Integration in European coal markets, 1833-1913

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Note

John Murray died on March 27, 2018 in Memphis, TN at the age of 58. He was the prime mover of this paper and the project on several issues related to European and US coal mining in which we were involved. He was first and foremost a friend as well as a mentor and respected colleague. This paper is dedicated to his memory and his family.

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Abstract

This paper analyzes coal market integration in Europe over the long nineteenth century. The market integration of coal, a key commodity associated with the Industrial Revolution, is an aspect of European economic history that has received little attention. The literature on the evolution of markets has concentrated on agricultural products, mostly cereals. We examine intra- and international market integration in the principal coal producing countries, Britain, Germany, France and Belgium; and we add three main consuming Southern European countries to the analysis of the international market. We provide new evidence on prices, as well as trade, and use a straightforward approach to address coal price behavior. Despite shocks, we observe clear trends toward integration in both domestic and international markets, even if by one of our measures the latter started at a later date. Processes of market integration, however, seemed to slow as from the end of the nineteenth century. We offer explanations as to the causes of the extent and timing of integrations: reductions, mainly, in transportation costs, but also in information costs, and, in the international market, protectionism. The influence of cartels, on the other hand, may have been limited, particularly in the international market.

The availability of coal has been one of the main subjects in the discussion about the causes of the European Industrial Revolution. It has been argued that a factor in the location of the Industrial Revolution in Britain was coal, and the first places to industrialize in Continental Europe tended to be those, such as Belgium, with ready supplies of the mineral.[1] The abundance of coal which made energy very cheap is at the center of Allen's interpretation of early technological change and industrial growth in Britain.[2] As Pomeranz hypothesized, if not for the sheer luck of its presence underground, Europe's prosperity would have been greatly muted.[3] The relevance of coal for economic growth has however been disputed in several accounts of the Industrial Revolution.[4] Scholars argue, for example, that the availability of coal is not enough to explain different experiences of neighboring countries such as Belgium and the Netherlands, and Britain and Ireland, and that coal could have been transported.[5] Heywood reviews the discussion concerning France.[6]

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[1] Wrigley, *Energy*. See also, for example, Landes, *Unbound Prometheus*; Cameron, 'New view'; Bardini, 'Without coal'.

[2] Allen, *British industrial revolution*.

[3] Pomeranz, *Great divergence*.

[4] As reviewed by Fernihough and O'Rourke, 'Coal', pp. 5-6. See especially Clark and Jacks, 'Coal'.

[5] Mokyr, *Why Ireland*, pp. 152-8; McCloskey, *Bourgeois dignity*, pp. 186-96; compare with Fernihough and O'Rourke, 'Coal'; Gutberlet, 'Cheap coal'.

[6] Heywood, *Development*, pp. 15-8.

In the rich debate on the place of coal in nineteenth-century European economic history, and despite references to the import option and transport costs, there remains a key aspect that has received little attention: the evolution of coal *markets*. As observed by Fernihough and O'Rourke, proximity to coal mattered less as transport improved.[7] As the quantity of coal used right at the mine itself to fuel the steam engines that powered pumps, fans, and lifts declined, the vast majority of production was sent elsewhere. Much of this trade went to locations within the country where it was mined, but in all mining countries a substantial amount was sold abroad. Increasing populations and incomes per capita contributed to higher demand for coal.[8]

This paper examines coal markets. Interest in the growing extent of markets lies in their beneficial effects on economic growth and welfare, as is well-known by economic historians and economists.[9] Market integration can lead to greater specialization and enable economies of scale. A further valuable effect is that manufacturers of tradable goods may adopt innovations sooner.[10]

The literature on the evolution of markets in nineteenth-century Europe mostly refers to grain prices, usually wheat, as surveyed by Federico, and Lampe and Sharp.[11] Federico and Persson suggested that one opportunity for further study is the extent to

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[7] Fernihough and O'Rourke, 'Coal', p. 6.

[8] Kander, Malanina, and Warde, *Power*, pp. 209-12.

[9] See Federico, 'Market integration'; Chilosi and Federico, 'Effects of market integration'.

[10] Findlay and O'Rourke, *Power and plenty*, p. 344.

[11] Federico, 'How much'; Lampe and Sharp, 'Cliometric', pp. 305-9; Federico, 'Market integration'.

which the results obtained hitherto with grains and other agricultural products hold true for other commodities.[12] One example considered being wax candles.[13] The current paper extends the market integration literature to coal, one of the most important elements of the Industrial Revolution.

The historical literature of coal market integration is thin. Studies such as those of Church, Bardini, Betrán, Balderston, and Kander et al. report price differences between- and within some countries.[14] Tan finds cointegration of two series of averaged regional prices in England for the 1833-1845 period.[15] Izmestieva finds some simultaneous correlation between coal prices in Britain and Russia (a net importer of coal), but she also finds a widening price gap over time.[16] Klovland reports that gaps between British and German coal prices differed in trend: the difference in steam coal prices declined slightly, but the difference in domestic coal prices did not.[17] Wolf uses trade flows instead of prices to suggest an increase in coal market integration within Germany, particularly after

[12] Federico, 'How much', p. 492; Federico and Persson, 'Market integration and convergence', p. 103; Federico, 'Market integration'; see also Chilosi, Murphy, Studer, and Tunçer, 'Europe's many integrations', p. 62.

[13] Federico, 'European markets'. Panza's, 'Globalization', study on cotton focuses on the integration of the Near East with Europe. Chilosi and Federico, 'Effects of market integration' also consider cotton.

[14] Church, *British coal*, pp. 48-70; Bardini, 'Without coal'; Betrán, 'Natural resources'; Balderston, 'Economics of abundance'; Kander, Malanina, and Warde, *Power*, pp. 203-6.

[15] Tan, 'Market structure'.

[16] Izmestieva, 'Integration'.

[17] Klovland, 'Commodity'.

the Great War.[18] In the 1885-1913 period he finds some within country barriers to trade. Beyond Europe, Wegerich examines price convergence between Cardiff and major global ports for Welsh bunker coal.[19] Research on nineteenth century U.S. coal prices is also scant. Slaughter estimates coal price convergence between Philadelphia and Cincinnati for the antebellum period.[20]

As coal was a pan-European phenomenon, [21] we first propose to study the evolution of coal markets as a process that proceeded across all the major coal producing nations: Britain, Germany, France and Belgium. In 1850, these four countries accounted for 99 percent of European output, and by 1900 they still produced 92 percent of European coal.[22] Britain was the leader in coal exploitation, in large measure due to its development of coking and pumping technologies.[23] Although in the second half of the nineteenth century Britain produced more coal than the rest of Continental Europe combined, coal production in Continental Europe is often overlooked. In fact, production in other countries and cross-border shipments increased dramatically over this time. To study the articulation of Europe-wide coal markets, we consider the period from the mid-nineteenth century, or the early 1830s in the case of Britain, to 1913.

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[18] Wolf, 'Germany'.

[19] Wegerich, 'Different trajectory'.

[20] Slaughter, 'Trade'.

[21] Kander, Malanina, and Warde, *Power*, esp. pp. 136-8.

[22] Murray and Silvestre, 'Small scale', p. 888, based on Mitchell, *International historical statistics*.

[23] Allen, *British industrial revolution*.

We examine intra-national and international market integration. In this latter approach, we move beyond producing countries and incorporate three mainly non-producing Southern European countries to the analysis, Italy, Spain and Portugal, which to a great extent relied on imported coal—and for which some of the necessary data are available.[24]

The rest of the article is organized as follows. In Section I, we present our data sources and discuss the preferred methods of estimating market integration. Section II discusses the importance of transport infrastructure and technology, organizational improvements, information flows, economic (trade) policy and coal cartels as potential factors influencing market integration. Section III presents evidence on domestic market integration in the four main producing countries. Section IV moves beyond the national level to estimate the extent of international market integration. Section V provides the conclusions.

I

As shown in Appendix I (Table a), our primary data sources were publications that report annual coal prices.[25] We completed the database using secondary literature (Appendix I). A price series was available online. We also used, mainly as a guide, the American volume *Coal mine labor in Europe*, edited by the great labor statistician Carroll Wright, which includes a fine collection of

[24] The Netherlands may have been a further country to compare. However, the country was rich in peat that for some uses constituted a substitute for coal; Mokyr, *Industrialization*, p. 204.

[25] These sources are taken to report annual averages of higher frequency price observations, although this is not always specified. On the scarcity of high frequency price data other than grain, see Wolf, 'Germany', p. 849.

bibliographies pointing to primary sources.[26] Price series gathered tend to present a notably low number of missing observations. We applied linear interpolation (Appendix I). These sources typically reported the price of coal in the local currency, per short ton (2,000 pounds), long or Imperial ton (2,240 pounds), or metric ton (1,000 kilograms or 2,204.6 pounds). For purposes of comparison we converted all weight measures into metric tons and expressed prices in grams of silver (per metric ton) as reported in historicalstatistics.org.[27] As proposed by Federico et al., before 1870 conversions are based on the pure silver content, while under the gold standard conversions are based on exchange rates between currencies and the Pound Sterling in combination with London silver prices.[28]

For the producing nations of Britain, France, Belgium and Germany we first consider pithead prices disaggregated at the regional level, which results in 10 regions for Britain, 27 for France, three for Belgium, and 12 for Germany, according to the official national statistics. The French source divides the country into 44 coal regions (departments), but price information was no longer available for 10 of them after the Franco-Prussian War (1870-1871); and information for seven further regions is very patchy. Therefore, we used a 27-region series that nevertheless embodies almost all the national production.[29] The comparison of our

[26] Wright, *Coal mine labor*; Leiby, *Carroll Wright*.

[27] Edvinsson, 'Historical currency converter'.

[28] Federico, Schulze, and Volckart, 'European goods market integration', p. 8.

[29] In 1869, the year before the war, and a date for which the quantity of information is rich, the production of coal in the consequently removed regions represented 4.07 percent of the national total; whereas the production of coal in the seven regions with incomplete information represented an additional 0.35 percent.

coefficient of variation (Appendix VI, Table b) with that based on Simiand's figures yields the same result for 1853 (0.33) and a slightly lower value for 1892 (0.18 vs. 0.24).[30]

Our second, complementary German dataset corresponding to the two principal coal basins in the country, i.e. the Ruhr and Upper Silesia, refers to prices that can be considered as pithead prices, taken from the intermediate market in the nearest city—Dortmund, Düsseldorf and Essen—to major coalfields.[31] The Ruhr accounted for about 48 percent of German coal in 1880 and about 58 percent in 1913; while Upper Silesia accounted for about 21 and 23 percent.[32]

Our longest British series refers to prices that are taken from declared f.o.b. values of coal at the nearest ports and supplements the shorter pithead price series, a common procedure among British scholars.[33] The available ports (eight English, three Welsh, and five Scottish) usually handled about 90 percent of British coal shipments.[34] We weighted each annual price observation by the coal tonnage handled at that port in that year, mainly in order to account for outlying price trends in one small Scottish port that carried

[30] Simiand, 'Prix du charbon', pp. 49-50.

[31] On the proximity of Dortmund, Düsseldorf and Essen to the coalfields, and their formation as major urban areas and centers for the mining industry, see Harris, 'Ruhr coal-mining', pp. 206-7; Wrigley, *Industrial growth*, p. 26; Blackbourn, *Germany*, p. 139.

[32] Burhop and Lübbers, 'Cartels', p. 503; Fremdling, 'Anglo-German', p. 620.

[33] Mitchell, *Economic development*, pp. 263-82; Church, *British coal*, pp. 52-9.

[34] United Kingdom, *Report of the Commissioners*; United Kingdom. Royal Commission on Coal Supplies, *First Report*.

relatively little trade in coal: Leith, near Edinburgh (Appendix II reports a comparison of unweighted, with- and without Leith, and weighted series).[35]

Based on prices described in the three previous paragraphs, we estimate trends in the coefficient of variation for a large number of markets within producing countries—and report them in appendices—, with the aim of confirming the main results using price gaps as the preferred measure. Thus, in the first part of our analysis, we consider prices in the main consumer cities and producing regions to estimate *specific* price differentials between areas in which the coal trade was well established. According to the available information, prices in consumer cities are near-consumption prices, either wholesale prices recorded at railyards, in Berlin, or docks, in Hamburg; or retail prices, in London, Paris and Ghent.[36] Prices in producing areas are pithead prices. The British series refer to relative prices between the regions of Yorkshire, the Northeast of England and South Wales and the consuming city of London.[37] The French series is the price in the regions of Loire, Nord and Pas-de-Calais versus a consumer price in Paris.[38] The

[35] Around 1860, when price disparity was near its peak, Leith handled only one-third of 1 percent of British coal shipments.

[36] The use of retail prices counsels caution since mark-ups may have changed over time. Our averaged series for London and Paris, in fact, include purchase prices for institutions that may have bought coal from either wholesale or retail traders—or been subsidized. Nevertheless, the London retail market has been described as increasingly competitive. Church, *British coal*, pp. 71-4.

[37] On this trade, see Morris and Williams, *South Wales Coal*, pp. 19-20; Church, *British coal*, pp. 18-21; Milne, *North East England*, p. 17; Tan, 'Market structure'.

[38] Gillet, 'L'age du charbon', pp. 31, 43; Pounds and Parker, *Coal and steel*, pp. 86-7, 144; Wrigley, *Industrial growth*, p. 47; Szostak, *Role*, pp. 146-9.

Belgium series is the price in the region of Hainaut versus a consumer price in Ghent.[39] The German series compare pairs of prices between the nearest cities to the Ruhr and Upper Silesia coal basins, and wholesale prices in Berlin and Hamburg—as reported by primary sources.[40]

Finally, pithead prices for producing nations are first compared with each other and imported coal prices for three, mainly, non-producing Southern European countries, Italy, Spain and Portugal—the latter approach, in the vein of Bardini—, to obtain a preliminary view of the effect of having or not having coal reserves.[41]

For greater precision, we also use prices at specific export and import points to estimate international price differentials between proven trading markets. We need to circumscribe the analysis to Britain, for whose trade both f.o.b. prices at export ports and imported coal prices at the main import points in Southern Europe, Germany and France, are available. Britain evidently was the main coal export country, by a considerable margin. The quantity of coal exported from Britain in 1913 was more than twice that exported from Germany, the second biggest exporter.[42] Appendix III reports major shipments. From 80 to 90 percent of British exports went to

[39] Wrigley, *Industrial growth*, pp. 16-7, 38.

[40] See also Wright, *Coal mine labor*, pp. 284-5; Milward and Saul, *Development*, p. 30; Fremdling, 'Anglo-German'.

[41] Bardini, 'Without coal', p. 636.

[42] United Kingdom. Parliament, *Statistical Tables*, pp. 45, 50.

Continental Europe.[43] The coal importing countries or regions (in the case of France) considered tended to rely almost exclusively on British supplies, with the principal exception of Germany (21 percent of imports came from other countries in 1913).[44]

Newcastle and Cardiff were, by far, the two main export ports for British overseas trade.[45] F.o.b. prices of coal at Cardiff were linked to prices of imported coal at the main import ports in Southern Europe, i.e. Lisbon, Bilbao, Cádiz and Barcelona, and Genoa; while f.o.b. prices of coal at Newcastle were linked to prices of Newcastle coal in Hamburg, the main import port for British coal in Germany—a complementary German price series is introduced in section IV.[46] A further available series refers to coal from Sunderland—still the third most important British export port in the early 1880s—at Hamburg.

The procedure followed in the case of the British-French coal trade is somewhat different—given available data. French statistics report wholesale prices disaggregated at the level of 89 regions, from which we chose those where a) British coal represented around 80-90 percent of total coal consumed, according to the classification put forward by Crouzet; b) from the resulting (ten) regions, those where the main import ports for British coal, that is, Saint Malo, Saint-Nazaire, Nantes, La Rochelle, and Bordeaux,

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[43] Harley, 'Coal exports', p. 314.

[44] United Kingdom. Parliament, *Statistical Tables*, p. 13, 16-8; Crouzet, 'Charbon anglaise', p. 192; Fremdling, 'Anglo-German'; Henriques, 'Energy', p. 61, 143, 281-2.

[45] Newcastle accounted for 30.28 and 21.55 percent of total coal shipped in 1879-81 and 1911-13, respectively; Cardiff accounted for 29.48 and 29.90 percent.

[46] On the origin of Cardiff and Newcastle coal imported, see Jevons, *Coal question*, p. 114; Morris and Williams, *South Wales Coal*, pp. 41-2; Coll and Sudrià, *Carbón*, p. 434; Harley, 'Coal exports'; Fremdling, 'Anglo-German', p. 627.

were located.[47] On account of which, wholesale prices for four French Atlantic regions, Ille et Vilaine, Loire Inférieure, Charente Inférieure, and Gironde, were linked to f.o.b. prices at Newcastle and Cardiff.

The rest of Appendix I reports the sources of trade figures (Table b) and variables used to support the evidence obtained by the analysis of the evolution of prices in the international market (Table c).

A potential shortcoming of coal data is that coal is not a completely homogeneous product. Mitchell states that coal is 'relatively homogeneous, and consequently comparisons over time are not so bedeviled by differences in definition as is the case with some industries'.[48] Similarly, Tan refers to the common usage of different coal types, in supplying energy in households and industries, an argument also made in contemporary accounts.[49] European data typically distinguished between lignite and other types of coal, and that outside of Germany, European mines produced little anthracite. For example, in 1903, of 460 million tons produced continent-wide, 85 percent was bituminous, 14 percent lignite, and 1 percent anthracite. Except for some years in France, lignite figures were reported separately and not used in this study. Hence, the vast majority of production discussed here was of bituminous coal.

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[47] Crouzet, 'Charbon anglaise', pp. 187, 192; Fremdling, 'Anglo-German', p. 612.

[48] Mitchell, *British historical statistics*, p. 236.

[49] Tan, 'Market structure', p. 353; United Kingdom, *Report from the Select Committee*, p. x.

Nevertheless, even within one category, coal differs by such characteristics as hardness, color, volatile content, density and energy content.[50] This is a concern that has received attention in the study of German and, more particularly, British coal markets—perhaps because the latter developed earlier than in other nations.[51] Historical coal price data for any country, especially for long-term series, are usually available in the form of averages—at different spatial levels—rather than for particular types. As demonstrated by Brunt and Cannon for grain, quality variation may result in evidence of market integration being spurious to some degree.[52]

The focus on particular domestic trades, that is, the estimation of price differentials between *specific* producing areas and consuming cities, may mitigate the problem, at least to some extent, due to the fact that the degree of coal heterogeneity in one particular producing area should be lower than that of the country as a whole. Coal basins in fact may have tended toward the sale of a uniform product directed at markets such as London, which demanded only certain types of coal.[53] Similar arguments may apply to international trade.[54] Although, as noted by Klovland, representative price series in the origin country that perfectly match similar

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[50] Thomas, *Coal geology*, p. 97.

[51] Pounds, 'Spread of mining'; Pounds, *The Ruhr*, 64-5; Mitchell, *Economic development*, pp. 266, 281-2; Church, *British coal*, pp. esp. 48-60, 372-85.

[52] Brunt and Cannon, 'Variation'.

[53] Morris and Williams, *South Wales coal*, p. 19; Kirby, *British coalmining*, p. 8; Benson, *British coalminers*, p. 9; Mitchell, *Economic development*, p. 270; Church, *British coal*, p. 375.

[54] Kirby, *British coalmining*, p. 8; Church, *British coal*, p. 60.

price series in the destination country may be difficult to obtain.[55] In short, due to the nature of coal data in national statistics, the markets we examine may imply a certain variation in characteristics, a limitation to be borne in mind when interpreting our evidence.

The data described above support our analysis of European coal market integration. For markets within coal producing countries, we follow Federico's proposal.[56] Theoretically the two dimensions of market integration go back to Cournot. First, the equilibrium level of prices must be equal, the well-known law of one price. Second, prices must return quickly to the equilibrium level after a shock.

Since the law of one price is almost never met (between trading markets prices would be equal only if transaction costs are nil; and prices could even be equal by chance in the absence of trade), a logical alternative is to follow a dynamic approach based on the *convergence* (or divergence) of prices over time. If it is assumed that in a competitive market equilibrium price differences between trading markets would be equal to trade costs, this method will permit us to attain knowledge on the *evolution* of trade costs—relative to local prices. To test trends in price convergence, Federico, based on Razzaque et al., proposes the following equation for C, if the series follows a difference-stationary process; where C_t is a measure of price dispersion at time t.[57]

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[55] Klovland, 'Commodity', p. 171.

[56] Federico, 'How much', esp. pp. 474-80; Federico, 'European markets', p. 95; Federico, 'Market Integration'. For further discussion on statistical methods see also, among others, Bateman, 'Evolution'; Uebele, 'Market integration'; Dobado-González, García-Hiernaux, and Guerrero, 'Early globalization'; Andersson and Ljunberg,'Grain'.

[57] Federico, 'How much', p. 479; Razzaque, Osafa-Kwaako, and Grynberg, 'Long-run trend', pp. 36-9.

$$\Delta LnC_t = \alpha + \beta*TIME + \psi*LnC_{t-1} + \varphi*\Delta LnC_{t-1} + \varepsilon_t \quad (1)$$

C_t first refers to relative prices, $((p_j-p_i)/p_i)$, between specific pairs of coal producing (i) and consuming (j) areas. Here equilibrium price gaps would correspond to actual trade costs, instead of their lower bound as obtained when using the coefficient of variation for a larger number of markets. We complement the analysis with the estimation of the coefficient of variation as a robustness check.

Table 1, panel *a*, for pairwise price differentials, and Appendix IV, for the coefficient of variation, report the results of the Augmented Dickey-Fuller test for unit roots. All but one of the domestic series tend to be non-stationary in levels and become clearly stationary when they are first differenced, and therefore equation (1) seems to apply. A simpler equation, $LnC_t = \alpha + \beta*TIME$, is estimated in the case of the stationary in levels "Ghent-Hainaut" series (Table 2). A negative and significant estimated coefficient β will indicate whether the prices are converging over time in the σ sense of diminishing dispersion, and so whether the markets are in the process of integrating. Here the long-run rate of change is given by $t = -(\beta/\psi)$.[58] One lag of the dependent variable is included to address possible serial correlation, as this is a common practice when using annual data. In Appendix V, we also looked at discontinuities in the convergence processes by means of a standard Bai-Perron test for structural breaks.[59]

[58] As in Chilosi and Federico, 'Early globalizations'.

[59] Bai and Perron, 'Estimating and testing'; Chilosi and Federico, 'Early globalizations'.

[Insert Table 1 around here]

The model in equation (1) only tests for price convergence. Price efficiency focuses on the availability of information and subsequent arbitrage, that is, how prices react to changes in other markets. In other words, do the series suggest that, following a shock, prices will return to their previous equilibrium? There are several measures of efficiency. With annual data, we adopt Chilosi et al.'s proposal of estimating efficiency with both *co-movement*, i.e. prices between integrated markets move together; and price *volatility*, i.e. integrated markets reduce the effect of local shocks and prices become more stable.[60] We measure co-movement with both the average 5-year and 11-year rolling correlation coefficient between the residual of the individual (Hodrick-Prescott) filtered price in each market and the average of residuals;[61] and volatility with both the average 5-year and 11-year rolling coefficient of variation of prices in each market (See also the *Notes* to Figures 1 and 2).

For the international market, we first consider the choice of appropriate export and import price series, as explained above, to estimate price differentials between particular locations.[62] Augmented Dickey-Fuller tests (Table 1, panel b), convergence equations, and Bai-Perron tests (Appendix V) also apply here. In Table 5, "Hamburg-Newcastle" and "Hamburg-Sunderland" were estimated

[60] Chilosi, Murphy, Studer, and Tunçer, 'Europe's many integrations'. See also Taylor, 'Potential pitfalls'; Klovland, 'Commodity'; Brunt and Cannon, 'Measuring', Federico, 'Market integration'.

[61] As in Federico, Schulze, and Volckart, 'European goods market integration'.

[62] For example, Klovland, 'Commodity'; Chilosi and Federico, 'Early globalizations'.

using the simpler version of the convergence equation. In the vein of what is proposed by Federico in his most recent survey, for selected routes, we complete the analysis with an econometric model to assess the importance of potential determinants of international market integration.[63] Second, to verify findings, we then use a variance analysis, as proposed by Federico and Persson, focused on the four coal producing nations, which allows us to estimate the contribution of both international and domestic markets to integration (or disintegration).[64]

II

Progress in transportation may have been an essential part of the market integration process in the case of a high transport cost commodity such as coal. The transport of coal, principally by water and rail, evolved markedly over the nineteenth century.[65] First, a countrywide network of canals had already been constructed in Britain by the early nineteenth century to connect mines and ports.[66] France, Belgium and Germany had also developed canal networks by the 1850s-1860s that permitted the transport of coal.[67] Large

[63] Federico, 'Market integration'. See also Chilosi and Federico, 'Early globalizations'.

[64] Federico and Persson, 'Market integration and convergence'; Federico, 'European markets'; see also Sharp and Weisdorf, 'Globalization revisited'.

[65] In the absence of water transport coal was transported by road over short distances. Szostak, *Role*, p. 119.

[66] Tan, 'Market structure', esp. p. 353; see also Szostak, *Role*, p. 118.

[67] For example, Pounds, *The Ruhr*, p. 71; Pounds and Parker, *Coal and steel*, p. 115; Clapham, *Economic development*, p. 351; Fremdling, 'European railways', p. 6.

water infrastructures often reached higher capacity as a result of further, non-revolutionary technological and organizational improvements.[68] Second, it is noteworthy that, once technical limitations were overcome, the conversion from sail to steam in the coal trade from the 1850s onwards was particularly rapid, as was the shift among steamships from sidewheels to iron screw propellers.[69]

Third, railway expansion was crucial to the opening up of landlocked coalfields, supplementing waterway transport and allowing long-distance transport. Coal-related railways in Britain expanded from the 1830s onwards.[70] The first wave of railway construction in Continental Europe tended to be concentrated in the 1850s and 1860s.[71] Belgium, which was the pioneer, was where the densest European network was built; Germany was the second.[72] In Germany, railway construction boosted the development of the two main coalfields, the Ruhr and Upper Silesia. However, the distribution of coal from these basins along the East-West axis was still modest.[73] Wolf has shown the poor overall integration between two broad economic areas in Germany—given the geography of

[68] Church, *British coal*, 45-8; Ejrnaes and Persson, 'Market integration', p. 154. Klemann and Schenk, 'Competition'.

[69] Hughes and Reiter, 'First 1,945'; Harley, 'Shift'; Fremdling, 'Anglo-German'; Milne, *North East England*, pp. 24-5.

[70] Church, *British coal*, pp. 41-4.

[71] Federico, 'European markets', p. 114. See also Clapham, *Economic development*, pp. 147-9; Fremdling, 'Anglo-German', p. 613.

[72] Wrigley, *Industrial growth*, p. 29; Clapham, *Economic development*, pp. 142-3, 150-5; Fremdling, 'European railways', p. 3; Strikwerda, 'If all of Europe'; Keller and Shiue, 'Institutions', p. 16; Gutberlet, 'Cheap coal', pp. 6-7, 14

[73] Pounds, *The Ruhr*, p. 71, 104; Milward and Saul, *Development*, p. 30.

navigable rivers and canals.[74] The East-West train routes, which were almost completed by the early 1880s, would eventually help to bridge the divide, at least to some extent.[75]

As with domestic markets, improvements in international coal transport occurred in seaborne and riverine shipping and railroads.[76] International British freight charges per ton-mile fell by as much as 55 percent between the mid-1860s and the early 1890s.[77] Similarly, river freight charges along the Rhine fell about three fourths from the 1860s to the turn of the century.[78] It was in Germany where railroads played the most important role in terms of trade with neighboring countries.[79]

Easier access to better information may have been another contributing factor to the understanding of the evolution of coal markets. A reduction in the cost of information from the late 1840s onwards, due to the spread of telegraph lines may have affected coal markets too.[80] It is, however, difficult to disentangle how much of this information was strictly about prices or about other characteristics of markets that affected prices. The latter case, although it would produce price adjustments even before any arbitrage,

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[74] Wolf, *Germany*.

[75] Ibid., pp. 853, 871-4.

[76] Gillet, 'L'age du charbon'; Milward and Saul, *Economic development*, p. 294; Fremdling, 'Anglo-German'.

[77] Harley, 'Coal exports', pp. 315-6.

[78] Klemann and Schenk, 'Competition, pp. 837-8.

[79] Clapham, *Economic development*, p. 355.

[80] For example, Ejrnæs and Persson, 'Market integration', p. 153; Federico, 'European markets', p. 112; Lew and Cater, 'Telegraph', p. 148.

may be more common.[81] In the coal industry, price, quantity, and quality information crossed national and international coal basins smoothly; as did investment flows.[82] The mining press, for example, was very active.[83] One remarkable feature was the creation of government-appointed commissions, which communicated with each other and described experiences with technological and regulatory innovations and their effects at different levels.[84]

Tariff systems tended to be complex, especially before around the mid-nineteenth century. The situation of Belgium is noteworthy. Around 1860 she exported nearly four million metric tons to France, which imposed a duty of two francs per metric ton. In turn Belgium levied the same duty of two francs per metric ton on French coal, an ad valorem equivalent of about 5 percent.[85] Another key example is France. Seven different rates were imposed on imported coal, depending on whether it entered France by sea, river, or land, and if by sea in French or foreign bottoms. The range was considerable: the equivalent of 1d. per 2 hundredweight if by the river Meuse, and 8d. if by sea in a foreign bottom.[86] Britain reduced export duties substantially in 1831, and then again in 1834 and

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[81] Federico, 'How much', pp. 476-7.

[82] Wrigley, *Industrial growth*, p. 21; Gillet, *Charbonnages du nord*; Broadberry, Fremdling, and Solar, 'Industry', p. 173; Ville and Wicken, 'Institutional foundations', p. 301.

[83] Pounds and Parker, *Coal and steel*, pp. 113-4.

[84] Murray and Silvestre, 'Small scale'.

[85] United Kingdom, *Manufactures*, pp. 223-4.

[86] Yapp, *Duties*, p. 89; Gillet, *Charbonnages du nord*, p. 130.

1845.[87] In any case, by 1850 all British export duties had been abolished, and from this point coal entered Germany freely; a treaty of 1862 provided for the most favored nation treatment between Britain and Belgium.[88] In 1863, French rates were unified and reduced to 1.2 francs per ton, a rate that was held constant throughout our period.[89] The ad valorem equivalent depended on the price of coal, in a typical year amounting to 4 percent.[90]

Just after the turn of the century Britain imposed an unevenly applied export tax on coal of 1s. per ton, representing less than 2 percent of the average price of coal exported.[91] This duty was soon revoked, in 1905. On the other hand, at the end of the century duties were raised to some degree in coal importing Southern European countries such as Spain and Portugal, but not Italy. In Spain, the only one of the three with certain valuable coal resources, duties had been being reduced from 1837 to 1877. From that point onwards, the rate underwent several increases, interspersed with some considerable reductions—reaching up to 15 percent of the price

[87] Wright, *Coal mine labor*, p. 409; Church, *British coal*, p. 65.

[88] Church, *British coal*, p. 65; Irwin, 'Free trade', p. 151; Klovland, 'Commodity', pp. 167-171; Dedinger, 'From virtual free-trade', p. 234.

[89] Crouzet, 'Charbon anglaise', p. 176; Smith, *Tariff reform*, pp. 90-6, 214-7.

[90] Lamb, 'Coal mining', pp. 272-4.

[91] Church, *British coal*, pp. 65-6.

at origin in the years before the First World War; while in Portugal modest duties were introduced to tax British coal, which up to 1884 entered freely—representing around 7 percent of the fuel price.[92]

One final possible influence on price behavior is that of coal cartels, by reducing price differentials within the cartel and interfering with market integration outside the cartel. In Britain, Tan proposes a low impact of the northeast cartel, which fixed prices in the London market, over its last thirty years, 1816-1845.[93] Whereas Church and Kirby confirm that competition was the principal coal price-determining factor in Britain before 1914, with few, narrow and only temporarily effective price-fixing practices.[94]

In Continental Europe the situation could have been otherwise, at least at the end of our period when price fixing materialized as a result of increasing competition within and between countries. In Germany, before the early 1890s collusive arrangements were restricted to local areas and were ineffective.[95] In 1893, however, the Ruhr cartel (Rheinisch-Westfälisches Kohlensyndicat (RWKS)), which fixed prices and quantities annually, was formed and went on to become the model to emulate. Nevertheless, it has been proposed that a series of internal and external obstacles impeded a more successful price collusion.[96] For example, members of the

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[92] United Kingdom. Parliament, *Statistical Tables*, p. 173; Nadal, *Fracaso*, pp. 135-40; Coll and Sudrià, *Carbón*, pp. 170-1, 434-8, 519; Henriques, 'Energy', p. 144. On Italy, see Bardini, 'Vapore', pp. 143-54; Federico and Tena, 'Italy', p. 88.

[93] Tan, 'Market structure'.

[94] Church, *British coal*, pp. 66-70; Kirby, *British coalmining*, p. 9.

[95] Pounds and Parker, *Coal and steel*, pp. 318-27; Bittner, 'Event study', p. 338; Burhop and Lübbers, 'Cartels', p. 504.

[96] Burhop and Lübbers, 'Cartels', esp. pp. 505-7.

cartel faced competition from mines in other German coal basins, state-owned mines in the Ruhr and British coal.[97] More than 50 percent of the total output had to be sold at competitive prices.[98] Still, a reduction of price variation after the cartel formation (1893) has been indicated.[99]

In Belgium, there had been some deals between coal companies that supplied the public railroad system, for example in 1880.[100] The rest of the Belgian cartels were founded in collaboration with the Société Générale bank. These cartels took decisions on price fixing and production quantities and almost all of them operated at the coal basin level.[101] Those that exercised actual control over their members appeared in the 1890-1906 period: 1890, Charleroi (Hainaut) and Liége; 1891, Charleroi (Hainaut) and Basse Sambre; 1894, Belgium, renewed in 1899 and 1904; 1897, Liége; 1898, Centre (Hainaut); 1905, Belgium; and 1906, several companies.[102] The Société Générale played a role similar to that of a cartel in the Borinage (Hainaut), the most important coalfield.[103]

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[97] For example, Peters, 'Managing competition', pp. 433-4.

[98] Burhop and Lübbers, 'Cartels', p. 507.

[99] Ibid., p. 505, presumably refer to one series of monthly wholesale prices at Essen, available at http://www.nber.org/databases/macrohistory/contents/chapter04.html (accessed on 18 Feb. 2018). See also Hickey, *Imperial Germany*, p. 16.

[100] A very minor coal dust cartel was also founded in 1887. Pounds and Parker, *Coal and steel*, p. 322.

[101] MacGregor, *Industrial combination*, p. 144; Gillet, 'Coalition germano-belge', p.167.

[102] Pounds and Parker, *Coal and steel*, pp. 322-5; Montant, 'Market power', p. 3.

[103] Kurgan-van Hentenryk and Puissant, 'Industrial relations', p. 206-8.

In France, although agreements between some companies were attempted throughout the nineteenth century, it was only in 1901 that the cartelization of the northern coalfields consolidated in response to the reduction in tariffs, and Belgian and German competition.[104] The Nord and Pas-de-Calais coal basins had expanded dramatically over the last quarter of the century or so, going on to produce three-quarters of the French coal output by the eve of the First World War. The Office de Statistique des Houillères du Nord et du Pas-de-Calais designated three areas according to the cartels' share of the market. In the northern coal areas and nearest departments (marché intérieur), minimum prices and quantities were fixed; in the departments where Belgian and German competition was more intense (marché d'expansion), minimum prices were also fixed, but not quantities; in the rest of the country, which was dominated by the remaining French coal basins and Britain (marché d'exportation), no control was established.[105] The biggest producer, the Anzin company (20 percent of total production of the coal basin at the end of the century), as well as other smaller companies, however, recurrently abandoned the cartel.[106] Furthermore, France being a net coal importer, control over prices was complicated and contested.

III

[104] Gillet, 'L'age du charbon', p. 48; Smith, *Emergence*, p. 322.

[105] The three areas were in fact comprised of a variable number of sub-areas, amounting to a total of 32 in 1911. Gillet, *Charbonnages du nord*, pp. 242-60.

[106] Gillet, *Charbonnages du nord*, pp. 120, 250-3.

Our first approach to integration in European coal markets considers trends in price gaps within countries. Table 2 reports the results of the convergence equation for pairwise price comparisons between identified trading markets. According to the statistical significance of the estimated coefficient β, the series indicate price convergence except for the French series that compare prices between the northern departments and Paris.[107] However, Table 3 shows that β becomes more significant for the sub-periods in which the Nord and Pas-de-Calais coalfields in earnest tended to increase their, until then very modest, production—contrary to that of the Loire, which had been the main coalfield since the beginning of the nineteenth century. Long-run rates of change in Tables 2 and 3 are statistically significant, according to a Wald test. Generally, fitted price differentials fall from at least about 40 percent (last column of both tables).[108] As a validity check, Appendix VI reports trends in the coefficient of variation.[109] Visually, the coefficients of variation tend to fall over the period—although the process is not always steady—thereby confirming results in Tables 2 and 3 on overall downward trends.

[Insert Table 2 around here]

[107] Changes in trends corresponding to different sub-periods are nevertheless common (Appendix V).

[108] Half-lives of shocks were also estimated. With the exception of the Paris-Nord series, they ranged from about two years for prices in Britain and France to less than one year for prices in Germany. However, it should be kept in mind that annual series are taken to only capture large shocks. See Chilosi and Federico, 'Early globalizations', and the works cited in footnote 60, above in this document.

[109] Convergence equations are available from the corresponding author upon request.

[Insert Table 3 around here]

Price convergence, as an assessment of the evolution of trade costs, has been argued to be the best way to gauge historical processes of market integration and its contribution to economic growth.[110] Collectively results in Tables 2 and 3 and Appendix VI suggest that within coal producing countries, without tariffs or language barriers, domestic coal prices were in the process of converging. Appendix VI, however, also shows that the coefficient of variation tended to plateau at around 10 percent at the end of our period, which may indicate that this is the lower bound given improvements in transport technology and quality differences of coal.[111]

In Continental Europe, a pertinent question would be if price behavior may have also been affected by the tendency toward cartelization in the coal industry. Thus, referring to reductions in price variation, Appendix VI (Table c) first shows that price dispersion were indeed lower in the Ruhr area than in Germany as a whole; and, second, that although the decline in price dispersion began before the formation of the RWKS in 1893, as was happening throughout the whole of Germany, it seems to accelerate afterwards.[112] In Belgium (Table b), there was a drop in price dispersion in the early 1890s, when the first cartels were founded; and

[110] O'Rourke and Williamson, 'Once more', p. 109; Federico, 'How much'.

[111] Some degree of quality variation means that prices will never fully converge, even with zero transport costs; Brunt and Cannon, 'Variation', p. 90.

[112] The temporary increase of the early 1900s may reflect a severe coal shortage. Peters, 'Managing competition', pp. 429-32.

another in the second half of the 1900s, after the government sanctioned an agreement by all Belgian companies that supplied the state railroads and locomotive coal became the benchmark price for coal in Belgium.[113] In France, price dispersion also fell, although unevenly, after zone pricing was established by the cartel in 1901. However, we may presume that before cartels began to consolidate their role, from the early 1890s in Germany and Belgium and the 1900s in France, domestic markets tended to be competitive. Furthermore, the timing of breaks detected in the domestic series (Appendix V) does not correspond with the dates of formation of cartels or major changes in their contracts,[114] which may suggest that price fixing arrangements took place within broader trends in the evolution of prices.

The second condition a market must fulfil to be integrated is efficiency: the tendency to return to equilibrium after a shock. In Figures 1 and 2, we consider co-movement and price volatility as measures of efficiency that test whether arbitrage forces prices to move together (i.e. prices are correlated); and reduces the effect of local shocks and therefore prices become more stable, respectively. With some exceptions, results tend to be consistent with each other. Certain inconsistencies between co-movement and volatility are in fact possible, as they refer to different facets of efficiency.[115] In Figure 1, co-movement displays an upward trend in the four countries; and it remains at high levels in smaller countries (Belgium) or areas (Ruhr) from early in the period. In the series corresponding to the

[113] Strikwerda, 'If all of Europe', pp. 515-6.

[114] Changes in the Ruhr cartel's contract were implemented in 1896, 1903 and 1909; and in the Nord and Pas-de-Calais cartel, in 1905, 1910 and 1911. On Belgium, see above.

[115] Federico, 'How much', pp. 485, 489; Chilosi, Murphy, Studer, and Tunçer, 'Europe's many integrations', p. 48.

Ruhr (panel d), a lower price correlation during the first years of the cartel's operation (established in 1893), even if contradictory at first sight, may be reflecting high negotiation and monitoring costs between a large number of different types of companies.[116] In Figure 2, volatility tends to display downward, if sometimes moderate, trends over the period covered in Britain, the Ruhr and, before the turn of the century, France.[117] In Belgium, the trend in volatility seems to be relatively stagnant.

[Insert Figure 1 around here]

[Insert Figure 2 around here]

In conclusion, in addition to long-term gains in the process of convergence, overall results in Figures 1 and 2 also suggest increasingly efficient coal markets, the latter pointing to the effect of improved information flows—as cited in section II. Even if, as in the case of co-movement in Britain, in particular, as well as France and Belgium, gains in efficiency continued to increase when most, or at least a significant part, of the gains in convergence may have already taken place.[118] Figures 1 and 2 also seem to confirm the importance of short-term changes in European coal prices, as suggested by earlier studies. Certainly, the impact of weather on coal

[116] Peters, 'Managing competition', p. 424; Burhop and Lübbers, 'Cartels', p. 505.

[117] The coal industry in the Ruhr underwent a "hectic boom" just before the foundation of the cartel. Spencer, *Management*, p. 16

[118] In this regard, see Federico, 'Market integration. See also Chilosi, Murphy, Studer, and Tunçer, 'Europe's many integrations', p. 52-53; Federico, Schulze, and Volckart, 'European goods market integration', pp. 24-25.

price behavior, in general, may have been less pronounced than in the case of agricultural products. However, coal prices in the four major producing countries, as compared to industrial prices, were subject to strong fluctuations and shocks over the long nineteenth century, especially from the early 1870s onwards.[119] For example, two common rises and subsequent falls in efficiency measures around the early 1870s and the turn of the century in Britain, France and Belgium coincide with the two greatest "coal famines". These were attributed to wars (the Franco-Prussian war and the Boer war), rapidly increased consumption, labor relations (reductions of hours worked, and strikes), and cold winters.[120]

IV

Table 4 provides a first comparison of coal prices between countries. This table helps us to reinforce the choice of countries analyzed in this paper and provides a first glimpse of the evolution of prices. Among producing countries, prices were lower in Britain and tended to be the highest in France; German and Belgian prices tended to hover in the mid-range.[121] As compared to countries such as those in Southern Europe, prices in producing countries—that is, Britain, France, Belgium and Germany—were clearly (much)

[119] Bivort, 'Rythmes séculaires', esp. p. 12. See also Wibail, 'Evolution économique', p. 11; Crouzet, 'Charbon anglaise', pp. 181-2; Kirby, *British coalmining*, p. 12; Spencer, *Management*, pp. 11-7; Church, *British coal*, p. 60; Parnell, *German tradition*, p. 21.

[120] Société Statistique de Paris, 'La crise', pp. 314-5; United Kingdom, *Report from the Select Committee*; Simiand, 'Prix du charbon'; Walker, *Monopolistic combinations*, pp. 65-9.

[121] Belgian prices rose rapidly in the early twentieth century. See also Wrigley, *Industrial growth*, p. 51; Strikwerda, 'If all of Europe', pp. 515-6.

lower due to their own coal supplies, and improved technologies that permitted the large scale exploitation of (sometimes new) coal basins.[122]

[Insert Table 4 around here]

If markets for coal within countries seem to be markedly integrated, a reasonable question to ask is whether cross country markets were reasonably well integrated too. We again begin estimating price differentials between proven trading markets. Figure 3 brings together price gaps between British ports and import points in consuming countries, and table 5 reports the results of the convergence equation. In general, the process of integration is confirmed. According to the statistical significance of the estimated coefficient β, the series tend to indicate price convergence regarding the trade between England with Germany and France, with the main exception of "Hamburg-Sunderland". The other England-Germany series, however, includes Newcastle, the main export port for British coal to Germany—and covers a slightly longer time period. Price convergence between Britain and France proceeded faster in the case of Wales, probably as a result of Cardiff being closer to French ports considered than Newcastle.[123] Long-run rates of change are statistically significant.[124]

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[122] For example, Allen, *British industrial revolution*.

[123] As in the case of domestic markets, changes in trends corresponding to different sub-periods are possible (Appendix V).

[124] Half-lives of shocks ranged from one year to 21 months.

[Insert Figure 3 around here]

[Insert Table 5 around here]

The evolution of price differences between Wales and the south of Europe suggests a weaker integration process (Table 5).[125] Portuguese price data are at any rate problematic. There are some missing observations (which we decided not to interpolate in Figure 3, although we did so in Table 5) and, more importantly, available prices for the 1890s and the decade or so before the First World War are strikingly low. We nonetheless decided to use them due to the overall trend in the price gap with Cardiff being similar to those of Italy and Spain; and the Portuguese price gap being smaller than those of these two countries (Figure 3), which makes sense in terms of transport costs.[126]

There is one aspect of the evolution of price differentials between Britain and France, Germany and Southern Europe, though, that tends to be similar (Figure 3). All three seem to reduce their pace of convergence by the turn of the century. This is a change that bears a resemblance to the evolution of British freight rates, as shown in Appendix VII. Despite the preceding, considerable long-term fall, freight rates to Continental Europe flattened out or even rose from the 1890s onwards. A change that has been attributed to the

[125] See also Wegerich, 'Different trajectory', p. 153.

[126] Thanks are also due to Sofia Henriques in this matter.

state of (overall) foreign trade, the increase in organizational, bunker fuel and labor costs and a slowdown in technological progress in transport.[127]

In Table 6 we adapt Chilosi and Federico's model to our time series evidence with the aim of confirming the contribution of transport costs, and further potential causes, to market integration between Britain and Continental Europe (The description of variables is completed in the *Notes* to Table 6).[128] In addition to freight rates, we first consider British export duties for the period (1901-1905) which were, irregularly, re-introduced. We also include import tariffs for France and Spain—coal entered Germany and Italy freely. The connection by telegraph is expected to reduce price differentials, although with the exception of the British-German route the telegraph was already in use from the beginning of the periods covered by available data.[129] An Eastern Britain-Hamburg connection was established in 1855, via Amsterdam. The British-German series in Table 6 covers a longer period (1850-1913) than

[127] Jevons, *Coal question*, pp. 687-8; Church, *British coal*, p. 65; Harley, 'Coal exports', p. 315; Mohammed and Williamson, 'Freight rate', p. 193,

[128] Chilosi and Federico, 'Early globalizations'.

[129] See Babinet, 'Télégraphie électrique', p. 929; Smith, *Submarine telegraphy*: Haigh, *Cableships and submarine cables*, pp. 74-96, 192-200, 302-92; Kieve, *Electric telegraph*, pp. 104-5; Huurdeman, *Worldwide history*, pp. 76, 97, 107-30; Lew and Cater, 'Telegraph', esp. p. 148; Roberts, Distant writing, available at http://distantwriting.co.uk/ (accessed on 15 May. 2019).

those used above (which started in 1880). Here we estimate the 'Hamburg-Northeast' price gap, in which f.o.b. prices at Newcastle were linked to prices of coal from the British **N**ortheast region in Hamburg, the latter taken from Klovland's sources.[130]

On the operation of cartels, Jevons proposed that the RWKS, while limiting competition and pushing up prices in some German markets, tried to respond to British competition in Northern Germany by reducing prices.[131] However, improvements in the transport system facilitated the export of Ruhr coal more toward the Northwest rather than Hamburg.[132] So, the expected, actual effect of the Ruhr cartel is unclear. We do not include a variable for the Nord and Pas-de-Calais cartel, founded in 1901, because no control of prices or quantities was established by the cartel in the 'marché d'exportation', of which the distant British-coal consuming French Atlantic departments were part—as described above. Finally, a break in the longest series that seems to be of note is related to the shock which occurred around 1873.

The model in Table 6 is estimated in levels.[133] Data for the four countries are pooled in the last columns. For the sake of comparison, we report both OLS and IV (instrumental variables) estimates, the latter in order to account for the potential endogeneity of transportation costs and tariffs. The Durbin-Wu-Hausman exogeneity F test rejects the null hypothesis that those variables are

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[130] See Jacobs and Richter, *Grosshandelspreise in Deutschland*, pp. 62-63; Klovland, 'Commodity', p. 192. For the 1880-1909 period, the new series is practically the same as the "Hamburg-Sunderland" series used above.

[131] Jevons, *Coal question*, p. 328. In "Hamburg-Newcastle" (Appendix V, Table a), a break is in fact detected in 1893, the year of the foundation of the cartel.

[132] Fremdling, 'Anglo-German', p. 624; Klemann and Schenk, 'Competition', p. 843.

[133] See the *Notes* on the stationarity and cointegration of series.

exogenous except for four estimates. First-stage regression tests find that the instruments are valid: the F-statistic is significant, and (when there are more than one endogenous regressor) the minimum eigenvalue statistic exceeds the Stock-Yogo critical value at low rejection rates.

[Insert Table 6 around here]

The Freight variable is positive and highly significant, thus eroding market integration. As also expected, the Tariff variable in France and Spain is positive and significant. While the estimated coefficient of export duties, which sometimes presents the wrong (negative) sign, is not significant—except from, slightly, in panel *b*, estimation (7). The lack of a clear effect of export duties confirms Church's skepticism on them actually affecting price behavior and trade.[134] The sign of the effect of the Ruhr cartel in the Hamburg market suggests a price-cutting policy only in the pooled estimate; more importantly, the relationship is not statistically significant. As expected, the Telegraph variable is negative, and significant.[135]

Table 7 delves deeper into the process of price convergence by estimating the contribution of each variable. As in Chilosi and Federico, our analysis decomposes the share of the total change accounted for by each variable (See the *Notes* to Table 7).[136] Even if

[134] Church, *British coal*, pp. 66.

[135] The addition of the lagged value of the dependent variable as a further regressor did not substantially change the results.

[136] Chilosi and Federico, 'Early globalizations'.

the model performs less well for Germany and the pooled data, as—in the last row—the difference between the cumulated effect of the variables and the actual change is higher, in general the results confirm transportation costs as the main factor in explaining market integration between Britain and consuming countries. The telegraph also seems to be of considerable importance (The cartel variable is not significant in Table 6). A further interesting result is that of import tariffs: their unification and reduction in France clearly contributed to convergence. However, protectionism in Spain seems to have had a minute effect. This result is in line with previous research, which refers to an erratic trade policy and the low effect of duties from c. 1850 to 1926. In fact, the remoteness of valuable coalfields coupled with high transport costs within Spain made domestic coal at least as expensive, if not even more so, than British coal, which was also of higher quality and supplied regularly.[137]

[Insert Table 7 around here]

The results of analyses based on price differentials indicate a trend toward integration in the main international market, especially until the end of the century, mainly guided by changes in the transport system, as well as reductions in information costs and protectionism. Such a detailed approach has not been possible for countries in Continental Europe. However, to verify the robustness of the findings, we apply a variance analysis. As a first step, Appendix VIII reports the coefficient of variation of prices

[137] Nadal, *Fracaso*, esp. pp. 135-43; Coll and Sudrià, *Carbón*, pp. 170, 519; Carreras and Tafunell, *Historia Económica*, pp. 168-9; Henriques, 'Energy', p. 143.

throughout coal producing Europe. The two series used display similar downward trends. The next step is to estimate the contribution of the international market to integration once changes in the domestic markets are accounted for. Appendix IX shows the results of the variance analysis for the two sets of data. With some discrepancies, results in the two panels tend to coincide. The decline in dispersion was mainly due to the reduction in the contribution of the within-countries component, especially before the mid-1880s.

This method, therefore, provides a more nuanced picture of international market integration than those obtained through specific price gaps. Protectionism, particularly before the early 1860s—as described in section II—, may contribute to understanding the lack of an early downward trend in between-countries variance (Appendix IX, Table a). Then, the most important boom-bust cycle in the European coal industry occurred in the 1872-1886 period. First, the spike around 1873 would likely be associated with a coal shortage, as argued above; following which, the next disintegration phase coincides with the greatest fall in European prices.[138] From 1886 onwards, the between-countries variance tended to reduce its contribution to total variance over time, at least until the turn of the century. There is no clear improvement afterwards, which may have been due to aforementioned factors such as the end of the reduction in transport costs, as well as coal quality differences. On the other hand, the available evidence suggests limited effects of

[138] Bivort, 'Rythmes séculaires', p. 14; Wibail, 'Evolution économique', p. 11; Crouzet, 'Charbon anglaise', pp. 181-2; Spencer, *Management*, p. 15; Church, *British coal*, p. 373; Parnell, *German tradition*, p. 21. The fall in French pithead prices was lower than in the other coal producing countries, thus contributing to increased dispersion in the international market during the end of the 1870s and the first half of the 1880s. During the same period, however, import prices in France, as well as export prices in Britain, tended to fall appreciably, which helps to explain the evolution of price gaps as reported in Figure 3; see also Simiand, 'Prix du charbon', pp. 36-7; Crouzet, 'Charbon anglaise', pp. 181-2.

cartels to restrict competition beyond their most immediate areas of influence—these being relatively well-protected by distance from competitors.[139]

V

Coal fueled the European Industrial Revolution. Over our period European production of coal increased by a factor of seven. The economic unification of European coal markets over time, however, remains almost neglected in literature that has been more focused on agricultural products. We have proposed here an examination of intra- and international market integration for a reasonably homogeneous commodity. We conclude that before the First World War, national and international markets in major coal producing countries tended toward integration.

Specifically, we find convergence within countries, since prices at pithead and consumer locations became closer, and since prices at several pithead and port locations merged together over time. As the nineteenth century progressed, our series for domestic markets also tended to behave more efficiently—that is to say, prices returned swiftly to previous levels after a shock. Even so, prices in the national coal industries suffered from strong fluctuations.

The timing of domestic market integration for coal fits only partially with the evidence for agricultural products, mostly cereals, which tend to show faster integration before around 1850, that is, mostly before revolutionary improvements in the transport

[139] Bivort, 'Rythmes séculaires', pp. 15-6; Gillet, 'L'age du charbon', p. 48; Gillet, *Charbonnages du nord*, p. 249; Hardy-Hémery, 'Limite au libéralisme' p. 328; Burhop and Lübbers, 'Cartels', p. 505; Montant, 'Market power', pp. 2-3.

system.[140] A longer process of integration in the case of coal, a bulky product with high weight relative to value, may suggest a greater importance of major changes in transport technology—without excluding non-revolutionary transport and organizational improvements, and better transmission of information. However, the process of convergence measured with the coefficient of variation, which considers price dispersion for a larger number of markets, tended to stabilize at the end of the period covered. A relatively stagnant level of price dispersion points to insignificant further reductions in transport costs and the existence of some degree of product heterogeneity. Cartelization in Continental Europe may have also been behind some changes in price dispersion only at the very end of our period; besides, no break detected in any domestic series coincides with the formation of cartels or major actions taken.

In the international market, we find that the extent of integration, measured with price differentials between the main exporter, Britain, and consuming countries, tended to increase over time, although stagnant or even increasing freight costs from the turn of the century seem to be associated with slower integration. An econometric model confirms the long-term decline in transport costs as the principal causal factor. The model also captures the contribution of reducing information costs, and a cut in tariffs. The latter being part of a nineteenth-century European trend in lowering tariff burdens that with some, albeit seemingly inconsequential, exceptions, did not slow or reverse from the 1870s—unlike agricultural goods. The extension of the analysis to other markets, based on scarce

[140] For example, Ejrnæs and Persson, 'Market integration'; Jacks, 'Intra- and International'; Shiue, 'Political fragmentation'; Federico and Persson, 'Market integration and convergence'; Federico, 'European markets'; Uebele, 'Market integration'; Chilosi, Murphy, Studer, and Tunçer, 'Europe's many integrations'; Uebele and Gallardo-Albarrán, 'Paving the way'.

data, suggests a more complex situation, though. A variance analysis reveals that, in addition to the integration process starting later, shocks could occur (as in the case of domestic markets), as they crossed national boundaries. Quantitative and qualitative evidence suggests a modest degree of interference by cartels in the international market integration.

The debate on the contribution of coal to the Industrial Revolution and economic growth in nineteenth-century Europe can be approached from many angles. Together with the abundant and cheap supply of coal and the knowledge to use it,[141] our results point to the development of markets as one of the reasons why, as argued in part of the literature, coal may have been a key factor in explaining economic growth and development. A strong relationship between per capita income and the share of coal in total energy consumption at the turn of the century has been shown, and one of the features of this process of transition to coal was domestic and cross border trade.[142] At least before the end of the nineteenth century, when the process of market integration slowed considerably, well-functioning domestic and international markets based on the reduction of transaction costs reflect how new coal basins were exploited, coal production was shipped to sales locations and the industry located away from coalfields.

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[141] Allen, *British industrial revolution*.

[142] Kander, Malanina, and Warde, *Power*, pp. 210-1.

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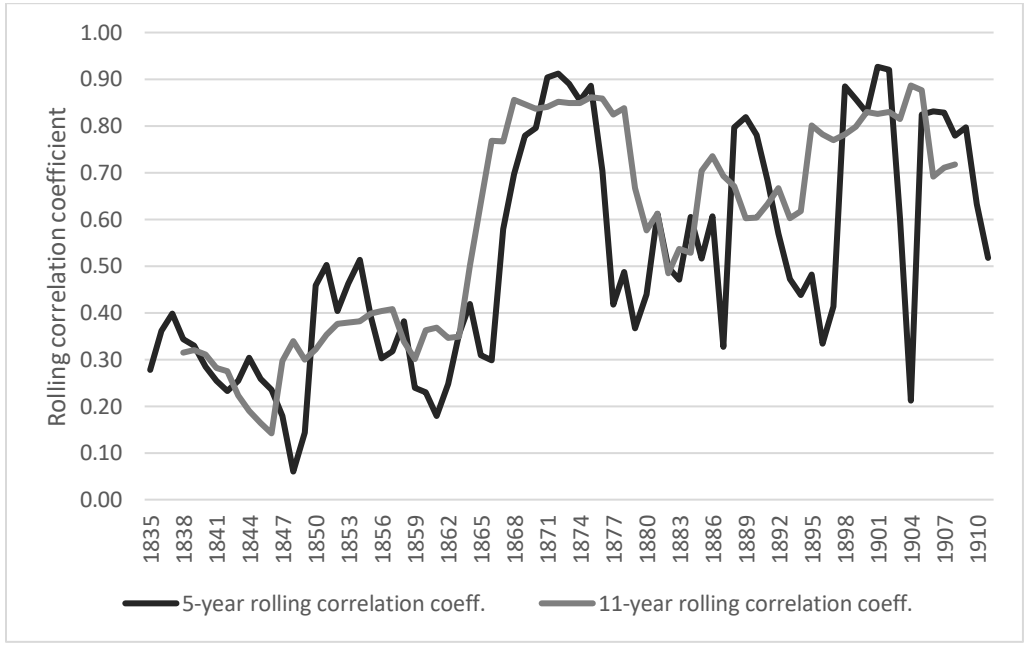
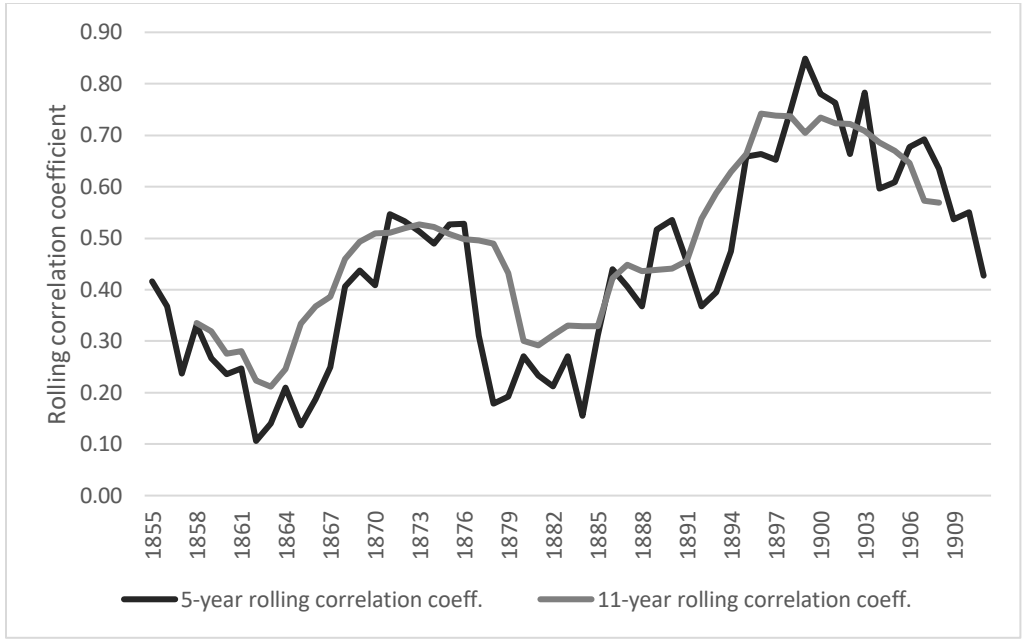
Figure 1. Price efficiency. Co-movement

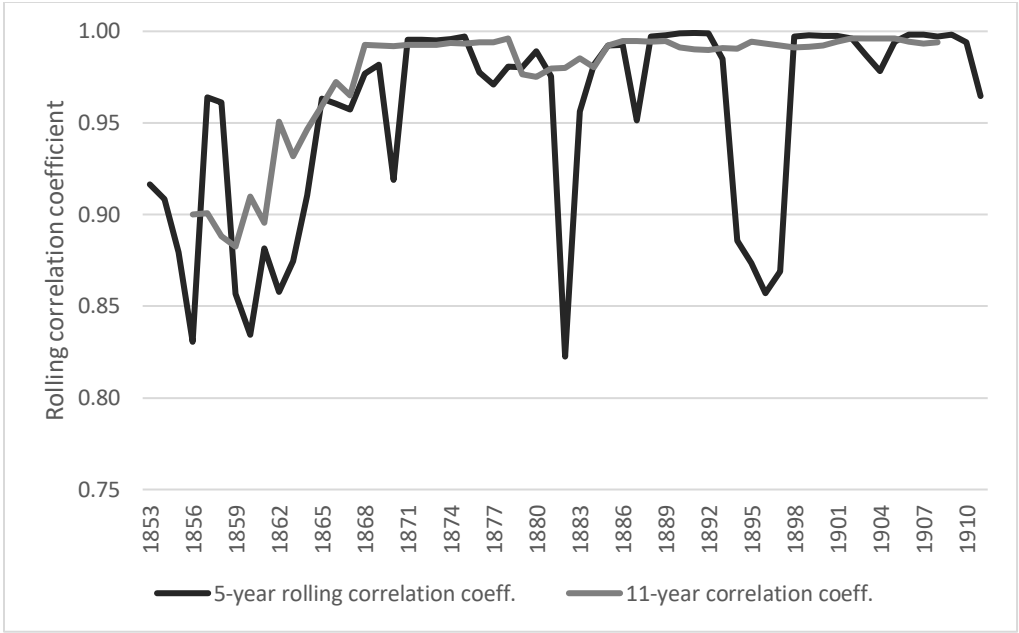
a. Britain



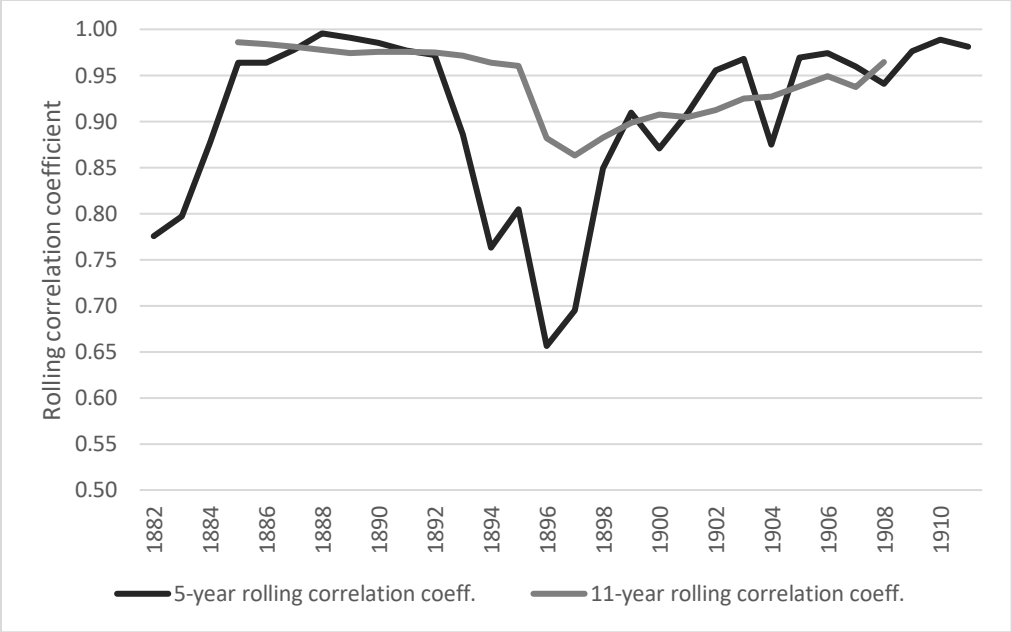
b. France


0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Rolling correlation coefficient
1855
1858
1861
1864
1867
1870
1873
1876
1879
1882
1885
1888
1891
1894
1897
1900
1903
1906
1909
5-year rolling correlation coeff.
11-year rolling correlation coeff.

c. Belgium



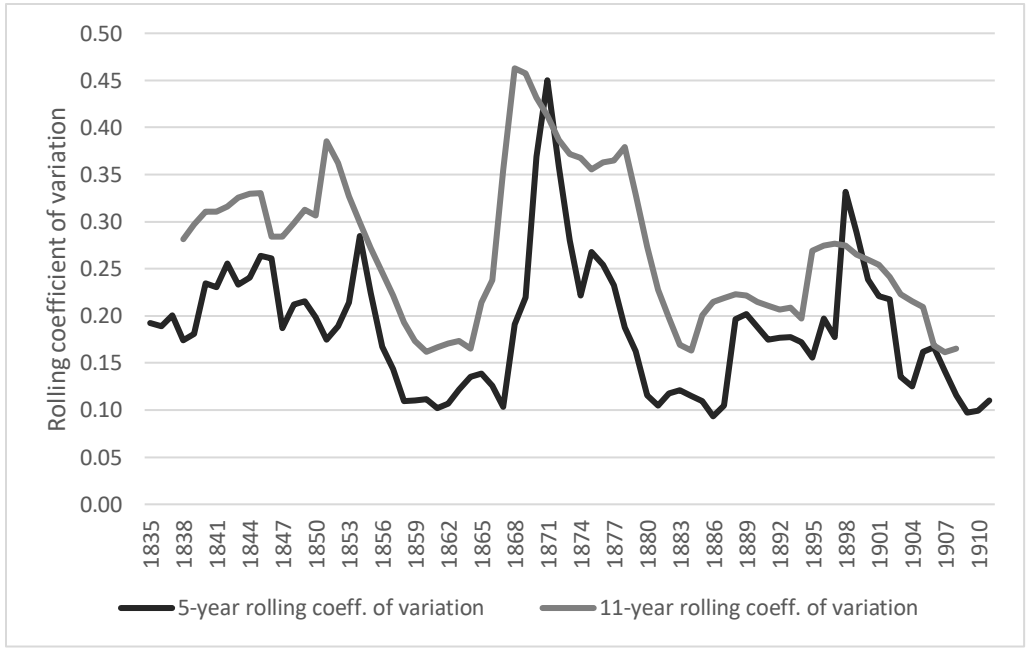
d. Germany, Ruhr



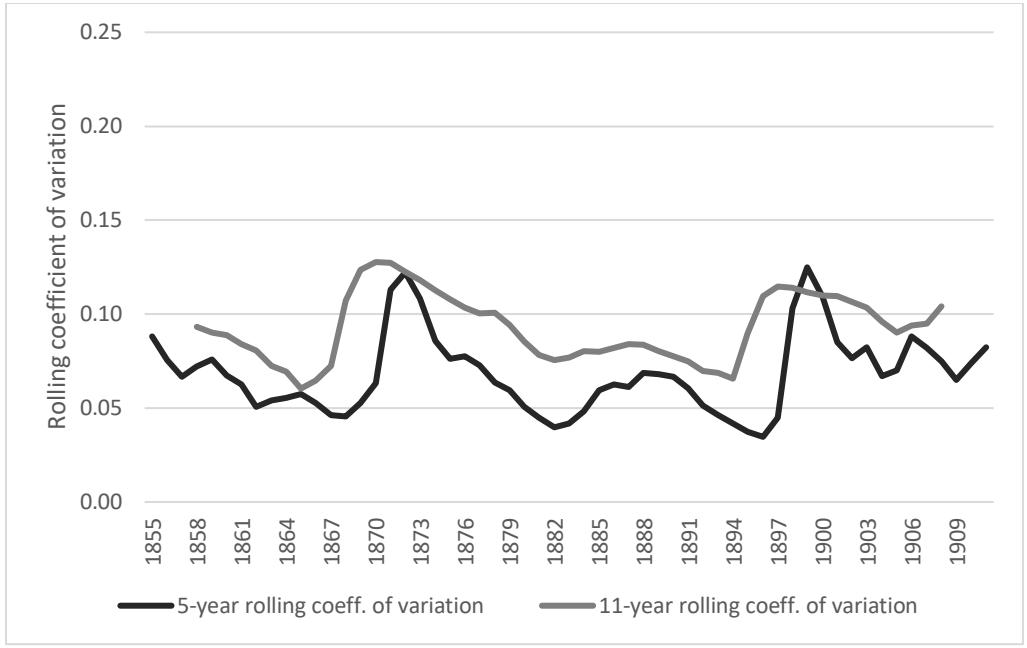
Notes: The national price series whose convergence is examined in Appendix VI are used. Co-movement is based on arbitrage, forcing prices to move together. It provides a single coefficient—the higher it is, the more integrated the market is—, which is derived from the average 5-year, and 11-year rolling correlation coefficient between the residual of each individual (Hodrick-Prescott) filtered price series and the average of the residuals. The interpretation of results must be a comparative one, as there is no minimum threshold. We experimented with 7-year, 15-year and 21-year rolling windows, but, given the number of observations, we finally present those that we think are most informative. The price series are de-trended using the filter to reduce spurious correlation due to common trends or shocks. We use 6.25 as the smoothing parameter, as the standard procedure with annual data—Chilosi, Murphy, Studer, and Tunçer, 'Europe's many integrations', p. 55.
Sources: Appendix I.

Figure 2. Price efficiency. Volatility

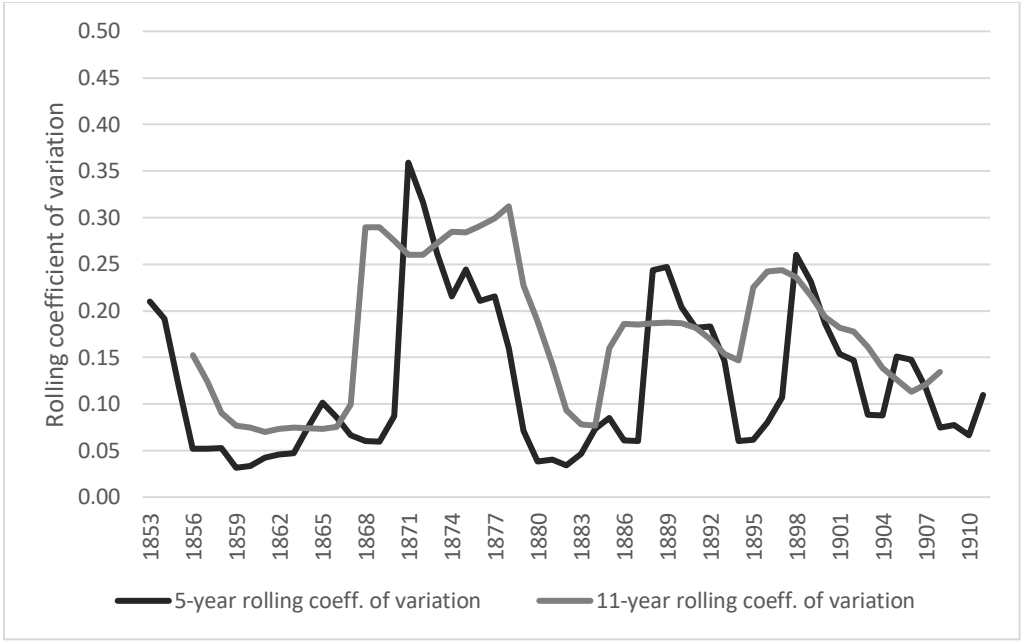
a. Britain



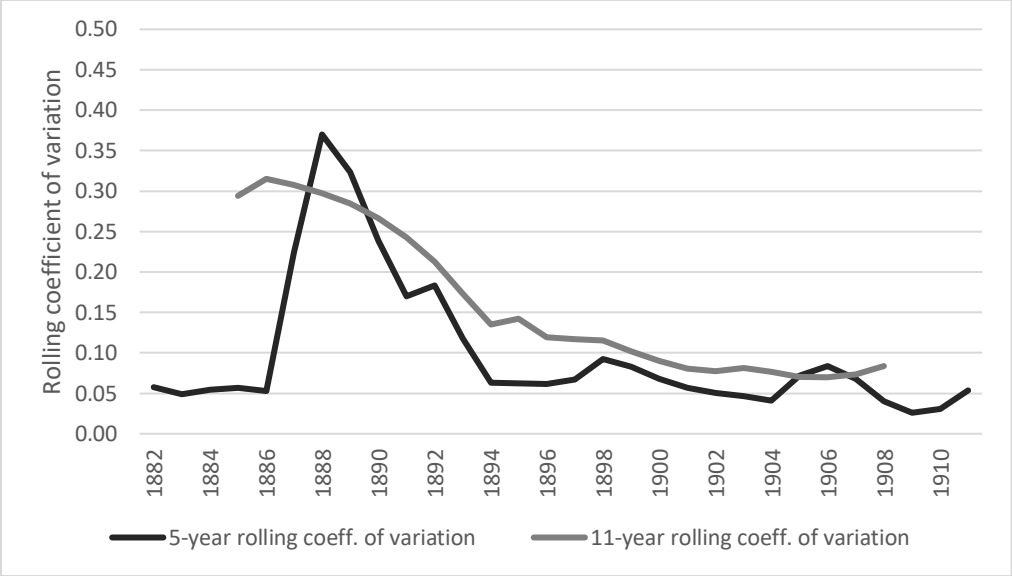
b. France


0.25
0.20
0.15
0.10
0.05
0.00
Rolling coefficient of variation
1855
1858
1861
1864
1867
1870
1873
1876
1879
1882
1885
1888
1891
1894
1897
1900
1903
1906
1909
5-year rolling coeff. of variation
11-year rolling coeff. of variation

c. Belgium



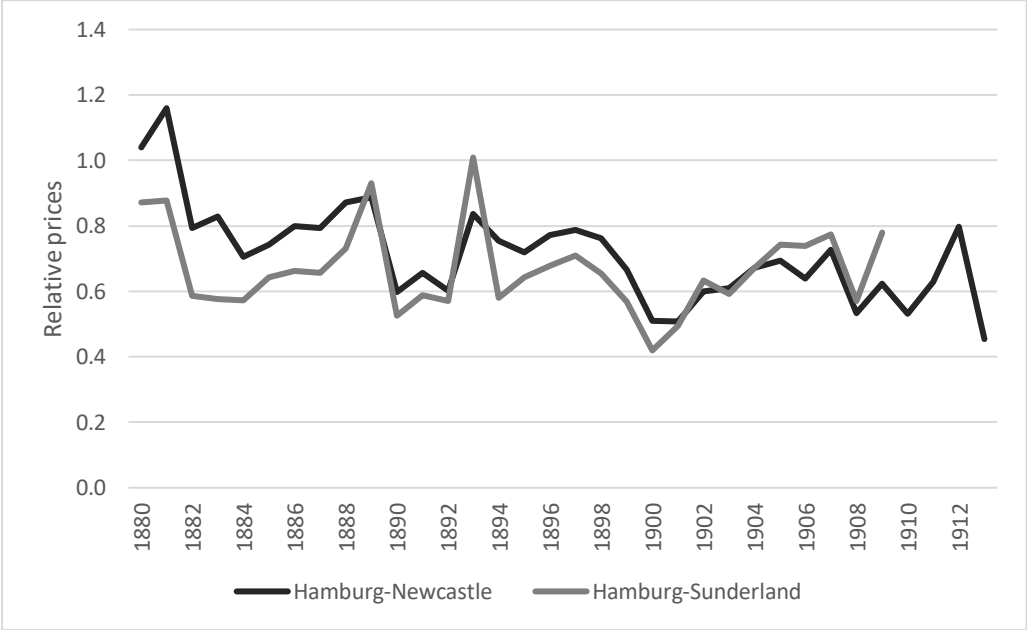
d. Germany, Ruhr



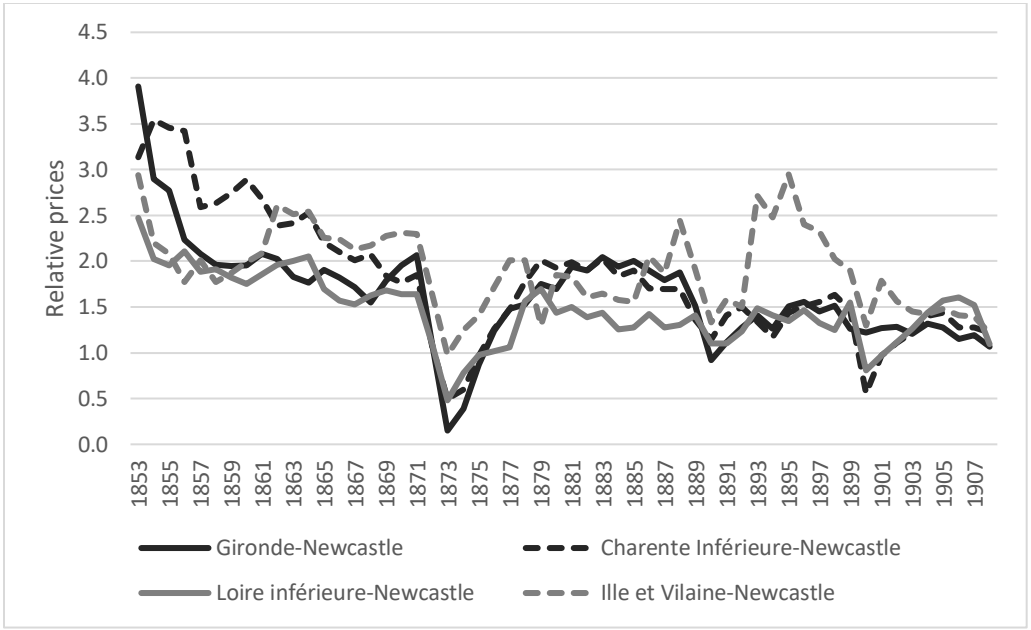
Notes: The national price series whose convergence is examined in Appendix VI are used. Volatility is based on arbitrage, reducing the effect of local shocks on individual markets. It provides a single coefficient—the lower it is, the more integrated the market is—, which is derived from the average 5-year, and 11-year rolling coefficient of variation of prices in each individual market. The interpretation of results must be a comparative one. See also the *Notes* to Figure 1.
Sources: Appendix I.

Figure 3. Pairwise price differentials in the international market

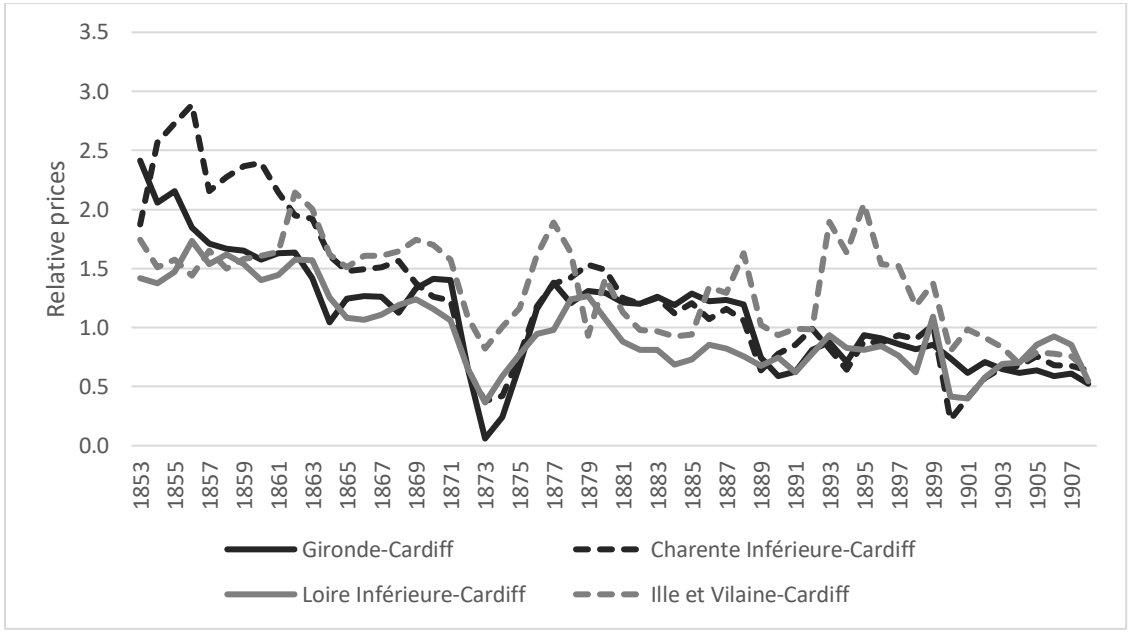
a. Import country: Germany - export country: England



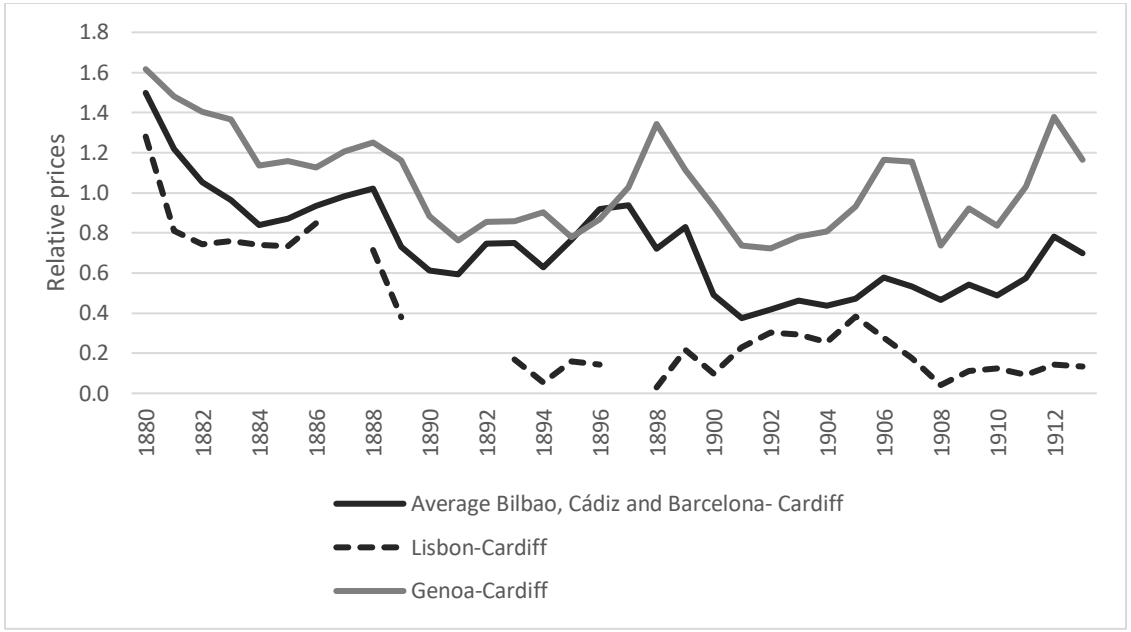
b. Import country: France - export country: England



c. Import country: France - Export country: Wales



d. Import countries: Italy, Spain and Portugal - export country: Wales



Notes: Relative prices, ((pj-pi)/pi), between export (i) and import (j) points. F.o.b prices at export points.
Sources: Appendix I.

Table 1. Augmented Dickey-Fuller (ADF) test for unit roots.
Pairwise price differentials between identified trading markets

a. Domestic markets

	Period	Intercept		Intercept and trend	
		Levels	First differences	Levels	First differences
Britain					
London-Northeast	1833-1913	-0.63	-10.01**	-3.36	-10.05**
London-Yorkshire	1833-1913	-1.59	- 8.13**	-3.42 †	-8.07**
London-South Wales	1833-1913	-2.12	-8.92**	-3.78*	-8.89**
France					

Paris-Loire	1853-1911	-1.25	-7.90**	-2.84	-7.82**
Paris-Nord	1833-1911	-1.81	-8.48**	-1.74	-8.52**
Paris-Pas-de-Calais	1833-1911	-2.45	-9.81**	-2.27	-9.86**
Belgium					
Ghent-Hainaut	1851-1913	-3.90*	-7.04**	-4.46**	-7.15**
Germany					
Berlin-Ruhr					
Berlin-Dortmund	1880-1913	-1.71	-4.82**	-4.07*	-4.76**
Berlin-Düsseldorf	1880-1913	-1.68	-5.41**	-2.76	-5.34**
Berlin-Essen	1880-1913	-1.99	-7.56**	-2.78	-7.40**
Hamburg-Ruhr					
Hamburg-Dortmund	1880-1913	-0.66	-4.98**	-2.99	-4.90**
Hamburg-Düsseldorf	1880-1913	-1.58	-6.28**	-2.96	-6.18**
Hamburg-Essen	1880-1913	-1.96	-6.97**	-3.04	-6.82**
Berlin-Upper Silesia	1880-1913	-1.11	-4.39**	-2.67	-4.32**

b. International market

	Period	Intercept		Intercept and trend	
		Levels	First differences	Levels	First differences
Germany-England					
Hamburg-Newcastle	1880-1913	-3.86**	-4.67**	-4.72**	-4.42**
Hamburg-Sunderland	1880-1909	-4.84**	-7.89**	-4.69**	-7.86**
France-England					
Ille et Vilaine-Newcastle	1853-1908	-2.60 †	-5.19**	-3.01	-5.15**
Loire Inférieure-Newcastle	1853-1908	-2.68 †	-7.29**	-3.17	-7.18**
Charente Inférieure-Newcastle	1853-1908	-2.77 †	-6.70**	-3.00	-6.77**
Gironde-Newcastle	1853-1908	-2.47	-5.67**	-2.76	-5.57**
Wales-France					
Ille et Vilaine-Cardiff	1853-1908	-2.16	-9.11**	-3.28 †	-9.05**
Loire Inférieure-Cardiff	1853-1908	-1.99	-7.36**	-3.45 †	-7.28**
Charente Inférieure-Cardiff	1853-1908	-2.17	-7.47**	-2.79	-7.45**
Gironde-Cardiff	1853-1908	-2.04	-4.68**	-2.84	-4.65**
Southern Europe-Wales					
Bilbao, Cádiz and Barcelona-Cardiff	1880-1913	-2.68	-4.37**	-2.84	-4.47**
Lisbon-Cardiff	1880-1913	-1.72	-6.94**	-1.55	-6.86**
Genoa-Cardiff	1880-1913	-3.01*	-4.31**	-2.76	-4.47**

Notes: † = significant at 0.10 level; * at 0.05 level; ** at 0.01 level. The number of lags of the dependent variable was determined by the Akaike Information Criterion (AIC).

Table 2. Price convergence within domestic markets.
Pairwise price differentials between identified trading markets

	Period	No. of years	No of markets	β	ψ	Wald Test (F)	Long run rate of change = - (β/ψ) (in percentage)	Cumulated change (in percentage)
Britain								
London-Northeast	1833-1913	81	2	-0.0036**	-0.2373*	10.19**	-1.52	-71
London-Yorkshire	1833-1913	81	2	-0.0040**	-0.3699***	87.76***	-1.09	-59
London-South Wales	1833-1913	81	2	-0.0044**	-0.3040**	26.95***	-1.46	-69
France								
Paris-Loire	1853-1911	59	2	-0.0049*	-0.3089**	40.23***	-1.60	-61
Paris-Nord	1833-1911	59	2	-0.0008	-0.1567*	0.95	-0.48	-25
Paris-Pas-de-Calais	1833-1911	59	2	-0.0006	-0.2416**	0.52	-0.25	-14
Belgium								
Ghent-Hainaut	1851-1913	63	2	-0.0396***	-	-	-	-92
Germany								
Berlin-Ruhr								
Berlin-Dortmund	1880-1913	34	2	-0.0151**	-0.5950**	55.39***	-2.54	-58
Berlin-Düsseldorf	1880-1913	34	2	-0.0109***	-0.4947***	31.42***	-2.21	-83
Berlin-Essen	1880-1913	34	2	-0.0072*	-0.4670**	9.68**	-1.54	-41
Hamburg-Ruhr								
Hamburg-Dortmund	1880-1913	34	2	-0.0244**	-0.6400**	67.25***	-3.82	-73
Hamburg-Düsseldorf	1880-1913	34	2	-0.0205***	-0.6531***	48.81***	-3.13	-66
Hamburg-Essen	1880-1913	34	2	-0.0117*	-0.5240***	17.47***	-2.22	-53
Berlin-Upper Silesia	1880-1913	34	2	-0.0208*	-0.5310*	114.97***	-3.91	-74

Notes: * = significant at 0.05 level; ** at 0.01 level; *** at 0.001 level. The dependent variable is the relative price $((p_j-p_i)/p_i)$, between producing (i) and consuming (j) areas. The regressions are estimated using Newey-West standard errors to account for heteroskedasticity and serial correlation.

Table 3. Price convergence between Paris and the Northern coalfields

	Sub-period	No. Of years	No. of markets	β	ψ	Wald Test (F)	Long run rate of change = - (β/ψ) (in percentage)	Cumulated change (in percentage)
Paris-Nord								
	1853-1872	20	2	0.0039**	-0.9665***	8.75*	0.41	9
	1873-1911	39	2	-0.0026 [a]	-0.1663 [†]	2.78 [b]	-1.57	-46
Paris-Pas-de-Calais								
	1853-1890	38	2	0.0052*	-0.5436**	9.82**	0.95	43
	1891-1911	21	2	-0.0159**	-0.7194**	25.52***	-2.21	-37

Notes: † = significant at 0.10 level; * at 0.05 level; ** at 0.01 level; *** at 0.001 level. The dependent variable is the relative price $((p_j-p_i)/p_i)$, between producing (i) and consuming (j) areas. The regressions are estimated using Newey-West standard errors to account for heteroskedasticity and serial correlation. Among breaks reported in Appendix V (Table A.V.a), the break associated with the main jump has been chosen to establish two sub-periods. a: the estimated coefficient of β is significant at the 0.151 level; b: p-value = 0.105.

Table 4. Coal prices, grams of silver per metric ton

	Britain, Northeast	Britain	France	Belgium	Germany, Ruhr	Germany	Italy	Spain	Portugal
1850	22.83								
1855	31.35		55.49	47.48					
1860	27.79		52.36	44.49					
1865	30.03		51.77	45.38					
1870	29.95		53.96	47.98					
1875	41.94		70.55	70.22					
1880	26.59		62.27	41.96	34.91	37.36	136.97	123.78	109.37
1885	25.79	29.56	57.79	36.88	32.30	35.94	111.44	104.63	98.63
1890	36.66	42.72	55.85	50.32	58.26	44.93	122.63	120.05	92.63
1895	29.67	35.18	54.20	41.06	46.27	43.98	94.57	101.97	64.56
1900	48.31	52.21	63.71	65.51	57.79	52.69	150.08	133.31	102.02
1905	36.66	40.84	60.14	59.38	56.18		122.69	105.87	92.29

1910	42.56	45.47	68.10	64.92	62.18		126.80	118.27	85.42

Notes: Pithead prices for Britain, France, Belgium and Germany; import prices for Southern European countries. See the text (section I) for currency conversion criteria. Three-year averages, except for Belgium (1889-1900); Germany, Ruhr (1880-1); Germany (1881; 1899-1900); Italy (1880-1); and Portugal (1880-1; 1889-1890).
Sources: Appendix I.

Table 5. Price convergence in the international market.
Pairwise price differentials between identified trading markets

	Period	No. of years	No. of markets	β	ψ	Wald Test (F)	Long run rate of change = - (β/ψ) (in percentage)	Cumulated change (in percentage)
Germany-England								
Hamburg-Newcastle	1880-1913	34	2	-0.0136***	-	-	-	-37
Hamburg-Sunderland	1880-1909	30	2	-0.0024	-	-	-	-7
France-England								
Ille et Vilaine-Newcastle	1853-1908	56	2	-0.0023 [a]	-0.3949***	3.15 [†]	-0.57	-27
Loire Inférieure-Newcastle	1853-1908	56	2	-0.0028 [†]	-0.3880***	4.33*	-0.71	-33
Charente Inférieure-Newcastle	1853-1908	56	2	-0.0044 [b]	-0.3253***	6.43*	-1.36	-53
Gironde-Newcastle	1853-1908	56	2	-0.0035*	-0.4432***	5.37*	-0.79	-36
France-Wales								
Ille et Vilaine-Cardiff	1853-1908	56	2	-0.0055*	-0.3901**	14.48***	-1.42	-55
Loire Inférieure-Cardiff	1853-1908	56	2	-0.0084**	-0.5112***	22.87***	-1.65	-60
Charente Inférieure-Cardiff	1853-1908	56	2	-0.0103*	-0.4274**	19.51***	-2.41	-74
Gironde-Cardiff	1853-1908	56	2	-0.0085**	-0.5138***	18.12***	-1.66	-61
Southern Europe-								

Wales								
Bilbao, Cádiz and Barcelona-Cardiff	1880-1913	34	2	-0.0080	-0.4230**	4.83*	-1.89	-48
Lisbon-Cardiff	1880-1913	34	2	-0.0177	-0.3587 †	2.75 c	-4.94	-81
Genoa-Cardiff	1880-1913	34	2	-0.0024	-0.4683**	0.50	-0.52	-16

Notes: † = significant at 0.10 level; * at 0.05 level; ** at 0.01 level; *** at 0.001 level. The regressions are estimated using Newey-West standard errors to account for heteroskedasticity and serial correlation. a: the estimated coefficient of β is significant at the 0.105 level; b: the estimated coefficient of β is significant at the 0.112 level; c: p-value = 0.109.

Table 6. Causes of market integration between consuming countries and Britain

a. OLS estimations

Dependent variable: Ln(Relative price)													
	Germany (1850-1913)			France (1853-1908)			Spain (1880-1913)		Italy (1880-1913)	Pooled			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Constant	0.032	0.056	0.240**	0.253***	0.327***	0.123	0.377***	0.160***	0.187***	0.194***	0.223**	0.127*	0.189*
	(0.042)	(0.040)	(0.077)	(0.049)	(0.040)	(0.128)	(0.017)	(0.022)	(0.028)	(0.011)	(0.014)	(0.027)	(0.034)
Ln(Freight)	0.764***	0.716***	0.720***	0.769***	0.699***	0.600***	0.618***	0.724***	0.437***	0.704**	0.658**	0.632**	0.599**
	(0.079)	(0.063)	(0.068)	(0.134)	(0.073)	(0.091)	(0.047)	(0.027)	(0.068)	(0.054)	(0.042)	(0.047)	(0.043)
Export duty	0.103	0.039	0.011	0.273	0.110	0.080	-0.021	0.039	-0.065	0.095	0.032	0.032	0.026
	(0.076)	(0.062)	(0.064)	(0.195)	(0.072)	(0.074)	(0.038)	(0.024)	(0.064)	(0.066)	(0.031)	(0.022)	(0.024)
Ln(Tariff)						1.624 a		1.121***				1.298*	1.387 †
						(0.980)		(0.102)				(0.305)	(0.455)
1873 Crisis		-0.410***	-0.366***		-0.963*	-0.903*					-0.698 †	-0.672*	-0.675*
		(0.034)	(0.050)		(0.405)	(0.408)					(0.227)	(0.205)	(0.208)
Cartel			0.074										-0.048
			(0.074)										(0.044)
Telegraph			-0.226*										-0.232**
			(0.085)										(0.027)
Fixed effects										Yes	Yes	Yes	Yes
N	64	64	64	56	56	56	34	34	34	188	188	188	188
Adjusted R^2	0.70	0.78	0.81	0.49	0.72	0.73	0.64	0.84	0.51	0.51	0.66	0.73	0.74
F	60.46***	93.09***	79.42***	159.75***	100.26***	79.73***	273.53***	502.03***	60.78***	245.37***	536.00***	228.49***	178.66***

b. IV estimations

Dependent variable: Ln(Relative price)													
	Germany (1850-1913)			France (1853-1908)			Spain (1880-1913)		Italy (1880-1913)	Pooled			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Constant	0.055	0.054 †	0.240**	0.180*	0.301***	0.077	0.363***	0.190***	0.187***	0.158*	0.215***	0.149***	0.219***
	(0.039)	(0.033)	(0.069)	(0.080)	(0.029)	(0.086)	(0.017)	(0.037)	(0.028)	(0.066)	(0.052)	(0.032)	(0.034)
Ln(Freight)	0.643***	0.708***	0.721***	0.524***	0.606***	0.498***	0.527***	0.681***	0.437***	0.554***	0.623***	0.604***	0.563***
	(0.071)	(0.059)	(0.106)	(0.076)	(0.046)	(0.055)	(0.052)	(0.042)	(0.068)	(0.037)	(0.029)	(0.056)	(0.049)
Export duty	0.030	0.034	0.011	0.037	0.019	-0.013	-0.063 †	0.018	-0.065	-0.002	0.009	0.008	0.000
	(0.619)	(0.061)	(0.061)	(0.053)	(0.045)	(0.047)	(0.033)	(0.026)	(0.064)	(0.022)	(0.013)	(0.015)	(0.008)
Ln(Tariff)						1.789**		0.945***				0.892**	0.928 †
						(0.688)		(0.196)				(0.303)	(0.487)
1873 Crisis		-0.413***	-0.366***		-0.984*	-0.917*					-0.706***	-0.688***	-0.697***
		(0.044)	(0.062)		(0.408)	(0.408)					(0.199)	(0.183)	(0.487)
Cartel			0.074										-0.068
			(0.093)										(0.047)
Telegraph			-0.226*										-0.242***
			(0.081)										(0.012)
Fixed effects										Yes	Yes	Yes	Yes
N	64	64	64	56	56	56	34	34	34	188	188	188	188
Adjusted R^2	0.67	0.77	0.79	0.43	0.69	0.70	0.85	0.97	0.64	0.51	0.66	0.72	0.74
F	48.86***	87.55***	71.24***	28.93***	159.99***	146.45***	139.29***	234.61***	77.43***	109.85***	218.96***	168.19***	140.36***
Durbin-Wu-Hausman Exogeneity test	13.19***	0.14	0.00	8.14**	6.21*	4.15*	6.56*	1.57	0.56	39.90***	4.15*	3.55*	4.57*
F, first-stage regression	161.06***	233.32***	166.53***	467.39***	577.69***		64.50***		129.77***	947.20***	1470.53***		
Minimum eigenvalue statistic						250.72		5.00				358.16	327.35
exceeds the Stock-Yogo critical value at						10 percent		15 percent				10 percent	10 percent

Notes: † = significant at 0.10 level; * at 0.05 level; ** at 0.01 level; *** at 0.001 level. In panel *a*, specification (6), a: the estimated coefficient is significant at the 0.104 level. The regressions are estimated using standard errors to account for heteroskedasticity. All the continuous variables are expressed in grams of silver. The dependent variable is the relative price $((p_j-p_i)/p_i)$, between British ports (i) and import points (j) in consuming countries; Hamburg-Northeast, Bordeaux (Gironde)-Cardiff, Bilbao, Cádiz and Barcelona (average)-Newcastle, and Genoa-Cardiff. 'Freight' refers to the freight factor: the ratio of freights to price in Britain; 'Export duty' is a dummy variable set to 1 for the 1901-1905 period; 'Tariff' is the ratio of import duties to price in Britain; '1873 crisis' is a dummy variable set to 1 for the 1872-1876 period; in the case of Germany, [Ruhr] 'Cartel' is a dummy variable set to 1 from 1893 onwards; and 'Telegraph' is a dummy variable set to 1 from 1855 onwards. In the IV regressions (panel *b*), as in Chilosi and Federico, 'Early

globalizations', as instruments we used the ratio of the trend component of a Hodrick-Prescott filter of the series of freights to the average British price throughout the period, and the ratio of annual duties to the average British price. According to the Augmented Dickey-Fuller test for unit roots, relative prices, freights and tariffs are stationary in first differences. According to the Engle-Granger test, the dependent and the explanatory variables are cointegrated.
Sources: See the text and Appendix I.

Table 7. Causes of market integration between consuming countries and Britain.
Decomposition analysis, in percentages

	Germany (1850-1913)	France (1853-1908)	Spain (1880-1913)	Pooled
Based on Table 4, panel *b*, specification:	(3)	(6)	(8)	(13)
Ln(Freight)	76.74	62.45	90.15	73.14
Ln(Tariff)		33.44	1.81	11.21
Cartel	14.28			14.34
Telegraph	43.61			51.15
Total	134.62	95.89	91.96	149.84

Notes: 'Pooled' includes Italy. The figures are computed as the percentage change in each explanatory variable multiplied by the estimated coefficient, the latter corresponding to Table 4, panel *b*. The figures reported refer to the share of the percentage change in the dependent variable accounted for each explanatory variable. Variables that do not affect the dependent variable at the beginning and/or the end of the covered period, i.e. 'Export duty' and '1873 crisis', have been omitted. The cartel variable is not significant in Table 6.

Appendix I. Data

Table A.I.a. Prices

COUNTRY / LOCATION	PERIOD	SOURCE
Domestic markets		
Britain		According to Church, *British coal*, p. 52, three main long-term price series may prices from 1882 onwards, f.o.b. values of coal exports at major ports, and prices of best See also Mitchell, *Economic development*, p. 263-72, for best London coals. Mitchell, *Economic development*, pp. 271-81 (Table 9.3), also uses pithead pr (*Mineral Statistics*), export values and further (shorter) series for periods prior to 1882 in order to estimate longer pithead price series for major coalfields. From these series, w Yorkshire and South Wales, in which the trade with London was well established nineteenth century. See section I for references relating to this matter.
Regions	1882-1913	10-region classification of pithead prices, published in *Mineral Statistics*, as pro *coal*, pp. 58-9. Regions: Scotland, Northeast, Cumberland, Lancashire and Cheshire, North Midlands, West Midlands, South Wales, and Southwest.
Ports (weighted)	1833-1913	16-port classification of f.o.b. prices, available from 1833 onwards. 1833-1902: of Trade, *Report*, pp. 14-7. 1903-1913: United Kingdom. Mines Department, *Mines a* entitled *Mineral Statistics*). English ports: Liverpool (in the Northwest); Newcastle (Tyne and Wear ports), (combined), Sunderland, Hartlepool, and Hull, Goole and Grimsby (Humber ports). Cardiff, and Newport (all on the Bristol Channel). Scottish ports: Leith, Borr Grangemouth and Kirkcaldy (in the east), and Glasgow (in the west). Interpolations: 15, 12 and three missing observations were interpolated in N Hartlepool and Grimsby, respectively. Each price observation was weighted by the tonnage handled at that port in th quantities shipped from ports, 1833-1902: United Kingdom, *Report of the Commissi* Royal Commission on Coal Supplies, *First Report*. 1903-1913: United Kingdom. Dep *and Quarries* (Originally entitled *Mineral Statistics*). Interpolations: The year 1834 wa three ports. Additionally, 11 and three missing observations were interpolated in H respectively.
London	1833-1913	Average of four available long-term retail price series, as reported by United K *Report*, pp. 10-1, and Mitchell, *British historical statistics*, pp. 747-8. Price series: Best coal at the shipside; Wallsend, Hetton; Bethlem Royal H Greenwich.

Northeast	1833-1913	Regional pithead prices. 1833-1886: Mitchell, *Economic development*, pp. 276-8. 1886-1913: Church, *British coal*, pp. 58-9. Mitchell reports prices as indices, 1886=100. We use the post-1881 period of overlap with prices from *Mineral Statistics* (as used by Church, *British coal*, pp. 58-9) to run prices back to 1833 and obtain price data for a longer period.
Yorkshire	1833-1913	As for "Northeast".
South Wales	1833-1913	As for "Northeast".
France		All coal price information at the regional level (departments) was gathered in France. Direction des Mines, *Statistique de l'Industrie Minérale*, from 1853 onwards. We also chose three main coal producing departments, Loire, Nord and Pas-de-Calais, in which the trade with Paris was well established. See section I for references relating to this matter.
Regions (departments)	1853-1913	27-region classification of pithead prices. In the *Statistique de l'Industrie Minérale*, France is divided into 44 departments. However, price information was no longer available for 10 departments after the Franco-Prussian War of 1870-1871 (Ain, Alpes (Basses), Aude, Bouches-du-Rhône, Dordogne, Drôme, Mosselle, Rhin (Bas), Vaucluse and Vosges); and information for seven further departments is very incomplete (Calvados, Côte-d'Or, Pyrénées (Basses), Pyrénées (Hautes), Savoie, Savoie (Haute), and Var). See section I for the implications. Regions: Allier, Alpes (Hautes), Ardèche, Aveyron, Cantal, Corrèze, Creuse, Gard, Hérault, Isère, Loire, Loire (Haute), Loire Inférieure, Lot, Maine-et-Loire, Mayenne, Nièvre, Nord, Pas-de-Calais, Puy-de-Dôme, Rhône, Saône (Haute), Saône-et-Loire, Sarthe, Sèvres (Deux), Tarn, and Vendée. Interpolations: 11missing observations scattered across four series (Creuse, Loire Inférieure, Puy-de-Dome and Sarthe).
Loire	1853-1911	*Statistique de l'Industrie Minérale*
Nord	1853-1911	*Statistique de l'Industrie Minérale*
Pas-de-Calais	1853-1911	*Statistique de l'Industrie Minérale*
Paris	1853-1911	Average of four available long-term retail price series, as reported by Singer-Kerel, *La coût de la vie*, pp. 346-7, 474-80. Price series: Lycee Louis-le-Grand; Assistance Publique, charbon de terre; Economat No. 1; Assistance Publique, tout venant.
Belgium		All coal price information at the level of the three main Belgian provinces was gathered in Belgium. Ministère de l'Industrie et du Travail, *Annales des Mines*, from 1851 onwards. We also chose the main coal producing region of Hainaut, in which the trade with Ghent was well established. See section I for references relating to this matter.
Regions (provinces)	1851-1913	Three-region classification of pithead prices. *Annales des Mines* Regions: Hainaut, Namur and Liége.
Hainaut		*Annales des Mines*
Ghent	1851-1913	Retail coal prices facing textile workers. GPIH group, *Consumer prices.*
Germany		German mineral statistics provide pithead prices by region and by ownership, either state or private, from 1881 onwards (reproduced in the source cited below). However, information aggregated at this level ceases in 1900. A complementary dataset on long-term (1880-1913) pithead price series focuses on the two principal coal

		basins, the Ruhr and Upper Silesia, and provides pithead prices taken from the intermediate market in the nearest city to main producing areas. For the Ruhr, we chose the most complete price series, corresponding to Dortmund (two different coal price series), Düsseldorf (three different coal price series) and Essen (four different coal price series). (See also section I for references relating to this matter). Further reported series for Cologne, were very incomplete. One price series is provided for Upper Silesia, corresponding to Breslau (the capital city of Silesia). We also use these series for the Ruhr and Upper Silesia (individually) to compare them with available wholesale prices of Ruhr and Upper Silesian coal in two principal consuming cities, Berlin (at rail yards) and Hamburg (at dock). See above, section I for references relating to this matter.
Regions	1881-1900	12-region classification of pithead prices. 1881-1890: Germany. Kaiserliches Statistisches Amt, *Vierteljahrshefte zur Statistik*, 1892, pp. 48-53. 1891-1900: Wright, *Coal mine labor*, pp. 281-3. Regions, privately owned mines: Inde und Worm, Lower Silesia, Rhenisch Westfalen, Saar, Saxony, Upper Bayer, Upper Silesia, and Wettin; state owned mines: Saar, Saxony, Upper Silesia, and Wettin.
Ruhr	1880-1913	Average of nine pithead price series for nearest cities to producing areas; Dortmund (2), Düsseldorf (3) and Essen (4). Germany. Kaiserliches Statistisches Amt, Vierteljahrshefte zur Statistik. Interpolations: Two missing observations were interpolated in one series for Essen.
Dortmund	1880-1913	Pithead prices Kaiserliches Statistisches Amt, *Vierteljahrshefte zur Statistik*.
Düsseldorf	1880-1913	Pithead prices Kaiserliches Statistisches Amt, *Vierteljahrshefte zur Statistik*.
Essen	1880-1913	Pithead prices Kaiserliches Statistisches Amt, *Vierteljahrshefte zur Statistik*.
Upper Silesia (Breslau)	1880-1913	Pithead prices Kaiserliches Statistisches Amt, *Vierteljahrshefte zur Statistik*.
Berlin	1880-1913	Wholesale prices, at rail yards, of Ruhr and Upper Silesian coal. Kaiserliches Statistisches Amt, *Vierteljahrshefte zur Statistik*.
Hamburg	1880-1913	Wholesale prices, at dock, of Ruhr coal. Kaiserliches Statistisches Amt, *Vierteljahrshefte zur Statistik*.
International market		
		Prices are expressed in grams of silver per metric ton. See section I for an explanation of the conversion procedure.
Export points, Britain		We use f.o.b. prices at two English ports and one Welsh as export point prices. See section I for the choice of these ports (according to the import points of British coal).
Newcastle	1850-1913	1850-1902: United Kingdom. Board of Trade, *Report*, pp. 14-7. 1903-1913: United Kingdom. Mines Department, *Mines and Quarries.*
Sunderland	1880-1909	1880-1902: United Kingdom. Board of Trade, *Report*, pp. 14-7. 1903-1913: United Kingdom. Mines Department, *Mines and Quarries.*
Cardiff	1880-1913	1880-1902: United Kingdom. Board of Trade, *Report*, pp. 14-7. 1903-1913: United Kingdom. Mines Department, *Mines and Quarries.*

Import points, Germany		We use three available series of British coal in Hamburg, the main port of entry of British coal in Germany. See sections I and IV for references relating to this matter.
Hamburg	1850-1913	Wholesale prices, at dock, of English (Newcastle, 1880-1913, Sunderland, 1880-1909, Northeast, 1850-1913) coal. Kaiserliches Statistisches Amt, *Vierteljahrshefte zur Statistik*; Jacobs and Richter, *Grosshandelspreise in Deutschland*, pp. 62-63. See also Klovland, 'Commodity'.
Import points, France		French statistics report wholesale prices (up to 1908) at a higher spatial level of disaggregation than in the case of pithead prices: 89 departments. From these, we chose four departments that qualify both for main import points and consuming areas of British coal, according to the procedure explained in section I.
Ille et Vilaine	1853-1908	Wholesale prices. *Statistique de l'Industrie Minérale* Interpolations: The year 1859 was interpolated.
Loire Inférieure	1853-1908	Wholesale prices. *Statistique de l'Industrie Minérale* Interpolations: The year 1859 was interpolated.
Charente Inférieure	1853-1908	Wholesale prices. *Statistique de l'Industrie Minérale* Interpolations: The year 1859 was interpolated.
Gironde	1853-1908	Wholesale prices. *Statistique de l'Industrie Minérale* Interpolations: The year 1859 was interpolated.
Import points, Southern Europe		We use available evidence for the price of British coal at import points for three Southern European countries. In our international comparison of national coal prices (Table 3), we use a further price series for Italy that covers for a more extensive set of origins of imported coal.
Spain	1880-1913	Average price of British coal at the ports of Bilbao, Cádiz and Barcelona. Coll and Sudrià, *Carbón*, pp 437-8.
Portugal	1880-1913	Price of imported coal from Britain shipped to Lisbon. Henriques, 'Energy', pp. 144, 302-3. Interpolations: five missing observations were interpolated in the series used in Table 4.
Italy, Genoa	1880-1913	British coal, exported from Cardiff, at the port of Genoa. Cianci, *Dinamica dei prezzi*, pp. 304-8 (series c).
Italy	1880-1913	British and German coal. Italy. Istituto Centrale di Statistica, *Sommario di Statistiche*, p. 194.

Table A.I.b. Exports

COUNTRY	PERIOD	SOURCE
Britain		
Exports to France	1856-1913	1856-1896: United Kingdom. Board of Trade (-1871) and Customs Establis *Statement of the Trade and Navigation.* 1897-1911: United Kingdom. Parliament, *Statist* 1913: Parliament, *Statistical Tables*, p. 42.
Exports to Belgium	1856-1913	1856-1913: United Kingdom. Board of Trade (-1871), Customs Establishment (1 Labour and Statistical Department (1909-1910) and Commercial Department (1911-191 *the Trade and Navigation*.
Exports to Germany	1856-1913	1856-1896: United Kingdom. Board of Trade (-1871) and Customs Establis

		Statement of the Trade and Navigation. 1897-1911: United Kingdom. Parliament, *Statistical Tables*, p. 37. 1912-1913: Parliament, *Statistical tables*, p. 41.
Exports to Italy	1870-1913	Palmer, 'British coal export', pp. 353-4, and, from 1897 onwards, United Kingdom, Parliament, *Statistical Tables*.
Exports to Spain	1870-1913	Palmer, 'British coal export', pp. 353-4, and, from 1897 onwards, United Kingdom, Parliament, *Statistical Tables*.
Exports to Portugal	1870-1913	Palmer, 'British coal export', pp. 353-4, and, from 1897 onwards, United Kingdom, Parliament, *Statistical Tables*.
Belgian-French trade		
Belgian exports	1811-1913	1811-1903: Wright, *Coal mine labor*, pp. 193-4. 1904-1913: France. Direction des Mines, *Statistique de l'Industrie Minérale*.
French exports	1836-1913	1836-1903: Wright, *Coal mine labor*, pp. 195-6. 1904-1913: France. Direction des Mines, *Statistique de l'Industrie Minérale*.
German-Belgian trade		
German exports	1861-1913	1861-1896: Wright, *Coal mine labor*, pp. 297. 1897-1911: United Kingdom. Parliament, *Statistical Tables*, p. 41. 1912-1913: Parliament, *Statistical Tables*, p. 48.
Belgian exports	1861-1913	Belgium. Ministère des Finances et des Travaux Publics. *Tableau Général du Commerce*.
German-French trade		
German exports	1811-1913	1837-1903: Wright, *Coal mine labor*, pp. 193-4. 1904-1911: United Kingdom. Parliament, *Statistical Tables*, p. 41. 1912-1913: Parliament, *Statistical Tables*, p. 48.
French exports	1837-1913	1837-1903: Wright, *Coal mine labor*, pp. 195-6. 1904-1913: France. Direction des Mines, *Statistique de l'Industrie Minérale*.

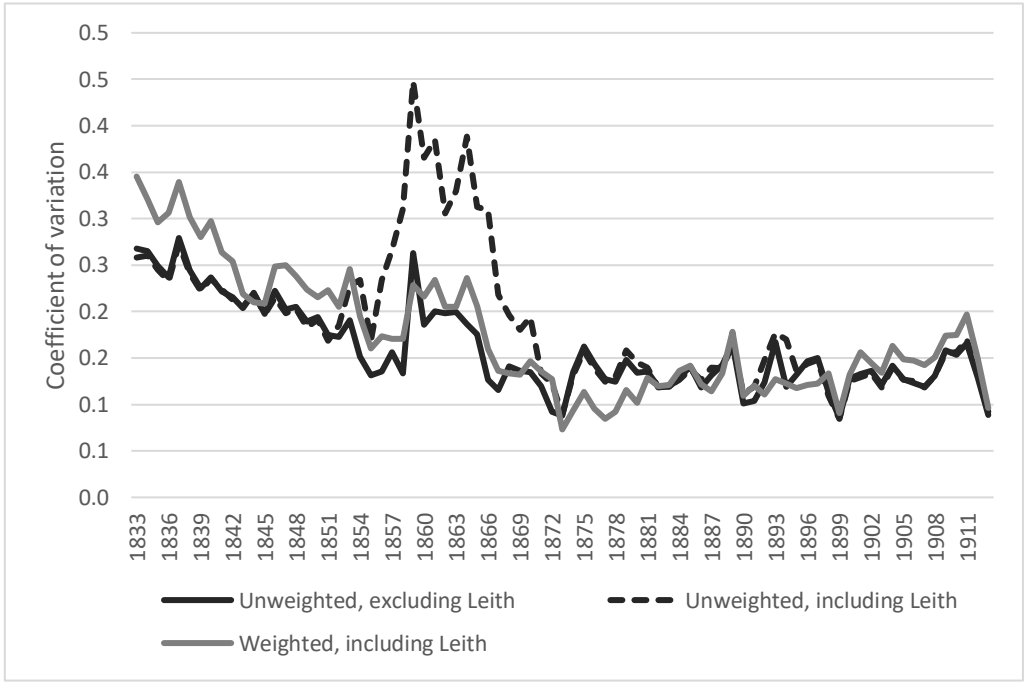
Table A.I.c. Explanatory variables of the model on the causes of international market integration

	PERIOD	SOURCE
Freight rates from Britain (Appendix VII and Tables 6 and 7)		
Welsh ports to Bordeaux	1838-1913	Harley, 'Coal exports', pp. 334-6.
Newcastle to Hamburg and Le Havre	1850-1913	Average. Harley, 'Coal exports', pp. 334-6.
Welsh ports to Genoa	1839-1913	Harley, 'Coal exports', pp. 334-6.
Cardiff to Lisbon	1883-1913	Jevons, *Coal* question, p. 692.
Newcastle to Bilbao, Cádiz and Barcelona	1870-1913	Average. Coll and Sudrià, *Carbón*, pp 437-8.
Tariffs		See the *Notes* to Table 6.
British export duty	1850-1913	See also Church, *British coal*, pp. 65-6.
France	1853-1908	See also Crouzet, 'Charbon anglaise', p. 176.
Spain	1880-1913	See also Coll and Sudrià, *Carbón*, pp 437-8.
Others		See the *Notes* to Table 6.
[Ruhr] Cartel	1850-1913	

Telegraph	1850-1913	See also footnote 129.
1873 Crisis	1850-1913	

Notes: Data are available from the corresponding author upon request.

Appendix II. Trends in the coefficient of variation. British ports



Notes: F.o.b prices. In the weighted price series, prices are weighted by tonnage handled annually.
Sources: Appendix I.

Appendix III. International coal trade

Table A.III.a. British exports to the other coal producing countries

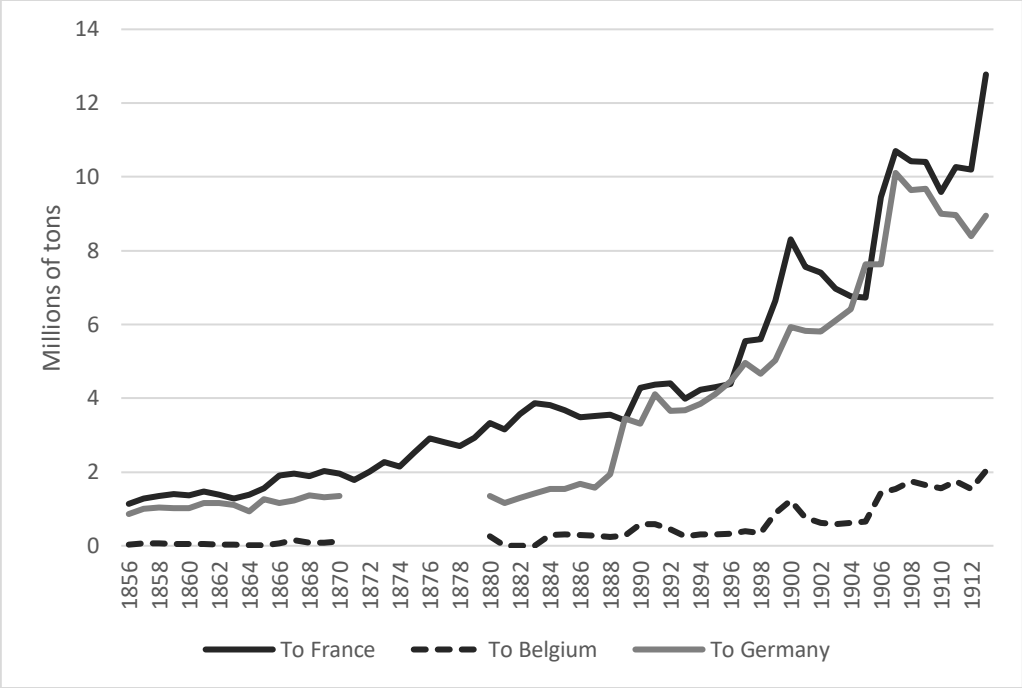


Table A.III.b. Belgian-French trade

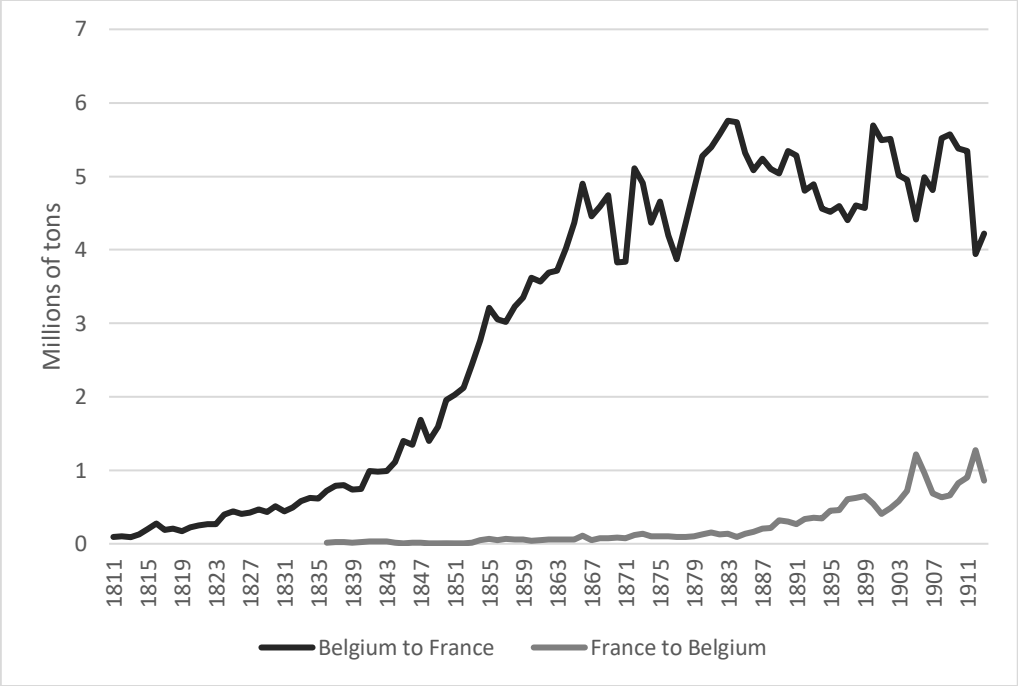


Table A.III.c. German-Belgian trade

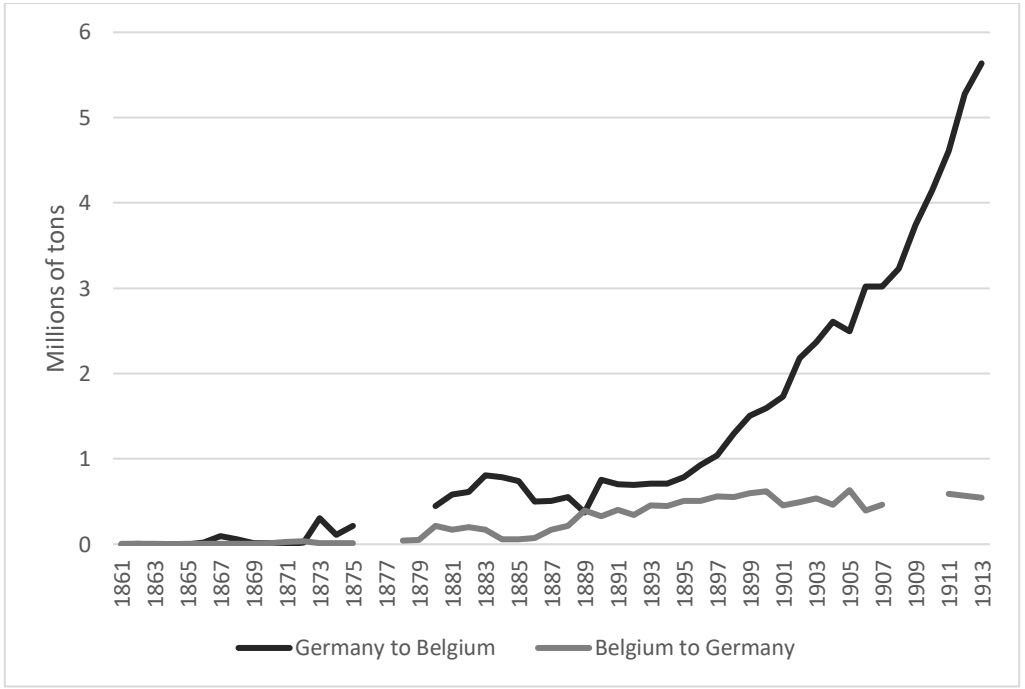


Table A.III.d. German-French trade

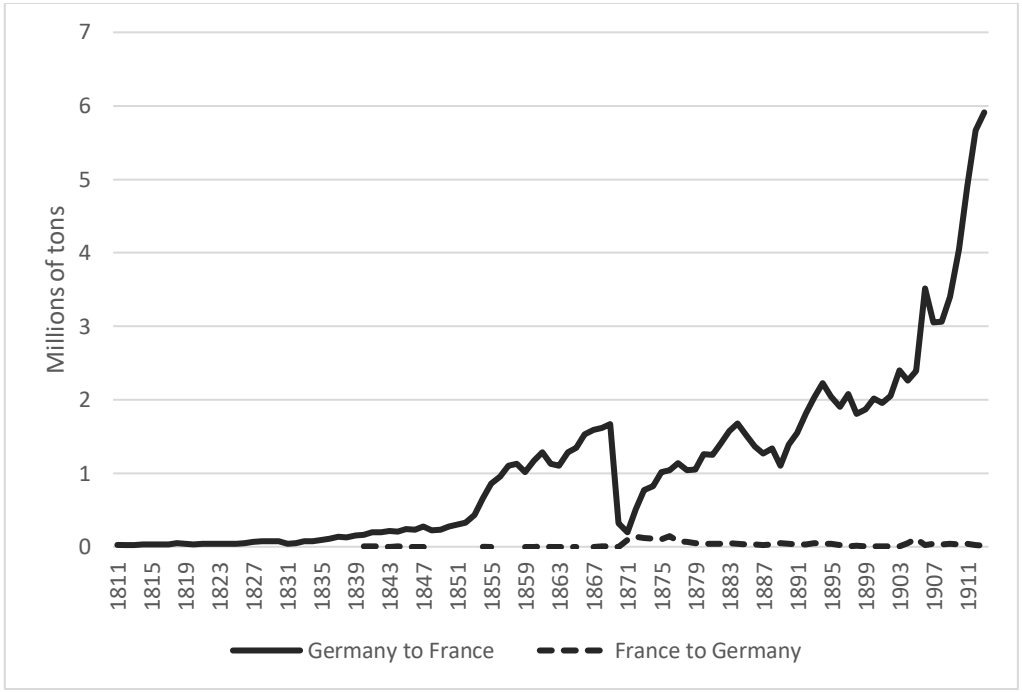
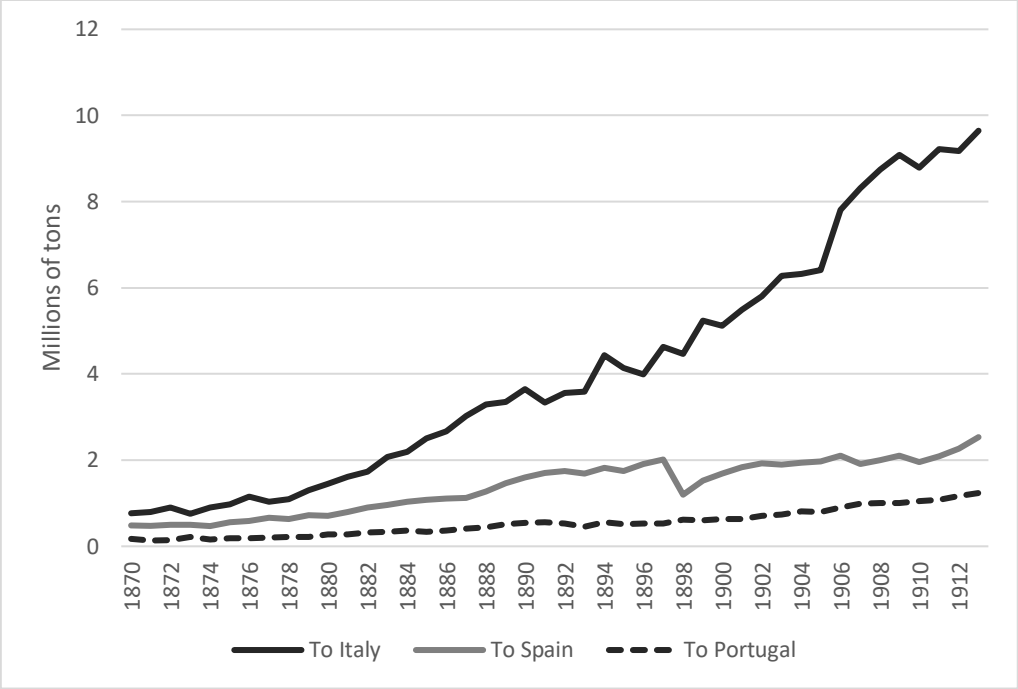


Table A.III.e. British exports to Southern European countries



Notes: Table A.III.b includes lignite.
Sources: Appendix I.

Appendix IV. Augmented Dickey-Fuller (ADF) test for unit roots.
Coefficient of variation, domestic markets

	Period	Intercept		Intercept and trend	
		Levels	First differences	Levels	First differences
Britain					
Regions	1882-1913	-2.27	-7.31**	-2.00	-7.33**

Ports (weighted)	1833-1913	-2.36	-9.91**	-2.71	-9.89**
France					
Regions	1853-1913	-1.89	-5.94**	-2.36	-6.02**
Belgium					
Regions	1851-1913	-0.40	-6.31**	-2.58	-6.30**
Germany					
Regions	1881-1900	-0.22	-2.91 †	-2.74	-2.88
Ruhr	1880-1913	-1.44	-5.94**	-2.73	-5.92**

Notes: † = significant at 0.10 level; ** at 0.01 level. The number of lags of the dependent variable was determined by the Akaike Information Criterion (AIC).

Appendix IX. Variance analysis, international market. Producing countries

Table A.IX.a. Britain, f.o.b.; France, pithead; Belgium, pithead

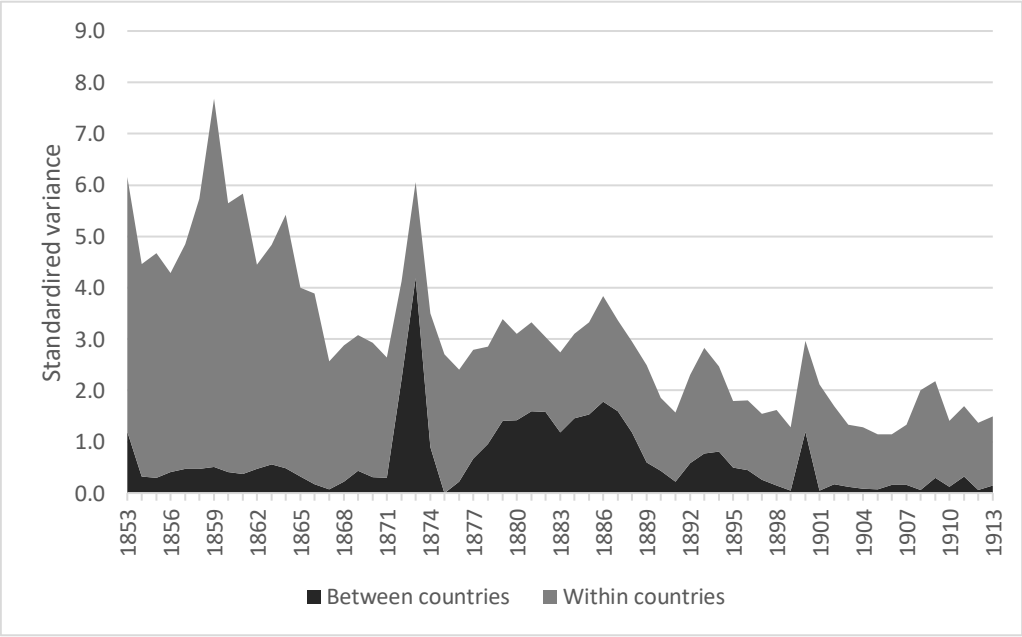
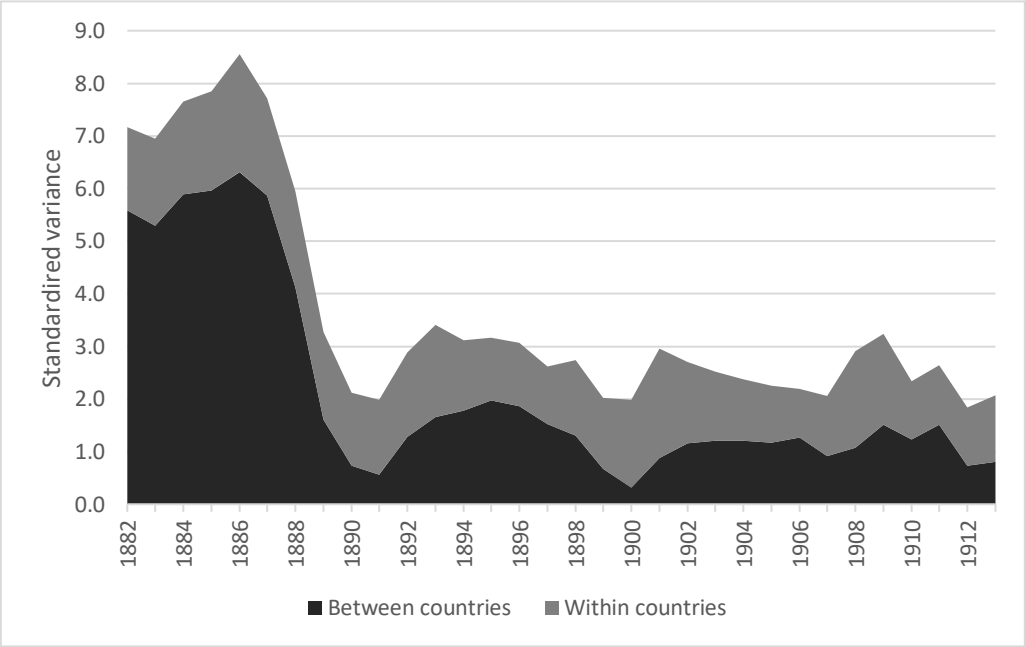


Table A.IX.b. Britain, France, Belgium and Germany, Ruhr, all pithead



Notes: See the text (section I) for currency conversion criteria. Evolution of the contribution of each component, within and between countries, to total standardized variance.
Sources: Appendices I and VIII.

Appendix V. Structural breaks

Table A.V.a. Dates and type of structural breaks

	Period	No. of years	No. of markets	No. of breaks (jump > 10 percent)		Break dates	
				Upward shock	Downward shock	Upward shock	Downward shock
Domestic markets							

-Price gaps-							
Britain							
London-Northeast	1833-1913	81	2	-	-	-	-
London-Yorkshire	1833-1913	81	2	-	2	-	1872, 1890
London-South Wales	1833-1913	81	2	-	2	-	1845, 1889
France							
Paris-Loire	1853-1911	59	2	-	2	-	1872, 1880
Paris-Nord	1853-1911	59	2	-	2	-	1865, 1873
Paris-Pas-de-Calais	1853-1911	59	2	-	3	-	1866, 1891, 1899
Belgium							
Ghent-Hainaut	1851-1913	63	2	-	-	-	-
Germany							
Berlin-Ruhr							
Berlin-Dortmund	1880-1913	34	2	-	2	-	1889, 1900
Berlin-Düsseldorf	1880-1913	34	2	-	1	-	1889
Berlin-Essen	1880-1913	34	2	-	1	-	1889
Hamburg-Ruhr							
Hamburg-Dortmund	1880-1913	34	2	1	1	1906	1901
Hamburg-Düsseldorf	1880-1913	34	2	-	1	-	1889
Hamburg-Essen	1880-1913	34	2	-	1	-	1889
Berlin-Upper Silesia	1880-1913	34	2	-	2	-	1890, 1908
-Coefficient of variation-							
Britain							
Regions	1882-1913	32	10	2	-	1888, 1899	-
Ports (weighted)	1833-1913	81	16	4		1846, 1859, 1881, 1900	-
France							
Regions	1853-1913	61	27	1	-	1898	-
Belgium							
Regions	1851-1913	63	3	1	-	1878	-
Germany							
Regions	1881-1900	20	12	-	-	-	-
Ruhr	1880-1913	34	9	2	-	-	1891, 1900
International market							
-Price gaps-							
Germany-England							
Hamburg-Newcastle	1880-1913	34	2	1	-	1893	
Hamburg-Newcastle	1880-1909	30	2	1	-	1902	

France-England							
Ille et Vilaine-Newcastle	1853-1908	56	2	-	2	-	1872, 1900
Loire Inférieure-Newcastle	1853-1908	56	2	-	2	-	1865, 1873
Charente Inférieure-Newcastle	1853-1908	56	2	-	-	-	-
Gironde-Newcastle	1853-1908	56	2	-	1	-	1872
France-Wales							
Ille et Vilaine-Cardiff	1853-1908	56	2	-	3	-	1864, 1872, 1900
Loire Inférieure-Cardiff	1853-1908	56	2	-	2	-	1864, 1872
Charente Inférieure-Cardiff	1853-1908	56	2	-	1	-	1864
Gironde-Cardiff	1853-1908	56	2	-	2	-	1863, 1872
Southern Europe-Wales							
Bilbao, Cádiz, Barcelona-Cardiff	1880-1913	34	2	-	-	-	-
Lisbon-Cardiff	1880-1913	34	2	1	1	1901	1889
Genoa-Cardiff	1880-1913	34	2	-	1	-	1890

Notes: Breaks, as detected by the Bai-Perron test, in which the jump exceeds the 10 percent of the last year of the previous trend. The natural logarithm of either the price gap or the coefficient of variation price is regressed on the time trend. The regression model allows for serial correlation.

Table A.V.b. Pace of convergence between endogenously selected breaks

	Sub-period	No. of years	Initial value (fitted)	Rate of change
Domestic markets				
-Price gaps-				
Britain				
London-Northeast	-	-	3.68	-
London-Yorkshire				
	1833-1871	39	2.61	-0.0027 †
	1872-1889	18	1.64	0.0177**
	1890-1913	24	1.33	0.0014

London-South Wales				
	1833-1844	12	3.07	-0.0119
	1845-1888	44	2.28	-0.0055**
	1889-1913	25	1.08	-0.0038
France				
Paris-Loire				
	1853-1871	19	3.00	-0.0151**
	1872-1879	8	1.87	-0.0135
	1880-1911	32	1.62	-0.0076**
Paris-Nord				
	1853-1864	12	2.03	0.0104*
	1865-1872	8	2.00	0.0215
	1873-1911	39	2.60	-0.0068*
Paris-Pas-de-Calais				
	1853-1865	13	1.56	0.0306***
	1866-1890	25	1.73	0.0175***
	1891-1898	8	2.24	0.0177 †
	1899-1911	13	2.00	-0.0171*
Belgium				
Ghent-Hainaut	-	-	1.40	-
Germany				
Berlin-Ruhr				
Berlin-Dortmund				
	1880-1888	9	1.27	0.0376***
	1889-1899	11	1.15	0.0124
	1900-1913	14	0.86	0.0013
Berlin-Düsseldorf				
	1880-1888	9	1.94	-0.0008
	1889-1913	25	1.33	-0.0119**
Berlin-Essen				
	1880-1888	9	1.85	0.0046
	1889-1913	25	1.39	-0.0071 †
Hamburg-Ruhr				
Hamburg-Dortmund				
	1880-1900	21	0.92	-0.0096
	1901-1905	5	0.33	0.0347
	1906-1913	8	0.51	-0.0663 †
Hamburg-Düsseldorf				

	1880-1888	9	1.30	-0.0006
	1889-1913	25	0.89	-0.0219**
Hamburg-Essen				
	1880-1888	9	1.24	0.0059
	1889-1913	25	0.94	-0.0148*
Berlin-Upper Silesia				
	1880-1889	10	1.87	-0.0315***
	1890-1907	18	1.24	-0.0190***
	1908-1913	6	0.68	-0.0035
-Coefficient of variation-				
Britain				
Regions				
	1882-1887	6	0.14	-0.0296
	1888-1898	11	0.17	-0.0448**
	1899-1913	15	0.15	-0.0110
Ports (weighted)				
	1833-1845	13	0.36	-0.0408***
	1846-1858	13	0.26	-0.0359***
	1859-1880	22	0.24	-0.0500***
	1881-1899	19	0.13	-0.0073
	1900-1913	14	0.15	0.0013
France				
Regions				
	1853-1897	45	0.29	-0.0131***
	1898-1913	16	0.18	-0.0119 †
Belgium				
Regions				
	1851-1877	27	0.27	-0.0286***
	1878-1913	36	0.19	-0.0339***
Germany				
Regions	-	-	0.27	-
Ruhr				
	1880-1890	11	0.15	-0.0195
	1891-1899	9	0.15	-0.0544**
	1900-1913	14	0.15	-0.0564***
International market				
-Price gaps-				
Germany-England				

Hamburg-Newcastle				
	1880-1892	13	0.98	-0.0360**
	1893-1913	21	0.75	-0.0139*
Hamburg-Sunderland				
	1880-1901	22	0.74	-0.0125 †
	1902-1909	8	0.64	0.0199
France-England				
Ille et Vilaine-Newcastle				
	1853-1871	19	2.23	0.0043
	1872-1899	28	1.48	0.0184**
	1900-1908	9	1.64	-0.0199
Loire Inférieure-Newcastle				
	1853-1864	12	2.21	-0.0109
	1865-1872	8	1.82	-0.0316
	1873-1908	36	1.16	0.0069 †
Charente Inférieure-Newcastle	-	-	2.73	-
Gironde-Newcastle				
	1853-1871	19	2.68	-0.0277***
	1872-1908	37	1.13	0.0078
France-Wales				
Ille et Vilaine-Cardiff				
	1853-1863	11	1.57	0.0217 †
	1864-1871	8	1.67	0.0079
	1872-1899	28	1.15	0.0095
	1900-1908	9	0.96	-0.0351*
Loire Inférieure-Cardiff				
	1853-1863	11	1.55	0.0053
	1864-1871	8	1.22	-0.0030
	1872-1908	37	0.89	-0.0055
Charente Inférieure-Cardiff				
	1853-1863	11	2.63	-0.0182
	1864-1908	45	1.44	-0.0184***
Gironde-Cardiff				
	1853-1862	10	2.32	-0.0426***
	1863-1871	9	1.27	0.0147
	1872-1908	37	0.85	-0.0014

Southern Europe-Wales				
Bilbao, Cádiz, Barcelona-Cardiff	-	-	1.06	-
Lisbon-Cardiff				
	1880-1888	9	0.96	-0.0356
	1889-1900	12	0.31	-0.1330*
	1901-1913	13	0.32	-0.1019*
Genoa-Cardiff				
	1880-1889	10	1.53	-0.0332**
	1890-1913	24	0.86	0.0091 †

Notes: Sub-periods between breaks reported in table A.V.a. The initial, fitted, value for series that display no structural breaks corresponds to 1833 for London-Northeast; 1851 for Ghent-Hainaut; 1881 for Germany, Regions; 1853 for Charente Inférieure-Newcastle; and 1880 for Bilbao, Cádiz, Barcelona-Cardiff. The rate of change refers to the estimated coefficient of the time trend—in an equation in which the natural logarithm of either the price gap or the coefficient of variation is regressed on the time trend. † = significant at 0.10 level; * at 0.05 level; ** at 0.01 level; *** at 0.001 level.

Appendix VI. Trends in the coefficient of variation within countries

Table A.VI.a. Britain, (regional) pithead prices and f.o.b prices at ports

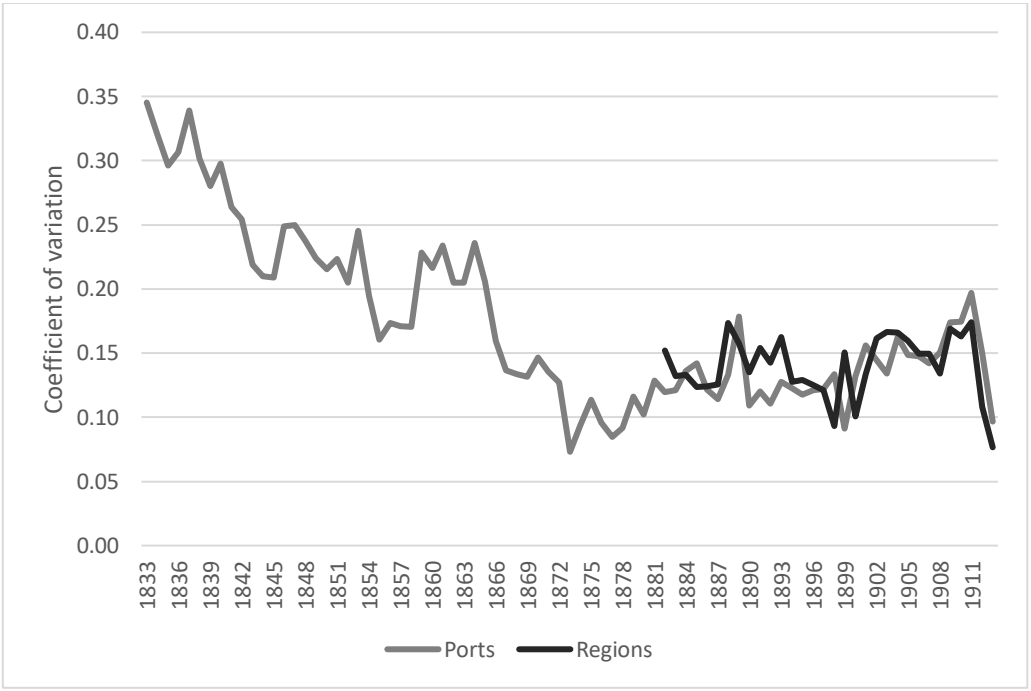


Table A.VI.b. France and Belgium, pithead prices

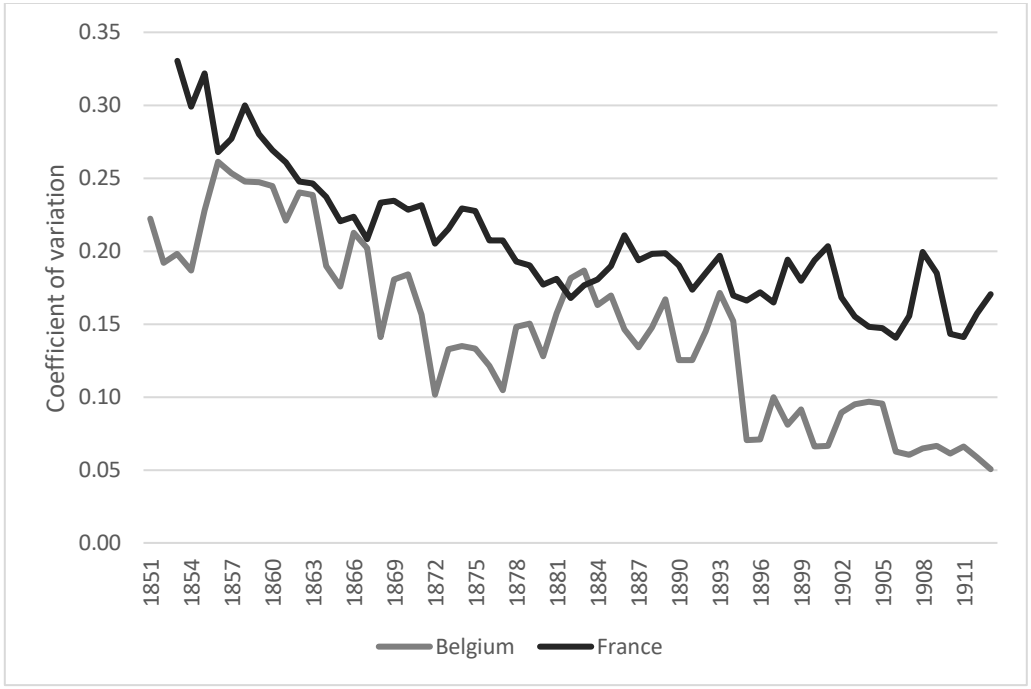
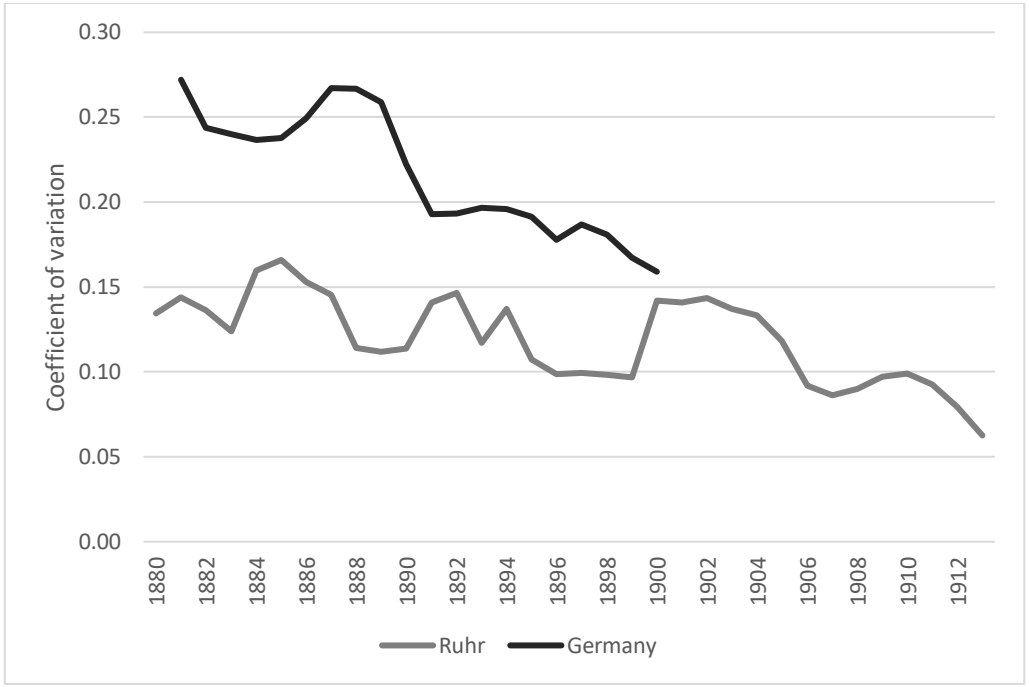


Table A.VI.c. Germany and Ruhr, pithead prices



Notes: Prices at British ports (table a) are weighted by tonnage handled annually. The coefficient of variation of our series for the whole of Germany (table c) at the start of the period covered by available data is higher than for the other countries. This may have been due to the uneven nature of the process of integration within Germany until the 1880s, as explained in section II.
Sources: Appendix I.

Appendix VII. Freight rates from Britain

Table A.VII.a. France and Germany

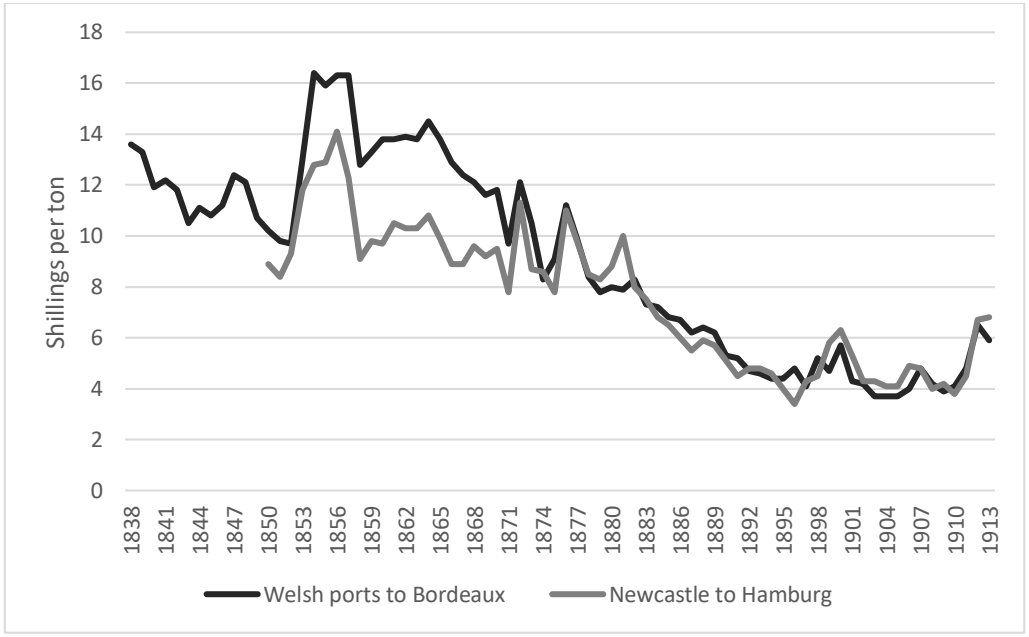
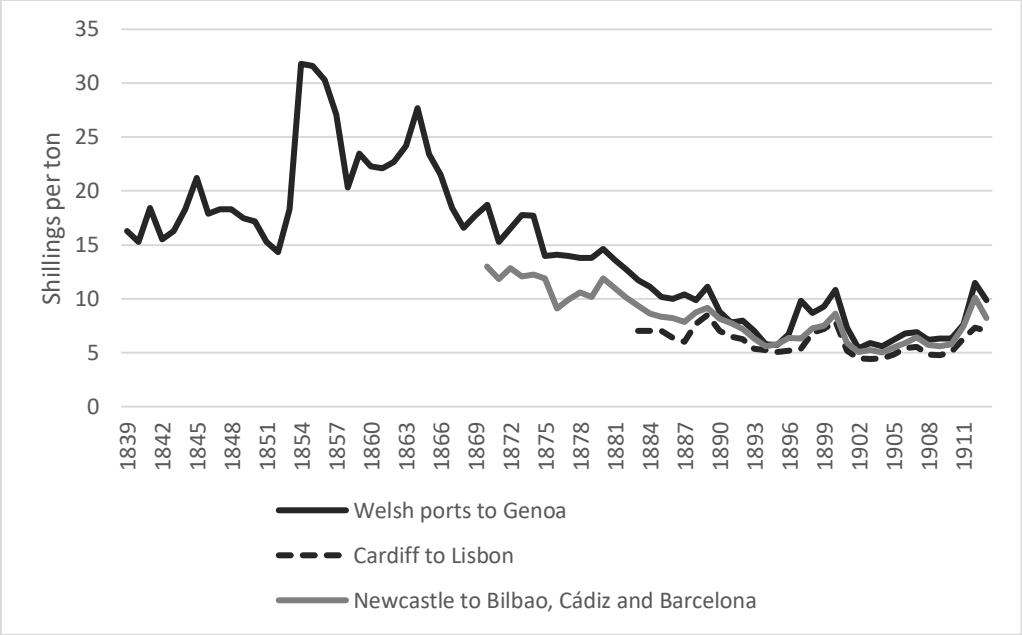
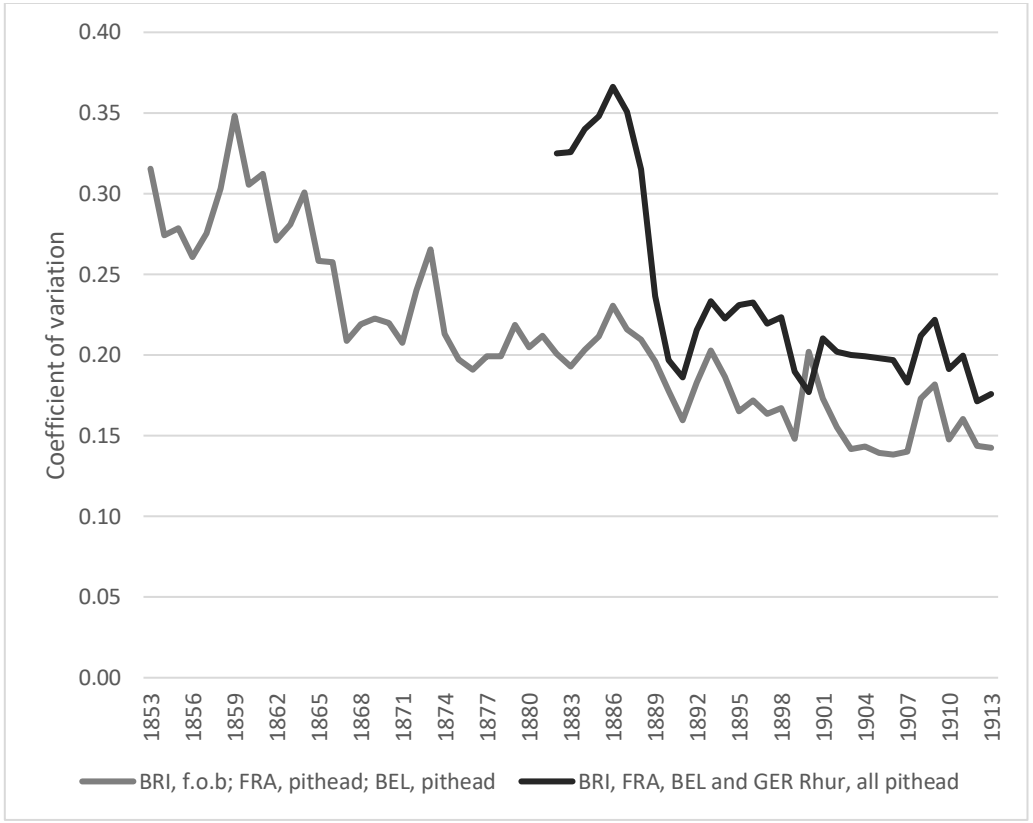


Table A.VII.b. Italy, Spain and Portugal



Notes: Le Havre as a destination point is included in 'Newcastle to Hamburg'.
Sources: Appendix I.

Appendix VIII. The coefficient of variation in the international market. Producing countries



Notes: See the text (section I) for currency conversion criteria. Each of the two series is comprised of a time-invariant set of markets, and refers to a different combination of available data, as introduced in Appendix VI. The main difference results from the substitution of f.o.b prices for pithead prices in Britain, which leads to a higher coefficient of variation. In order to confirm both the effect of replacing British f.o.b prices with pithead prices, and the evolution of overall price dispersion, we used two further series—available upon request—that yielded similar trends.
Sources: Appendix I.