Commodity market integration 1850 - 1913: Evidence from Britain and Germany

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Abstract

In a sample that contains annual prices of 39 selected commodities in Britain and Germany in the period 1850 to 1913 substantial evidence of well integrated commodity markets is found. The degree of integration is not universal across markets and varies over time, however. Absolute price variability was in general decresing over the period, indicating more closely integrated markets. But the reintroduction of tariffs in Germany beginning in 1879 implied that this trend was broken for a number of commodities. Nevertheless, once the impact of tariffs is accounted for, grain market prices are well synchronized. In contrast, markets for animal foodstuffs appear not to be integrated, which is to be expected given the existence of non-tariff barriers affecting meat and livestock markets. The price movements of non-ferrous metals, many textiles and some other raw materials are in accordance with the law of one price. The speed of adjustments of prices, measured by estimates of the half-life of LOP deviations, is a little more than one year, which is substantially lower than what is found in many other studies of market integration.

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1 Introduction

Between 1850 and 1913 the German and British economies showed considerable convergence with respect to income levels and manufacturing productivity. In contrast to the situation in the 1850s, Germany had become, on the eve of the of great war, a major competitor to Britain on the world's export markets for manufactures.[1] On the financial side, however, markets were not fundamentally changed; the capital of the house of Rothschild was flowing as easily between London, Frankfurt, Paris and Vienna in 1850 as it did sixty years later.[2] But what characterized North European commodity markets - to what extent were they integrated by 1850 and how did they develop towards the war? This paper brings new empirical evidence on commodity market integration between Germany and Britain to shed some light on this issue.

The degree of commodity market integration is affected by numerous factors, including barriers to trade and capital flows, market power as well as transportation and information costs. The latter costs fell over time, but German import duties, after being virtually abolished by the early 1870s, were reintroduced on a large scale and increased in several steps as from 1879.[3] The net effects of these factors may be difficult to quantify directly. One way of obtaining an indirect summary measure of these factors is to exploit the close connection between the concept of market integration and the degree of price dispersion across markets.[4]

The law of one price (LOP) states that once prices are converted to a common currency, each commodity should sell for the same price in each country. If markets become more integrated, we would expect deviations from LOP to decrease. However, testing the absolute version of LOP requires information on local currency prices of (nearly) identical commodities. These are less freely available than price indices; hence most empirical work relates to relative LOP using price index data. Cointegration and other time series methods can be employed to shed light on such issues as how closely the price levels move together over time and how fast price index differentials vanish when shocks to relative prices occur. These are important aspects of market integration, but because indices give no information on the *level* of prices, the studies of *relative* LOP miss one key aspect of the market integration issue: how large are *absolute price gaps* and how do they evolve over time? In fact, relative LOP might be rejected in a case where the absolute price gap falls over time, due to the fact that there was a transition from an initially segmented to eventually an integrated market.[5]

Few propositions in economics have engendered more empirical research than the law of one price and its extension to the aggregate level, purchasing power parity (PPP).[6] There now seems to be a consensus that, in general, a systematic convergence toward PPP can be expected to occur, but only in the very long run. This conclusion is less controversial now than a decade ago, to some extent due to the proliferation of studies using long-horizon data sets spanning a

[1] Fremdling (1991); Broadberry (1997).
[2] Ferguson (2000).
[3] Bairoch (1989); O'Rourke and Williamson (1999).
[4] Knetter and Slaughter (2000).
[5] This point is emphasized by O'Rourke and Williamson (1999) and Knetter and Slaughter (2000).
[6] See for example Froot and Rogoff (1995), Rogoff (1996) and Taylor (2000) for a review of the empirical literature.

century, which significantly increases the power of the statistical tests. The conventional view of the speed of convergence to PPP is that it is surprisingly low, however, as deviations from PPP seem to damp out slowly, typically at a rate of 15 per cent per year.[7] This implies that the expected time period it takes for a deviation from PPP to decay by 50 per cent is more than 4 years. Similar empirical regularities have been established with respect to the speed at which price differentials return to their long-run level (relative LOP) using data from the more recent years. Cases where it has been convincingly established that LOP shocks damp out very quickly are few.[8]

Evidence from empirical studies of PPP using data from 19th century metallic standard periods gives some support to the hypothesis that the speed of adjustment was reasonably high during this fixed exchange rate era, although the most striking impression left by these studies is how well models estimated with 19th century data fit the experience of the 20th century. Diebold et al. (1991) and Lothian and Taylor (1996) estimated half-life of shocks of 2.5 to 3 years in bilateral sterling, French franc and German mark real exchange rates, but, interestingly, somewhat more for European currencies against the US dollar. The greenback period 1862-1879 is one crucial difference between intra-European and European-US exchange rates that could contribute to an explanation of this fact. This is consistent with the findings of Taylor (2000), who estimated half-lives of 2.5 for Germany and 3.1 years for the UK against the US dollar over the period 1870 - 1914. Using a century of data from Britain and Norway beginning 1870, Edison and Klovland (1987) found evidence of long-run PPP yielding half-life estimates of about 3 years when different short-run dynamics during the 1914-1928 period of fluctuating krone-sterling exchange rate was accounted for; moreover, in a specification that allowed for secular changes in the terms of trade and productivity levels the speed of adjustment increased substantially, to a little over one year. What these studies show is that deviations from PPP are quite persistent, yet systematically influenced by mean-reverting influences that drive aggregate price levels, converted to a common currency, back to equilibrium. In a general sense, this supports the notion that in a long-run perspective the international markets for goods have been fairly well integrated (in the weaker mean-reversion sense) over the past two centuries, but that the mechanisms of goods arbitrage are operating slowly.

This conclusion is useful as a general starting point for the analysis of goods market integration, but it does not lead us very far. Aggregating the prices of all goods into one single price index and comparing the course of the real exchange rate may draw a veil over many of the issues underlying the analysis of market integration that are of interest to economic historians. We would like to know more specifically *which* commodity markets were integrated and which were not, both from the point of view of absolute price differentials and in the weaker sense of co-movement of prices. It is also of importance to know what the likely causes of various aspects of non-integration were: transportation costs, tariffs, non-tariff barriers, information costs or non-competitive price behaviour. Such information requires the analysis of individual price series rather than aggregates; hence the law of one price rather than purchasing power parity

[7] Rogoff (1996).

[8] Goldberg and Verboven (2001), using a carefully selected sample of European car prices for the period beginning in 1970, report considerably lower half-life estimates, appoximately 1.5 years for relative LOP.

should be the focus of the analysis.

This paper makes an attempt at examining the comparative behaviour of individual commodity prices in Britain and Germany during the period 1850 - 1913 across a wider range of commodities than has been done in the past. Extending the range of commodities to 39, which is achieved here, is made possible by matching the fairly rich published material on German prices with a data base of unpublished British commodity price series collected from contemporary price currents, newspapers and trade journals.

2 Exchange rate regime and tariff policy

2.1 The exchange rate

By the mid-nineteenth century the London and continental European capital markets were well integrated.[9] Britain was on a gold standard and Germany was on a silver standard until 1872, but the sterling-Hamburg banco exchange rate did not fluctuate much during this period. The maximum range of variation of the price of silver in terms of gold in London between 1851 and 1872 was about 3 per cent, ranging from a high of 62.1 in 1859 to a low of 60.3 in 1872.[10] The movements of the market price of silver in terms of gold are indirectly reflected in Figure 1, which shows a German reichsmark-sterling exchange rate index, linked to the Hamburg banco price of sterling for the period before February 1873. Values below par, which is set equal to the 1911-1913 average, imply a weaker pound sterling. The German currency appreciated 3.75 per cent from 1849 to 1853, remained fairly stable during the remainder of the 1850s, before depreciating slightly in the 1860s in line with the silver price. Annual rates of change were small, the largest ones being an appreciation of Hamburg banco in 1853 (1.4 per cent) and a depreciation in 1861 (1.3 per cent). Later, exchange rate movements within the gold standard were of course small; after 1874 annual rates of change were always below 0.4 per cent per year. The financial environment thus represented no obstacle to highly integrated commodity markets; rather, the case of Germany and Britain represents an unusual long period of a practically fixed exchange rate and free capital flows.

2.2 Tariff policy

Table 1 presents an overview of tariff rates applying to the commodities in our sample.[11] In the 1850s only the 'registration duty' on grains and import duties on butter, tallow and timber remained in Britain; these duties were all repealed during the 1860s. Apart from a one year interlude of renewed corn duties in the 1902 budget, and an export duty of coal that was abolished in 1906, no tariffs were imposed on the commodities considered here after the small

[9] Neal (1985).

[10] Soetbeer (1886).

[11] The main sources of tariff data are for Britain: *Customs Tariffs of the U.K., 1800-1897,* British Parliamentary Papers, C. 8706 of 1898; *The Economist*, various issues, notably June 11, 1853 and April 11, 1863; for Germany: Matlekovits (1891), Elster et al. (1926-1927), supplemented by Norwegian Parliamentary Papers, *St. prp. no. 5 (1896)*, and *St. prp. no. 5 (1904/05).*

corn duties were repealed in 1868. Germany had more extensive import duties in the 1850s, but these were reduced and abolished in several steps during the next decades, so that by the late 1870s she was also largely a free trader regarding the range of commodities in focus here.

The invasion of cheap grain from America and Russia, later also from India, Australia and Argentina, was no doubt a crucial factor in the move to reintroduce tariffs on agricultural products. In Germany the year 1879 represents a watershed in trade policy, tariffs were introduced to protect arable agriculture, animal husbandry and iron - creating an 'empire of rye, pork and iron'.[12] Tariff rates were increased in several steps during the 1880s, somewhat lowered in the nineties, but further increased in 1906. By 1913 duty rates as a percentage of market prices were 35 - 40 per cent for cereals, 27 per cent for beef and pork, and 11 per cent in the case of butter and lard. Pig iron and soda were also subjected to duties, amounting to about 13 per cent of the market price. Unlike agricultural products, however, these semi-manufactures were less protected than in the 1850s. In addition, with respect to meat there were non-tariff restrictions of trade that were as important as tariffs in keeping meat prices at a high level in Germany. Germany used health regulations in the 1890s to stop much of the importation of live cattle and hogs. After the turn of the century tariff rates on fresh pork and frozen beef were used as additional measures to protect the domestic meat markets from foreign competition. [13]

The extent to which the imposition of a tariff affects the domestic price of a commodity depends in theory on its elasticities of supply and demand. The effective level of protection is thus an empirical issue to be studied separately in each market. Nevertheless, considering the scale of tariff protection in Germany after 1879 it is reasonable to expect that this raised German prices relative to British. O'Rourke (1997) concluded that wheat tariffs were generally binding, i.e. domestic prices were raised above world prices by the amount of the tariff, but this did not occur with respect to oats and barley until the late 1880s or early 1890s.[14]

3 Absolute price gaps

3.1 The price data

Annual price data of reasonably comparable goods in the two countries have been found for 39 commodities. The sample covers the years from 1850 to 1913. In general, more than one commodity description has been used to form the price series for each good with a view to getting an accurate representation of the price movements over time.[15] In some cases it is possible to find one description that was quoted over the whole period considered here, but often it is the

[12] Webb (1982). For a comparative tariff history of European countries see Bairoch (1989).

[13] Elster et al. (1926-1927, vol. 7, p. 291) state explicitly that these measures were openly used as 'indirektes Schutzmittel'. An overview is given by Webb (1982). Britain did also introduce veterinary restrictions on livestock imports, particularly from European countries (see Perren (1978)), but maintained a large transatlantic trade in frozen and chilled meat.

[14] Webb (1982) also found that wheat and rye prices were significantly affected by tariffs in the period 1872 to 1899, in contrast to some previous research that concluded that wheat tariffs did not affect German prices.

[15] For example, to get a representative time series of the price of butter in Britain, five descriptions are used (two Irish, Dutch, French and Danish), and two domestic butter qualities constitute the German price series.

case that those that were considered the leading ones in the markets in the 1850s, were no longer actively traded by 1913.

The German price data are largely taken from the comprehensive price history compiled by Jacobs and Richter (1935). In their study great care is taken to ensure that the price series are measured in a consistent way over time. In a few cases more recent research has brought alternative price series that are believed to be more representative of the market prices. In several cases prices of imported commodities quoted in Hamburg do not include customs duties, or only for part of the period; here, duty rates were added to the price to obtain German domestic market prices. The details are given in the appendix.

For Britain all price series have been constructed from averaging monthly price quotations collected from a large number of sources, including London, Liverpool, Belfast and Dundee price currents and various trade journals. Some of the price series were used in Klovland (1993), but most of the material have not yet been employed in published work. All price series reflect wholesale market prices with duty paid.

3.2 Measuring price gaps

The price gap is defined as the percentage difference between the prices (in common currency) of the same commodity in the two countries. The price gap is in several respects an attractive and highly informative price measure, but in practice such information may be difficult to obtain for many commodities. Finding price series of goods over a long time span that are representative of the price movements in each country *and* at the same time being identical or of matching quality is often impossible.

For some products domestic production was the dominant source of supply, either due to protectionist measures (cereals and meat in part of the period) or because of high transportation costs (potatoes, hay, straw, coal). In such cases direct quality comparisons across countries may be difficult. In other cases the situation is made easier by imports; the leading description of raw zinc in Britain was Silesian spelter, wheat from Danzig and Königsberg was of great importance before 1880, and Germany imported English linseed oil as well as special qualities of British pig iron and coal. The uncertainty of quality matching is often less acute in cases where both countries relied on imports from third countries, being prominent in such cases as lard, cotton, flax, hemp, saltpetre, palm oil and rosin.

It is sometimes also a question of whether the researcher should use the domestic price of the 'standard' international commodity, which might be available in a port of transit, or select the price of a domestically produced good, which may be the dominant commodity on the domestic market. To take the example of coal, Hamburg quotations of the prices of steam coal from North-East England are available, but 'Fettkohle' from Silesia and the Ruhr were of more importance to the domestic economy because the bulk of coal fed into the furnaces in German manufacturing industries was domestic. Here, the prices of both types of coal are compared, because they may shed light on two slightly different issues. If a detailed examination of the mechanisms of price arbitrage is called for, the internationally traded good is presumably of most interest; otherwise, a case can be made for selecting the economically more important

domestic good to address the broader issue of general price movements.[16]

A similar caveat as to the comparability of prices arises from the fact that there are often large discrepancies between the various qualities of a seemingly well defined commodity, such as 'steam coal'. For example, in mid-December 1899 coal prices in Cardiff ranged from 25 - 27 shillings per ton for best steam coal to 9 - 12 shillings for small steam coal. Best large Northumbrian steam coal sold for $14s\ 6d$ and small steam for $8s$.[17] It is obvious that in such cases it may be rather difficult to compute a price series of steam coal of 'average quality' which may be assumed to correspond to a foreign series with matching characteristics.

3.3 German-British price gaps

We begin our examination of the data by looking at the German-British price gaps, defined as

$$G_{it} = 100 \cdot (P_{it}^{G} - P_{it}^{BE})/P_{it}^{BE}$$

where P_{it}^{G}, P_{it}^{B} are the prices of commodity i in year t in Germany and Britain, respectively, E_t is the exchange rate and $P_{it}^{BE} = E_t \cdot P_{it}^{B}$ is the British price in German currency value.[18] This measures the percentage excess (when positive) of German prices over British prices.

Even if the quality matching problems discussed above may be serious enough the real stumbling block in making absolute price gap comparisons over a long time period is the lack of a similar well-defined price series in both countries. The fact that it is far easier to compare absolute prices *at one point in time* than over the whole sample may, however, suggest a workaround of the consistency problem. In Table 2 price gap series are presented, which are based on estimates of the average German-British price gaps of one or a few selected representative descriptions of each commodity in 1911 to 1913, then using the broader based price index series to backcast the gaps to 1850. Thus, there are two sources of uncertainty underlying these estimates: (1) how well the chosen commodities match in quality in 1911-1913, and (2) how representative the price indices of the general price movements of each commodity are over the years from 1850 to 1913. The underlying price series, converted to a common currency, are reproduced in the forty graph windows contained in Figures 2 to 6.

The case of cereals, in particular wheat, has been discussed in the literature previously, and here we are probably on firmer ground regarding the years immediately prior to World War I. Contemporary estimates of the difference between English Gazette average of wheat and a similar quality in Berlin were made by the Liverpool firm Messrs. Montgomery, Jones & Co. and published in *The Economist*. Their estimates for late June levels in the years 1911 to 1913

[16] Even if commodity descriptions in the two countries are seemingly similar, though, this does not always ensure that the price series are wholly comparable. A good example of how strict the requirements of intimate knowledge of quality descriptions and quotation basis are is given by Harley (1992), referring to the case of Liverpool-New York cotton price comparisons. One would have thought that the price of 'a bale of middling Upland cotton' was strictly comparable in the two cities, after being properly converted to a common currency, but this was far from the case. Not only did the grading change over time (Liverpool 'middling' was not equal to New York 'middling' until November 1853), but allowance for tare and draft differed by as much as 6 per cent.

[17] *The Economist*, December 23, 1899, p. 1826.

[18] As is evident from Figure 1, exchange rate corrections only play a minor role during the German silver standard period.

are 31, 38, and 33 per cent, respectively.[19] The data underlying O'Rourke (1997) indicate a price gap of 31 per cent against Prussia and 42 against Bavaria. The estimates shown in Table 2 imply that average market prices of wheat in eight German cities were 29 per cent higher than the level in Britain in 1911-1913.[20] The price gaps of barley, oats and rye in 1911-1913 are all close to that of wheat.[21]

All cereals, as well as flour, share a distinct common trend in relative German-British prices over the period from 1850. Before 1880 grain prices were mostly lower in Germany than in Britain, but markedly higher thereafter. The introduction of the protectionist tariff regime in 1879 may go a long way towards explaining this feature. But the fact that Germany went from being a net grain exporter to a being a net importer in the 1880s may also bear some relevance on this issue.[22] In the mid-19th century Prussian wheats were of great importance to the British market; a symbol of which is the fact that the first entry of foreign wheats in 'prices current of corn' was traditionally reserved for Danzig and Königsberg wheat until the 1880s, when it rapidly lost its importance.

In the case of other vegetable products, such as peas, potatoes, hay and straw, German prices were mostly lower throughout the period. Except for peas, tariffs played little or no role for these commodities, which illustrates the effect of tariffs when compared to cereals. Animal produce (beef, pork, butter, lard) is an interesting case, somewhat parallel to cereals; initially prices in Germany were significantly lower, but by the end of the period they were on average 15 per cent higher than the British ones.

Coal and iron price gaps are large throughout the period, showing generally much higher prices of these goods in Germany than in Britain, which is consistent with the evidence in Fremdling (1991). The data in Table 2 include two price series of both coal and pig iron, one description in each case which represents imports into Germany (English steam coal and Scottish pig iron) and one domestic. The general conclusions are largely invariant to this distinction, except for domestic (bituminous) coal in the first part of the period, which shows German prices

[19] *The Economist*, June 29, 1912 and June 28, 1913.

[20] The British wheat benchmarks of 1911-1913 are averages of English wheat and London quotations of American red winter wheat, a medium priced description fairly representative of imported wheat. Foreign wheats, which accounted for the bulk of domestic consumption, obtained higher prices than the domestic wheat averages of market towns in England and Wales (Gazette averages). The latter were about 15 per cent lower than American red winter in 1911-1913. Only the best Kent and Essex wheats obtained prices similar to imported wheat. Consequently, price gap estimates inferred from English Gazette averages alone, which have been used by previous researchers, tend to show somewhat higher price differentials than the estimates given here. A further issue affecting these figures is the conversion factors used in transforming wheat sold by imperial quarters, which was the standard in Britain, into a weight measure. The procedure followed here applies the conventional conversion factors of 480 lbs per quarter for English Gazette averages of wheat (400 lbs for barley and 312 lbs for oats, see Vamplew (1980)). Price currents of grain (e.g. in *Mark Lane Express*) indicated 496 lbs as the weight of a quarter of foreign wheats.

[21] Rye was the main bread grain in Germany, but of negligible importance in Britain, where only a very small quantity was produced and marketed.

[22] This was suggested by Fremdling (1991). A similar case is the huge import flow of cattle, frozen beef and other animal products from the United States into Britain that dried up entirely in the years before World War I. This was accompanied by a marked increase in the relative prices of US products. Because domestic production then met with the resource constraint domestic US prices increased and exports were no longer profitable. This suggests that a similar mechanism may have affected German grain exports, but any such price effects were most likely dwarfed by the increased tariffs.

more in line with British.[23] Non-ferrous metal prices, except zinc, were slightly higher in Germany throughout the period. It makes sense that zinc was relatively cheaper in Germany because she was a net exporter of this commodity.

Textiles and raw materials present a rather varied picture, where some of the more extreme variations over time may be due to events peculiar to individual commodities.[24] Disregarding the German linen yarn prices of the 1850s, the quality of which may be suspect, the data suggest that British cotton and linen yarn prices remained somewhat lower than the German prices during the whole period, which is consistent with industry structure. To some extent this may be due to lower raw material prices; this applies to cotton, but less generally to flax. An interesting case from the point of view of market structure and pricing is soda, because cartelization and non-competitive pricing was a characteristic of the alkali industry in both countries. Initially, the German soda industry was small and inferior to the British in terms of efficiency, being shielded by a tariff, which resulted in higher German prices. From the 1880s, however, the German industry progressed rapidly, being quicker than the British to adopt the technologically superior ammonia based Solvay process in replacement of the Leblanc process. As can be seen in Table 2, this led to a convergence of the price level in the two countries, and an Anglo-German price agreement was signed in 1901, which kept market prices fixed for a number of years.[25] Finally, we note the large and persistent price gaps of timber, German prices being generally around 30 percent lower than the British throughout the period.

The short review market price gaps of individual commodities has revealed that there are many idiosyncratic features regarding commodity price behaviour, which is a useful background to the interpretation of the formal market integration tests conducted below. But there are also some general features that stand out clearly, in particular the marked and sustained relative increase in German prices on cereals, flour and animal produce beginning in the 1880s. For some commodities, notably vegetable feeding stuffs, coal, iron and timber, there are persistent price gaps throughout the period.

3.4 A comparison with previous research on price gaps

Our results relating to Germany and Britain differ from the marked Anglo-American convergence exhibited by the data in Harley (1980) and O'Rourke and Williamson (1994). The greater significance of transportation costs relative to tariffs in the Anglo-American case may be a

[23]It may seem anomalous that German coal prices were lower than British in the years 1875-1877, but this result is confirmed using other data sources of German coal, e.g. the average pitmouth prices in the Dortmund region reported by Holtfrerich (1973). It appears that British coal prices were slower to return to a normal level after the grand 1873 peak than the German prices. The estimates in Fremdling (1991) show that the 1875-1884 period marks an exception to the general conclusion that coal prices in Britain were lower than in Germany.

[24]The case of tallow may illustrate this point. The German series are based on locally produced tallow in the Hamburg region as well as St Petersburg tallow (the latter only to 1859). These price series were very close both with regard to level and annual changes, indicating that they were close substitutes. The British series is composed of equally weighted English town tallow and foreign tallow, which were represented by St Petersburg and Australian until 1880 and only the latter thereafter. In the British market Australian tallow completely drove out the higher priced Russian commodity during the 1880s, which may have exerted a downward pressure on market prices, as the price of English tallow adjusted to the leading foreign description.

[25]Haber (1958, p. 256). See also Schallermair (1997) and Krause and Puffert (2000) for the development of the German soda industry.

large part of the explanation of the apparent differences in commodity price convergence. The effects of tariffs have important implications for the hypothesis of market integration. O'Rourke (1997) concluded that the reintroduction of Continental European tariff protection hindered grain market integration within western Europe, which is clearly consistent with the German-British case depicted here. Between 1870 and 1913 absolute price gaps of wheat, using Odessa prices as the benchmark, increased in France, Bavaria and Sweden, but declined in the free trade nations, Britain and Denmark.[26]

There is some evidence that this conclusion can be extended to comprise meat as well. Fremdling (1991) found that the trends in food prices in general showed an increasing gap relative to Britain after 1880, but that this was only a continuation of the trend increase that prevailed from the 1850s. Our data in Table 2 confirms this conclusion with respect to the development after 1880, but the evidence regarding the pre-1880 trend is more ambiguous. Fremdling (1991) noted in the case of Germany and Britain that in both absolute and relative terms the price levels of the two countries converged around 1880. The general picture emerging from Table 2 and the lower right window of Figure 6 is closer to the conclusion that absolute price levels were *on the average* quite close from the 1850s through 1870s, thereafter the German price level drifted upward relative to the British.

The hypothesis of North European market integration in other commodity markets than cereals has been less thoroughly researched. An early comprehensive study of Danish, British, Swedish and German prices from 1855 to 1913 by Pedersen and Petersen (1938) illustrated several cases of diminishing price gaps between the two free traders, Denmark and Britain. Ljungberg (1996) studied prices of butter, iron, machinery and ships in Britain, Germany and Sweden, concluding that convergence took place, but slowly and incompletely.

3.5 Aggregate price gaps

A crude aggregate measure of the absolute price gaps is the unweighted all commodities average index (shown in the lower right window in Figure 6), computed on the basis of the British price level of 1911/13 set equal to 100. This index is close to zero before the 1880s, but shifting upward by 5 - 9 per cent thereafter. Note that this measure does not give any conclusive evidence regarding absolute price level convergence or divergence for individual commodities in general, because an approximately equal aggregate price level in the two countries may for example come about by large positive price gaps for some commodities cancelling negative ones for other goods.

To study the issue of absolute price convergence in more detail we now turn to a more appropriate aggregate measure of annual absolute deviations from LOP. For a group consisting of J commodities this is given by

$$A_t = \frac{1}{J}\sum_{i=1}^{J} Abs[1 - P_{it}^{G}/P_{it}^{BE}]$$

[26] See also Goodwin and Grennes (1998).

To get an intuitive notion of the measure consider two extreme cases: (1) LOP holds exactly for all commodities included, then A_t would equal zero; (2) price gaps were 100 per cent (German prices being twice as large as the British prices) the measure would be equal to one.[27] A falling value over time thus implies absolute price convergence. Annual values of this measure are plotted in Figure 7 for seven commodity groups and for the aggregate of all 39 commodities. In the latter case a series based on median, rather than mean, values are presented as well.

These graphs show clearly that the degree and direction of absolute price gaps differed considerably between the groups. For all seven groups except cereals and the coal and iron composite there was a distinct absolute price *convergence* between 1850 and 1913; in the case of textiles most of the convergence had taken place by the early 1860s, whereas for animal foods there was a partial reversal of the falling trend in the 1900s. The graph window showing cereals presents a totally different picture, indicating strongly that price level *divergence* was taking place as from the 1880s. Initially, absolute LOP deviations in the grain markets were lower than for non-ferrous metals, but this changed radically with the new German protectionist policy. In this connection it is noteworthy that absolute price deviations for animal foods were relatively small and seemingly much less affected by changes in trade policy than cereals. The aggregate for all commodities exhibits some price convergence over time, although this is less marked when the median is considered, the mean being more strongly influenced by the significant fall in the LOP deviations of feeding stuffs.

4 Econometric evidence on relative LOP deviations

4.1 Cointegration tests

Leaving the issue of absolute price dispersion we now turn to the examination of relative price level movements over time. If two time series move together and do not drift apart they are said to be cointegrated. This makes the concept of cointegration a useful one in studies of market integration. Before proceeding with the tests for cointegration it should be reiterated that such tests focus on one particular aspect of relative price behaviour; other aspects, such as the degree of correlation, volatility of price deviations and the speed of adjustment to shocks are also reviewed below.

Table 3 reports cointegration tests based on the trace statistic of the Johansen (1991) procedure. The *simple LOP model* (omitting the commodity subscript i for simplicity) is specified as

$$p_t^G = c_1 + \beta_1 p_t^{BE} + u_{1t} \tag{1}$$

The first column under the heading simple model of Table 3 reports cointegration tests between price levels (logs) in Germany (p_t^G) and Britain converted to common currency (p_t^{BE}), allowing price levels to differ by a constant (c). Thus, we are testing for mean reversion to a constant (possibly non-zero) level of absolute price gaps. If the two variables are cointegrated at the 1

[27] If British prices were twice as large as the German prices the A_t measure would equal 0.5 - this points to the fact that numerical values are not independent of which price level is in the numerator.

per cent significance level, or, if that is not the case, at the 5 per cent level, this is noted in the second column. However, the simple LOP model is strictly valid only if the cointegration slope is unity ($\beta_1 = 1$). This is tested for and reported in the third column (proportionality), using a 5 per cent significance level for the likelihood ratio test here. A successful outcome of the tests therefore requires a 'yes' in column one as well as three, otherwise the simple LOP model does not hold.

Following the discussion in the text an extended model is also considered, formed by adding the differential tariff rate (Germany - Britain) to the model for the commodities on which duty was imposed.[28] The *extended model* is

$$p_t^G = c_2 + \beta_2 p_t^{BE} + \gamma z_t + u_{2t} \tag{2}$$

A similar procedure is reported for this model in Table 3, first asking whether the two price levels and the tariff rate are cointegrated. If differential tariffs are fully reflected in relative price levels, the domestic price level (Germany) should be proportional to the sum of foreign prices and tariffs under the LOP hypothesis. This is tested by imposing the restriction $\beta_2 + \gamma = 1$. The final column reports whether this restriction is acceptable at the 5 per cent level.

We first consider the results for the agricultural commodities. Here an interesting difference emerges between vegetable products on one hand and the animal products - beef, pork and butter - on the other hand. The simple LOP model is rejected for cereals, although unrestricted price levels are cointegrated. When tariffs are added to the model *all* cereals and vegetable feeding stuffs, with the exception of peas, are cointegrated at the 1 per cent significance level and pass the proportionality test. These results show that the market prices of grains and feeding stuffs were closely integrated when import duties are duly accounted for.

In contrast, there is no evidence of cointegration with respect to beef, pork and butter even in the extended model taking into account tariffs. In contrast to grain markets, the markets for meat were not integrated, which is easily explained by the comprehensive non-tariff barriers discussed above. Butter was largely a domestically produced commodity in Germany and apparently not integrated with the international butter market in Britain. Lard, however, was a standard internationally traded commodity, both countries getting large supplies from the United States, and there is more support for the LOP hypothesis here.

Coal and pig iron prices appear to be integrated, but only the two coal descriptions obey the coefficient restrictions. Considering the large and variable price gaps recorded for these goods these results are not surprising. Non-ferrous metals all conform to the simple LOP model, as might be expected. Except for cotton yarn, textile prices are cointegrated, and, with the exception of silk, in accordance with the LOP model. Other materials present a very mixed picture; only hides, leather and linseed oil pass all tests.

In summary, the formal tests of the law of one price have shown that there are marked differences between various commodity groups. Markets for non-ferrous metals are well inte-

[28]The rates of duty were computed as (ignoring subscripts) $\tau = D/P^*$, where D is the specific duty and P^* the mean commodity price over the whole sample period. The variable entering the cointegration regression is the German-British differential duty rate in logs, $z = \ln(1 + \tau^G) - \ln(1 + \tau^B)$.

grated and well represented by the simple LOP model. A similar, but less consistent, pattern of price behaviour seems to characterize many textile markets, feeding stuffs, coal and sundry raw materials. The substantial tariff protection on agricultural goods after 1879 easily explains why the simple law of one price breaks down in these cases. Once this is accounted for, however, grain markets are firmly integrated. Animal foodstuffs, in contrast, are not integrated, most likely due to the extensive non-tariff barriers.

4.2 Correlations, volatility and speed of adjustment of prices

Table 4 reports additional evidence relating to the synchronization of commodity price movements in the two countries. The first two columns give the simple correlation coefficients between the price variables in the two countries, in levels and as rates of change. The next two columns present volatility measures. The unconditional measure is the standard deviation of relative law-of-one price (LOP) deviations, which are defined as

$$p_{it} = \ln(P_{it}^{G}) - \ln(P_{it}^{BE})$$

The conditional volatility measure is the standard deviation of the residuals after regressing the LOP deviations, p_{it}, on a constant, German-British duty rates and a time trend. Viewed in conjunction with the graphs of the price series in Figures 2 - 6, this gives additional information on how closely the commodity prices moved together in the two countries.

A summary measure that can give some perspective on the rate of damping of LOP deviations is an estimate of the half-life of LOP-deviations, i. e. the expected number of years for a LOP deviation to decay by 50 per cent. Assuming that a first-order autoregressive process

$$p_{it} = \mu_i + \alpha p_{i,t-1} + \gamma t + u_{it} \tag{3}$$

can adequately characterize the price data, the half-life statistic HL is computed by inserting the estimated value of α, denoted, $\widehat{\alpha}$, into the equation $\widehat{\alpha}^{HL} = 0.5$, which gives

$$HL = \frac{\ln 0.5}{\ln \widehat{\alpha}}$$

Half-life statistics are also computed for an extended model including German-British duty rates in the AR model (3).

Which commodity markets were most closely integrated from the point of view of these statistics? The degree of correlation is perhaps the most intuitive measure. It singles out the prices of the standard internationally traded commodities as the most synchronized ones across the borders: non-ferrous metals, cotton and oils. Commodities for which domestic production is the dominant source of supply in at least one of the countries is much more weakly correlated; this applies to coal, wool and timber, and in particular to many foodstuffs, although less so for wheat, flour and animal fats.

Comparing the two volatility measures gives an indication of how much the inclusion of duties

and allowing for a time trend affects the variation of price differentials over time. For many agricultural commodities there is a substantial reduction in volatility. These measures give a ranking list with regard to the degree of synchronization of price movements that is surprisingly similar to the one inferred from the correlation statistics; again it is non-ferrous metals, cotton and oils. Note also the relatively low volatility of wheat, and especially butter; the latter case in direct contrast to the non-cointegration results.

The final two columns of Table 4 present the estimates of half life to LOP deviations. Recalling the fact that Rogoff (1996, p. 656) concluded that 'the consensus ... on the half-life of PPP deviations is remarkable (three to five years)', it is of some interest to note that the average outcome for all commodities in Table 4, using a simple AR model with a time trend, is only 1.4 years. Such 'average' results may be a poor indication of the degree of commodity market integration, however, because of a few large outliers that unduly affect the average speed of adjustment. Allowing for the effects of duties reduces the half-life statistics even further in some cases, although the differences are mostly small.

These half-life estimates are much lower than those estimated by Froot et al. (1995, p. 21) for British-Dutch wholesale prices of wheat, barley and butter, which were 2.8, 3.9 and 6.2 years, respectively. Their conclusion was that '[d]eviations from LOP, even in these relatively homogenous and highly traded commodities, is remarkably slow'.[29] These results were obtained with an exceptionally long sample period extending over seven centuries. But, allowing for a differential speed of adjustment in the twentieth century, it turned out that the rate of convergence during the more recent time period was not significantly different from that in earlier centuries. This interpretation appears to lend support to the notion of a sluggish speed of price adjustment in commodity markets that is largely invariant over time.

Our results strongly suggest that such a generalization is not warranted.[30] The model underlying the estimates in the final column of Table 4 is similar to the one used by Froot et al. (1995, p. 21), which also included a time trend. The difference is that our specification allows for the impact of duties in cases where this is relevant. Cereals, feeding stuffs and metals exhibit a rather quick speed of adjustment, one year or less. The average for all commodities is now down to 1.3 years. In our data there is no puzzle regarding the rate of convergence of prices - it was in general quite fast.[31]

5 Conclusion

The empirical analysis of commodity market integration between Britain and Germany has highlighted two general features: the degree of market integration varied considerably across individual commodity markets and it was changing over the years 1850 to 1913. From a

[29] Froot et al. (1995, p. 21).

[30] The half-life estimates are generally quite sensitive to the inclusion of a linear time trend in the equation, being higher when this variable is excluded. A time trend may be motivated by the secular decline in transportation costs as well as measurement problems.

[31] To obtain a more precise estimate of half-lives data with higher frequency than a year would of course have been desirable, particularly in view of the fact that Taylor (2001) has shown that temporal aggregation may impart an upward bias on the half-life statistic.

methodological point of view this underscores the need for studying the development of absolute price gaps over time, using a broad sample of individual commodity prices.

Between 1850 and throughout the 1870s, when there was a movement towards free trade in Germany, a general trend towards lower absolute price variability applies more or less to all commodity groups (Figure 7). Lower transportation and information costs, well-functioning financial markets and a competitive manufacturing climate may all have contributed to this development. The trend towards lower absolute price variability continues from 1880 to World War I with respect to most commodities that were little affected by import duties. In contrast, the trend is broken for commodities that were comprised by the German protectionist trade policy, most notably in the case of cereals.

Grain markets had been closely integrated before 1880, even more so than non-ferrous metals, as measured by absolute price variability. Cointegration tests show that once the differential duty rates are accounted for grain markets can be characterized as well integrated throughout the period. Animal foodstuffs, on the other hand, do generally not conform to the law of one price, presumably due to non-tariff trade barriers.

The evidence presented here exhibits several examples of commodities that are fairly weakly correlated and being subject to volatile relative price movements, nevertheless passing formal tests of cointegration. There are also examples of the reverse situation - of highly correlated variables with low relative price variability that fail in formal LOP model tests. These results point to the need for *supplementing* econometric testing with other descriptive statistical measures, and analyzing price behaviour in each commodity markets from a historical perspective.

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DATA APPENDIX

All **German** data are from Jacobs and Richter (1935) with the following exceptions: *Flour* is from *Statistisches Jahrbuch für das Deutsche Reich*, various issues 1892 to 1914 for the period beginning in 1880, and from Soetbeer (1886) for previous years; *hay* and *straw* are from *Vierteljahrshefte zur Statistik des Deutschen Reiches*, Heft IV in 1896 and 1914; *beef* and *pork* are taken from Hoffmann (1965); *cotton yarn* is from Kirchhain (1977, tables 42 and 43) (the yarn prices quoted in Jacobs and Richter (1935) are for extremely fine counts of no. 130 and higher, which are not representative of the bulk of market prices); *saltpetre* before 1868 is linked to the data in Soetbeer (1886). In several cases prices of imported commodities quoted in Hamburg do not include customs duties, or only for part of the period; here, duty rates were added to the price to obtain German domestic market prices; specifically, this concerns the following commodities: lard, Scottish pig iron, palm oil and linseed oil.

The **British** data are compiled as monthly price quotations from contemporary sources. The main sources used include: *The Economist, London Mercantile Price Current, Prince's Price Current, The Public Ledger, The Times, The Statist, Mark Lane Express, The Grocer, Broomhall's Corn Trade News, Annual Reports of the Board of Trade of Chicago, Meat Trades' Journal, Iron and Coal Trades' Review, Colliery Guardian, Bradford Observer, Belfast Mercantile Register, Belfast Linen Trade Circular (Linen Market* as from 1889*), Chemist and Druggist* and *Chemical Trade Journal.*

All British data are calculated as annual averages of twelve monthly quotations; this seems generally to be case with respect to the German data as well, cf. Jacobs and Richter (1935, p. 51)

Commodity descriptions underlying price gap estimates 1911/1913

The following list contains the descriptions used in estimating **average German-British price gaps for the years 1911, 1912 and 1913**. The source of the German data are as above unless specified as *SJDR (Statistisches Jahrbuch für das deutsche Reich 1914).* Except otherwise stated, German prices are Hamburg quotations, and British prices are London quotations.

1. WHEAT average of 8 German cities *(SJDR)* | mean of *Gazette* (England and Wales average) and American red winter
2. BARLEY average (excluding feeding barley) of 4 German cities *(SJDR)* | mean of *Gazette* (England and Wales average) and Odessa-Danube barley
3. OATS average of 8 German cities *(SJDR)* | mean of *Gazette* (England and Wales average) and Russian oats
4. RYE average of 8 German cities *(SJDR)* | English average quality (Mark Lane, London)
5. FLOUR Berlin quality 00 and München quality no. 2 *(SJDR)* | mean of English town white and American first bakers
6. PEAS German white Breslau | average UK imports
7. POTATOES edible Berlin *(SJDR)* | good English (Up-to-date)
8. HAY domestic Berlin | prime average meadow hay Whitechapel (London)
9. STRAW domestic Berlin | average oat straw Whitechapel (London)
10. BEEF Oxen deadweight Berlin *(SJDR)* | Scotch sides (short and long)
11. PORK Pigs deadweight Berlin *(SJDR)* | middling pork
12. BUTTER prime Hamburg | fine Danish
13. LARD American (duty added) | American pails
14. COAL STEAM West Hartley large Hamburg | large steam North-East England
15. COAL BITUMINOUS gas coals Nieder- and Ober-Schlesien | prime Durham gas coals North-East England
16. PIG IRON SCOTTISH Scottish pig no. 1 Hamburg | Scottish pig no.1 Glasgow

17. PIG IRON FOUNDRY best German foundry (Puddeleisen) Düsseldorf | Cleveland pig no. 3 North-East England
18. COPPER average of foreign and German in 3 cities *(SJDR)* | standard copper
19. LEAD average of German in 3 cities *(SJDR)* | average of English and Spanish pig
20. TIN Banca Hamburg | English blocks
21. ZINC RAW Prussian average | Silesian spelter
22. ZINC SHEETS Silesian sheets | English sheets
23. WOOL Cape snow white |Cape superior scoured
24. COTTON Middling Upland Bremen | Middling Upland Liverpool
25. COTTON YARN German, equal to English no. 40 Stuttgart | no. 40 mule twist Manchester
26. SILK Milan Grege | fair Milan raw
27. FLAX Litauen ZK free on border | Riga ZK cif
28. LINEN YARN German, equal to English no. 30 | no. 30 tow yarn Belfast
29. HEMP St Petersburg clean Lübeck | St Petersburg clean
30. HIDES salted Rio Grande | salted Australian
31. LEATHER Kips (Dacca) | East India kips
32. SODA calcined soda 48-52 % | soda ash 48 %
33. SALTPETRE Chile saltpetre (nitrate of soda) | Chilean nitrate of soda
34. LINSEED OIL English or foreign (duty added) | English
35. PALM OIL Lagos | Lagos
36. TALLOW domestic | English town tallow
37. ROSIN American brown | American common
38. FIR TIMBER round fir timber Potsdam | Russian hewn timber average imports
39. SPRUCE TIMBER round spruce timber Erfurt | Russian hewn timber average imports

Commodity descriptions underlying price series 1850 - 1913

This is a listing of the commodity price descriptions underlying the price index series covering 1850 - 1913. Common descriptions are given, following the market place where it was quoted; if no place is indicated these are London and Hamburg, respectively. For most commodities the price indices are calculated using several descriptions that were representative of the market prices. In the case of Britain higher weights are given to the leading descriptions within each price category, for example Gazette average prices (wheat, barley, oats), Friesland (butter), American Upland middling (cotton), Chinese Tsatlee (silk). In cases where the British data contain both domestic and foreign commodities these are each given a weight of 50 per cent; the exception is leather (domestic descriptions account for 75 per cent).

Commodity price descriptions 1850 - 1913

BRITAIN	GERMANY
1 WHEAT	
Gazette average (England and Wales) English (Essex) red top price English (Essex) white top price South Russian soft (Ghirka, Azima) American red / American Northern / Manitoba Danzig and Königsberg (1850-1880) California floating cargoes (1880-1913)	unspecified German Berlin Mecklenburg Hamburg German München
2 BARLEY	
Gazette average (England and Wales) English distilling English malting Foreign malting (French, Californian) Foreign grinding (Odessa, Danube)	unspecified German Königsberg German München German Berlin (1850-1854) Mecklenburg Hamburg (1850-1854)
3 OATS	
Gazette average (England and Wales) Best Scottish or English (1850-1880) Irish black (1850-1880) Russian or Riga Swedish or Danish feeding (1850-1880)	unspecified German Königsberg German München German Berlin Mecklenburg Hamburg (1850-1854)
4 RYE	
English average quality	Berlin, Königsberg, Hamburg and München
5 FLOUR	
English town made white Norfolk and Suffolk / best country patents American barrels / patents	import price Hamburg (1850-1880) Bavarian quality no. 2 München (1880-1913) Breslau (1880-1895) and Berlin (1895-1913) no. 00
6 PEAS	
English white boilers / maple Foreign boilers / Canadian and Indian white	German white Berlin (1850-1866) German white Breslau (1857-1913)

BRITAIN	GERMANY
7 POTATOES	
British best English Regents / good average	unspecified German Berlin German Breslau German Königsberg (1850-1854) German Köln (1850-1854)
8 HAY	
Meadow hay prime average Whitechapel market	Berlin
9 STRAW	
Oat straw average price Whitechapel market	Berlin
10 BEEF	
Beef prime / Scotch sides (deadmeat) Live oxen prime Scots (livemeat)	German beef Berlin (1850-1865) Live oxen Berlin (1856-1913) Beef München (1850-1859) Live oxen München (1886-1913)
11 PORK	
Pork large / middling Pork small / first	German Pork Berlin (1850-1867) Live pigs Berlin (1858-1913) Pork München (1850-1873) Live pigs München (1864-1913)
12 BUTTER	
Carlow / Cork 1st (from 1862) Waterford / Cork 2nd (from 1862) Friesland fine Normandy first (1880-1913) Danish finest (1880-1913)	Holstein / German 1st Hamburg Mecklenburg / German 1st
13 LARD	
Waterford Irish firkins and kegs American casks London / US pails Liverpool	unspecified Hamburg (1850-1869) American Hamburg (1861-1913) American Bremen (1880-1913)

BRITAIN	GERMANY
14 COAL STEAM	
West Hartley / Steam large North East	English steam or manufacturing coal Hamburg
15 COAL BITUMINOUS	
Wallsend Hetton / Housecoal best London Durham gas coal	Rhenish coal (Fettkohle) Essen
16 PIG IRON SCOTTISH	
Scottish pig iron Glasgow	Scottish pig no. 1 Hamburg
17 PIG IRON FOUNDRY	
Wales pig no. 1 (1850-1863) Cleveland pig no. 3 (1863-1913)	German or Luxemburg (Puddeleisen) Düsseldorf
18 COPPER	
English tough cake Chili bars / Chili gmb or Standard	Swedish Hamburg (1850-1870) English blocks Hamburg (1873-1913) German Mansfeld
19 LEAD	
English pig Spanish pig / Spanish or foreign	German Hamburg German Berlin
20 TIN	
English blocks and ingots Straits Banca (1850-1880)	Saxon Freiberg (1850-1854) Banca Hamburg
21 ZINC RAW	
Silesian spelter	Silesian Breslau
22 ZINC SHEETS	
English rolled sheets	Silesian sheets Hamburg

BRITAIN	GERMANY
23 WOOL	
English half-bred hoggs Leicester ewes and weathers Port Phillip fleece / Victoria scoured Adelaide unwashed Cape scoured snow white/super East India low yellow (1850-1880) Victoria crossbred (1880-1913)	Schlesien Breslau Northern Germany Berlin
24 COTTON	
American Upland middling Liverpool Brazilian Pernambuco fair Liverpool Indian Surat Dhollerah fair / Bhownuggar gf Egyptian brown good fair Liverpool	Georgia Hamburg (1850-1861) Upland middling Hamburg (1860-1885) Upland middling Bremen (1879-1913)
25 COTTON YARN	
Water twist no. 30 Manchester Mule twist no. 40 Manchester Twist no. 32 (1880-1913) Manchester	English no. 24 (1850-1878 Reichsenquete, thereafter Stuttgart) English no. 40 (1850-1878 Reichsenquete, thereafter Stuttgart)
26 SILK	
Chines Tsatlee nos. 4-5 / Blue elehphant Indian Cossimbuzar Inidian Surdah / Japan raw Italian Fossombrone or Milan trams (1850-1880)	Milan organzine Krefeld
27 FLAX	
Riga (equal to ZK) or Archangel crown St Petersburg 12 head (1880-1913)	domestic Berlin, Breslau or Schlesien
28 LINEN YARN	
Line 60s weft Belfast Tow 30s weft Belfast	domestic Schlesien (1850-1870) domestic yarn no. 30 Schlesien (1859-1913)
29 HEMP	
St Petersburg clean	St Petersburg clean Hamburg/Lübeck

BRITAIN	GERMANY
30 HIDES	
Buenos Aires and Montevideo dry East India drysalted Cape salted Australian salted	Buenos Aires and Montevideo salted (1850-1870) Rio Grande salted (1861-1913)
31 LEATHER	
Calf skin light Dressing hides English butts 16-24 lbs Foreign butts 16-24 lbs	Calf skin Hamburg/Frankfurt
32 SODA	
Soda ash refined 48 degrees	Soda ash calcined 48-52 degrees
33 CHILE SALTPETRE	
Bengal raw (1850-1861) English refined (1862-1880) Chile nitrate of soda (1862-1913)	East India raw (1850-1864) refined saltpetre (1862-1877) Chile nitrate of soda (1868-1913)
34 LINSEED OIL	
English	English or unspecified Hamburg unspecified Berlin (1850-1854)
35 PALM OIL	
Lagos	Lagos
36 TALLOW	
English town St Petersburg yellow candle (1850-1880) Australian mutton	German Hamburg (1850-1913) St Petersburg (1850-1859)
37 ROSIN	
American common	American brown

BRITAIN	GERMANY
38 FIR TIMBER	
Danzig and Memel Canada yellow pine Canada red pine	building timber (round) Potsdam
39 SPRUCE TIMBER	
Swedish common American spruce	building timber (round) Erfurt

Table 1. Duty rates as a percentage of market prices

Commodity	1850/52	1875/77	1889/91	1901/03	1911/13
	Germany				
1 Wheat	7.1	0.0	24.3	20.9	35.6
2 Barley	13.0	0.0	13.3	12.8	35.9
3 Oats	19.2	0.0	24.4	18.6	38.1
4 Rye	10.6	0.0	28.3	24.5	39.7
5 Flour	0.0	0.0	34.1	30.0	63.7
6 Peas	0.0	0.0	12.8	10.1	18.9
7 Potatoes	0.0	0.0	0.0	0.0	4.0
10 Beef	15.8	0.0	17.0	16.1	27.0
11 Pork	19.9	0.0	19.2	20.2	27.0
12 Butter	15.0	2.9	9.1	8.8	11.2
13 Lard	0.0	0.0	11.8	9.6	10.7
16 Pig iron Scottish	30.6	0.0	12.0	11.8	11.2
17 Pig iron foundry	26.8	0.0	13.1	15.3	13.6
25 Cotton yarn	6.7	5.2	10.0	10.9	8.4
28 Linen yarn	8.7	1.3	5.0	4.5	4.0
32 Soda	17.1	6.8	21.5	21.7	13.0
34 Linseed oil	4.9	0.0	9.6	7.6	6.3
35 Palm oil	1.6	0.0	3.9	3.8	3.0
36 Tallow	0.0	0.0	2.7	2.9	3.1
38 Fir timber	9.3	0.0	11.9	10.5	7.8
39 Spruce timber	9.7	0.0	9.7	10.1	7.1
	Britain				
1 Wheat	2.6	0.0	0.0	1.2	0.0
2 Barley	4.7	0.0	0.0	1.4	0.0
3 Oats	5.5	0.0	0.0	1.3	0.0
4 Rye	3.8	0.0	0.0	1.5	0.0
5 Flour	1.9	0.0	0.0	2.8	0.0
6 Peas	2.5	0.0	0.0	0.9	0.0
12 Butter	11.0	0.0	0.0	0.0	0.0
14 Coal steam	0.0	0.0	0.0	-7.5	0.0
15 Coal butiminous	0.0	0.0	0.0	-7.7	0.0
36 Tallow	4.0	0.0	0.0	0.0	0.0
38 Fir timber	44.2	0.0	0.0	0.0	0.0
39 Spruce timber	38.2	0.0	0.0	0.0	0.0

NOTE: Average rates of duty are computed from information on specific duty rates and market prices. The British duty on coal is an export duty. The British timber duty rates apply to non-colonial timber.

Table 2. German-British price gaps.

Commodity	1850/52	1875/77	1889/91	1901/03	1911/13
1 Wheat	-7.8	-1.9	27.9	24.5	28.9
2 Barley	1.6	7.9	25.5	24.9	28.5
3 Oats	-17.0	-9.6	23.7	15.0	28.3
4 Rye	0.7	-12.9	36.0	25.4	26.6
5 Flour	1.7	-2.7	31.1	24.9	30.9
6 Peas	-36.0	-26.4	-10.6	-14.1	7.3
7 Potatoes	-56.5	-62.6	-40.3	-50.7	-19.7
8 Hay	-49.3	-38.3	-29.9	-39.3	-31.6
9 Straw	-17.2	4.3	9.9	-1.7	-15.5
10 Beef	-22.9	-34.7	-1.1	10.1	27.3
11 Pork	-32.2	-13.1	20.3	-4.5	18.6
12 Butter	-16.1	-3.0	-5.7	3.8	5.4
13 Lard	-17.6	-3.7	13.9	6.4	10.3
14 Coal steam	50.2	44.4	40.4	44.8	29.0
15 Coal butiminous	17.7	-9.5	27.8	32.7	24.7
16 Pig iron Scottish	47.1	43.7	72.1	57.9	45.7
17 Pig iron foundry	20.7	28.9	55.4	23.2	17.4
18 Copper	5.4	10.8	14.2	9.6	5.0
19 Lead	3.6	5.1	6.2	3.7	0.5
20 Tin	3.1	11.7	6.9	3.4	4.1
21 Zinc raw	-19.1	-12.4	-5.8	-4.5	-2.9
22 Zinc sheets	-20.0	-10.9	-6.0	-15.5	-14.3
23 Wool	27.9	-6.9	-5.6	10.2	5.0
24 Cotton	15.9	8.7	5.0	3.2	-0.5
25 Cotton yarn	34.2	5.8	9.8	9.8	15.2
26 Silk	17.7	25.1	3.1	0.0	2.3
27 Flax	7.0	11.9	-5.9	-8.9	-10.1
28 Linen yarn	-26.1	-1.1	5.8	4.3	7.4
29 Hemp	7.2	0.1	-2.5	24.9	16.2
30 Hides	7.3	40.3	10.9	15.7	16.2
31 Leather	24.6	3.5	-11.7	-6.5	-2.8
32 Soda	42.3	67.8	15.8	-1.8	0.2
33 Saltpetre	36.9	12.9	11.8	3.9	4.2
34 Linseed oil	11.0	6.5	5.8	8.2	5.1
35 Palm oil	7.6	-0.3	-0.4	-2.4	-4.2
36 Tallow	4.4	5.5	42.0	16.6	19.0
37 Rosin	7.1	-3.2	-12.3	-10.3	-7.5
38 Fir timber	-40.8	-30.0	-22.7	-26.2	-33.3
39 Spruce timber	-49.0	-30.0	-16.3	-38.4	-27.2
40 CEREALS (1-5)	-4.2	-3.9	28.8	23.0	28.7
41 FEEDING STUFFS (6-9)	-39.7	-30.8	-17.7	-26.5	-14.9
42 ANIMAL FOODS (10-13)	-22.2	-13.6	6.8	3.9	15.4
43 COAL and IRON (14-17)	33.9	26.9	48.9	39.7	29.2
44 NON-FERROUS METALS (18-22)	-5.4	0.9	3.1	-0.7	-1.5
45 TEXTILES (23-29)	12.0	6.2	1.4	6.2	5.1
46 MATERIALS (30-39)	5.2	7.3	2.3	-4.1	-3.0
47 ALL COMMODITIES (1-39)	-0.6	0.8	8.8	4.7	6.7

NOTE: Price gaps are estimated from comparisons of similar commodity descriptions in the years 1911-1913. Estimates of the price levels for previous years are derived by extrapolating backwards using the price indices for each commodity. The group averages 40 - 47 are unweighted means.

Table 3. Cointegration test statistics.

Commodity	Simple model			Extended model		
	Cointe-gration	Significance-level	Proportio-nality	Cointe-gration	Significance-level	Proportio-nality
1 Wheat	yes	5	no	yes	1	yes
2 Barley	yes	1	no	yes	1	yes
3 Oats	yes	1	no	yes	1	yes
4 Rye	yes	1	no	yes	1	yes
5 Flour	yes	5	no	yes	1	yes
6 Peas	yes	1	no	yes	1	no
7 Potatoes	yes	1	yes			
8 Hay	yes	1	yes			
9 Straw	yes	1	yes			
10 Beef	no			no		
11 Pork	no			no		
12 Butter	no			no		
13 Lard	yes	1	yes	yes	1	no
14 Coal steam	yes	1	yes	yes	1	yes
15 Coal butiminous	yes	5	no	yes	1	yes
16 Pig iron Scottish	yes	1	no	yes	1	no
17 Pig iron foundry	yes	1	no	yes	1	no
18 Copper	yes	1	yes			
19 Lead	yes	1	yes			
20 Tin	yes	1	yes			
21 Zinc raw	yes	1	yes			
22 Zinc sheets	yes	1	yes			
23 Wool	yes	1	yes			
24 Cotton	yes	1	yes			
25 Cotton yarn	no			yes	1	no
26 Silk	yes	5	no			
27 Flax	yes	1	yes			
28 Linen yarn	yes	5	yes	yes	5	yes
29 Hemp	yes	5	yes			
30 Hides	yes	5	yes			
31 Leather	yes	5	yes			
32 Soda	yes	5	no	no		
33 Saltpetre	no					
34 Linseed oil	yes	1	yes	yes	1	yes
35 Palm oil	no			no		
36 Tallow	yes	1	no	yes	5	no
37 Rosin	yes	1	no			
38 Fir timber	no			yes	1	no
39 Spruce timber	no			yes	1	no

NOTE: Tests for cointegration are based on the trace statistic using the Johansen(1990) procedure. In the simple model proportionality requires that the coefficient on the foreign price level term is unity; in the extended model coefficients on the foreign price level and the tariff variable should add up to one. A 5 per cent significance level is used in the proportionality tests.

Table 4. Correlation coefficients, volatility and half-life statistics.

Commodity	Correlation		Volatility		Years to half-life	
	Level	Difference	Uncon-ditional	Con-ditional	Simple AR model	Extended AR model
1 Wheat	0.868	0.929	0.149	0.042	1.5	1.0
2 Barley	0.613	0.666	0.138	0.070	1.2	1.1
3 Oats	0.304	0.700	0.191	0.062	1.3	0.8
4 Rye	0.664	0.674	0.169	0.089	1.0	0.7
5 Flour	0.919	0.863	0.131	0.053	1.4	1.1
6 Peas	0.475	0.468	0.163	0.080	0.6	0.6
7 Potatoes	0.171	0.252	0.288	0.204	0.8	
8 Hay	0.366	0.424	0.190	0.145	1.2	
9 Straw	0.390	0.092	0.205	0.186	0.7	
10 Beef	-0.033	0.158	0.247	0.089	2.5	1.8
11 Pork	0.282	0.451	0.188	0.085	1.3	1.3
12 Butter	0.874	0.857	0.069	0.027	1.4	1.4
13 Lard	0.863	0.863	0.111	0.065	0.6	0.6
14 Coal steam	0.874	0.816	0.093	0.072	0.8	0.7
15 Coal butiminous	0.675	0.299	0.219	0.154	1.8	1.7
16 Pig iron Scottish	0.957	0.916	0.075	0.052	1.9	1.8
17 Pig iron foundry	0.947	0.852	0.105	0.083	1.3	1.3
18 Copper	0.989	0.932	0.040	0.037	0.8	
19 Lead	0.986	0.897	0.035	0.031	0.7	
20 Tin	0.991	0.977	0.038	0.027	1.1	
21 Zinc raw	0.949	0.950	0.056	0.026	0.6	
22 Zinc sheets	0.956	0.918	0.052	0.041	0.8	
23 Wool	0.714	0.464	0.143	0.099	1.6	
24 Cotton	0.992	0.934	0.054	0.035	0.9	
25 Cotton yarn	0.974	0.950	0.103	0.052	3.4	3.1
26 Silk	0.946	0.737	0.126	0.078	0.9	
27 Flax	0.823	0.345	0.128	0.121	0.6	
28 Linen yarn	0.849	0.789	0.111	0.072	2.1	2.1
29 Hemp	0.900	0.770	0.082	0.065	0.9	
30 Hides	0.942	0.889	0.074	0.053	1.8	
31 Leather	0.758	0.799	0.137	0.080	1.9	
32 Soda	0.873	0.762	0.208	0.069	4.3	3.5
33 Saltpetre	0.834	0.382	0.132	0.086	1.9	
34 Linseed oil	0.993	0.988	0.032	0.025	1.0	1.0
35 Palm oil	0.984	0.970	0.048	0.020	1.1	1.1
36 Tallow	0.949	0.778	0.112	0.068	1.7	1.6
37 Rosin	0.967	0.939	0.119	0.087	1.0	
38 Fir timber	0.772	0.153	0.143	0.094	1.7	1.4
39 Spruce timber	0.759	0.347	0.176	0.095	2.5	1.7
40 CEREALS	0.674	0.766	0.156	0.063	1.3	0.9
41 FEEDING STUFFS	0.351	0.309	0.211	0.154	0.8	0.8
42 ANIMAL FOODS	0.497	0.582	0.154	0.066	1.5	1.2
43 COAL and IRON	0.863	0.721	0.123	0.090	1.5	1.4
44 NON-FERROUS METALS	0.974	0.935	0.044	0.032	0.8	
45 TEXTILES	0.885	0.713	0.107	0.075	1.5	1.4
46 MATERIALS	0.883	0.701	0.118	0.068	1.9	1.7
47 ALL COMMODITIES	0.772	0.691	0.125	0.075	1.4	1.3

NOTE: The unconditional volatility measure is the standard deviation of LOP deviations; conditional volatility is the standard deviation of residuals after regressing LOP deviations on a constant, a time trend and German-British duty rates. The duty rates are also used in the extended model. The group averages 40 - 47 are unweighted means.

Figure 1: *Hamburg banco and reichsmark against sterling 1845 - 1913*

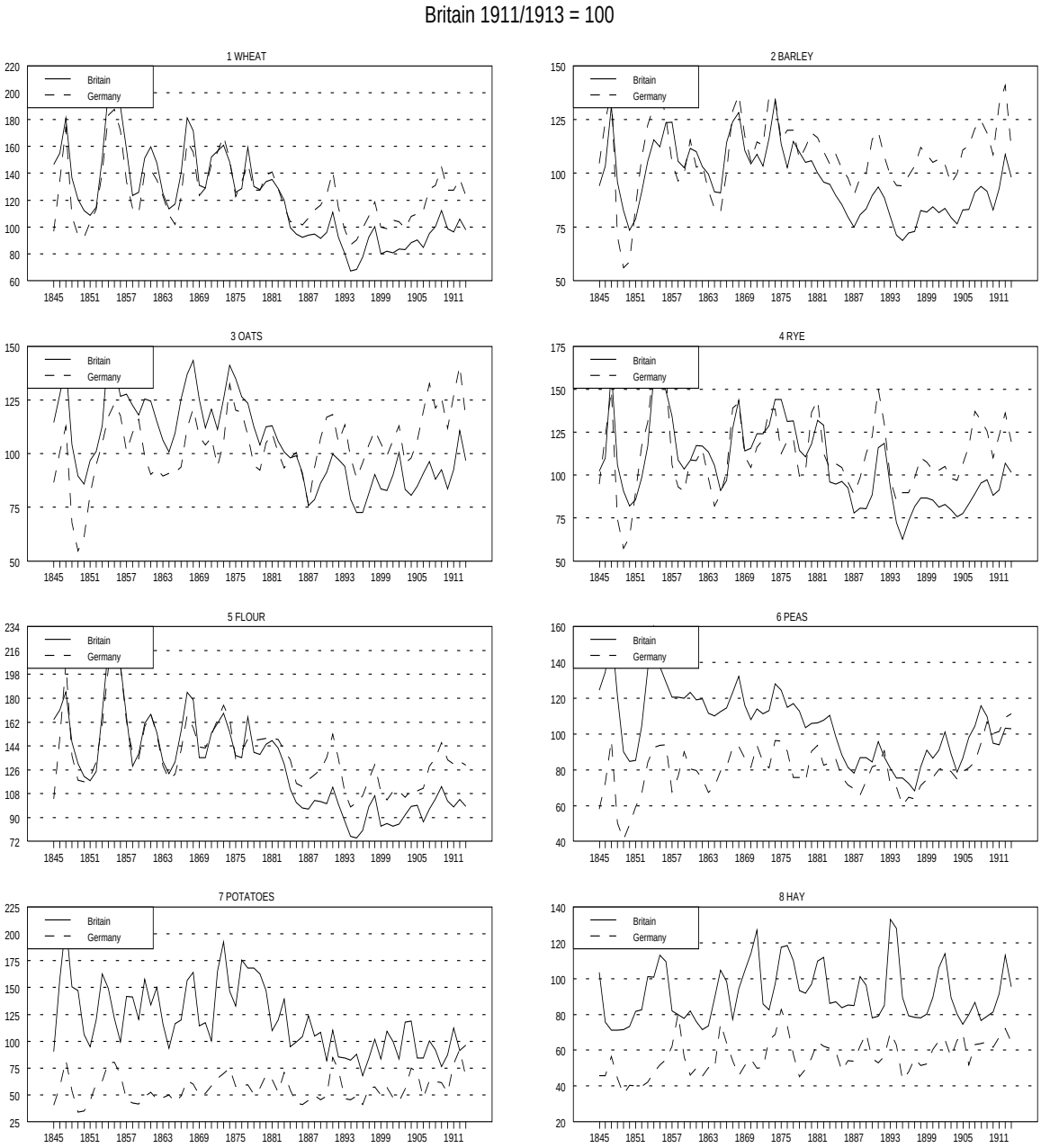

Figure 2: *British and German commodity prices in common currency 1845 - 1913*

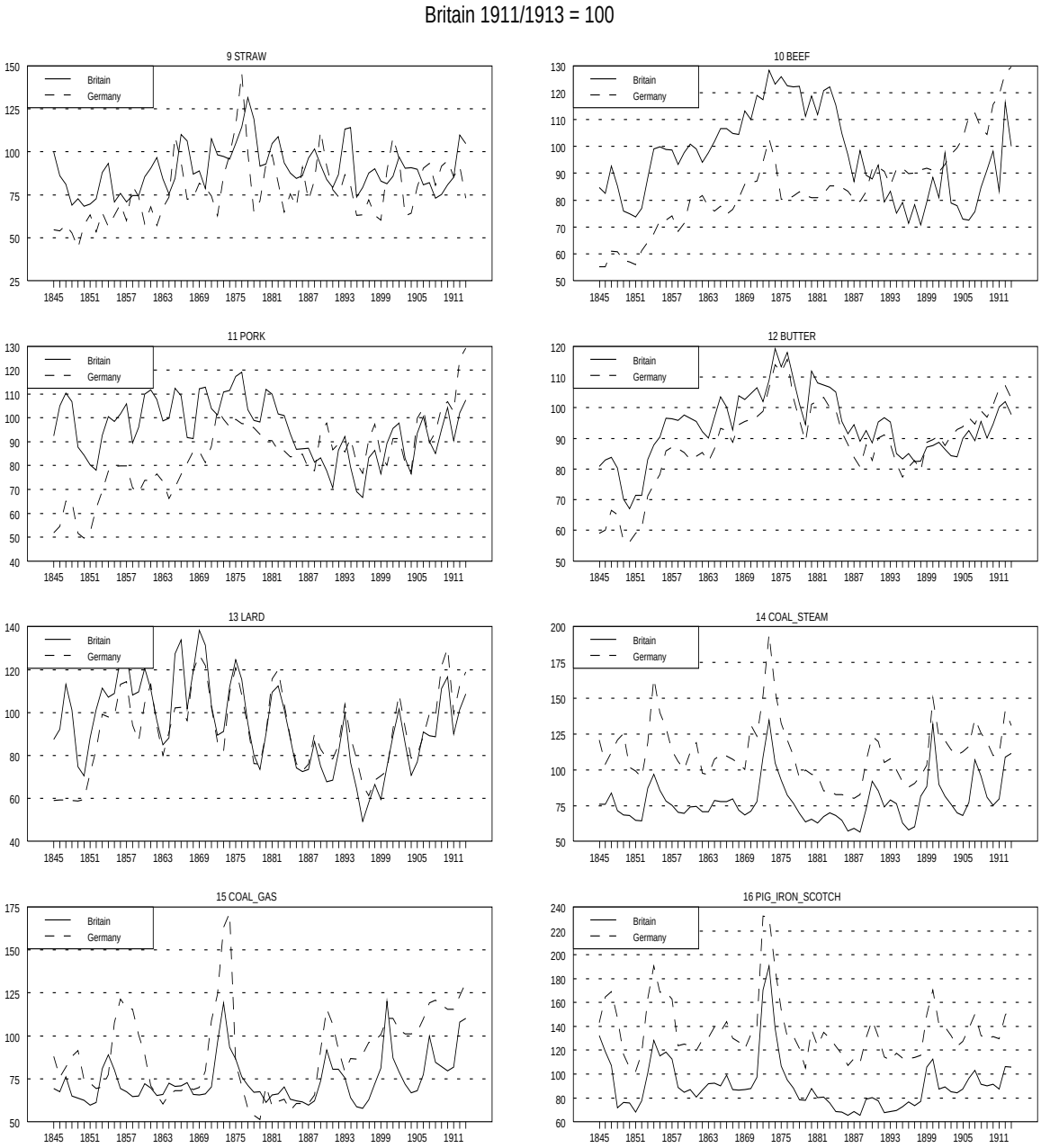

Figure 3: *British and German commodity prices in common currency 1845 - 1913*

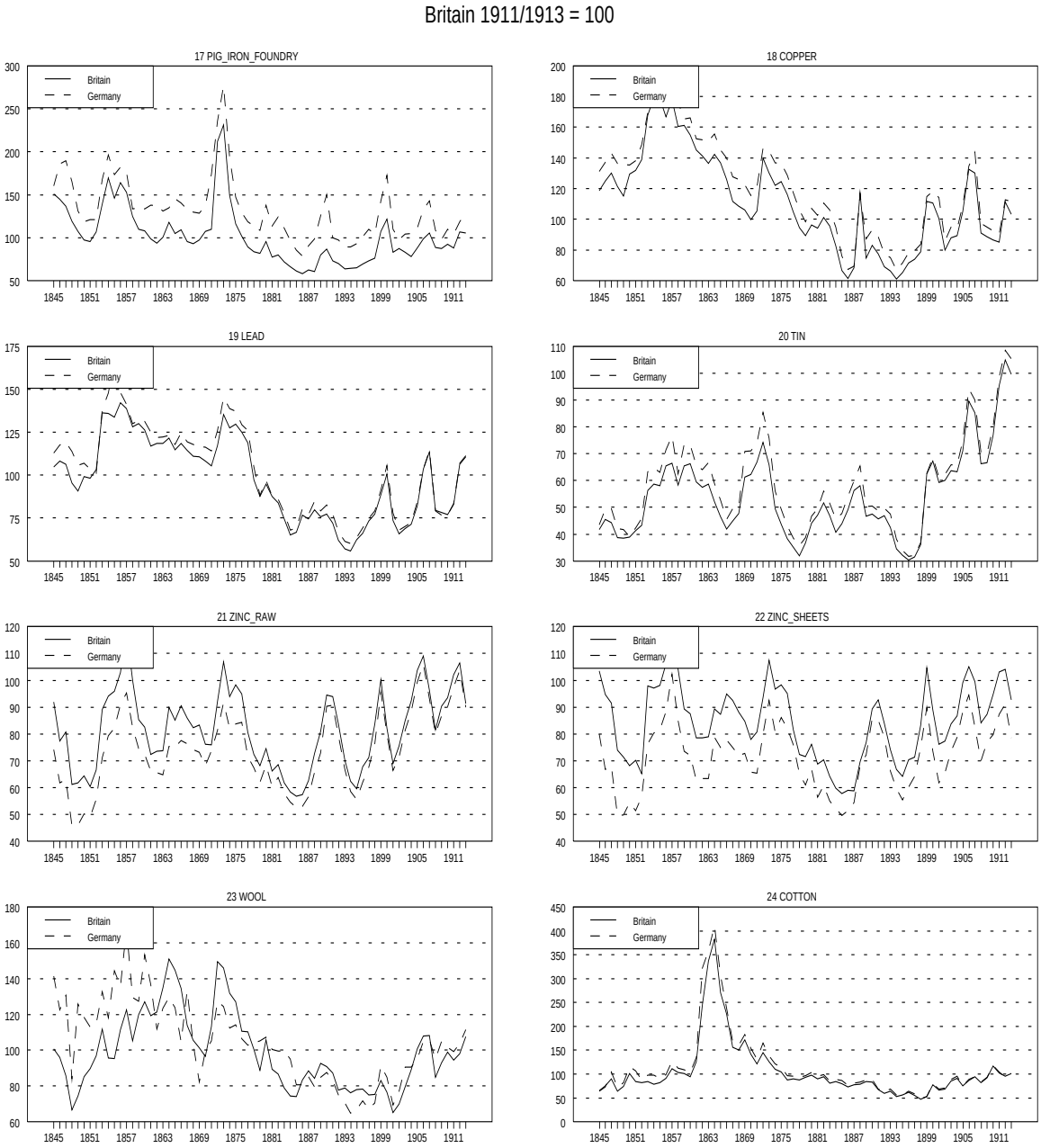

Figure 4: *British and German commodity prices in common currency 1845 - 1913*

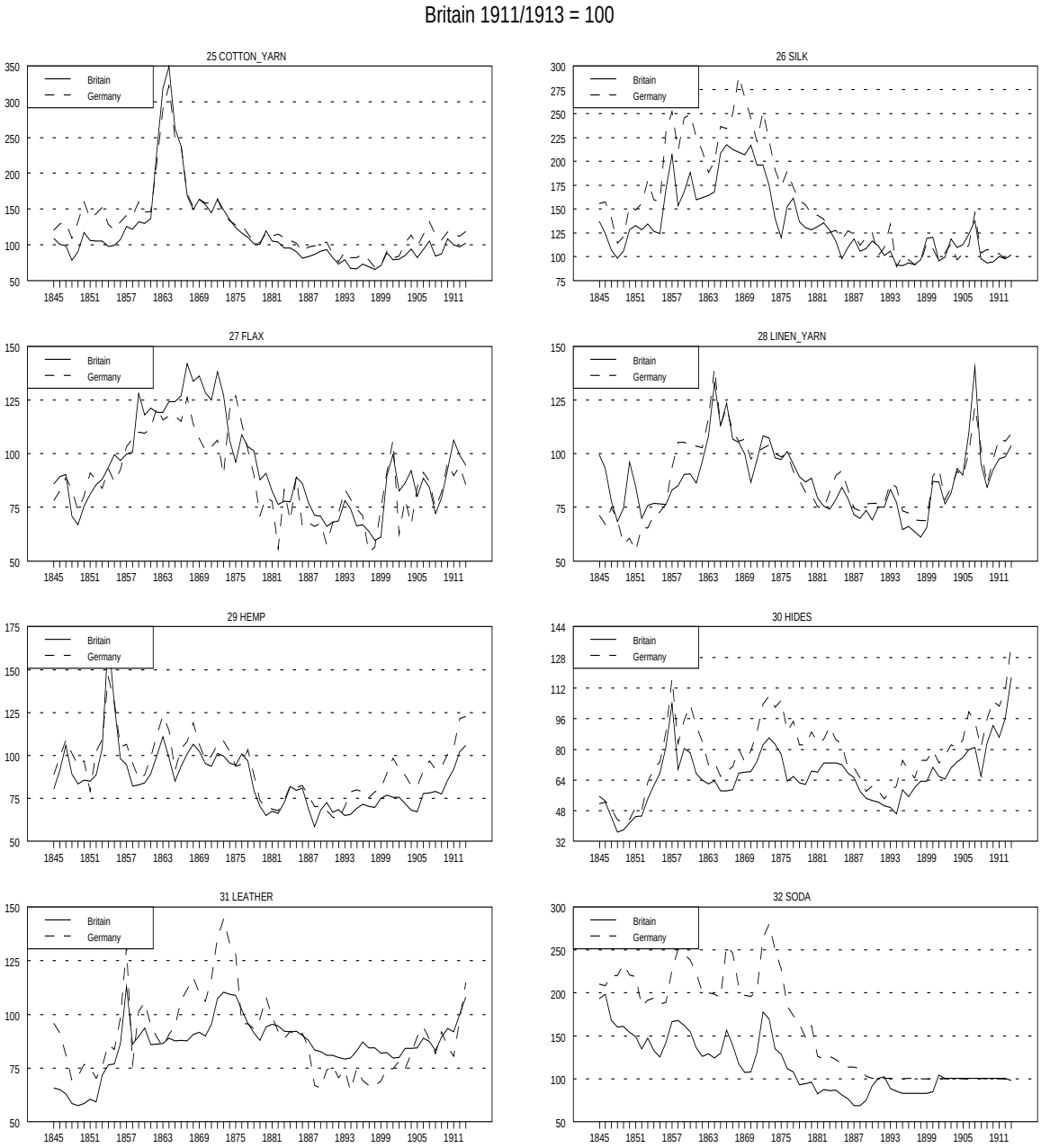

Figure 5: *British and German commodity prices in common currency 1845 - 1913*

Figure 6: *British and German commodity prices in common currency 1845 - 1913*

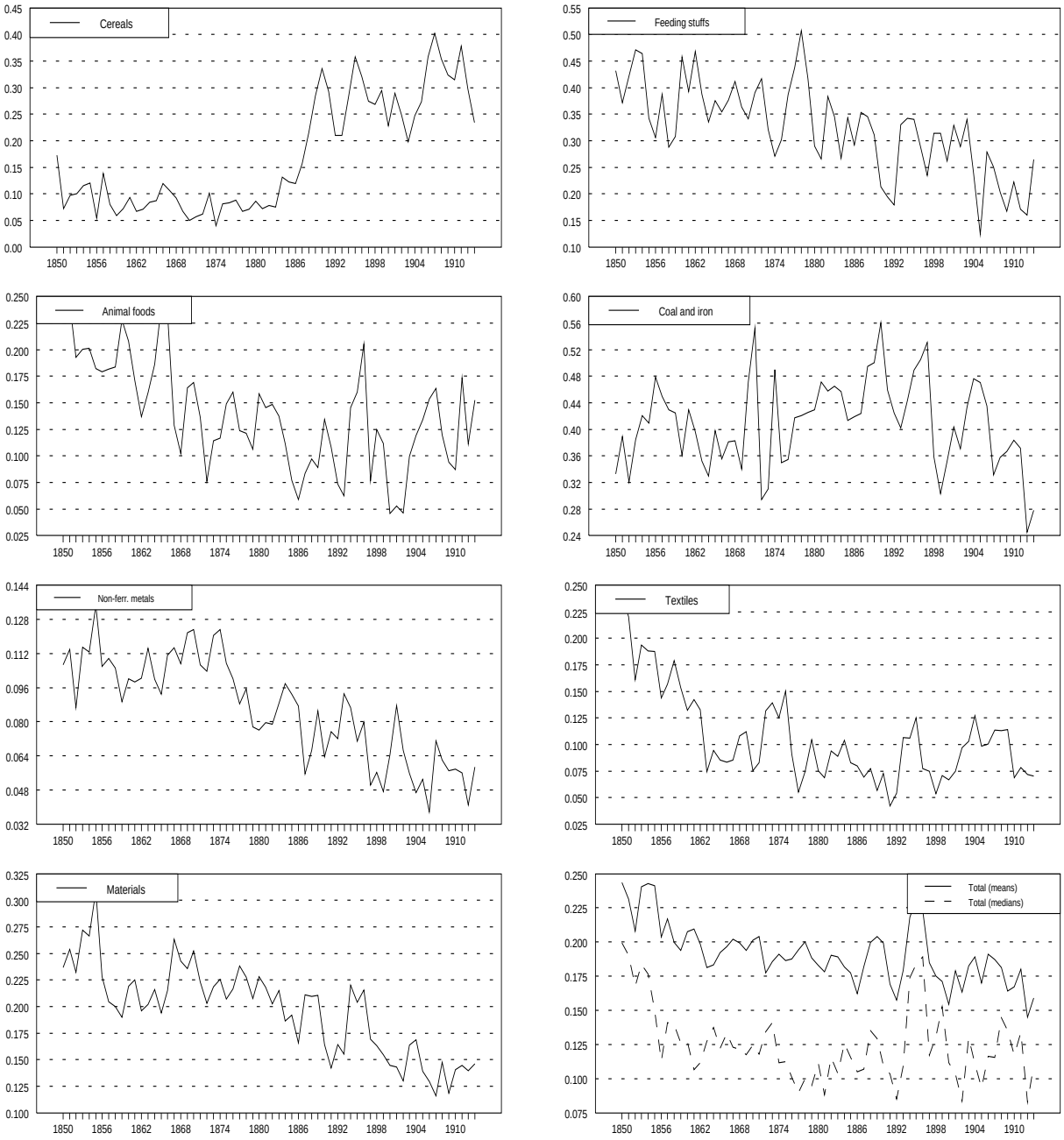

Figure 7: *Absolute price variability by groups of commodities 1850 - 1913*