as a supplementary element in the process of market integration. To this end, we propose the simultaneous consideration of these two independent conditions, convergence and synchronization, as the proper approach to studies of market integration.

ON THE SYNCHRONICITY OF PRICES

Fairly dramatic developments have occurred in furthering our understanding of precisely how to model price synchronization in market integration. What we have specifically in mind is a class of econometric models for goods market arbitrage that explicitly account for those elements thought to be most important in determining the degree of market integration, namely time and space. As has been shown (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 elements of transportation and transaction costs associated with trade and, hence, proffer significantly biased results.

In order to capture the effects of transportation and transaction costs, the model to be used incorporates a band equilibrium whereby prices in one market vis-à-vis those in another market are allowed a certain degree of latitude not allowed for in other models of market integration: 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).

Sparing some of the details and referring the interested reader to Appendix I, we can state that for any pair of localities, the change in price in one locality 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 localities in the previous period *t-1*, $(M_{t-1}^{12} = P_{t-1}^1 - P_{t-1}^2)$, if the margin exceeds the band of transaction/transportation costs, $(|C_{t-1}^{12}|,\ |C_{t-1}^{21}|)$.[1] If the margin is less than the band of transaction/transportation 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:

$$(1)\ \Delta P_t^1 = \begin{cases} \rho_1 (M_{t-1}^{12} - C^{21}) + \eta_t^1 & \text{if } M_{t-1}^{12} > C^{21} \\ \eta_t^1 & \text{if } -C^{12} \le M_{t-1}^{12} \le C^{21} \\ \rho_1 (M_{t-1}^{12} + C^{12}) + \eta_t^1 & \text{if } M_{t-1}^{12} < -C^{12} \end{cases}$$

$$(2)\ \Delta P_t^2 = \begin{cases} \rho_2 (M_{t-1}^{21} - C^{12}) + \eta_t^2 & \text{if } M_{t-1}^{21} > C^{12} \\ \eta_t^2 & \text{if } -C^{21} \le M_{t-1}^{21} \le C^{12} \\ \rho_2 (M_{t-1}^{21} + C^{21}) + \eta_t^2 & \text{if } M_{t-1}^{21} < -C^{21} \end{cases}$$

where $(\eta_t^1, \eta_t^2) \sim Nid(0, \Omega)$. The sum of the ρ-coefficients (designated as *rho* below) will equal zero in the case of no integration and negative one (or below) in the case of perfect integration.[2]

[1] In what follows, we will remain agnostic as to the form and composition of the transaction costs term. Although certain elements can easily be enumerated as belonging in the set of transaction-cost determinants (i.e. transportation costs, brokerage costs, storage costs, tariffs, taxes, and spoilage), others remain decidedly recalcitrant in terms of incorporating them into the present model (i.e. exchange rate risk, prevailing interest rates, the risk aversion of agents, and the quality of information available). As such, we will interpret the transaction cost term in an appropriately broad fashion.

[2] Conceptually, the summed coefficients may indeed exceed unity in that the concept of the 'corridor' of inaction implies that we can observe price movements in excess of the initial price margin; here, a simple numerical example might be instructive. Let city A in time *t-1* have a price of $10 and city B a price of $5; the transaction costs associated with transporting the good from A to B is $5 while the costs from B to A are $3; finally, the price in A and B in time *t* are $7.60 and $7.10, respectively. Basic algebra reveals that the sum of the coefficients on ρ must be less than –1. As we will see below, this is hardly a pedantic exercise as we actually observe estimates lower than -1.

With no closed form solution available due to the non-linearity introduced by the thresholds, estimation takes place by maximization of the likelihood function via a grid search on the observed price differentials. In this case, the likelihood function should follow that of the SUR estimator, or namely

$$(3)\quad \log L = -\frac{TM}{2}\log(2\pi) - \frac{T}{2}\log|\Omega| - \frac{1}{2}\sum_{t=1}^{T}\eta_t^{'}\Omega^{-1}\eta_t \ ,$$

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

Naturally, this type of highly-detailed modeling does come at a cost, in terms of the need for high frequency price data. Add to this the wide-ranging geographic and temporal scale of our project and the data requirements become truly prodigious. To avoid compounding the dimensionality of the project, the focus will exclusively be on the intra- and inter-national markets for (constant-quality-adjusted) wheat. Motivating this choice of commodities is an easy task: throughout the 19th Century, the intra- and inter-national markets for wheat can be taken as high watermarks for commodity market integration due to the heavy weight of wheat in production, consumption, and commerce alike. Appendix II below summarizes the coverage and sources of the dataset.

ON THE CONVERGENCE OF PRICES

Returning to the economically substantive aspect of market integration, our attention now turns to the means of assessing the degree of price convergence. As a starting point, it is suggested that we make use of the output generated from the ATECM model above, as one of the chief attractions of the model is that it provides estimates of the combined transportation and transaction costs directly based on observed price differentials. Thus, if for any particular pair of cities we observe that the estimated transaction cost parameters decline through time, it can be inferred that the level of the price differential between the two cities has fallen as well. Additionally, coupled with information on the general level of prices, we can scale our estimates of the transaction costs 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 *reltc* below) appropriate for the type of cross-country comparisons we would like to make.[3]

III. DATA CONSTRUCTION

To assess the intranational components of price synchronicity and convergence, the first step is to construct a matrix of prices of dimension n (the number of cities; generally twelve) by t (generally, 11 years, for 132 observations) and to form all pair-wise combinations of cities in the set of prices in order to arrive at estimates of our asymmetric ρ-coefficients (or adjustment parameters) and the transaction costs (divided by average price) inferred from the behavior of the data. The next step was to then record 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 we have a full panel of 12 cities for 114 years, we 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, we in large part followed the precedent set above on intranational market integration. Here, instead of constructing our variables from observations

[3]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

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

This measure was constructed for the database at hand and explored under all regression specifications discussed below. Given the high degree of correlation between this variance term and the *reltc* variable (R>.90), it will come formed from every pair-wise combination available in any given country, it was decided that the panels of price data for each country should be matched with prices from a set of 5 cities (Bruges, London, Lwow, Marseille, 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.[4] Apart from this distinction, our methodology was identical to that identified previously: estimate our asymmetric ρ-coefficients and the transportation/transaction costs (divided by average price) inferred from the behavior of the data; record the average value of these estimated parameters; and iterate this procedure at 5-year steps for each country.

Finally, appropriate explanatory variables were considered and constructed. Table 1 below provides summary statistics of our dependent and independent variables. Notes on the particulars underlying their construction made be found in Appendix III.

IV. EMPIRICAL RESULTS

To weigh the determinants of 19th Century commodity market integration, we proceed by first considering a benchmark case inspired by the work of Engel and Rogers (1995, 1996) and Parsley and Wei (1996, 2001a). As a unique contribution to the literature we explore not only the two facets of commodity market integration (price convergence and synchronicity) but also the differential effects implied by the inclusion of variables meant to capture of proxies for technological, geographical, and institutional variations across time and space.

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as no surprise that the results added little further information on the process of price convergence and, therefore, are not reported here.

[4] Please note that we have fully separated out the intra-national component from our various datasets. Thus, for Spain, we compare the observations on all 12 cities available against those in our 5 sample cities whereas for France, we compare the observations on all 12 cities available against all sample cities expect Marseille.

BENCHMARK ANALYSIS

As mentioned before, certain researchers looking into the forces affecting market integration for the late 20th Century have used a gravity-model-inspired framework of inquiry. Generally, this has been implemented as a regression of the following type, taken from Engel and Rogers' seminal work (1996):

$$(4)\ V(P_{j,k}) = \beta_1 r_{j,k} + \beta_2 B_{j,k} + \sum_{m=1}^{n} \gamma_m D_m + u_{j,k},$$

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., a dummy for international exchange), and D_m is a dummy variable for each city in the sample. Additions to this model have included trade barriers and regional dummies (Engle and Rogers, 1995), of lagged dependent variables (Parsley and Wei, 1996), of the difference of the changes in the logged prices as the dependent variable (Parsley and Wei, 2001b), and of a squared distance term (Engel and Rogers, 2001).

Here, we follow in broad form the same exercise, but with a view towards more explicitly modeling the structure of errors. Typically, estimation of equation (5) has taken place within the framework of OLS estimation with partial attempts to control for heteroscedasticity (via fixed-effects estimation or the use of city dummies) and the possibility of serial correlation when using time series (via the inclusion of the lagged dependent variable). What we propose is the use of GLS estimation,[5] explicitly incorporating group-wise heteroscedasticity (based on country-

[5] GLS estimation also has the desirable property of controlling for the fact that our 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).

rather than city-pairs) and serial correlation[6] into the structure of the variance-covariance matrix. Thus, our baseline results come from the following regression:

$$(6)\ Integration_{j,k,T} = \beta_1 dist_{j,k} + \beta_2 distsq_{j,k} + \beta_3 evol_{j,k,T} + \beta_4 border_{j,k} + \sum_{t=1}^{22} \gamma_T D_T + u_{j,k,T}\ ,$$

where the dependent variable is time-specific and is defined either as one of our measures of market integration (i.e., the transaction-cost-adjusted adherence to the LOP (ρ) or the estimated relative transaction cost); the first two terms on the right-hand side, $dist_{j,k}$ and $distsq_{j,k}$, refer to distance and squared distance variables, respectively; $evol_{j,k,t}$ is the variance of the logged nominal exchange rate between the currencies of *j* and *k* in time t; $border_{j,k}$ denotes the existence of a border between *j* and *k*; and D_t is a set of time dummies.

Furthermore, a suitable weighting matrix for the dependent variables must be specified in order to implement our estimator with group-wise and serially-correlated disturbance terms. In all results reported below, the weights used were the differences between one and the p-value of each city-pair regression (calculated according to the methodology set out in Appendix III) for the relative transaction cost and LOP-adherence terms.[7]

The results from this initial regression are reported in Table 2 below. The patterns look sensible. Price convergence (as measured inversely by relative transaction costs) decreases with distance, nominal exchange rate volatility, and the border. The degree of price synchronization (as measured by ρ) decreases as these same variables rise.

[6] As a further corrective for the possibility of serial correlation, we also estimated our models on non-overlapping observations. In this case, the results were not fundamentally altered, although this approach entailed a general loss of power, especially when we consider our model on sub-samples (see below). Consequently, we opt for using all available data and correcting for serial correlation as described above.

[7] It should also be noted that the results presented are seemingly invariant to any set of plausible weights selected, such as the value of summed squared errors, log-likelihoods, and F-test values.

TECHNOLOGY

One of the most noticeable gaps in the existing literature is any consideration of technological change. Understandably, this gap is primarily a function of the limited time horizons considered (i.e., the 1990s) in which one would reasonably expect no fundamental changes in the technology of transport or transaction. Here, we make a unique contribution to the literature by attempting to successfully integrate technological change into our analysis.

As even the most cursory review will reveal, the historical literature for the 19th 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, we have constructed a series of variables which capture the historical development of American and European rail networks. These variables take the form of indicator variables which switch "on" with the completion of an inter-city rail connection.

The effects of including one of these variables, *rr1*, along with an interaction term with distance, *rrdist*, on our initial results are reported in the first panel of Table 3 below.[8] The *rr1* variable proves to be significant in the case of both price convergence and synchronization. The motivation for including our interaction term, *rrdist*, is that a railroad between Maddaloni and Naples (our shortest rail route at 30 km.) may have had a different impact than that between Samara and Brugges (our longest route at 8080 km.) The results in Table 3 bear out this

[8] This variable, *rr1*, indicates the existence of a railroad connection in any year of the eleven years considered. The railroad indicator was variously defined to indicate the existence of connection in a majority of years (*rr2*) and all years (*rr3*) in order to potentially capture a delay in the general diffusion of railroad use. All specifications reported were ran with these alternate variables with no material effect on the estimated coefficients.

suspicion. The interaction of railroads with distances is significant, simultaneously promoting price convergence and muting price synchronization as distance increases.

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 panel of Table 3 implies is that while canals' contribution to price synchronization was overshadowed by that of railroads, canals were associated with lower thresholds.[9]

Finally, to assess technological change in maritime shipping, exploratory regressions were ran on the variables included in our final specification (see below) along with an interaction term between time and a dummy on port city-pairs (*ports)*. The results of these exercises are depicted in Figures 1 & 2 which plot the sum of the coefficients attached to this interaction term along with those associated with the original set of time dummies. Broadly, they offer a very compelling story of the integration of ports through time: following the turbulence of the Napoleonic Wars, prices were strongly converging until mid-century at which time integration slowed while price synchronization saw no deterministic pattern. These results imply that technological change in the maritime industry (read steamships) may have had far more muted

[9] In a preliminary exercise, an interaction term between *canal* and *distance* was employed. The estimated coefficients were highly insignificant. 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 well. Consequently, interaction terms for the other variables have been suppressed.

effects than previously supposed. Until we can more explicitly capture the diffusion of maritime technology, however, these results will remain only suggestive.

GEOGRAPHY

Much of the recent literature on long-term growth patterns has tried to assess the implications of geography for economic activity and evolution—some finding a critical role (Sachs, 2000, 2001) and others a negligible one (Acemoglu et al., 2002a). 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, border, or non-adjacency variables.

We can offer a slight remedy by including indicator variables on the existence of port facilities on both sides of our city-pairs (*port*) and of a shared navigable river system (*river*). As can be seen in Table 4, the inclusion of these variables significantly adds to the explanatory power of our regressions on price convergence (with the expected negative signs confirmed) and synchronization (with the expected positive signs confirmed).

INSTITUTIONS

In this section, we will interpret the term institutions in an appropriately broad fashion to include such variables as the choice of monetary standard, the existence of a common language, and the outbreak of intra- and inter-state conflict. The motivation for the first two variables is that they have been consistently shown to be strong determinants (or at least, correlated with other unobserved determinants) on market integration and the directions and dimensions of the volume of trade.[10] As to the last variable, we are confronted with a literature which has focussed almost exclusively on geographic and temporal units which are free from such incidences of war and insurrection, so we might do well in giving them their proper do for the 19th Century—a relatively peaceful century, but one to which the depredations of war were not unknown.

As a first pass, we consider the effects of two key variables, the emergence of the gold standard[11] and the existence of a common language, on the process of market integration. The first panel of Table 5 clearly indicates that these two variables consistently and significantly contribute to the total process of market integration. This is especially true for the gold standard variable as the nearly equal but opposite coefficients respectively associated with *border* and *gs1* in the regressions on price convergence and synchronization 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 we are already explicitly controlling for exchange rate volatility, the adoption of the gold standard must be symptomatic of deeper integrative forces at work (Bordo and Flandreau, 2003).[12]

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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 (2001).

[11] Following the precedent set by our analysis of railroad development, the gold standard indicator was variously defined to indicate the existence of a common adherence in any year (*gs1*), a majority of years (*gs2*) and all years (*gs3*) in order to potentially capture delays in transmission of the effects of the gold standard. All specifications reported were ran with these alternate variables with, again, no material effect on the estimated coefficients.

[12] The inclusion of these institutional variables also affected changes in some of our original estimates which are worth mentioning. First, we find that the mere existence of a railroad is now significant for price convergence while the distance-interacted railroad term has no effect. In any case, our original conclusion of the predominance of canals is borne out as the coefficient attached to the former is over twice as large as that for railroads. Second, we are confronted with the seemingly surprising result that *port*, although correctly signed, yields insignificant results—and as we shall see, does so consistently in the remainder of the analysis. However, given that the distances separating *river* cities are generally much smaller than those separating *port* cities and that the *river* and *port* variables are almost exclusively delineated along the lines of intra- and inter-national trade, there seems little trouble in aligning these results with our *a priori* expectations. Finally, the addition of the gold standard indicator, now nullifies the effect of nominal exchange rate volatility on price synchronization, suggesting our original result was proxying for the gold standard (and its correspondingly low levels of exchange rate volatility).

Unfortunately, less dramatic results are forthcoming when we included the *mu* variable, our indicator of the existence of a shared monetary union. In unreported exercises, *mu* fails to be uniformly significant; what is more, it is also signed contrary to our priors—positively correlated with both relative transaction costs and transaction-cost-corrected adherence to the LOP. Given the peculiar history of monetary unions in the 19th Century, however, these results may not be surprising. In our sample countries, we were effectively able to code up one monetary union from 1800-1913—the Latin Monetary Union which saw Belgium, France, and Italy 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 was set to fall by over 55% in the next fifty years or so. Thus, the effectiveness of the LMU in terms of its purported stabilizing properties was severely circumscribed. In what follows, we, therefore, will omit the *mu* variable from our regressions.

The final element we will consider under the heading of institutions is the outbreak of intra- and inter-state conflict. Again, the contemporary literature is noticeably silent on the issue, given its relatively limited geographic and temporal scope. Using data collected under the auspices of the Correlates of War project, we were able to code up suitable indicator variables for the occurrence of war, capturing the effects of intra- or inter-national conflict on the internal economy (*intrawar*), of one country's neutrality in the face of a time of war for a trading partner (*neutral*), of the outbreak of open conflict between trading partners (*atwar*), and finally, of the outbreak of open conflict between trading partners and a common enemy (*allies*).

The results of this exercise are reported in Table 6. Of the two specifications, it is the price convergence regression which performs best with respect to all variables. Thus, we find *intrawar* and *neutral* to be insignificant but correctly signed while the *atwar* and *allies* variables are significant and consistent with reasonable priors. As to price synchronization and its response to intra- and inter-state conflict we are first confronted with a lack of priors—the justifications conceivably associated with price convergence (or divergence) are not as apparent in this case. The *intrawar* and *neutral* variables yield results congruent to those of price convergence. The results that *atwar* was associated with higher levels of price synchronization than *allies* is somewhat puzzling, but citing our lack of priors these results must be accepted until a more finely-grained analysis is explored (see below).

Rounding things out, Table 7 below summarizes our preferred specification into a more easily translated format. Decomposing the effects of standard-deviation or discrete changes in the independent variables on the various measures of market integration, we can come to a few conclusions regarding the relative contributions of technology, geography, and institutions. First, the sub-process of price convergence was dominated by institutional factors (*gs1* and *comlang*) with a healthy contribution of geographic factors (if we consider *border* to be a geographic variable) and little contribution from technology. Second, the sub-process of price synchronization represents a much more balanced account as institutions cede some of their pride of place, most notably to technology. Finally, we can see that across all independent variables the gold standard alone acted as a means to deconstruct the artificial geographic barriers implied with national borders.

INTERTEMPORAL COMPARISONS

Having explored the pooled results of our panel data, we might do well to step back and ask whether the results we found for the aggregate hold in discrete sub-periods. To this end, we ran our preferred specification on three easily demarcated eras (i.e., the pre-railroad and pre-gold-standard, the pre-gold-standard but post-railroad, and the post-railroad and post-gold-standard eras).

In table 8 below, these disaggregated results are presented for the transactions-cost-adjusted adjustment parameters (*rho*) and the relative transactions costs (*reltc*) in Panels A and B, respectively. The changes in specification and sample suggest not only that inference from our panel estimates is generally valid, but also allow for some further insights into the process of integration.

With respect to *rho*, we will limit ourselves to two observations. First, what is most striking about the results of this exercise is the marked failure of our independent variables to explain the variation in *rho* in the period from 1800 to 1830. We can partially justify this poor performance in light of the enormous disruption caused by the Napoleonic Wars, thus, providing the first explicit demonstration of the price effects of the wars (Findlay and O'Rourke, 2003).[13] Second, the two variables, *border* and *port*, appear to have become more prominent through time. This result is somewhat surprising in that our priors would lead us to believe that the simultaneous action of increasing economic interaction along with the development of internal transport linkages would have sapped, not augmented, the variables' force.

Turning to *reltc*, the disaggregated results tell some interesting stories. To begin, we can see that intra- and inter-state conflict served to aggravate the convergence of prices more at the end than the beginning of the period. This probably reflects the high degree of mobilization attendant with the Napoleonic Wars, but again, this is a topic open for discussion. Second, the insignificance of the *port* variable—in spite of its earlier contribution to convergence—raises further suspicions regarding the true effect of maritime technology in fundamentally altering the

[13] Furthermore, the notable insignificance of *evol* and *port* in the panel estimates seem to be explained by this generalized failure as well.

course of market integration, citing the fact that widespread adoption of steam technology came only after 1870. Our results suggest this adoption had little discernible impact on narrowing price differentials in the Atlantic economy. In a similar vein, the question of the efficacy of technological change in the form of railroads is demonstrated in the reversal of signs and significance attached to *rr1* and *rrdist* from 1830-1872 to 1872-1913. The story emerging is one which challenges the received wisdom in which railroads played a singular role in conquering time and space and, thus, creating factor and output markets of unprecedented scale.

V. CONCLUSION

Building on the insights provided by the contemporary literature on the determinants of the extent of commodity market integration, we have attempted in this paper to lay a framework for assessing the determinants of the evolution of commodity market integration.

First, we have been successful in determining a number of variables 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, thus, verifying the commonality of experience with commodity market integration in the 19th and 20th Centuries. Additionally, we have been able to identify further variables which heretofore have been relatively underrepresented in the literature: the establishment of inter-city railroad linkages (our proxy for technological development); enduring, trade-enhancing geographical features associated with navigable waterways; and the classical gold standard. Furthermore, we have been able to lay some foundations for more precisely determining the effects of intra- and inter-state conflict as in the course of market integration.

Second, we have been able to justify our decision of splitting commodity market integration into the sub-processes of price convergence and price synchronization as all of our results have confirmed the fact that two different sets of causal factors predominant in each case. The fundamental sub-process of price convergence seems to be more responsive to changes in institutional and (to a lesser extent) geographic variables than changes in the underlying technology of trade. Running somewhat counter to this finding, we note that the sub-process of price synchronization represents a more balanced account as technological, geographic, and institutional variables all seem to play a part. In any case, we see that explanations of market integration in terms of exogenous, technological change (and railroads, in particular) has unduly diverted our attention from analyzing the more important endogenous elements of the organization of trade and its institutional apparatus.

Finally, intertemporal analysis allows for an even greater sense of not only the most significant factors under consideration but also the rich variety of experience partially masked by our panel results. Chief among the findings in this respect were the continued relevance of many of the variables identified in the panel exercises as well as more results consistent with our maintained thesis that traditional explanations of the evolution of market integration have been overly reliant on technological change as an explanatory variable, given the apparently more substantive role of the organization of trade.

The implications from these results are interesting in at least two respects. On the one hand, if current disparities in economic development worldwide are best explained in terms of a dynamic process which extends far into the past, the degree to which institutions or technology matters in terms of "getting prices right" through market integration is essential in the sense that the promotion of well-developed markets has long been, at least a tacit, if not explicit, goal of many development agencies.

On the other hand, the recent work of Acemoglu et al. (2002a, b) proposes a path of causality stretching from (geographically-dependent) trade to institutional change to economic growth. The results proffered here suggest another line of thinking, namely that trade itself could potentially be a function of existing institutions. Thus, Acemoglu et al.'s explanation for the rise of Europe would necessarily be incomplete as the path of causality would again originate from institutions. Needless to say, this an area which demands further research.

APPENDIX I: THE ATECM MODEL & DIAGNOSTICS

We begin by positing the following two conditions, which encapsulate the relation of prices in two locations consistent with efficient goods-market arbitrage:

(1) $P_t^1 \leq P_t^2 + C^{21}$, or namely, that the price in the first location (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^{21}).

What condition (1) then implies is the following inequalities:

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

(1b) $P_t^1 - P_t^2 \leq C^{21}$

Likewise, if we reverse the order, we arrive at

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

(2a) $-C^{12} \leq P_t^1 - P_t^2$

(2b) $P_t^2 - P_t^1 \leq C^{12}$

For the sake of simplicity, 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)-(2b), then imply are the following restrictions:

(3) $-C^{12} \leq M_t^{12} \leq C^{21}$

(4) $-C^{21} \leq M_t^{21} \leq C^{12}$

To operationalize conditions (3)-(4), we state that the change in price in one market should be negatively related to the level of the margin between the two markets in the previous period if the margin exceeds either band of transaction/transportation costs while in the 'corridor' between the two bands the change in price is free to follow a random walk. The asymmetric-threshold error-correction-mechanism (ATECM) is then given by:

$$(5)\ \Delta P_t^1 = \begin{cases} \rho_1(M_{t-1}^{12} - C^{21}) + \eta_t^1 & if\ M_{t-1}^{12} > C^{21} \\ \eta_t^1 & if\ -C^{12} \leq M_{t-1}^{12} \leq C^{21} \\ \rho_1(M_{t-1}^{12} + C^{12}) + \eta_t^1 & if\ M_{t-1}^{12} < -C^{12} \end{cases}$$

$$(6)\ \Delta P_t^2 = \begin{cases} \rho_2(M_{t-1}^{21} - C^{12}) + \eta_t^2 & if\ M_{t-1}^{21} > C^{12} \\ \eta_t^2 & if\ -C^{21} \leq M_{t-1}^{21} \leq C^{12} \\ \rho_2(M_{t-1}^{21} + C^{21}) + \eta_t^2 & if\ M_{t-1}^{21} < -C^{21} \end{cases}$$

where $\left(\eta_t^1, \eta_t^2\right) \sim Nid\left(0, \Omega\right)$. The sum of the ρ-coefficients will equal zero in the case of no integration and negative one (or below) in the case of perfect integration.

Moving on, as $M_{t-1}^{21} < -C^{21}$ is equivalent to $M_{t-1}^{12} > C^{21}$ and $M_{t-1}^{21} > C^{12}$ is equivalent to $M_{t-1}^{12} < -C^{12}$, we conveniently have three regions defined to describe the movement of the dependent variables:

I.) If $M_{t-1}^{12} > C^{21}$, then $\Delta P_t^1 = \rho_1(M_{t-1}^{12} - C^{21}) + \eta_t^1$ and $\Delta P_t^2 = \rho_2(M_{t-1}^{21} + C^{21}) + \eta_t^2$.

II.) If $-C^{12} \leq M_{t-1}^{12} \leq C^{21}$, then $\Delta P_t^1 = \eta_t^1$ and $\Delta P_t^2 = \eta_t^2$.

III.) If $M_{t-1}^{12} < -C^{12}$, then $\Delta P_t^1 = \rho_1 (M_{t-1}^{12} + C^{12}) + \eta_t^1$ and $\Delta P_t^2 = \rho_2 (M_{t-1}^{21} - C^{12}) + \eta_t^2$.

With no closed form solution available due to the non-linearity introduced by the thresholds, estimation takes place by means of maximization of the likelihood function given above via a grid search on the range of observed price differentials.

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 transaction cost (M^{12}-C^{21}) . The approximation converges weakly in probability to the null distribution of the F-statistic, so we bootstrap (with 1000 replications) to approximate the asymptotic distribution and calculate:

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

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 $C_\xi(\beta)$, we determine minimum and maximum values of Γ for which:

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

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

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

An informal review of the standard errors and p-values strongly suggests the applicability and significance of the ATECM specification; for those interested, the complete set of diagnostic statistics is available from the author by request.

FURTHER CONCERNS: DATA HORIZONS, DATA TRANSFORMATIONS, AND ESTIMATED TRANSACTION COSTS

In this space, we can also review evidence on some other causes of concern over the use of the ATECM model, namely the suitability of monthly data for the 19th Century, the models use of untransformed price levels, and the general validity of the estimated threshold values.

Panel A of Table A.1 below positively demonstrates that for even the end of the 19th 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) our estimates of ρ and β are similar both in absolute and relative magnitude. What is more, the estimates of the threshold are remarkably similar.

TABLE A.1: THE ATECM MODEL, DAILY VS. MONTHLY DATA, NYC-PARIS-BERLIN, 1896-1905
(t-statistics reported in brackets)

PANEL A: ESTIMATION VIA PRICE LEVELS

DAILY		*Rho*	*Rho*	*Threshold*	*Threshold*		
City 1	City 2	*for city1*	*for city 2*	*from 2 to 1*	*from 1 to 2*	p-value	Obs.
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]	[7.47]	[-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]		

PANEL B: ESTIMATION VIA LOGGED PRICES

DAILY		*Rho*	*Rho*	*Threshold*	*Threshold*		
City 1	City 2	*for city1*	*for city 2*	*from 2 to 1*	*from 1 to 2*	p-value	Obs.
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 Table A.1 also raises the issue of data transformation. Although it may seem that we are making undue (or at least, unstated) assumptions 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 original specification. The two specifications do, however, offer similar stories which is further demonstrated in Table A.2 below which contrasts the results of our preferred regression analysis reported above and results using a database solely composed of logged prices.

TABLE A.2:PREFERRED SPECIFICATION USING PRICE LEVELS v. LOGGED PRICES

	Dependent Variable:							
	Reltc (levels)		*Reltc (logs)*		*Rho (levels)*		*Rho (logs)*	
Independent Variables:	Coefficient	P>|z|	Coefficient	P>|z|	Coefficient	P>|z|	Coefficient	P>|z|
dist	0.027000	0.000	0.028800	0.000	-0.009150	0.000	-0.014800	0.005
distsq	-0.000128	0.000	-0.000674	0.045	0.000240	0.027	0.000166	0.047
evol	0.741747	0.000	0.292632	0.000	*0.109694*	*0.546*	*0.168250*	*0.662*
border	0.252436	0.000	0.204645	0.000	-0.101505	0.000	-0.169718	0.000
rr1	-0.017810	0.022	0.017925	0.000	0.182243	0.000	0.265532	0.000
rrdist	*-0.002020*	*0.385*	*-0.001340*	*0.663*	-0.033400	0.000	-0.047800	0.000
canal	-0.042563	0.000	-0.029527	0.003	0.070038	0.000	0.042257	0.000
river	-0.035596	0.000	-0.014477	0.005	0.066407	0.000	0.042251	0.000
port	-0.019397	0.000	-0.018054	0.000	*0.013890*	*0.110*	*0.033630*	*0.184*
gs1	-0.202311	0.000	-0.211561	0.000	0.132036	0.000	0.192747	0.000
comlang	-0.137952	0.000	-0.171649	0.000	0.029355	0.020	0.037886	0.000
intrawar	*0.002252*	*0.855*	*0.002043*	*0.325*	-0.093747	0.000	-0.122700	0.009
neutral	*0.024066*	*0.105*	*0.000835*	*0.609*	*-0.007894*	*0.533*	*-0.002465*	*0.354*
atwar	0.084237	0.002	0.130300	0.000	*-0.025698*	*0.265*	*-0.047950*	*0.311*
allies	-0.058264	0.018	-0.025922	0.082	-0.054341	0.004	-0.044109	0.001
N:	11576		11576		11576		11576	
Weighted by:	(1-"p-value")		(1-"p-value")		(1-"p-value")		(1-"p-value")	
Wald χ-squared:	8750.43		3214.07		27926.99		7154.24	
Prob > χ-squared:	0.0000		0.0000		0.0000		0.0000	

NB: Year dummies suppressed; distance coefficients scaled to 1000 km.

As to the validity of the estimated thresholds themselves, we consider two elements. First, we need to see that our estimates of bilateral transaction costs are consistent. Table A.3 below demonstrates that for the sample considered we see no violations of arbitrage potentials across multiple cities, i.e., $C_t^{12} + C_t^{23} \geq C_t^{13}$. Second, we would hope to find correspondence to actual transaction costs. Table A.4 below presents compelling (albeit very limited) evidence to the effect that our estimates are indeed a good approximation to reality, especially given the wide temporal, geographical, and technological range considered.

TABLE A.3: TRILATERAL GOODS MOVEMENT,1850-60

Origin (1)	Transit Point (2)	Destination (3)	(1) via (2)	(1) to (3)
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

TABLE A.4: ESTIMATED v. OBSERVED TRANSACTION COSTS

	Route (from-to):	*Date:*	*Means:*	*Transaction costs (per 100 kg):*	*Cost Components:*	*Observed relative transaction cost:*	*Estimated relative transaction costs:*
1.)	Chateauroux-Bordeaux	1820	Cart	9.372 francs	Freight	0.323	0.354
2.)	Bar le Duc-Lyon	1835	Road	10.18 francs	Freight	0.374	0.381
3.)	New York City-San Francisco	1849	Clipper	$2.35	Freight	1.256	1.349
4.)	Cincinnati-New Orleans	1850	Steamboat	$0.74	Freight	0.178	0.171
5.)	Chicago-New York City	1869	Lake & canal	$2.06	Freight, inspection, storage, commissions, insurance, & handling	0.423	0.413
6.)	Oviedo-Lerida	1878	Horse & cart	4.44 pesetas	Freight	0.145	0.141
7.)	Chicago-Liverpool	1879	Rail	$1.34	Freight, insurance, & charges	0.305	0.292
8.)	Leipzig-Danzig	1885	Rail	2.44 marks	Freight	0.129	0.132
9.)	San Francisco-London	1886	Clipper	$0.88	Freight	0.261	0.284
10.)	Kansas City-Chicago	1897	Rail	$0.39	Freight	0.032	0.029
11.)	Samara-Warsaw	1901	Rail	1.66 rubles	Freight	0.314	0.333
12.)	New York City-Liverpool	1910	Tramp	$0.27	Freight, insurance, & charges	0.068	0.061

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APPENDIX II: DATA COVERAGE AND SOURCES

N.B.: All data employed were calculated as average 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 differences in quality would be 'soaked up' in our estimates of transaction cost as detailed in Appendix I, 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.

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

New Orleans, 1818-1861; A.H. Cole, *Wholesale Commodity Prices in the United States, 1700-1861: Statistical Supplement*. Cambridge: Harvard University Press, 1938.

Richmond, 1825-1865; A.G. Peterson, *Historical Study of Prices Received by Producers of Farm Products in Virginia, 1801-1927*. Technical Bulletin of the Virginia Polytechnic Institute, 1929.

Chicago, 1841-1913; NBER Macrohistory Database.

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

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

San Francisco, 1852-1913; Annual Report of the Chamber of Commerce of San Francisco. San Francisco: Neal Publishing Company, various years; *Annual Report of the San Francisco Merchants Exchange.* San Francisco: Commercial News Publishing, various years; *Annual Report of the San Francisco Produce Exchange*. San Francisco: Commercial Publishing Company, various years; T.S. Berry. *Early California: Gold, Prices, Trade*. Richmond: The Bostwick Press, 1984; H. Davis, "Appendix I: Tables Relating to California Breadstuffs." *The Journal of Political Economy*, 2(4) 1894, 600-12; *Sacramento Union,* various years; *Transactions of the California State Agricultural Society*. Sacramento: O.M. Clayes, various years.

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

APPENDIX III: EXPLANATORY VARIABLE SOURCES

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

For Belgium: Buyst, E., S. Dercon, and B. van Campenhout (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, mimeo.

For France: Geiger, R.G. (1994), *Planning the French Canals*. Newark: University of Delaware Press.

For 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*. Milan: Universita Bocconi, 105-118; Kunz, A. (1996), *Statistik der Binnenschiffahrt in Deutschland 1835-1989*. Berlin: St. Katharinen.

For the United Kingdom: Crompton, G. (1996), *Canals and Inland Navigation*. Aldershot: Scolar; and Rolt, L.T.C. (1971), *Navigable Waterways*. London: Longman.

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

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(s) and the trade-route-specific (nonlinear) distance between departure ports taken from Philip, G. (1935), *Philip's Centenary Mercantile Marine Atlas*. London: Philip George & Son.

Exchange rates: Taken from the Global Financial Database.

Gold standard indicators: Equal to one if both countries in which the cities reside were on the gold standard; defined according to the database compiled by Chris Meissner, King's College, University of Cambridge.

Intra- and inter-state conflict variables: Coded according to the Correlates of War Militarized Interstate Disputes database. The minimum criteria for inclusion were the existence of (non-colonial) open conflict for a duration of at least six months and with a minimum of 1000 casualties. Accordingly, the following conflicts were included:

Napoleonic Wars: Belgium/France vs. Austria-Hungary/United Kingdom, 1800-1815
War of 1812: United Kingdom vs. United States, 1812-1815
Mexican-American War: United States, 1843-1848
Crimean War: France and United Kingdom allied, 1853-1856
War of Italian Unification: Austria-Hungary vs. France, 1859
American Civil War: United States, 1861-1865
Seven Weeks War: Austria-Hungary vs. Germany, 1865-1866
Franco-Prussian War: France vs. Germany, 1870-1871
Spanish-American War: Spain vs. United States, 1898
Russo-Japanese War: Russia, 1903-1905

Port: Equal to one if both cities in the city-pair are oceanic ports; defined singly, port cities include:

For Austria-Hungary: Trieste
For Belgium: Antwerp
For France: Bayeux, Bordeaux, Marseille, St. Briec
For Germany: Danzig, Königsberg, Stettin

For Italy: Genoa, Naples
For Norway: Christiania, Bergen, Stavanger
For Russia: Libau, Nicolaief, Novorosslisk, Odessa, Riga, St. Petersburg
For Spain: La Coruña, Santander
For the United Kingdom: Dover, Liverpool, London, Newcastle
For the United States: New Orleans, New York City, Philadelphia, San Francisco

Railroad indicators: The following sources were used to construct route maps of railroads. Please note that we consider cities to be 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).

For 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: Princeton University Press; Milward, A.S. and S.B. Saul (1977), *The Development of the Economies of Continental Europe, 1850-1914*. London: George Allen & Unwin; Plaschka, R.G., A.M. Drabek, and B. Zaar (1993), *Eisenbahnbau und Kapitalinteressen in der Beziehung der Österreichischen mit der Südslawischen Ländern*. Vienna: Verlag der Österreichischen Akademic der Wissenshaften; Szabad, G. (1961), 'Das Anwachsen der Ausgleichstendenz der Produktenpreise im Habsburgerreich um die Mitte des 19. Jahrhunderts.' In V. Sándor and P. Hanák (Eds.), *Studien zur Geschichte der Österreichisch-Ungarischen Monarchie*. Budapest: Akadémiai Kiadò, 213-235.

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

For France: The primary source was Joanne, A. (1858), *Atlas Historique et Statistique des Chemins de Fer Francais*. Paris: Librairie de L. Hachette. Supplementary data from Leclercq, Y. (1987) *Le Reseau Impossible*. Geneva: Librairie Droz; Milward, A.S. and S.B. Saul (1973), *The Economic Development of Continental Europe 1780-1870*. London: Geogre Allen & Unwin; Mitchell, A. (2000), *The Great Train Race: Railways and the Franco-German Rivalry, 1815-1914*. New York: Berghahn Books; and Price, R. (1983), *The Modernization of France*. London: Hutchinson.

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

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

For Norway: Milward, A.S. and S.B. Saul (1973), *The Economic Development of Continental Europe*.

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

For Spain: The primary source was Cordero, R. and F. Merendez (1978), 'El sistema ferroviario espanol.' In M. Artola (Ed.), *Los Ferrocarriles en Espana, 1844-1943, Vol. I.* Madrid: Banco de Espana, 163-340. Supplementary data came from Milward, A.S. and S.B. Saul (1977), *The Development of the Economies of Continental Europe*.

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

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

River: Equal to one if both cities in the city-pair are connected by a navigable river system; defined jointly, river cities include:

For Austria-Hungary: Budapest/Linz/Prague/Vienna
For Belgium: Antwerp/Ghent
For France: Lyon/Marseille, Bordeaux/Mende/Toulouse
For Germany: Berlin/Magdeburg/Stettin, Danzig/Posen, Frankfurt AM/Köln
For Russia: Rostov/Samara/Saratof
For Spain: Burgos/Segovia, Cordoba/Granada, Lerida/Zaragoza
For the United Kingdom: Gloucester/Worcester, Liverpool/Manchester
For the United States: Cincinnati/Indianapolis/Kansas City/Minneapolis/New Orleans/St. Louis

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344-353.
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Prakash, G. (1996), ‘Pace of Market Integration.’ Northwestern University.
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TABLE 1: DATA SUMMARY

	Description:	N	Mean	Standard Deviation	Minimum	Maximum
	DEPENDENT VARIABLES					
reltc	Sum of estimated transaction costs over average price	11614	0.416	0.905	0	31.263
rho	Sum of estimated asymmetric adjustment parameters (unrestricted band)	11614	0.584	0.334	-1.432	3.643
	WEIGHTS					
p-value	P-value derived from Hansen's F-test on the null of linearity	11614	0.204	0.121	0	1
	INDEPENDENT VARIABLES					
dist	Distance (km.)	11614	2542	3259	30	27270
distsq	Distance squared (km.)	11614	17100000	49900000	900	744000000
evol	Variance of logged nominal exchange rate	11576	0.0047	0.019	0	0.156
devol	Variance of change in logged nominal exchange rate	11576	0.00066	0.0027	0	0.019
border	Indicator of external trade	11614	0.466	0.499	0	1
rr1	Indicator of existence of railroad connection in any year	11614	0.474	0.499	0	1
rr2	Indicator of existence of railroad connection in majority of years	11614	0.444	0.497	0	1
rr3	Indicator of existence of railroad connection in entirety of years	11614	0.409	0.492	0	1
rrdist	Interaction term between "rr1" and "dist"	11614	614	1394	0	8079
canal	Indicator of existence of canal connection in any year	11614	0.050	0.218	0	1
river	Indicator of a shared river system (bilaterally defined)	11614	0.028	0.166	0	1
port	Indicator of ports (bilaterally defined)	11614	0.099	0.299	0	1
gs1	Indicator of existence of gold standard in any year (bilaterally defined)	11614	0.132	0.339	0	1
gs2	Indicator of existence of gold standard in majority of years (bilaterally defined)	11614	0.119	0.324	0	1
gs3	Indicator of existence of gold standard in entirety of years (bilaterally defined)	11614	0.099	0.298	0	1
comlang	Indicator of a common language	11614	0.065	0.247	0	1
mu	Indicator of a monetary union (bilaterally defined)	11614	0.020	0.142	0	1
intrawar	Interaction term between (1-"border") and "war"	11614	0.139	0.346	0	1
neutral	Indicator of neutrality in set of "war" (bilaterally defined)	11614	0.095	0.293	0	1
atwar	Indicator of open conflict in set of "war" (bilaterally defined)	11614	0.028	0.165	0	1
allies	Indicator of common enemy in set of "war" (bilaterally defined)	11614	0.047	0.213	0	1

TABLE 2: BENCHMARK ANALYSIS

	Dependent Variable:			
	Reltc		*Rho*	
Independent Variables:	Coefficient	P>|z|	Coefficient	P>|z|
dist	0.038900	0.000	-0.023700	0.000
distsq	-0.023300	0.000	0.000699	0.000
evol	1.420201	0.000	-0.466355	0.010
border	0.144420	0.000	0.010449	0.000
N:	11576		11576	
Weighted by:	(1-"p-value")		(1-"p-value")	
Wald χ-squared:	8630.35		24165.08	
Prob > χ-squared:	0.0000		0.0000	

NB: Year dummies suppressed; distance coefficients scaled to 1000 km.

TABLE 3: TECHNOLOGY VARIABLES

PANEL A:

	Dependent Variable:			
	Reltc		Rho	
Independent Variables:	Coefficient	P>|z|	Coefficient	P>|z|
dist	0.043300	0.000	-0.011900	0.000
distsq	-0.002500	0.000	0.000317	0.003
evol	1.418400	0.000	-0.354218	0.051
border	0.134886	0.000	-0.049587	0.000
rr1	-0.014288	0.056	0.152621	0.000
rrdist	-0.009280	0.000	-0.032800	0.000
N:	11576		11576	
Weighted by:	(1-"p-value")		(1-"p-value")	
Wald χ-squared:	8529.22		25324.71	
Prob > χ-squared:	0.0000		0.0000	

PANEL B:

Independent Variables:	Coefficient	P>|z|	Coefficient	P>|z|
dist	0.036700	0.000	-0.013400	0.000
distsq	-0.001950	0.000	0.000396	0.000
evol	1.490442	0.000	-0.434595	0.015
border	0.142457	0.000	-0.043971	0.000
rr1	*-0.001550*	*0.838*	0.142555	0.000
rrdist	-0.008000	0.000	-0.031000	0.000
canal	-0.045522	0.000	0.069418	0.000
N:	11576		11576	
Weighted by:	(1-"p-value")		(1-"p-value")	
Wald χ-squared:	9330.51		26042.03	
Prob > χ-squared:	0.0000		0.0000	

NB: Year dummies suppressed; distance coefficients scaled to 1000 km.

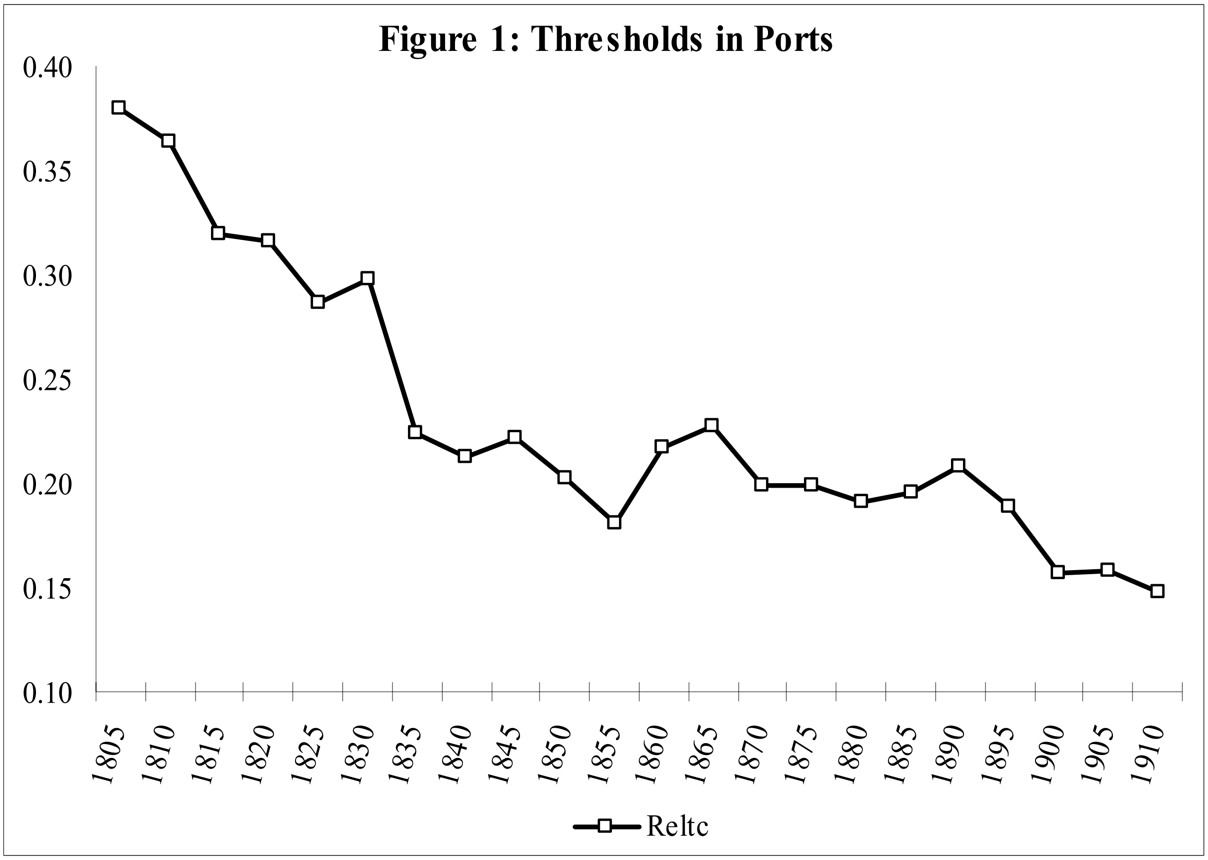
Figure 1: Thresholds in Ports
0.40
0.35
0.30
0.25
0.20
0.15
0.10
1805
1810
1815
1820
1825
1830
1835
1840
1845
1850
1855
1860
1865
1870
1875
1880
1885
1890
1895
1900
1905
1910
Reltc

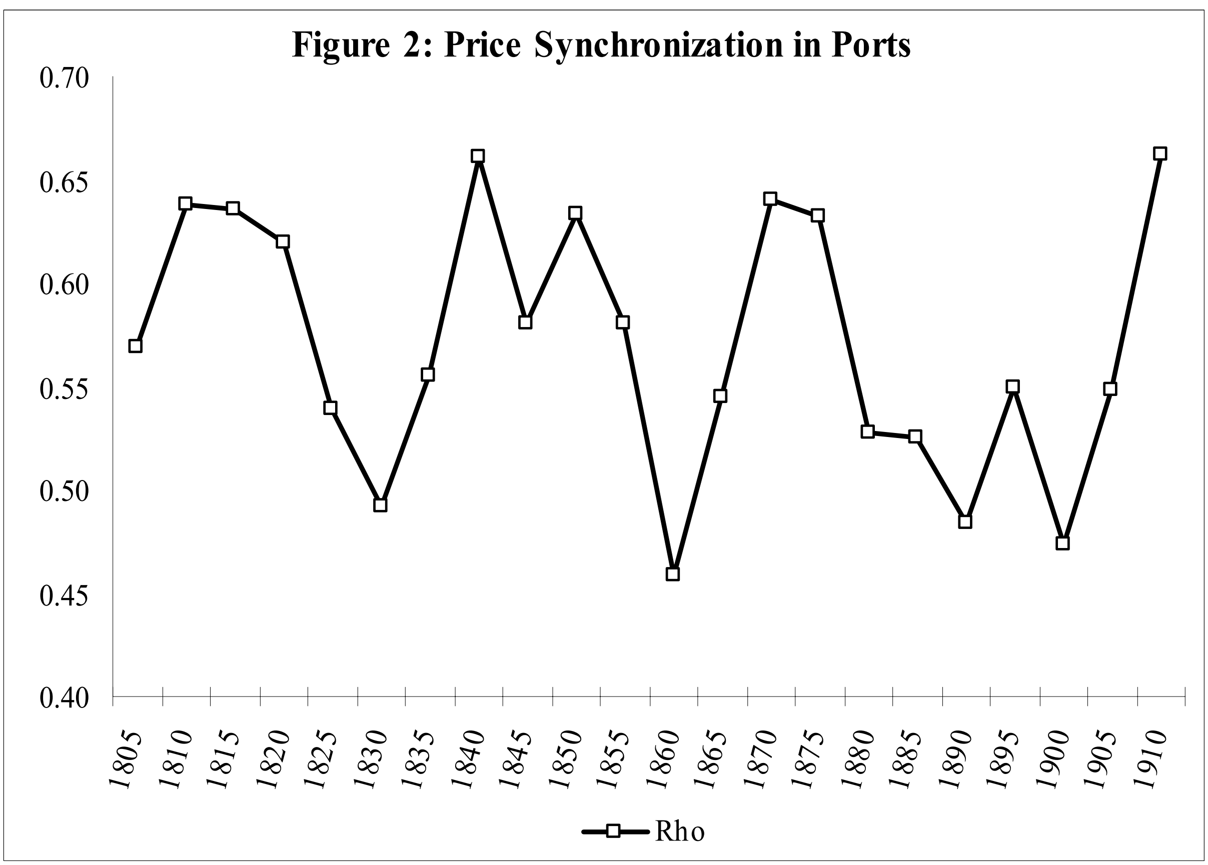
Figure 2: Price Synchronization in Ports
0.70
0.65
0.60
0.55
0.50
0.45
0.40
1805
1810
1815
1820
1825
1830
1835
1840
1845
1850
1855
1860
1865
1870
1875
1880
1885
1890
1895
1900
1905
1910
Rho

TABLE 4: GEOGRAPHY VARIABLES

	Dependent Variable:			
	Reltc		*Rho*	
Independent Variables:	Coefficient	P>|z|	Coefficient	P>|z|
dist	0.031000	0.000	-0.013500	0.000
distsq	-0.000181	0.000	0.000415	0.000
evol	1.422356	0.000	-0.429796	0.017
border	0.139500	0.000	-0.044546	0.000
rr1	*-0.004715*	*0.523*	0.139859	0.000
rrdist	-0.007930	0.000	-0.030700	0.000
canal	-0.039755	0.000	0.067292	0.000
river	-0.042584	0.000	0.059648	0.000
port	-0.021832	0.000	0.018980	0.028
N:	11576		11576	
Weighted by:	(1-"p-value")		(1-"p-value")	
Wald χ-squared:	9554.94		25977.42	
Prob > χ-squared:	0.0000		0.0000	

NB: Year dummies suppressed; distance coefficients scaled to 1000 km.

TABLE 5: INSTITUTIONAL VARIABLES

	Dependent Variable:			
	Reltc		*Rho*	
Independent Variables:	Coefficient	P>|z|	Coefficient	P>|z|
dist	0.032500	0.000	-0.010000	0.000
distsq	-0.001640	0.000	0.000254	0.018
evol	0.851138	0.000	*0.179468*	*0.334*
border	0.240847	0.000	-0.083448	0.000
rr1	-0.015577	0.033	0.173454	0.000
rrdist	*-0.003220*	*0.156*	-0.032900	0.000
canal	-0.039816	0.000	0.065169	0.000
river	-0.036942	0.000	0.061477	0.000
port	-0.015292	0.000	*0.012230*	*0.156*
gs1	-0.198134	0.000	0.124233	0.000
comlang	-0.140626	0.000	0.028743	0.025
N:	11576		11576	
Weighted by:	(1-"p-value")		(1-"p-value")	
Wald χ-squared:	10555.24		26820.99	
Prob > χ-squared:	0.0000		0.0000	

NB: Year dummies suppressed; distance coefficients scaled to 1000 km.

TABLE 6: INTRA- AND INTER-STATE CONFLICT VARIABLES

	Dependent Variable: *Reltc*		*Rho*	
Independent Variables:	Coefficient	P>|z|	Coefficient	P>|z|
dist	0.027000	0.000	-0.009150	0.000
distsq	-0.000128	0.000	0.000240	0.027
evol	0.741747	0.000	*0.109694*	*0.546*
border	0.252436	0.000	-0.101505	0.000
rr1	-0.017810	0.022	0.182243	0.000
rrdist	*-0.002020*	*0.385*	-0.033400	0.000
canal	-0.042563	0.000	0.070038	0.000
river	-0.035596	0.000	0.066407	0.000
port	-0.019397	0.000	0.013890	0.110
gs1	-0.202311	0.000	0.132036	0.000
comlang	-0.137952	0.000	0.029355	0.020
intrawar	*0.002252*	*0.855*	-0.093747	0.000
neutral	*0.024066*	*0.105*	*-0.007894*	*0.533*
atwar	0.084237	0.002	*-0.025698*	*0.265*
allies	-0.058264	0.018	-0.054341	0.004
N:	11576		11576	
Weighted by:	(1-"p-value")		(1-"p-value")	
Wald χ-squared:	8750.43		27926.99	
Prob > χ-squared:	0.0000		0.0000	

NB: Year dummies suppressed; distance coefficients scaled to 1000 km.

TABLE 7: DECOMPOSITION OF PREFERRED ESTIMATES

Change in dependent variable (expressed as % of a standard deviation) brought on by a:

	RELTC	RHO
*a.) One standard deviation increase in independent variable**		
dist	**9.72**	**-8.92**
distsq	**-1.50**	**0.76**
evol	**1.57**	0.63
rrdist	-0.31	**-13.93**
b.) Discrete change from 0 to 1 in indicator variable		
border	**22.89**	**-30.39**
rr1	**-1.96**	**54.57**
canal	**-4.70**	**20.97**
river	**-3.93**	**19.88**
port	**-2.14**	4.16
gs1	**-22.35**	**39.53**
comlang	**-15.24**	**8.79**
intrawar	0.25	**-28.07**
neutral	2.66	-2.35
atwar	**9.31**	-7.69
allies	**-6.44**	**-16.27**

* 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 10% significance.

TABLE 8: INTERTEMPORAL COMPARISONS

PANEL A: RHO THROUGH TIME

Independent Variables:	*Pre-RR and GS: 1800-1830* Coefficient	P>|z|	*Post-RR and Pre-GS: 1830-1872* Coefficient	P>|z|	*Post-RR and GS: 1872-1913* Coefficient	P>|z|	*Full Panel: 1800-1913* Coefficient	P>|z|
dist	*-0.003390*	*0.743*	-0.016400	0.000	-0.017200	0.000	-0.009150	0.000
distsq	*0.001030*	*0.333*	0.000537	0.000	0.000458	0.005	0.000240	0.027
evol	*-0.458320*	*0.121*	-2.096031	0.000	0.484772	0.039	*0.109694*	*0.546*
border	*-0.025441*	*0.435*	-0.096499	0.000	-0.136851	0.000	-0.101505	0.000
rr1	*dropped*		0.187558	0.000	0.114841	0.000	0.182243	0.000
rrdist	*dropped*		-0.032500	0.000	-0.019600	0.000	-0.033400	0.000
canal	*0.004149*	*0.904*	0.160665	0.000	0.031706	0.090	0.070038	0.000
river	0.113944	0.028	*0.023998*	*0.395*	*-0.017455*	*0.148*	0.066407	0.000
port	*-0.008329*	*0.718*	0.051641	0.000	0.065317	0.004	0.013890	0.110
gs1	*dropped*		*dropped*		0.140334	0.000	0.132036	0.000
comlang	0.120299	0.000	*-0.005219*	*0.789*	*0.014771*	*0.423*	0.029355	0.020
intrawar	-0.163055	0.032	*-0.029694*	*0.173*	-0.162299	0.000	-0.093747	0.000
neutral	*-0.040528*	*0.627*	0.056805	0.004	*-0.026699*	*0.108*	*-0.007894*	*0.533*
atwar	-0.272616	0.001	0.091543	0.040	*0.051521*	*0.213*	*-0.025698*	*0.265*
allies	-0.244605	0.003	*0.011395*	*0.584*	*dropped*		-0.054341	0.004
N:	1165		4052		6359		11576	
Weighted by:	(1-"p-value")		(1-"p-value")		(1-"p-value")		(1-"p-value")	
Wald χ-squared:	3555.76		8119.09		18069.91		27926.99	
Prob > χ-squared:	0.0000		0.0000		0.0000		0.0000	

PANEL B: RELTC THROUGH TIME

Independent Variables:	*1800-1830* Coefficient	P>|z|	*1830-1872* Coefficient	P>|z|	*1872-1913* Coefficient	P>|z|	*1800-1913* Coefficient	P>|z|
dist	0.033300	0.001	0.016600	0.020	0.017300	0.000	0.027000	0.000
distsq	-0.002250	0.040	*0.000023*	*0.978*	-0.000418	0.000	-0.000128	0.000
evol	2.173797	0.000	2.826465	0.002	0.275941	0.057	0.741747	0.000
border	0.317853	0.000	0.260990	0.000	0.188787	0.000	0.252436	0.000
rr1	*dropped*		*-0.006815*	*0.690*	-0.032964	0.000	-0.017810	0.022
rrdist	*dropped*		-0.014000	0.043	0.013700	0.000	*-0.002020*	*0.385*
canal	-0.079379	0.000	-0.039271	0.037	-0.023283	0.000	-0.042563	0.000
river	-0.050133	0.011	-0.051999	0.025	-0.025343	0.000	-0.035596	0.000
port	-0.040745	0.071	-0.079208	0.000	0.000348	0.920	-0.019397	0.000
gs1	*dropped*		*dropped*		-0.138226	0.000	-0.202311	0.000
comlang	-0.052672	0.092	-0.206154	0.000	-0.086082	0.000	-0.137952	0.000
intrawar	-0.204379	0.000	-0.090379	0.008	0.071212	0.000	*0.002252*	*0.855*
neutral	-0.195777	0.007	*0.032726*	*0.397*	0.028474	0.005	*0.024066*	*0.105*
atwar	-0.160188	0.016	*0.047036*	*0.697*	0.081546	0.003	0.084237	0.002
allies	-0.246686	0.001	-0.173919	0.000	*dropped*		-0.058264	0.018
N:	1165		4052		6359		11576	
Weighted by:	(1-"p-value")		(1-"p-value")		(1-"p-value")		(1-"p-value")	
Wald χ-squared:	5302.93		3227.7		12352.63		8750.43	
Prob > χ-squared:	0.0000		0.0000		0.0000		0.0000	

NB: Year dummies suppressed; distance coefficients scaled to 1000 km.