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What drove 19th century commodity market integration?

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Abstract

This paper seeks to answer the titular question of what drove commodity market integration in the 19th century. Using grain markets during the first wave of globalization as a testing ground, the paper builds on the insights of the contemporary trade literature and the economic history of the 19th century and relates levels of market integration to cross-sectional and temporal variations in transport technology, geography, monetary regimes, commercial networks/policy, and conflict. The results of this decomposition analysis are interesting on two counts: first, they verify the commonality of experience of the 19th and late 20th centuries; second, they suggest a very strong role for the commercial, diplomatic, and monetary environment in which market integration took place.

Keywords: Commodity market integration; Trade costs; Globalization

1. Introduction

In recent years, the 19th century has enjoyed a fresh round of interest as economic historians have repositioned the period as the so-called first wave of the globalization process sweeping much of the world at the present time. Thus, the corpus of work by O'Rourke, Williamson, and others has directed the attention of historians and econ-

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omists 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).

Historical accounts as well as popular conceptions of the long 19th century (1800–1913) have generally stressed the singular role played by developments in transportation and communication technologies in conquering time and space, creating in their wake commodity markets of immense scale. Nowhere was this transformation thought to have been more readily felt than in the newly settled frontier of the United States and in the emergent nation states of Europe, namely Germany, Italy, and Russia. In this account, the dynamic twins of the railroad and telegraph take pride of place in creating economically and socially unified national polities while the wholesale adoption of steam propulsion in the maritime industry plays a similar role with respect to international markets (see James, 2001, pp. 10–13).

In light of this position, the question which this paper seeks to answer is what were the proximate causes of the evolution of commodity market integration in the 19th century? Building on the insights provided by the contemporary trade literature and the economic history of the 19th century, the paper uses evidence from grain markets in over 100 cities to first construct measures of intra- and international commodity market integration and then decompose cross-sectional and temporal variations in the measures with information on transport, geographic, monetary, commercial, and diplomatic linkages.

The first fundamental result is that the findings presented below can be aligned with results for the late 20th century, verifying the commonality of the two waves of globalization. Additionally, the economic history literature allows for the identification of further variables, which have been relatively underrepresented in the contemporary trade literature: technological change in the transport sector; enduring, trade-enhancing geographical features associated with navigable waterways; the choice of monetary regime and commercial policy; and intra- and interstate conflict.

Second, econometric analysis of temporal and cross-country variation in trade costs (roughly, the size of price differentials) and speeds of price adjustment (roughly, the speed at which profitable price differentials are arbitraged away) points to the fact that two different combinations of causal factors predominate in each case. Surprisingly, variables associated with the state of the diplomatic environment and the choice of commercial policy and monetary regime are estimated to have the largest effects on trade costs.

2. Motivation

In confronting the economic history literature, there are certain themes which seem to dominate the narrative of the 19th century. Although diplomatic, commercial, and financial advances are given some credit, one of the prevailing views seems to be that the main drivers of commodity market integration in this period were fundamental changes in the technology of communication and transport. Thus, O'Rourke and Williamson write that the "impressive increase in commodity market

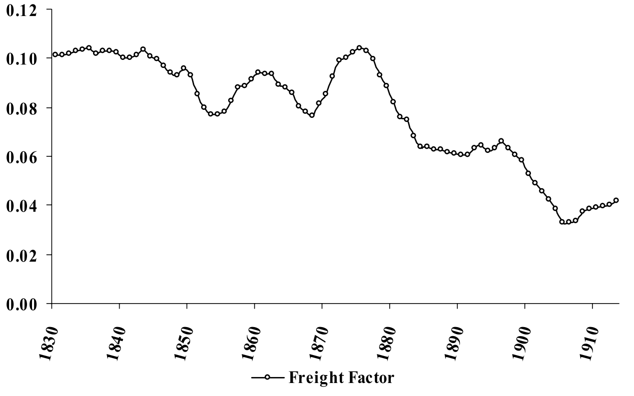

Fig. 1. NYC-to-London freight costs for 100 kg of wheat (as a share of average price).

integration in the Atlantic economy [of] the late 19th century'' was a consequence of ``sharply declining transport costs'' (1999, p. 33).

When only considering the record of transport costs in the 19th century, this view seems somewhat vindicated. Fig. 1 depicts North's (1958) series on the course of freight costs (as a share of price) for wheat from New York City 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 19th century, the most impressive declines took place in the post-1875 period. Thus, the movements in freight costs correspond nicely with the introduction and eventual domination of steam over sail on this route. Such improvements in observed freight costs can be demonstrated for railroads as well. Fig. 2 depicts the course of freight costs by rail and by lake-and-rail from Chicago to New York City (NYC) in the period from 1860 to 1902 (taken from Fremdling, 1999; Veblen, 1892).

However, for most of the 19th century only a small portion of price differentials can be attributed to transport costs.[1] This phenomenon is clearly seen in Figs. 3 and 4, which compare transport costs against the size of price differentials in the NYC–London and Chicago–NYC markets, respectively. What this suggests is that for the 19th century transport costs were swamped by other costs to trade, in both domestic and international markets. Clearly, explaining this disparity between trade and transport costs as well as its evolution is an important task for economic historians—a task which has even been taken up by trade economists (Anderson and van Wincoop, 2004).[2]

What this paper seeks to do in the following sections is to use estimates of trade costs and of speeds of price adjustment in wheat markets, to determine the drivers of commodity market integration in the 19th century. Specifically, these estimates will

[1] In a highly detailed study, Persson (2004) finds a similar result for the NYC and London markets in the period from 1850 to 1900—by the end of this period, transport costs account for a little over 50% of the total price differential separating NYC and London.

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

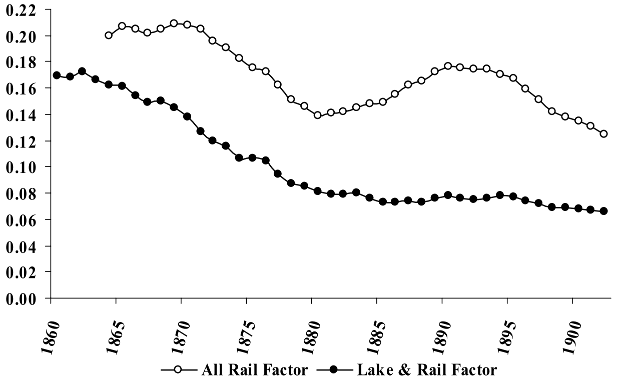

Fig. 2. Chicago-to-NYC freight costs for 100 kg of wheat (as a share of average price).

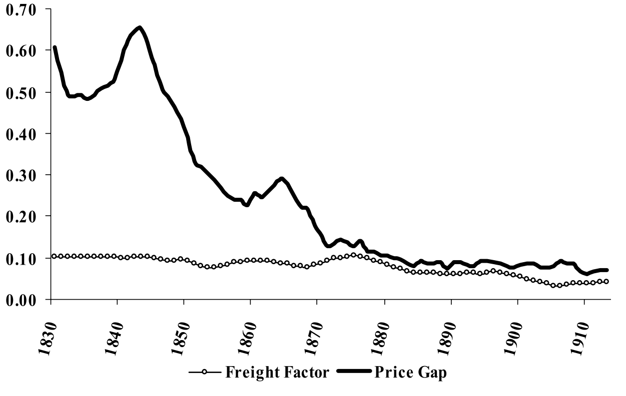

Fig. 3. NYC-to-London price gaps and freight costs for 100 kg of wheat (as a share of average price).

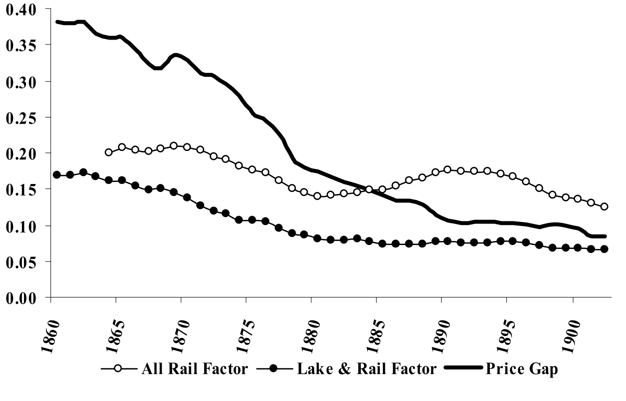

Fig. 4. Chicago-to-NYC price gaps and freight costs for 100 kg of wheat (as a share of average price).

be related to cross-sectional and temporal variations in transport technology, geography, monetary regimes, commercial networks/policy, and conflict.

3. Analytical framework

In assessing the degree of commodity market integration across time and countries, this paper will make use of threshold regressions on bilateral (city-pair) price data from wheat markets over the period from 1800 to 1913 in over 100 North Atlantic cities. This approach is generally recognized as 'state-of-the-art' in the applied econometrics literature (cf. Balke and Fomby, 1997; Hansen and Seo, 2002; Prakash, 1996) and has been employed in many recent studies of historical market integration (cf. Canjels et al., 2004; Ejrnæs and Persson, 2000; Goodwin and Grennes, 1998).

The basic assumption is that agents in two locations will always arbitrage price differentials away—once the price differential becomes large enough to compensate them for all costs of exchange, both observed (e.g., freight, brokerage, insurance, storage, and spoilage costs) and unobserved (e.g., information costs, exchange rate risk, and/or the risk aversion of agents). This assumption is succinctly captured by the following conditions:

$$-C_t^{12} \leqslant M_t^{12} \leqslant C_t^{21}, \tag{1}$$

$$-C_t^{21} \leqslant M_t^{21} \leqslant C_t^{12}, \tag{2}$$

where $M_t^{ij} = P_t^i - P_t^j$ is the price margin between cities i and j for an identical good; and C_t^{ij} is the trade cost associated with physically transferring the identical good from city i to city j.

Conditions (1) and (2) are put to work in an asymmetric-threshold error-correction-mechanism (ATECM) model. The intuition is that for any pair of cities, the change in price in one market at time t ($\Delta P_t^1 = P_t^1 - P_{t-1}^1$) should be negatively related to the level of the margin between the two markets in the previous period $t-1$ ($M_{t-1}^{12} = P_{t-1}^1 - P_{t-1}^2$) but only if the margin exceeds the band of trade costs, ($|C_{t-1}^{12}|, |C_{t-1}^{21}|$). If the margin is less than the band of trade costs (i.e., the thresholds), the change in price is free to follow a random walk within the 'corridor' between the two bands. The following equations capture the estimating strategy:

$$\Delta P_t^1 = \begin{cases} \rho_1(M_{t-1}^{12} - C_{t-1}^{21}) + \eta_t^1 & \text{if } M_{t-1}^{12} > C_{t-1}^{21}, \\ \eta_t^1 & \text{if } -C_{t-1}^{12} \leqslant M_{t-1}^{12} \leqslant C_{t-1}^{21}, \\ \rho_1(M_{t-1}^{12} + C_{t-1}^{12}) + \eta_t^1 & \text{if } M_{t-1}^{12} < -C_{t-1}^{12}, \end{cases} \tag{3}$$

$$\Delta P_t^1 = \begin{cases} \rho_2(M_{t-1}^{21} - C_{t-1}^{12}) + \eta_t^2 & \text{if } M_{t-1}^{21} > C_{t-1}^{12}, \\ \eta_t^2 & \text{if } -C_{t-1}^{21} \leqslant M_{t-1}^{21} \leqslant C_{t-1}^{12}, \\ \rho_2(M_{t-1}^{21} + C_{t-1}^{21}) + \eta_t^2 & \text{if } M_{t-1}^{21} < -C_{t-1}^{21}, \end{cases} \tag{4}$$

where $(\eta_t^1, \eta_t^2) \sim Nid(0, \Omega)$. The sum of the ρ-coefficients (designated as *adjustment speed* 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 at which profitable price differentials are arbitraged away.

The ρ-coefficients in Eqs. (3) and (4) are estimated by OLS via a grid search on all possible combinations of $(|C^{12}_{t-1}|, |C^{21}_{t-1}|)$. This latter set is taken as the range of price margins between two cities over a given period of time (below, this will generally be 132 months, i.e., 11 years). The values of $(|C^{12}_{t-1}|, |C^{21}_{t-1}|)$ which maximizes the corresponding likelihood function (or equivalently, minimizes the sum of squares) is recorded along with the ρ-coefficients corresponding to them.[3] These maximizing values are the estimates of trade costs and adjustment speeds used below. Additionally, the estimated trade costs are scaled by the average price of wheat prevailing in the two cities. This results in a unit-less measure of trade costs which is comparable to the freight and price-gap factors displayed in Figs. 3 and 4 above and may be thought of as the 'markup' in prices between two cities.

Of course, the procedure described above is that for generating one observation on trade costs and adjustment speeds for a single city-pair in a single period of time. To assess the evolution of commodity market integration, a panel of such observations is needed. To that end, the general methodology was as follows.

First, the long 19th century was broken into overlapping 11-year periods (1800–1810, 1805–1815,..., 1900–1910, 1905–1913). Second, within a given country, all possible pair-wise combinations of domestic cities were formed and observations on trade costs and adjustment speeds were estimated for all possible 11-year periods. Finally, across countries, the price data for each country were matched with prices from a set of five cities (Bruges, London, Lwow, Marseilles, and NYC), which represent important markets for wheat in the international economy in the 19th century *and* for which data exists over the entire period (thus, allowing for a consistent means of comparison across time and countries). Again, all possible pair-wise combinations of domestic and international cities were formed and observations on trade costs and adjustment speeds were estimated for all possible 11-year periods. Table 1 provides an extended summary of the underlying price data and resulting observations on trade costs and adjustment speeds.[4]

4. Empirical results

To weigh the determinants of the 19th 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,

[3] For a fuller exposition of the estimation procedure, please see Jacks (2005) in this journal. The *t*-statistics on the estimated speeds of price adjustment are calculated in the standard fashion. The procedure for generating the *t*-statistics on the trade cost estimates is detailed in Appendix A of Jacks (2005) and is available at http://www.sfu.ca/~djacks/data/.

[4] A second appendix to Jacks (2005) reports the exact coverage and source of each of the underlying price series and is available at http://www.sfu.ca/~djacks/data/.

which seem likely contenders in driving commodity market integration. Thus, the exercise can be thought of as parallel to the recent work of Estevadeordal et al. (2003), which employs a gravity model to decompose the forces driving the rise and fall of trade volumes between 1913 and 1938.

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, 2001). Along the way, further explanatory 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 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.

4.1. Benchmark analysis

Researchers looking into the forces affecting market integration for the late 20th century have generally used a modified gravity model. Typically, a regression of the following form, taken from Engel and Rogers' (1996) seminal work, is estimated:

$$V(P_{j,k}) = \beta_1 r_{j,k} + \beta_2 B_{j,k} + \sum_{m=1}^{n} \gamma_m D_m + u_{j,k}, \tag{5}$$

where the dependent variable equals the standard deviation of the (first-differenced) logged price ratio in cities j and k over a given time horizon; $r_{j,k}$ 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.

Here the same exercise will be followed in broad form, but with a view towards more explicitly modeling the structure of errors. Previously, estimation of Eq. (5) has taken place within the framework of ordinary-least-squares estimation with limited controls for heteroscedasticity or serial correlation. What is currently proposed is the use of GLS estimation,[5] explicitly incorporating group-wise, cross-sectionally correlated heteroskedasticity (based on country-pairs) and serial correlation[6] into the structure of the variance–covariance matrix. Thus, our baseline results come from the following regression:

$$\text{Integration}_{j,k,T} = \beta_1 \text{dist}_{j,k} + \beta_2 \text{distsq}_{j,k} + \beta_3 \text{evol}_{j,k,T} + \beta_4 \text{border}_{j,k} + \sum_{T=1}^{22} \gamma_T D_T + u_{j,k,T}, \tag{6}$$

[5] 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).

[6] 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 explanatory power. Consequently, it was opted to use all available data and correct for serial correlation as described above; Appendix A reports the results of this exercise and other robustness checks.

Table 1
Detailed summary of underlying price data and resulting observations on trade costs and adjustment speeds

Underlying observations on wheat prices	Austria–Hungary 7044	Belgium 4104	France 16416	Germany 5040	Italy 4752	Norway 2880	Russia 3024	Spain 13008	United Kingdom 16416	United States 9876	Full panel 82560
Resulting observations on intranational markets											
1800–1810	6	3	66						66	3	144
1805–1815	6	3	66						66	3	144
1810–1820	6	3	66					28	66	6	175
1815–1825	6	3	66					36	66	6	183
1820–1830	6	3	66					36	66	10	187
1825–1835	6	3	66					45	66	10	196
1830–1840	6	3	66			1		55	66	10	207
1835–1845	6	3	66			3		66	66	36	246
1840–1850	6	3	66			3		66	66	36	246
1845–1855	6	3	66			3		66	66	45	255
1850–1860	6	3	66			1		66	66	45	253
1855–1865	6	3	66			1		66	66	45	253
1860–1870	6	3	66		66	3		66	66	45	321
1865–1875	10	3	66		66	3		66	66	28	308
1870–1880	10	3	66		66	3		66	66	28	308
1875–1885	10	3	66	66	66	3		66	66	28	374
1880–1890	10	3	66	66	66	3		66	66	28	374
1885–1895	45	3	66	66	66	3		66	66	28	409
1890–1900	45	5	66	66		3	66	66	66	28	411
1895-1905	45	3	66	66		3	66	66	66	45	426
1900–1910	45	3	66	66		3	66	66	66	45	426
1905–1913	45	3	66	66		3	66		66	45	360
1800–1913	343	68	1452	462	396	42	264	1124	1452	603	6206

Resulting observations on international markets											
1800–1810	38	35	62						62	35	116
1805–1815	38	35	62						62	35	116
1810–1820	47	44	71					40	71	47	160
1815–1825	48	45	72					45	72	48	165
1820–1830	49	46	73					45	73	52	169
1825–1835	50	47	74					50	74	53	174
1830–1840	53	50	77			10		55	77	56	189
1835–1845	59	56	83			15		60	83	74	215
1840–1850	59	56	83			15		60	83	74	215
1845–1855	60	57	84			15		60	84	78	219
1850–1860	59	56	83			10		60	83	77	214
1855–1865	59	56	83			10		60	83	77	214
1860–1870	72	69	96		60	15		60	96	90	279
1865–1875	74	68	95		60	15		60	95	83	275
1870–1880	74	68	95		60	15		60	95	83	275
1875–1885	86	80	107	60	60	15		60	107	95	335
1880–1890	86	80	107	60	60	15		60	107	95	335
1885–1895	106	85	112	60	60	15		60	112	100	355
1890–1900	107	89	113	60		15	60	60	113	101	359
1895–1905	108	87	114	60		15	60	60	114	108	363
1900–1910	108	87	114	60		15	60	60	114	108	363
1905–1913	96	75	102	60		15	60		102	96	303
1800–1913	1536	1371	1962	420	360	225	240	1075	1962	1665	5408

Table 2
Summary of dependent and independent variables

	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

|r| = (.66, 1.00)
|r|=(0.33, 0.65)
|r| = (0, 0.32)

		(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

Note: r between TCs/price and speed of adjustment =−0.3913.

where the dependent variable is time-variant 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 from Eqs. (3) and (4)). The first two terms on the right-hand side, $\text{dist}_{j,k}$ and $\text{distsq}_{j,k}$, refer to the distances and squared distances separating cities j and k; $\text{evol}_{j,k,T}$ is the variance of the logged nominal exchange rate between the currencies of j and k over the period, T; $\text{border}_{j,k}$ denotes the existence of a border between j and k; and D_T is a set of indicator variables for each of the 22 periods considered.

Furthermore, a suitable weighting matrix for the dependent variables needs to be specified 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 (Balke and Fomby, 1997; Chan, 1993; and Hansen, 1997), it is assumed that the number of observations will be inversely proportional to the asymptotic variance of the resulting estimates. In any case, 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. The patterns look sensible. Trade costs increase with distance, nominal exchange rate volatility, and the border. 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.

4.2. Transport technology variables

To assess 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.[7] These variables switch

[7] In discussing transport technology, two important points must be made. First, there seems to be no way for completely accounting for the trade-creating effects of transport technology. For instance, Salt Lake City was founded in 1847 and operated under near-autarkic conditions for many years in relation to foodstuffs until the completion of the trans-continental railroad in 1869 (Alexander and Allen, 1984). Assuming that the relevant price data for Salt Lake City could be found, the estimation procedure above could *potentially*, but not *necessarily* capture the effect of railroads in incorporating the city into American and international wheat markets. However, an extended review of the secondary literature as in Jacks (2004) suggests that for the cities in this sample commercial linkages—albeit indirect ones—did exist prior to the introduction of railroads. A valuable source, in this regard, is Persson (1999), which documents the spread of domestic and international markets for wheat from 1500. Second, the data for constructing a separate variable capturing the introduction of the telegraph do not exist. On the other hand, all indications 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. The author thanks one of the referees for bringing this first point to his attention.

Table 4
GLS regression results

	(1) Benchmark		(2) Transport 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 speed	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

Note: Figures in bold denotes statistical significance and figures in italics denotes statistical insignificance. Year dummies suppressed, distance coefficients scaled to 1000 km; *p* values reported in parantheses.

'on' with the completion of an intercity rail connection. However, since estimates of trade costs and adjustment speeds are generated over 11-year periods, it was decided not to code these variables as strictly binary, since doing so will most likely impart a downward bias on the estimated coefficients (Greene, 2003, pp. 379–390).[8] Rather, they are continuously defined, capturing the portion of an 11-year 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 1840–1850, 0.09 for the period of 1845–1855, 0.55 for the period of 1850–1860, and 1 for the period of 1855–1865. Implicitly, this approach should also provide some allowance for TFP growth in the transport sector. Consequently, this coding technique was employed for the other variables considered below.[9]

The effects of including the railroad variable along with an interaction term with distance on the initial results are reported in column 2 of Table 4. The motivation for including the 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. Consider two cities, say, Brussels and Paris. The exercise in Table 4 would predict that the level of the trade costs between the two cities was reduced by 0.0263 and the speed of price adjustment was increased by 0.1516 when a railroad link was introduced between the two in 1842. This is, then, equivalent to a 25.9% increase in adjustment speeds but only a 6.8% reduction in trade costs when evaluated at their respective means of 0.585 and 0.384 as reported in Table 2.

A further issue to be addressed is one touched off 40 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 extendable 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, but decisive. 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 broadly equivalent reductions in trade costs for wheat.[10]

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[8] Appendix Table A.4 reports results using a strictly binary coding scheme, with materially the same results.

[9] A separate appendix provides definitions as well as sources for all independent variables and is available at http://www.sfu.ca/~djacks/data/.

[10] 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.

4.3. Geography variables

The economic history literature has generally found a strong place for geography in the process of market integration. Specifically, navigable waterways have long been associated with greater access to and participation in external markets. Thus, among others, the work of Fishlow (1964), Haites et al. (1975), Milward and Saul (1973, 1977); North (1955); Pollard (1974); and Ville (1990) has forcefully shaped the view that 'water mattered' for the development of Atlantic markets. To incorporate these insights, 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 preliminary analysis presented below on the role of maritime technology.

4.4. 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 trade.[11]

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 significantly contributes to the process of market integration. Consider again the city-pair Brussels/Paris. The point estimates predict that the common adoption of the gold standard by Belgium and France in 1878 would have reduced trade costs by 0.1557 and increased adjustment speeds by 0.1324, which are equivalent to changes of 40.5 and 22.6% from their respective mean values. The nearly equal but opposite coefficients associated with *border* and *gold standard* in the regressions on trade costs and adjustment speeds, also, 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

[11] For 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).

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 19th 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 to 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, the monetary union variable is, therefore, omitted from the regressions.

4.5. 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 a 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 role of commercial policy, its course in the 19th century Atlantic economy is a familiar one in the economic history literature. Following the disruptions of the Napoleonic Wars, commercial policy in the early 19th century was still formulated in near-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 far-flung, low-cost producers 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.[12]

[12] Governments imposed specific tariffs throughout the 19th century. These, however, are not suitable for our purposes as the trade cost dependent variable is scaled to the average price of wheat. Following O'Rourke (1997), specific tariffs have been converted to ad valorem equivalents by dividing the specific tariff by the average national price.

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 independent variables, it may be possible in future research to diminish the border effect even further.

4.6. Conflict variables

With respect to this last category, the intuition is pretty clear: open conflict must be detrimental to the process of commodity market integration as it simultaneously raises the risk underlying exchange and disrupts peacetime conduits of goods and information—both across and within countries. Clear examples of such breakdowns in commodity markets are provided by Barbieri (1996), Broomhall and Hubback (1930), Findlay and O'Rourke (2003), Kaukiainen (2001), and Olson (1963).

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 a time of war for a trading partner (*neutral*), open conflict between trading partners and a common enemy (*allies*), and open conflict between trading partners (*At war* (*external*)). A final element added was the *At war* (*internal*) variable which seeks to capture the effects on intranational integration when a country is at 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. Consider the two city-pairs, Paris/Madrid and Madrid/Zaragoza. With the outbreak of the French–Spanish War in 1822, trade costs would be predicted to have risen between Paris and Madrid by 0.1809 and between Madrid and Zaragoza by 0.1741 while adjustment speeds would be predicted to have fallen between Paris and Madrid by 0.1855 and between Madrid and Zaragoza by 0.2304. Even more impressive are the estimated effects of civil wars. Thus, with the outbreak of the First Carlist War in 1833, trade costs would be predicted to have risen between Paris and Madrid by 0.3747 and between Madrid and Zaragoza by 0.4607 while adjustment speeds would be predicted to have fallen between Paris and Madrid by 0.1895 and between Madrid and Zaragoza by 0.1695.

Bearing in mind that the respective means for trade costs and adjustment speeds are 0.384 and 0.585, the figures given above 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 very little work has been done by economists and historians in explicitly quantifying the effects of conflict on trade (a recent, notable exception being Glick and Taylor, 2004).

4.7. Confronting technological improvement

In the preceding sections, no attempt has been made to control for potential technological improvement associated with canals, port, railroads, and rivers. As the decline in freight rates in Figs. 1 and 2 might suggest, these were not necessarily static technologies, i.e., their contribution to market integration may have been changing over time and the panel estimates reported in Table 4 might mask particular eras of significant improvement. To assess technological change in the transport sector, regressions were run on the variables included in the final specification (see column 6 of Table 4) along with interaction terms between time and the indicator variables on city-pairs with shared canal, port, railroad, and river connections. As a means of comparison, a regression was also run on the final specification variables plus an interaction term between time and *gold standard*. The results of these exercises for the trade cost variable are depicted in Fig. 5. In panel A, we have the pure time effect. Thus, controlling for all other independent variables, the conditional mean for the period of 1800–1810 is estimated to be 0.2599 with a 95% confidence interval of (0.1936, 0.3263). What panels B through F trace are the deviations (and associated 95% confidence intervals) from the pure time effect for the respective interaction terms. Thus, if for any series, the 95% confidence interval crosses the dotted zero-axis, the point estimates of the time-interacted variable cannot be statistically distinguished from the general time trend in panel A.

Panel D, for instance, offers an interesting story of the integration of ports through time: if there were any advantages associated with ports in terms of trade costs, these were dissipated sometime before 1870. However, the post-1870 period is precisely when one would expect the advantages of ports to mount as steam overtook sail in maritime shipping. These results suggest that technological change in the maritime industry may have had far more muted effects on trade—as opposed to transport—costs than previously supposed.

Likewise, the remaining panels illustrate two important points. Namely, there were appreciable differences in the effects of the transport variables through time, but these were not consistently in one direction. Thus, the panel estimates in Table 4 are representative of the general effects of transport technology on trade costs.[13] Second, these results are interesting, in that they relate back to the issue raised in the second section with regard to Figs. 1–4. Namely, transport costs undoubtedly fell throughout the 19th century in both domestic and foreign markets. However, the decline in trade costs—whether econometrically estimated as in section 3 or proxied for by price gaps as in section 2—was even

[13] A similar exercise on the speeds of price adjustment yields similar results and, thus, remains unreported in the interests of space.

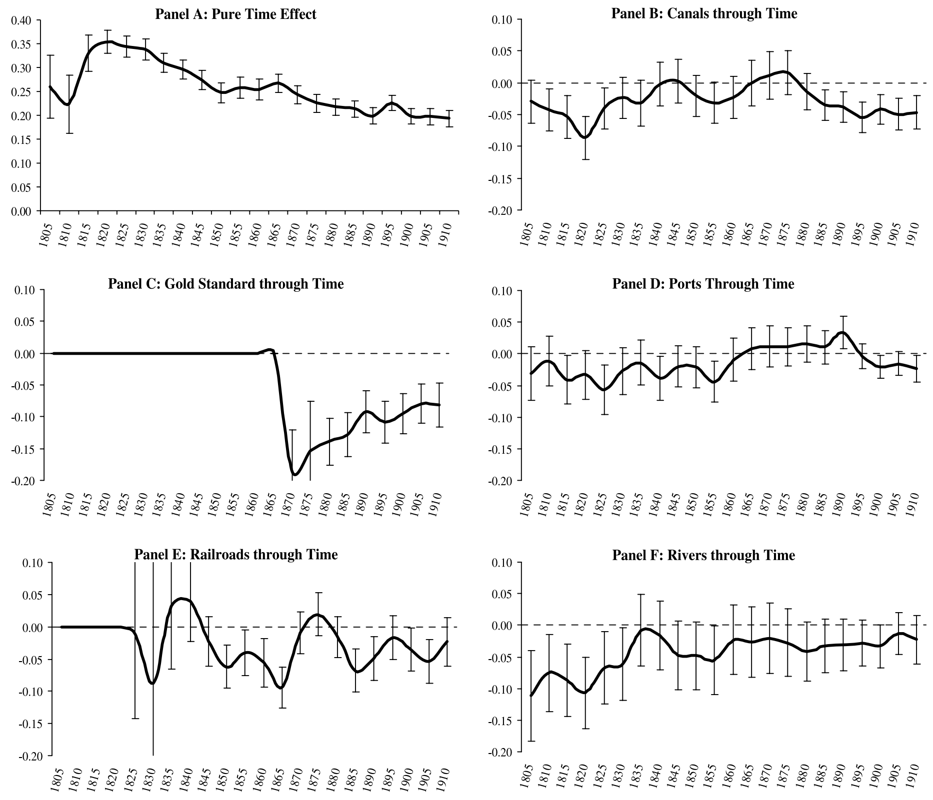

Fig. 5. Estimated time interactions in the trade cost regression.

more dramatic. One of this paper's main contributions, then, is in identifying along what other margins beyond transport was the fall in trade costs potentially attributable to.

4.8. A ranking of independent variables in the final specification

Rounding things out, Table 5 summarizes the final specification into a more easily digestible format. The point of the exercise is to simply sort the effects of like changes in the levels of the independent variables on the levels of the two measures of market integration. The reported values are the ranked products of the point estimates in column 6 of Table 4 and a uniform change in the respective independent variables (i.e., either a one standard deviation increase for the variables in panel A or a change from zero to one for the variables in panel B). The intuitive interpretation of the values is the same as in previous sections, e.g., the adoption of the gold standard by the Belgians and French in 1878 is estimated to have reduced the level of the trade cost between Belgium and France by 0.1009. The figures can also give the reader a sense of the relative orders of magnitude of change. For instance, consider the city-pair

Table 5
Ranking of independent variables

	Trade costs/average price	Adjustment speed	
Change in the level of dependent variable brought on by a:			
(a) One standard deviation increase in independent variable[a]			
Distance	**0.079**	**−0.053**	Railroad–distance
Exchange rate volatility	**0.019**	**−0.018**	Distance
Distance squared	**−0.005**	**−0.009**	Exchange rate volatility
Railroad-distance	**0.004**	*0.001*	Distance squared
(b) Discrete change from 0 to 1 in indicator variable			
Ad valorem	**0.619**	**−0.230**	At war (internal)
Civil war (internal)	**0.461**	**0.201**	Railroad
Civil war (external)	**0.375**	**−0.189**	Civil war (external)
Prohibition	**0.269**	**−0.185**	At war (external)
At war (external)	**0.181**	**−0.169**	Civil war (internal)
At war (internal)	**0.174**	**−0.143**	Prohibition
Border	**0.126**	**0.128**	Gold standard
Gold standard	**−0.101**	**−0.089**	Ad valorem
Allies	**0.099**	**0.059**	Canal
Railroad	**−0.047**	**−0.056**	Border
River	**−0.032**	**0.051**	River
Common language	**−0.030**	**−0.037**	Allies
Canal	**−0.029**	**0.010**	Port
Port	**−0.014**	*−0.119*	Neutral
Neutral	*0.043*	*0.009*	Common language

Note: Figures in bold represent variables with coefficients at least 5% significance.
[a] Change in "distsq" taken as the square of a standard deviation of the "dist" variable.

Brussels and Paris before 1842, the year when a railroad was introduced between the two. What Table 5 suggests is that a move from this initial state to one where Belgium and France both adhere to the gold standard would be associated with a decrease in trade costs which is roughly 2.1 ($\approx -0.1009/-0.0474$) times greater than a move from the initial state to one in which a rail link exists between Brussels and Paris.

A few conclusions are clearly forthcoming with regard to the relative contributions of transport 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 19th century was one of the primary drivers 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 19th century. This is particularly so in the case of trade costs in which the two commercial policy variables (*ad valorem* and *prohibition*) and the *gold standard* variable appear at the head of the list.

5. Conclusion

Building on the insights provided by both the contemporary trade literature and the economic history of the 19th century, this paper has attempted to lay a foundation for assessing the determinants of 19th century 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 trade 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 19th and 20th centuries. Additionally, further variables were identified which have long been considered likely contenders in the economic history 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 interstate conflict.

Second, trade costs seem to be more responsive to changes in the choice of monetary regimes and commercial policy than changes in the underlying technology of transport. Running somewhat counter to this finding, speeds of price adjustment present a more balanced account as transport, monetary, and commercial variables all seem to play a part. Tasks for future work might then be in refining the measures standing in for transport technology and in relating earlier developments in the commercial and diplomatic environment as preconditions for changes in the technologies of communication, transaction, and transport.

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Science Research Council's Program in Applied Economics. All those implicated above, of course, are absolved of any remaining errors.

Appendix A. Robustness checks

As was seen in earlier work (Jacks, 2005), it appears that the use of price levels (rather than logged prices) is to be preferred in the first stage of estimation. As a further check, the final specification of the estimating equation above was run on estimates of trade costs and the speed of price adjustment generated from ATECM models implementing both logged and non-logged prices. The two approaches offer similar stories as demonstrated in Table A.1.

Additionally, the validity of the particular estimation strategy employed should be assessed. In the second stage of estimation, the output of the

Table A.1
Final specification using price levels vs. logged prices

Independent variables	Dependent variable							
	TCs/price (levels)		TCs/price (logs)		Adjustment speed (levels)		Adjustment speed (logs)	
	Coefficient	$P>\|z\|$	Coefficient	$P>\|z\|$	Coefficient	$P>\|z\|$	Coefficient	$P>\|z\|$
Distance	**0.0245**	**0.000**	**0.0030**	**0.000**	**−0.0057**	**0.020**	**−0.0010**	**0.070**
Distance squared	**−0.0005**	**0.000**	**−0.0001**	**0.000**	*0.0001*	*0.452*	**0.0000**	**0.774**
Exchange rate volatility	**0.9939**	**0.000**	**0.3212**	**0.000**	**−0.4505**	**0.016**	**0.0493**	**0.023**
Border	**0.1258**	**0.000**	**0.0072**	**0.000**	**−0.0558**	**0.000**	**−0.0531**	**0.000**
Railroad	**−0.0474**	**0.000**	*0.0007*	*0.222*	**0.2012**	**0.000**	**0.0372**	**0.000**
Railroad–distance	**0.0028**	**0.014**	**−0.0009**	**0.000**	**−0.0398**	**0.000**	**−0.0061**	**0.000**
Canal	**−0.0285**	**0.000**	**−0.0010**	**0.000**	**0.0587**	**0.000**	**0.0450**	**0.000**
River	**−0.0321**	**0.000**	**−0.0014**	**0.000**	**0.0513**	**0.001**	**0.0282**	**0.000**
Port	**−0.0140**	**0.004**	**−0.0011**	**0.000**	**0.0096**	**0.024**	**0.0045**	**0.003**
Gold standard	**−0.1009**	**0.000**	**−0.0110**	**0.000**	**0.1284**	**0.000**	**0.0270**	**0.000**
Common language	**−0.0302**	**0.027**	*0.0003*	*0.840*	*0.0089*	*0.536*	**0.0024**	**0.511**
Ad valorem	**0.6187**	**0.002**	**0.0472**	**0.033**	**−0.0886**	**0.000**	**−0.0236**	**0.000**
Prohibition	**0.2691**	**0.000**	**0.0496**	**0.000**	**−0.1427**	**0.000**	**−0.0313**	**0.000**
Neutral	*0.0429*	*0.271*	*0.0042*	*0.276*	*−0.1188*	*0.536*	*−0.0069*	*0.582*
Allies	**0.0994**	**0.045**	**0.0322**	**0.000**	**−0.0367**	**0.019**	**−0.0754**	**0.000**
At war (external)	**0.1809**	**0.000**	**0.0880**	**0.000**	**−0.1855**	**0.002**	**−0.0923**	**0.000**
At war (internal)	**0.1741**	**0.000**	**0.0199**	**0.000**	**−0.2304**	**0.000**	**−0.1034**	**0.000**
Civil war (external)	**0.3747**	**0.000**	**0.0839**	**0.000**	**−0.1895**	**0.000**	**−0.0282**	**0.005**
Civil war (internal)	**0.4607**	**0.000**	**0.0527**	**0.000**	**−0.1695**	**0.000**	**−0.1013**	**0.000**
N	11540		11540		11540		11540	
Weighted by	Obs		Obs		Obs		Obs	
Wald χ-squared	32267.2		10963.40		31472.17		10206.82	
Prob > χ-squared	0.000		0.0000		0.000		0.0000	

Note: Figures in bold denotes statistical significance and figures in italics denotes statistical insignificance. Year dummies suppressed; distance coefficients scaled to 1000 km.

Table A.2
Time and country fixed effects, with and without controls for auto-correlation

Independent variables	GLSAC	P > |z|	FE	P > |z|	GLS	P > |z|	MLE	P > |z|
Dependent variable: TCs/price								
Distance	**0.0245**	**0.000**	**0.0367**	**0.000**	**0.0353**	**0.000**	**0.0355**	**0.000**
Distance squared	**−0.0005**	**0.000**	**−0.0009**	**0.000**	**−0.0008**	**0.000**	**−0.0008**	**0.000**
Exchange rate volatility	**0.9939**	**0.000**	**1.0019**	**0.000**	**1.0026**	**0.000**	**1.0025**	**0.000**
Border	**0.1258**	**0.000**	(dropped)		**0.1599**	**0.000**	**0.1593**	**0.000**
Railroad	**−0.0474**	**0.000**	**0.0239**	**0.003**	**0.0229**	**0.004**	**0.0231**	**0.004**
Railroad-distance	**0.0028**	**0.014**	**−0.0130**	**0.000**	**−0.0120**	**0.000**	**−0.0120**	**0.000**
Canal	**−0.0285**	**0.000**	**−0.0324**	**0.000**	**−0.0328**	**0.000**	**−0.0328**	**0.000**
River	**−0.0321**	**0.000**	**−0.0581**	**0.000**	**−0.0582**	**0.000**	**−0.0582**	**0.000**
Port	**−0.0140**	**0.004**	**−0.0161**	**0.004**	**−0.0166**	**0.003**	**−0.0165**	**0.003**
Gold standard	**−0.1009**	**0.000**	**−0.0599**	**0.000**	**−0.0619**	**0.000**	**−0.0615**	**0.000**
Common language	**−0.0302**	**0.027**	(dropped)		*−0.1006*	*0.135*	*−0.1005*	*0.178*
Ad valorem	**0.6187**	**0.002**	**0.3607**	**0.014**	**0.3547**	**0.015**	**0.3559**	**0.015**
Prohibition	**0.2691**	**0.000**	**0.0568**	**0.000**	**0.0615**	**0.000**	**0.0606**	**0.000**
Neutral	*0.0429*	*0.271*	*0.0176*	*0.530*	*0.0188*	*0.502*	*0.0186*	*0.506*
Allies	**0.0994**	**0.045**	**0.1070**	**0.001**	**0.1072**	**0.001**	**0.1072**	**0.001**
At war (external)	**0.1809**	**0.000**	**0.2659**	**0.000**	**0.2673**	**0.000**	**0.2671**	**0.000**
At war (internal)	**0.1741**	**0.000**	**0.1072**	**0.000**	**0.1104**	**0.000**	**0.1098**	**0.000**
Civil war (external)	**0.3747**	**0.000**	**0.1659**	**0.000**	**0.1704**	**0.000**	**0.1695**	**0.000**
Civil war (internal)	**0.4607**	**0.000**	**0.1239**	**0.000**	**0.1258**	**0.000**	**0.1255**	**0.000**
Wald χ-squared:	32667.22		153.88		5878.67		4776.44	
Prob > χ-squared:	0.00		0.00		0.00		0.00	
Overall R-squared:	*n/a*		0.44		0.52		*n/a*	
Breusch and Pagan Lagrangian multiplier test for random effects (Var(fixed effects terms) =0)								
Wald χ-squared:					1988.87		205.54	
Prob > χ-squared:					0.00		0.00	
Dependent variable: Adjustment speed								
Distance	**-0.0057**	**0.020**	**−0.0091**	**0.067**	**−0.0122**	**0.005**	**−0.0114**	**0.012**
Distance squared	*0.0001*	*0.452*	*0.0002*	*0.314*	**0.0003**	**0.096**	*0.0002*	*0.140*
Exchange rate volatility	**0.4505**	**0.016**	**−0.5238**	**0.003**	**−0.5010**	**0.005**	**−0.5080**	**0.004**
Border	**−0.0558**	**0.000**	(dropped)		**−0.0558**	**0.013**	**−0.0581**	**0.019**
Railroad	**0.2012**	**0.000**	**0.1763**	**0.000**	**0.1734**	**0.000**	**0.1742**	**0.000**
Railroad-distance	**−0.0398**	**0.000**	**−0.0430**	**0.000**	**−0.0380**	**0.000**	**−0.0400**	**0.000**
Canal	**0.0587**	**0.000**	*0.0192*	*0.167*	*0.0217*	*0.117*	*0.0209*	*0.133*
River	**0.0513**	**0.001**	**0.0735**	**0.000**	**0.0730**	**0.000**	**0.0732**	**0.000**
Port	**0.0096**	**0.024**	**0.0099**	**0.035**	**0.0103**	**0.032**	**0.0101**	**0.033**
Gold standard	**0.1284**	**0.000**	**0.0427**	**0.015**	**0.0526**	**0.002**	**0.0496**	**0.003**
Common language	*0.0089*	*0.536*	(dropped)		*0.0599*	*0.282*	*0.0625*	*0.366*
Ad valorem	**−0.0886**	**0.000**	**−0.1133**	**0.000**	**−0.1039**	**0.000**	**−0.1066**	**0.000**
Prohibition	**−0.1427**	**0.000**	**−0.1155**	**0.000**	**−0.1109**	**0.000**	**−0.1118**	**0.000**
Neutral	*−0.1188*	*0.536*	*−0.0069*	*0.895*	*−0.0173*	*0.741*	*−0.0138*	*0.792*
Allies	**−0.0367**	**0.019**	*−0.0434*	*0.482*	*−0.0522*	*0.397*	*−0.0491*	*0.424*
At war (external)	**−0.1855**	**0.002**	**−0.2051**	**0.001**	**−0.2088**	**0.000**	**−0.2072**	**0.000**
At war (internal)	**0.2304**	**0.000**	**−0.1549**	**0.002**	**−0.1680**	**0.001**	**−0.1635**	**0.001**
Civil war (external)	**−0.1895**	**0.000**	**−0.1259**	**0.002**	**−0.1363**	**0.001**	**−0.1327**	**0.001**

(*continued on next page*)

Table A.2 (*continued*)

Independent variables	GLSAC	$P>\|z\|$	FE	$P>\|z\|$	GLS	$P>\|z\|$	MLE	$P>\|z\|$
Civil war (internal)	**−0.1695**	**0.000**	**−0.1543**	**0.021**	**−0.1638**	**0.014**	**−0.1605**	**0.016**
Wald χ-squared:	31472.17		31.89		1280.15		1177.52	
Prob > χ-squared:	0.00		0.00		0.00		0.00	
Overall R-squared:	*n/a*		0.47		0.48		*n/a*	
Breusch and Pagan Lagrangian multiplier test for random effects (Var(fixed effects terms) = 0):								
Wald χ-squared:					17323.36		846.95	
Prob > χ-squared:					0.00		0.00	

Note: Figures in bold denotes statistical significance and figures in italics denotes statistical insignificance. Year dummies suppressed; distance coefficients scaled to 1000 km.

ATECM model was regressed via generalized least squares with time-specific fixed effects and controls for potential auto-correlation (GLSAC). In Table A.2, the estimates of the preferred specification are compared with alternate results which assume different structures of the error terms—either country-pair and time-specific fixed effects or time-specific fixed effects with no auto-correlation correction. These results provide clear support for our particular choice of estimation strategy as the country-pair fixed effects (FE) specification destroys all information on the *border* and *common language* variables and the alternate models (GLS and MLE) actually demonstrate even stronger support for our maintained hypothesis on the primacy of conflict and policy as seen in the positive coefficients on *railroad* in the regressions on trade costs. However, as the GLSAC approach captures more of the variation in the dependent variables, it remains the preferred specification.

A further element to consider is the auto-correlation arising from estimation with overlapping periods (1800–1810, 1805–1815,...,1900–1910, 1905–1913). In Table A.3, the estimation results for the pooled and segmented dataset are displayed. The pooled specification is the one reported in the text. The other specifications refer to estimation on only those periods which are centered on even or odd years (e.g., 1800–1810, 1810–1820,...,1900–1910 for odds). The insignificance of some of the explanatory variables in the segmented results suggest that the use of the pooled sample allows for greater precision in estimation, thus, vindicating their use.

Finally, given that estimation takes place on an unbalanced panel, it was thought that some of the results may be driven by the fact that certain sample countries (namely Germany, Italy, and Russia) entered the database with the *gold standard* and/or *railroad* variables fully switched 'on.' In the first column of Table A.4 reports the results from the regression using all available observations and where all indicator variables are *strictly* binary. Comparing these results with column 6 of Table 4, it can be clearly seen that the strictly binary definitions do impart a downward bias on the indicator variables' coefficients. The remaining two columns in Table A.4 are the results for regressions only on those observations in which there has been a discrete change (from 0 to 1) in one of these two variables between two consecutive periods. The results are suggestive in that they seem to confirm the findings reported in the text.

Table A.3
Estimation with overlapping vs. non-overlapping periods

Independent variables	Pooled	$P>\|z\|$	Evens	$P>\|z\|$	Odds	$P>\|z\|$
Dependent variable: TCs/price						
Distance	**0.0245**	**0.000**	**0.0226**	**0.000**	**0.0269**	**0.000**
Distance squared	**−0.0005**	**0.000**	**−0.0004**	**0.001**	**−0.0007**	**0.000**
Exchange rate volatility	**0.9939**	**0.000**	**1.0643**	**0.000**	**0.9259**	**0.000**
Border	**0.1258**	**0.000**	**0.1375**	**0.000**	**0.1263**	**0.000**
Railroad	**−0.0474**	**0.000**	**−0.0664**	**0.000**	**−0.0444**	**0.000**
Railroad-distance	**0.0028**	**0.014**	**0.0071**	**0.014**	*0.0172*	*0.504*
Canal	**−0.0285**	**0.000**	**−0.0207**	**0.000**	**−0.0281**	**0.000**
River	**−0.0321**	**0.000**	**−0.0366**	**0.000**	**−0.0350**	**0.000**
Port	**−0.0140**	**0.004**	**−0.0138**	**0.003**	**−0.0162**	**0.000**
Gold standard	**−0.1009**	**0.000**	**−0.1169**	**0.000**	**−0.1100**	**0.000**
Common language	**−0.0302**	**0.027**	**−0.0333**	**0.073**	**−0.0298**	**0.012**
Ad valorem	**0.6187**	**0.002**	**0.2273**	**0.041**	**0.8890**	**0.001**
Prohibition	**0.2691**	**0.000**	**0.2793**	**0.000**	**0.2637**	**0.000**
Neutral	*0.0429*	*0.271*	*0.0326*	*0.548*	*0.0255*	*0.607*
Allies	**0.0994**	**0.045**	*−0.0010*	*0.989*	**0.1099**	**0.095**
At war (external)	**0.1809**	**0.000**	**0.1219**	**0.054**	**0.2262**	**0.000**
At war (internal)	**0.1741**	**0.000**	**0.1238**	**0.004**	**0.2012**	**0.000**
Civil war (external)	**0.3747**	**0.000**	**0.3519**	**0.000**	**0.2749**	**0.000**
Civil war (internal)	**0.4607**	**0.000**	**0.3683**	**0.000**	**0.5551**	**0.000**
N	11540		5676		5864	
Wald χ-squared	32667.22		15441.40		18229.97	
Prob > χ-squared	0.00		0.00		0.00	
Dependent variable: Adjustment speed						
Distance	**−0.0057**	**0.020**	**−0.0038**	**0.025**	**−0.0086**	**0.009**
Distance squared	*0.0001*	*0.452*	*0.0001*	*0.905*	*0.0002*	*0.135*
Exchange rate volatility	**−0.4505**	**0.016**	**−0.2891**	**0.024**	*-1.1460*	*0.234*
Border	**−0.0558**	**0.000**	**−0.0934**	**0.000**	**−0.0271**	**0.018**
Railroad	**0.2012**	**0.000**	**0.1861**	**0.000**	**0.1973**	**0.000**
Railroad-distance	**−0.0398**	**0.000**	**−0.0380**	**0.000**	**−0.0380**	**0.000**
Canal	**0.0587**	**0.000**	**0.0659**	**0.000**	**0.0503**	**0.009**
River	**0.0513**	**0.001**	**0.0805**	**0.001**	**0.0444**	**0.060**
Port	**0.0096**	**0.024**	**0.0177**	**0.012**	**0.0153**	**0.018**
Gold standard	**0.1284**	**0.000**	**0.1359**	**0.000**	**0.1082**	**0.000**
Common language	*0.0089*	*0.536*	*0.0200*	*0.294*	*−0.0008*	*0.969*
Ad valorem	**−0.0886**	**0.000**	**−0.0730**	**0.021**	**−0.0818**	**0.021**
Prohibition	**−0.1427**	**0.000**	**−0.1733**	**0.000**	**−0.0955**	**0.003**
Neutral	*−0.1188*	*0.536*	*−0.0625*	*0.341*	*−0.2040*	*0.303*
Allies	**−0.0367**	**0.019**	*−0.0046*	*0.954*	**−0.0915**	**0.006**
At war (external)	**−0.1855**	**0.002**	**−0.1772**	**0.023**	**−0.2295**	**0.014**
At war (internal)	**−0.2304**	**0.000**	**−0.2552**	**0.000**	**−0.2886**	**0.000**
Civil war (external)	**−0.1895**	**0.000**	**−0.0765**	**0.011**	**−0.3100**	**0.000**
Civil war (internal)	**−0.1695**	**0.000**	**−0.1454**	**0.014**	**−0.1737**	**0.009**
Wald χ-squared	31472.17		15559.40		15502.16	
Prob > χ-squared	0.00		0.00		0.00	

Note: Figures in bold denotes statistical significance and figures in italics denotes statistical insignificance. Year dummies suppressed; distance coefficients scaled to 1000 km.

Table A.4
Discrete changes in gold standard and railroad

Independent variables	Pooled	$P>\|z\|$	Gold	$P>\|z\|$	Railroad	$P>\|z\|$
Dependent variable: TCs/price						
Distance	**0.0242**	**0.000**	**0.0675**	**0.025**	**0.1290**	**0.000**
Distance squared	**−0.0005**	**0.000**	**−0.0001**	**0.000**	**−0.0135**	**0.000**
Exchange rate volatility	**0.9718**	**0.000**	**0.9846**	**0.076**	**0.5156**	**0.000**
Border	**0.2005**	**0.000**	**0.6709**	**0.000**	**0.5574**	**0.000**
Railroad	**−0.0286**	**0.000**	*0.1788*	*0.353*	**−0.0541**	**0.005**
Railroad-distance	*0.0004*	*0.804*	**−0.0310**	**0.000**	*−0.0270*	*0.290*
Canal	**−0.0206**	**0.000**	(dropped)		**−0.0206**	**0.028**
River	**−0.0328**	**0.000**	(dropped)		**−0.0336**	**0.022**
Port	**−0.0163**	**0.000**	**−0.0169**	**0.012**	*0.0033*	*0.855*
Gold standard	**−0.1471**	**0.000**	**−0.1550**	**0.000**	(dropped)	
Common language	**−0.0460**	**0.000**	**−0.1474**	**0.006**	**−0.2171**	**0.037**
Ad valorem	**−0.6145**	**0.048**	**0.8182**	**0.000**	**0.5741**	**0.004**
Prohibition	**0.0403**	**0.001**	(dropped)		**0.4179**	**0.001**
Neutral	*−0.0257*	*0.301*	*0.3227*	*0.425*	*−0.7598*	*0.024*
Allies	**0.0365**	**0.000**	(dropped)		(dropped)	
At war (external)	**0.0689**	**0.000**	(dropped)		(dropped)	
At war (internal)	**0.0211**	**0.002**	(dropped)		*−0.1791*	*0.449*
Civil war (external)	**0.1484**	**0.000**	(dropped)		**0.4232**	*0.214*
Civil war (internal)	**0.1587**	**0.000**	(dropped)		**0.9452**	**0.000**
N	11540		153		340	
Wald χ-squared	31222.22		4149.46		2656.91	
Prob > χ-squared	0.00		0.00		0.00	
Dependent variable: Adjustment speed						
Distance	**−0.0037**	**0.011**	**−0.0019**	**0.009**	**−0.1000**	**0.000**
Distance squared	*0.0000*	*0.706*	*−0.0001*	*0.890*	**0.0140**	**0.005**
Exchange rate volatility	**−0.5162**	**0.003**	**−0.7151**	**0.083**	**−0.4977**	**0.036**
Border	**−0.0918**	**0.000**	**−0.0233**	**0.043**	**−0.0553**	**0.053**
Railroad	**0.1888**	**0.000**	*−0.0680*	*0.633*	*−0.0555*	*0.648*
Railroad-distance	**−0.0379**	**0.000**	*−0.0267*	*0.352*	*−0.0130*	*0.708*
Canal	**0.0407**	**0.000**	(dropped)		**0.1528**	**0.010**
River	**0.0570**	**0.001**	(dropped)		**0.2185**	**0.001**
Port	**0.0085**	**0.030**	**0.0034**	**0.012**	*0.0060*	*0.907*
Gold standard	**0.1230**	**0.000**	**0.0980**	**0.025**	(dropped)	
Common language	*0.0181*	*0.195*	0.0364	0.000	*−0.0506*	*0.562*
Ad valorem	**−0.0657**	**0.006**	**− 0.0564**	**0.032**	**−0.3141**	**0.019**
Prohibition	**−0.0554**	**0.000**	(dropped)		**−0.2854**	**0.013**
Neutral	*−0.0104*	*0.301*	*0.1932*	*0.425*	*0.4207*	*0.120*
Allies	*0.0250*	*0.306*	(dropped)		(dropped)	
At war (external)	**−0.0167**	**0.044**	(dropped)		(dropped)	
At war (internal)	**−0.0966**	**0.000**	(dropped)		**−0.8396**	**0.001**
Civil war (external)	**−0.1006**	**0.000**	(dropped)		*−0.2044*	*0.444*
Civil war (internal)	**−0.1122**	**0.000**	(dropped)		*0.4263*	*0.172*
Wald χ-squared:	31472.17		1983.29		15502.16	
Prob > χ-squared:	0.00		0.00		0.00	

Note: Figures in bold denotes statistical significance and figures in italics denotes statistical insignificance. Year dummies suppressed; distance coefficients scaled to 1000 km.

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