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An empirical study of price correlations: 1. How should spatial interactions between interdependent markets be measured?

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Abstract. Price fluctuations are known to be rather chaotic and unpredictable. However, when these fluctuations are compared at different marketplaces some regular patterns appear. The precise nature of such regularities and what can be learned from them about the internal structure of an economic system are the purpose of this series of two papers. In this first paper the evolution of an economic system is analysed, namely in Germany during the period of its economic integration, that is to say during the 19th century. Different statistical measures are compared: the price ratio, the price correlations, the price dispersion, in order to characterise the increasing interdependence of economic activity centres. It is shown that this interdependence increases for every commodity according to a specific trend. Last, in order to link these results with the economic and political history of Germany some data are presented pertaining to the development of its domestic trade during the 19th century.

1 Introduction

The paper has the following structure. Section 1 is an introduction to price series and market interdependence. In section 2, I shall discuss the methodology used to estimate market interdependence and in section 3, I shall present some typical graphs showing the evolution of the market integration. Then I shall give quantitative orders of magnitude for the correlation and for its evolution. In section 4, I shall discuss briefly the relation of market integration with some specific features of the economic and political evolutions in Germany. I should mention that a preliminary, and in some respects more detailed version, of these papers exists (Roehner, 1987).

1.1 *Price series in economics*

In economics there are two kinds of variables: so-called 'extensive' variables such as production data for agriculture and industry, national income data, etc; and so-called 'intensive' variables such as prices, productivity indexes, and so on.

An intensive variable characterises an equilibrium between different forces. In the case of prices, these forces have been classified under two headings, namely supply and demand. However, in reality many different processes are involved. As a result, prices constitute a thermometer of economic life. The only trouble is that the readings of that thermometer are not easily interpreted, precisely because they are related to so many different economic forces.

The long-term evolution of prices, or more specifically of the ratio of different prices, can be interpreted as revealing changes in productivity. Medium-term price changes are related to the evolution of the money supply as shown by Friedman and his followers.

In comparison, less attention has been paid to short-term price fluctuations, mainly because they have been known to be rather chaotic and unpredictable. Usually they are averaged out by means of some moving average or filtering techniques! But, in this paper, it is these short-term fluctuations that will be analysed.

My objective is twofold. First, we shall see that short-term fluctuations reveal some regular patterns when compared at different marketplaces. Second, I shall try to clarify the relationship between the process of market integration and the interdependence of local price fluctuations.

1.2 *Spatial interaction in geography*

"All our efforts to understand spatial pattern, structure and process have indicated that it is precisely the interdependence of spatial phenomena that allows us to substitute pattern and therefore predictability and order for chaos of things in time and space."

This extract from Gould (1970, pages 443–444) attests that spatial interaction has been an important concern for geographers in the last twenty years. In fact, several pioneering studies have shown what methods could be used to analyse several spatially interdependent time series. Let us mention, for instance, the analysis of interdependence between regional unemployment series by Granger (1969) and by Basset and Haggett (1971), and the extensive studies of measles epidemics by Cliff et al (1975; 1981).

Spatial interaction analysis is very often conditioned by the availability of statistical materials. Market prices, especially for the 19th century (see section 2.1), are obviously good candidates because they have a very good spatial localisation in contrast to migration or traffic data which relate two areas to each other; and because many detailed price statistics are available, even for past centuries.

1.3 *Intuitive conjectures about price interdependence*

Let us now list some of the regularities of connected price series which can be intuitively anticipated.

1.3.1 *Evolution of market interdependence over time* It is clear that prices in different regional markets in the well-integrated economy of the 20th century (especially after 1920) should be almost perfectly correlated. By contrast, these prices would be rather loosely related two or more centuries before, when trading was rather marginal. Between these extremes, there is room for a progressive evolution.

1.3.2 *Attenuation of market interaction with geographical distance* At an intermediate stage in the development of trade, around 1850, we would expect a higher correlation between the price series at two markets, the closer together they are.

1.3.3 *Price connection of different commodities* If we now consider price series for different commodities, we would expect that their degree of interdependence will in some way reflect their economic relationship. For instance, the prices of wheat and rye, interchangeable products in the making of bread, should be closely related. Furthermore, this interdependence is bound to change with economic progress.

1.3.4 *Connection of prices with economic situation* As far as agricultural products are concerned, we would expect a relationship between price series and local meteorological data. For industrial products, we would expect a relationship between price series and the overall economic situation, for instance a lowering of prices accompanying recessions.

In this paper, I shall try to clarify my first conjecture about the evolution of market interdependence. A second paper will be devoted to the second conjecture, namely the change in market interaction with geographical distance. The third and the fourth conjectures will be studied in subsequent papers.

1.4 *The concept of market integration*
Price fixing in a given market is a complex process, which implies that several factors are involved.

1.4.1 *Interaction with surrounding markets* Price interaction is embodied by different flows between markets: commercial flows of exchanges of goods; information flows of news transmission. As a consequence, price interaction is critically dependent upon the efficiency of the transportation system, and also upon the existence of or lack of political or customs barriers.

1.4.2 *Influence of the physical environment* For agricultural goods, for instance (with which I shall be mainly concerned in this paper), weather and soil fertility are clearly two important factors: together they determine the crop yields and as a consequence, the cost price of the goods. Whereas weather is largely uncontrollable, soil fertility can be improved with fertilizers. Hence, this second factor depends heavily upon technical and industrial progress.

1.4.3 *Influence of the socioeconomic environment* Under this heading, we should mention: trading customs, for instance, the existence or lack of national or regional commodity markets permitting speculative transactions; the degree of political unification of the country; the influence of government or large corporations and wholesalers on markets. These factors will clearly operate only in a country that has already achieved a certain degree of centralisation and market integration.

We find from our discussion that the different factors, some of which are internal forces in the market system, whereas others are external forces, are unfortunately tightly intertwined. They have the common property that they induce increasing dependence between markets. Now, such an *overall* interdependence is just what is revealed by spatial price connections. In short, the market-integration process will be the result of a number of evolutions which are in close conjunction. To disentangle them would be rather difficult, except perhaps for one factor, namely the weather, which we shall now discuss.

Because weather has been, at least until recently, independent of economic evolution, it should be possible to separate its influence from other economic factors. This will be attempted in the second paper of this series.

As far as the influence of weather is concerned, we have to answer an argument, put forward, in particular, by Metzer (1974). In the event of a countrywide crop failure, it is clear that prices on all markets will rise simultaneously, especially if imports from abroad are too expensive. This simultaneous price increase will result in a sudden jump in the price correlation. This will indeed be observed in the second paper (section 3.1).

In this case, however, the correlation jump will have nothing to do with market integration. Fortunately, such a sudden crop failure will result only in a *short-term* correlation peak; the correlation trend is unaffected and can still be considered as a convenient measure of market integration.

2 The methodology

2.1 *Why the 19th century in Germany?*
Let me now explain why I preferred to concentrate on the market integration that occurred in Germany during the 19th century.

(1) The 19th century gives us the opportunity to observe the market-integration process down to a regional level. At that time, grain markets were open every week in almost all cities, and many price records are available.

(2) The technical condition of market integration, namely an efficient transportation system began to be achieved after 1850 with the development of railroads and of the telegraph. The economic condition of market integration, namely the production of a permanent surplus which could be put on a nationwide market, also began to be realised for agricultural products during the 19th century. Furthermore, economic and political unification, which began with the Zollverein, favoured market integration from 1825 on.

(3) Prices have always been subject to speculative operations such as hoarding, exporting, or importing at the right moment. However, since the development of trading in future commodity markets at the end of the 19th century, speculation has probably become more financial than commercial. Fortunately, for the largest part of the 19th century, this influence on prices, which can be considered as somewhat artificial, is absent.

(4) My last point is a consequence of the first. Working within the limits of one country we are not bothered by the problem of currency exchange rates and their fluctuations. Furthermore, since the 19th century was one of stable money, we shall mainly face stationary time series.

The 19th century thus appears as a privileged period for studying market integration, and some economists have already devoted attention to this problem: Price (1983) has studied France, and Kovalchenko and Milov (1970), Metzer (1974), and Kelly (1976) have studied the case of Russia.

2.2 *Why work with the logarithm of prices?*

It is well known that when one is comparing two prices, it is their ratio that is economically pertinent rather than their difference. A price increase from 1 to 2 dollars is obviously comparable with an increase (for another product or for the same product but at different time) from 50 to 100 dollars. In contrast, an increase from 50 to 51 dollars will be experienced as almost negligible. Price ratios can be easily compared by means of the logarithm of prices. Thus, in these papers, only logarithms of prices will be considered. For short, I shall speak of logprices (or even simply of prices) and denote them by p': $p' = \ln p$.

2.3 *Three measures of price interdependence*

Let us consider two price series, namely $p_1(t)$ and $p_2(t)$. Different measures can be proposed for their interdependence. Let us discuss them briefly in this context.

2.3.1 *The ratio of prices*

$$\mathrm{r}(t) = \frac{p_1(t)}{p_2(t)} .$$

The ratio of prices reflects only their relative absolute values. Two prices can be approximately equal, whereas their fluctuations are opposite. Thus, the ratio is only a partial measure of price interdependence.

2.3.2 *The correlation of log prices*

$$\mathrm{c}(t) = \mathrm{c}(p_1', p_2') = \frac{\overline{(p_1' - \bar{p}_1')(p_2' - \bar{p}_2')}}{[\overline{(p_1' - \bar{p}_1')^2}\,\overline{(p_2' - \bar{p}_2')^2}]^{1/2}} ,$$

where c is correlation and a bar indicates a time average over a period $2W$, which is called the *correlation window*:

$$\overline{p'(t)} = \frac{1}{2W} \int_{t-W}^{t+W} p'(t_1) \mathrm{d}t_1 .$$

Other variables such as the covariation could also be considered. Experience showed, however, that the evolution of the covariation is much more irregular and, as a result, difficult to interpret.

Let us comment on these definitions: (a) Both r(t) and c(t) are homogeneous functions of degree zero in prices, which means that multiplying both prices by the same factor k does not change them. In other words, r(t) and c(t) are invariant when the measure of volume changes or when a monetary change occurs. Function c(t) has even a stronger invariance than r(t), since it is unchanged even when multiplying only *one* of the prices by a factor k. (b) Whereas the ratio can be computed for each single year, the correlation has to be evaluated over a much larger time window, $2W$. This realises a kind of averaging process. As a result, we could expect the correlation curve to be much smoother than the ratio curve: this is indeed what will be observed below.

2.3.3 *Price dispersion* Yet another function could be considered in order to characterise market integration, namely the dispersion of prices on a given market:

$$\mathrm{D}(t) = \overline{(p' - \bar{p}')^2} \,.$$

Indeed, it seems natural that price fluctuations should be partially damped in a well-integrated market, since local underproduction or overproduction can then be eased thanks to exchanges with surrounding markets.

This view is somewhat naive, however. Indeed, the increased commercial exchanges developing with market integration bring along their own (national or even worldwide) dynamics and it is by no means evident why this dynamics should be smoother than the local one. In other words, price dispersion is connected to market integration in a rather indirect way. It will be mentioned only occasionally in this paper.

2.4 *The problem of the trend and the choice of the window width*
2.4.1 *To detrend or not?* If two series show evidence of a definite trend, it is a common practice to separate out the trend component before computing their correlation. Otherwise, that correlation would be overestimated if the trends have the same direction, and underestimated if the trends have opposite directions.

Let me explain why I did not use such a procedure. (1) Figures 1(a) and 1(b) show two price series for wheat. No definite trend appears, or, in other words, the series are first-order stationary. The same will be true, because of monetary stability, for most agricultural products. (2) Some products such as butter, copper, or lead, show a definite trend over the whole century: increases for butter, decreases for copper and lead because of productivity gains. However, the correlation will

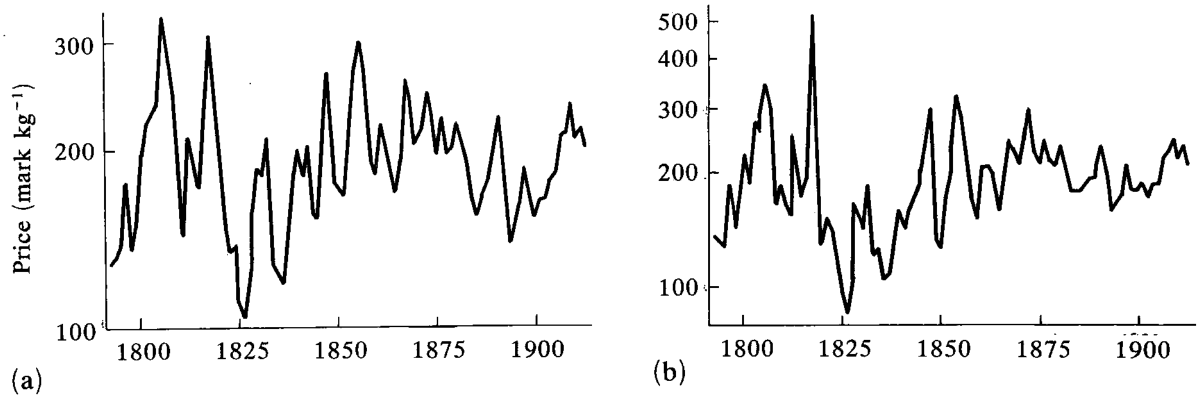

Figure 1. Wheat prices on (a) the Berlin market and (b) the München market (log scale).

be evaluated over a rather narrow window, of the order of twenty years; in such a small interval the influence of the trend compared with the fluctuations is negligible. (3) One possible way to detrend a time series is to evaluate the correlation for price *changes* rather than for the prices themselves. Both methods were tested. It turned out that the curves are almost parallel whenever the correlation between the series is high enough (the correlation for price changes being generally below that of prices). When the correlation between both series is lower, the correlation of price changes becomes very erratic because the 'noise' component of the data becomes predominent in price changes.

2.4.2 *The choice of the window W* There is another reason to choose a rather small window width; indeed, if $2W$ becomes of the order of, say, forty years, then the correlation can be computed only for a rather short time interval, centred on the middle of the whole period. Furthermore, using such a large window would smooth out all medium-term changes due, for instance, to tariff modifications. On the other hand, using a very narrow window would result in a large confidence interval for the correlation.

The compromise adopted in this paper is to take a window of seventeen years; this rather small interval does not result here in confidence intervals that are too large, since the level of the correlations encountered in this study is fairly close to one.

2.5 *An important scale transformation*

The last point to be mentioned in this methodological introduction concerns a scale transformation performed on the correlation in order to magnify the values in the vicinity of 1. This is a rather technical point, but one which proved very helpful in order to exhibit the market-integration trend. Let me explain why.

A correlation increase from an already high level (such as 0.93, for instance), to a still higher level (say 0.97) will be almost imperceptible on a graph with a linear scale. Nevertheless, such an increase corresponds to a true gain of mutual interdependence; the small value of the absolute change (0.04 in this example) is merely a consequence of the fact that a correlation is, by definition, bounded by 1.

To make the correlation gains in the vicinity of 1 apparent, we need a scale transformation which magnifies the values around 1. The transformation:

$$g = \tfrac{1}{2}\ln\left[\frac{1+c(t)}{1-c(t)}\right] = \mathrm{artanh}[c(t)]$$

(that is the inverse hyperbolic tangent) has this property. When $c(t)$ tends to one, $\mathrm{artanh}[c(t)]$ will tend to infinity; in addition, it leaves the small values of the correlation almost unchanged.

3 Analysis of market interdependence

3.1 *Some typical graphs*

3.1.1 *The data* The data to be analysed are prices of wheat, rye, oats, potatoes, butter, copper, and lead on a number of German markets during the period 1791–1914 (Jacobs and Richter, 1935a; 1935b).

To compute price ratios and price correlations we have to select market pairs. With six marketplaces, fifteen pairs can be constructed. To draw the graphs, I picked out mainly those formed by Berlin and the other cities, since Berlin has a geographically central position.

3.1.2 *Wheat and rye prices* Figures 1(a) and 1(b) depict the evolution of wheat prices in Berlin and München, respectively. The curves are, as expected, rather chaotic. It would be difficult to estimate any correlation by visual inspection.

Figures 2(a) and 2(b) show the evolution of the price ratio and of the price correlation, respectively, for the Berlin - München wheat prices. München was one of the most important cereal markets in Germany.

The market-integration process reveals itself on both curves: The price ratio exhibits a trend to 1 [figure 2(a)]. This trend toward price uniformity is, however, accompanied by swift fluctuations above and below 1, the variance of which decreases with time. This is in contrast to the observation presented by Metzer (1974) for the difference in wheat prices between Petersburg and Odessa (Russia), where the Odessa price always remained the lower. The price correlation shows a trend to 1, that is, the function artanh[$c(t)$] increases steadily [figure 2(b)].

The price-ratio and the price-correlation curves look very different. The fluctuations of the price ratio seem almost chaotic, whereas the price correlation shows some medium-term fluctuations, for instance in the interval 1820 - 1835. This feature will be even more evident for the rye prices to which we now turn.

For the rye prices we display only the correlation curve, since the price-ratio curves are similar for all cereals, with the same trend to 1 and the same fast fluctuations. The Berlin - München correlation curve for rye (figure 3) exhibits the same trend to high correlation levels that we saw in figure 2(b), but this time with three pronounced peaks. To make sure that those peaks are not special to the Berlin - München correlation, I also looked at other pairs: Berlin - Königsberg, Berlin - Hamburg, Berlin - Mannheim, Berlin - Köln. The same peaks were apparent on all curves. They should thus be considered as revealing something about the economic evolution of Germany. I shall come back to this point in section 4.2.

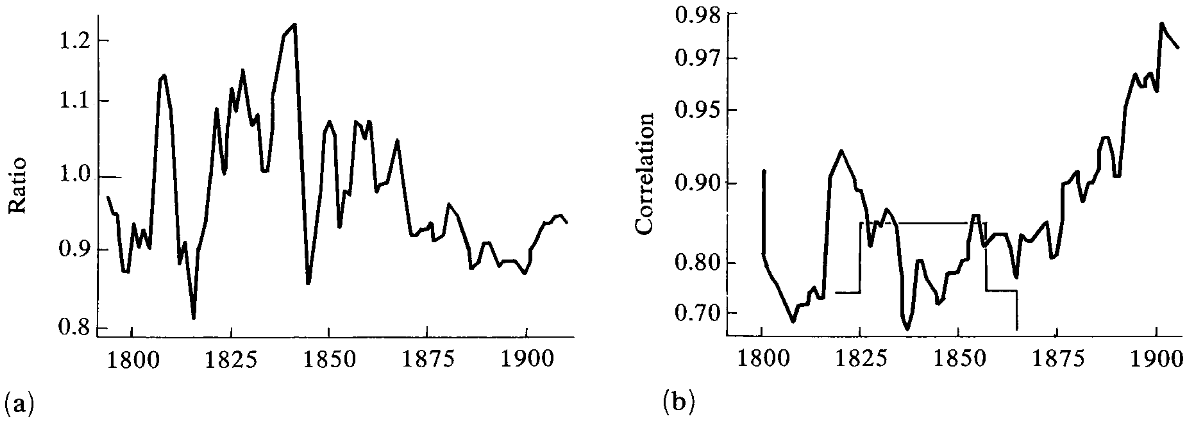

Figure 2. (a) Ratio of the Berlin and München wheat prices (log scale); (b) correlation of the Berlin and München wheat prices (artanh scale).

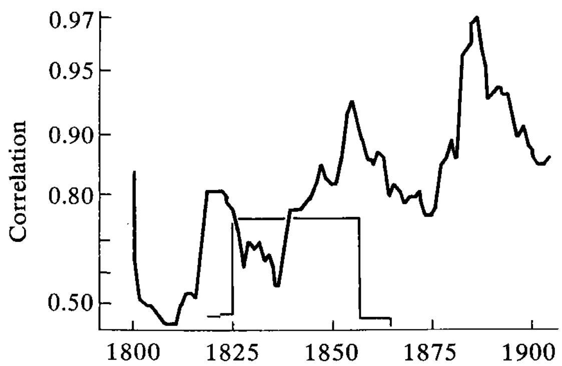

Figure 3. Correlation of the Berlin and München rye prices (artanh scale).

3.1.3 *Lead prices* This study is mainly centred on agricultural products. However, it is important to analyse at least a few industrial products in order to point out the similarities as well as the differences between industrial products and foodstuffs.

We may observe in figure 4(a) that the Berlin-Hamburg price ratio for lead also has a trend to 1. The curve is, however, much smoother than the curves for agricultural products. This is indeed to be expected since industrial prices do not depend upon meteorological hazards. Furthermore, the Berlin price almost always remains above the Hamburg price.

When comparing the Berlin-Hamburg correlation curve for lead [figure 4(b)] with the correlation curves for wheat and rye [figures 2(b) and 3(a)] we observe, first, an overall resemblance with a trend to 1 and a few medium-term fluctuations, second, an increase which is much faster than in previous cases. The difference will be estimated more precisely below (section 3.2.1).

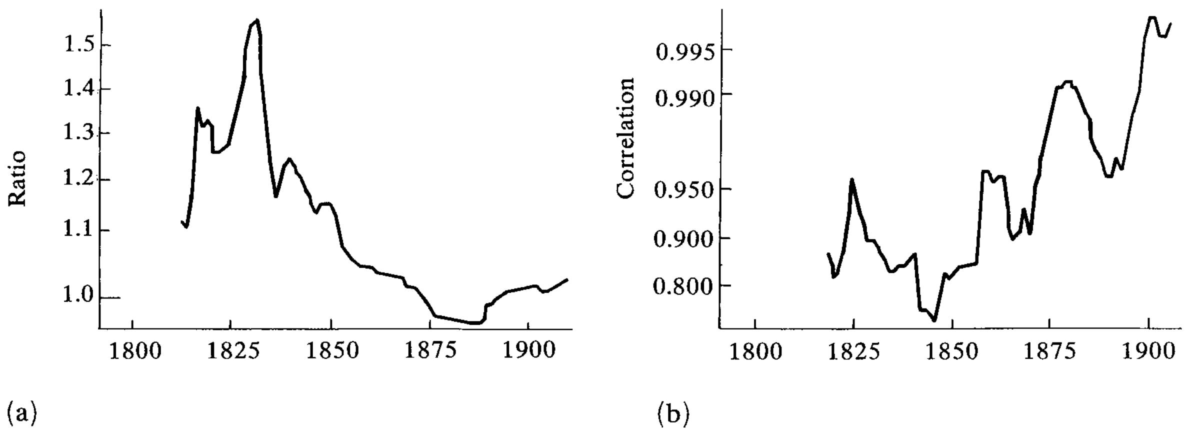

Figure 4. (a) Price ratio of the Berlin and Hamburg lead prices (log scale); (b) correlation of the Berlin and Hamburg lead prices (artanh scale).

3.2 *Estimates of average correlations and of the trends*

The previous curves give a general idea of the interdependence between markets. Let us now give some quantitative and systematic evaluations.

3.2.1 *Average level of price correlation and dispersion* Since the correlations show a sharp trend to increase, one could think that it does not make much sense to compute average correlations. Here we shall be interested in *orders of magnitude* which will be seen to reveal some interesting features. The averages we are considering are not only time averages over the entire period 1790-1914, but also space averages over all market pairs.

In table 1, I summarise the prices, the average correlation, and dispersion level for seven products. Among cereals, wheat has the highest correlation level and it is also the most expensive. On the other hand, the foodstuff with lowest correlation level, namely potatoes, is also the cheapest. How could those observations be interpreted?

The correlation level for two products certainly depends upon a large number of factors including production, stocking, transportation, and consumption conditions. If two products are similar with respect to production, stocking, and consumption, then transportation costs should play a predominant role according to the rule:

$$\begin{matrix}\text{high} & & \text{low relative} & & \text{good} & & \text{high} \\ \text{specific} & \Rightarrow & \text{transportation} & \Rightarrow & \text{trading} & \Rightarrow & \text{correlation} \\ \text{value} & & \text{costs} & & \text{opportunity} & & \text{level}\end{matrix}\ .$$

Wheat, rye, and potatoes, the three basic foodstuffs in Germany at that time, can be considered as examples of this situation; hence the relation between specific value and correlation level disclosed by table 1.

On the other hand, butter and oats obviously have different stocking and consumption conditions: storing butter was rather difficult at that time and oats were mainly intended for consumption by horses. Hence it is not surprising that their correlation levels are not in line with their specific prices. The same remark holds for copper and lead.

Table 1. Average level of prices, correlations, and dispersions for seven products in Germany, 1790–1914.

	Indicative price (mark per 100 kg)	Average correlation		Average dispersion	Consumption (kg per capita) 1873–1894
		c	g		
Wheat	20	0.93	1.70	6.2	57
Rye	16	0.92	1.62	6.8	116
Oats	16	0.82	1.17	4.8	83
Potatoes	4	0.79	1.09	4.8	380
Butter	250	0.86	1.30	1.6	
Copper	150	0.90	1.48	3.0	
Lead	39	0.95	1.85	3.2	

3.2.2 *Increasing trends of price correlation* When one looks at the correlation curves of figures 2(b), 3, and 4(b), it does not appear unreasonable to attempt a linear fit. Figure 5 gives linear least square fits for the average correlation over all market pairs. The values of the slope and of the correlation coefficient characterising the goodness of fit are summarised in table 2 (see over), along with the confidence intervals. The fit appears to be pretty good for wheat, rye, copper, and lead. It is somewhat poorer, but still significant for oats, potatoes, and butter.

As a result, we may summarise our observations in the following statement.

Proposition *The increase of the average correlation* c(t) *between markets for a product p can be modelled by the following function of time:*

$$c(t) = \tanh(at+b),$$

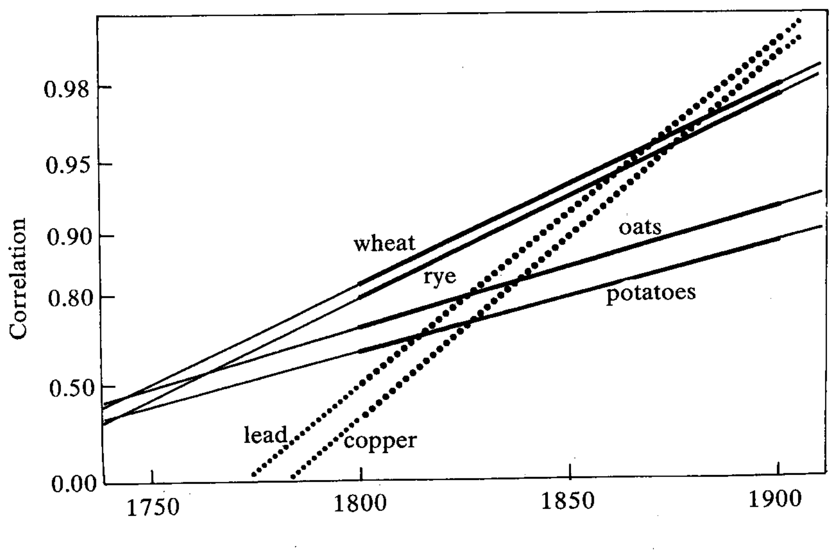

Figure 5. Increasing trend in the correlation (artanh scale)

where t represents the time (expressed in centuries), starting from 1790, and a, b are coefficients (given in table 2) specific to the product p; a is of the order of 1 for cereals and of the order of 2 for metals such as lead and copper.

Table 2. Growth trends of the price correlation in the form $c(t) = \tanh(at+b)$ for seven products in Germany, 1790-1914.

	a[a]	b	Goodness of fit[a]
Wheat	1.15 (1.02, 1.28)	0.84	0.86 (0.80, 0.90)
Rye	1.22 (1.10, 1.35)	0.73	0.88 (0.83, 0.92)
Oats	0.74 (0.57, 0.90)	0.60	0.66 (0.53, 0.75)
Potatoes	0.63 (0.36, 0.89)	0.65	0.44 (0.26, 0.60)
Butter	1.01 (0.71, 1.31)	0.59	0.57 (0.42, 0.70)
Copper	2.19 (1.85, 2.53)	0.13	0.77 (0.69, 0.84)
Lead	2.12 (1.79, 2.45)	0.36	0.80 (0.71, 0.86)

[a] The figures in parentheses are lowest and highest values of the confidence interval.

4 Market integration in the light of Germany's economic and political evolution

We saw that price correlation increased along with two major processes occurring in Germany during the 19th century, namely the development of trade and especially railroad extension and economic and political unification. However, neither of these evolutions was linear: the railroads developed rapidly between 1850 and 1870 and as far as tariff barriers are concerned, there was a succession of suppressions and reinforcements.

My purpose here is to give a few brief landmarks of these evolutions and to discuss their relation with the previous curves. However, this will be a qualitative discussion rather than a quantitative interpretation. There are at least three reasons for this. First, for a clear interpretation of the medium-term fluctuations, we would need correlation curves with higher time definition; the use of monthly data instead of annual data would permit such an improvement, because in this case the window width could be reduced to a few years. Second, to relate the market-integration process to the intensity of commercial flows between markets would require detailed intermarket trade statistics which I have not yet found. However, below I shall give railroad transportation statistics for a short period, 1890-1910. And last, but not least, there would need to be quantitative estimates of the effect of political unification.

4.1 *Railroad extension and trade development*

It is clear that the major transformation in transportation conditions during the 19th century was the creation and extension of the rail network (see figure 6).

Engel (1861, page 262) evaluates railroad transportation as being four times cheaper than road transportation. Henceforth, whereas trade was previously confined to rather high-priced products (wheat, for instance), even low-priced products (such as rye, oats, or even potatoes) could now be transported over appreciable distances. This effect is quite apparent in table 3, which gives railroad transportation statistics (*Statistisches Jahrbuch für das Deutsche Reich*, 1895 and following): among foodstuffs the products which experienced the highest rate of increase are the cheapest.

Two other remarks are in order.

(a) The traded quantities of potatoes appear at first to be rather high for a product of such a low price. Those quantities should, however, be compared with the average consumption per capita given in table 1. It then appears that trade on

potatoes represents only 64% (in 1890) of wheat trade, whereas its consumption was six times larger. The same remark holds for rye: its trade represents 65% of wheat trade, whereas its consumption was twice as large.
(b) The increase in rates of trade cannot really be compared with the increase in rates of correlation given in table 2. First, the period 1890-1910 is too short compared with the whole period (namely 1790-1910) considered in table 2. Second, railroad trade is probably only a small part of total trade.

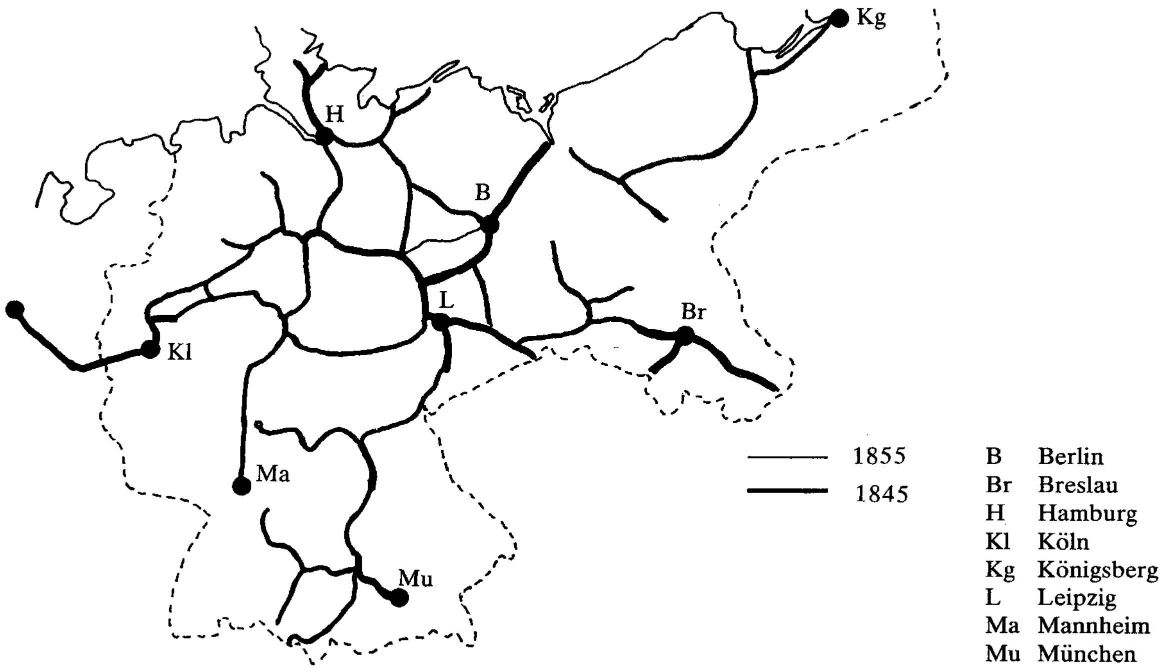

Figure 6. Two stages in the development of the German railroad network.

Table 3. Increase in railroad transportation per commodity (in 1000 tons).

	Wheat	Rye	Oats	Potatoes	Lead
1890	2075	1366	804	1331	171
1895	2389	1338	1032	1522	194
1900	2616	1603	1396	1954	259
1905	2670	1925	1683	2757	333
1910	2690	2914	1964	4183	328
Rate of increase (%) 1890-1910	30	93	112	160	118

4.2 *Economic and political unification*
The customs union progressed along with political unification from 1825 on. In 1828, the situation was as follows. Berlin, Breslau, Königsberg, and Köln belonged to the Prussian 'Zollverein'. Leipzig belonged to the 'Mitteldeutscher Handelsverein'. Mannheim and München belonged to the 'Süddeutscher Zollverein'. In 1834, the three previous customs unions had merged. Hamburg is a special case; it joined the 'Zollverein' only in 1888.

This process certainly resulted in a strengthening of economic coupling forces. Locally, however, the result of this large transformation could have been to disrupt traditional commercial flows and hence for a short while to decrease price correlations.

Let us now concentrate on cereals for which more specific observations are possible. Special duties were introduced for cereals between 1824 and 1857 to protect Prussian farmers. The evolution of the tariff barrier between Prussia and the rest of Germany is illustrated in table 4. The respective tariff levels for wheat and rye are indicated in figures 2(b) and 3. It seems quite clear that the low correlation occurring in figure 2(b) for the wheat correlation between 1825 and 1865 should be attributed to the tariff increase. For rye the situation is somewhat less clear: there is indeed a low after 1825; it is, however, rather short and the tariff increase does not prevent a strong correlation increase in the years 1840 to 1850. A closer analysis of the effects of tariff modifications on the correlation between prices would require series of monthly prices.

Table 4. Evolution of duties (in marks per scheffel) between Prussia and the rest of Germany (source: Jacobs and Richter, 1935b, page 287).

	Wheat	Rye	Oats	Barley
1 January 1819	0.19	0.06	0.04	0.06
1 January 1822	0.19	0.07	0.04	0.06
19 November 1824	0.50	0.50	0.50	0.50
1 January 1857	0.20	0.05	0.05	0.05
1 January 1865	0	0	0	0

4.3 *The shift to an industrial economy*

To close this section let me mention still another evolution. From 1791 to 1914, Germany shifted from a mainly agricultural economy to an economy with industry as the prominent sector. At the same time, shortage crises characterised by price increases for foodstuffs were progressively replaced by overproduction crises accompanied by price decreases for agricultural as well as for industrial goods. In this paper, I have considered mainly agricultural goods; that is the reason why I did not undertake a closer analysis of this important evolution.

5 Conclusion

In this paper my objective was to measure economic interdependence between several markets. A transition period was considered which was characterised in that respect by a very striking evolution. The correlation between prices (or more precisely between logarithms of prices) enabled this evolution to be followed even sometimes in such details as the effect of temporary tariff modifications.

Finally, let me summarise some questions which require further analysis. First, in order to weight the importance of transportation improvements on one hand and of the suppression of tariff barriers on the other, one should compare Germany with a country, such as Great Britain or France, which already had achieved its political and economic unification at that time. Second, in order to analyse the shift to an industrial economy from the viewpoint of price fluctuations one would need industrial price series for raw materials, for intermediate products, and for consumer goods.

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