Markets in China and Europe on the Eve of the Industrial Revolution

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Abstract

Does trade cause growth? How about the Industrial Revolution? A widely held view is that the more efficient markets in Europe provided an important reason of why the Industrial Revolution started its spread from Europe in the late 18th century, and not from China. Among the reasons that have been proposed for this supposed efficiency gap are differences in terms of geography, culture, nationality, population, institutions, or historical 'accidents' such as the discovery of the Americas. In this paper we compare the actual efficiency of markets using data on the spatial dispersion of grain prices from the 15th to the early 20th century. This analysis is made possible by a new detailed and consistent set of grain price data covering about 60% of China in the 18th century—a part of China larger than Western Europe and contributing about one-fifth of the world's population at the time. We find, first, that the efficiency of markets in China and Europe was broadly comparable in the late 18th century, except perhaps for local economic activity, in areas of 150 kilometers or less, where Europe seems to have been ahead. This provides new evidence on a number of explanations for the Industrial Revolution. Second, the differences in market efficiency appear to be small relative to the differences in economic performance between China and Europe during the 19th century. Rather than being a key condition for subsequent growth, gains in market efficiency and growth might occur essentially simultaneously. More research on global and quantitative comparisons is needed to resolve these issues.

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One of the most striking features in world economic history is the divergence in relative living standards and productivity levels that emerged in the late 18th century with the onset of the Industrial Revolution. Many economists believe that the break from millennia of economic stagnation to modern growth is closely related to the availability of market-supporting institutions and the widespread presence of markets for economic transactions. Among the reasons that have been proposed for this supposed efficiency gap are differences in terms of geography, culture, nationality, population, institutions, or historical 'accidents' such as the discovery of the Americas.[1] This paper examines historical markets in a large cross-section of regions to determine whether differences in market performance and integration prior to the Industrial Revolution could have had a significant role in explaining the divergence between regions that grew fast and those that didn't.

Efficient markets permit the gains from the specialization of labor and increasing returns to be realized. Widely maintained views about contemporary economies hold that underdevelopment results from markets not doing their job properly and that speeding the economic growth of the poor countries of today will require, among other things, the reform of their market-supporting institutions.[2] North America and Western Europe, by contrast, are examples of how the successful application of market supporting institutions—in these economies, state-supplied laws and regulatory oversight—help lower transactions costs. In addition, free markets are evidently also a key channel that permits innovations to be transformed into productivity and output growth and to find its best use, creating gains not only from static

[1] For varying explanations on why economic development paths differ, see for example, Acemoglu, Johnson, and Robinson (2002); Diamond (1997); Engerman and Sokoloff (2002); Galor and Mountford (2003); Galor and Weil (2000); Mokyr (1990); Olson (1965); O'Rourke and Williamson (1999); Rodrik, Subramanian, and Trebbi (2002); Sachs (2003); Weber (1993).
[2] McMillan (2002), pp. 11 and 205.

efficiency, but also from a self-regenerating process of innovation and invention.[3]

Empirical studies of contemporary cross-sectional growth seem to confirm that a country's stance towards openness is positively correlated with subsequent growth.[4] Its main policy implication, that large rewards tend to accrue to economies that adopt a more open stance, is reflected in the policy recommendations of major international organizations such as the World Bank and the IMF. While developing countries have made large strides in the last several decades in overall development, in general it is still unclear how much of the gains can be attributed solely to more integrated markets.

Our understanding of why certain economies flourish where others stagnate is in large part also determined by a historical reading of how the advanced economies of today industrialized. Productivity increases are possible as economies become increasingly integrated and move away from self-sufficiency. But was this the driving force initiating modern growth? While fast growing economies are also more likely to have smoothly functioning markets, this may be in large part a consequence of fast growth rather than its cause. If so, there may not be as strong a causal link from market integration to growth as is often argued.

In a contemporary sample, where one never observes the counterfactual of advanced economies (i.e., OECD countries) in a situation of low growth, it is difficult to know with certainty that market integration is a good predictor of economic growth. Historical studies are valuable because in studying the link between trade and growth, we can compare the market integration of the 'OECD countries-in-waiting' to see whether their markets were exceptional already early on. This would constitute a better prediction of subsequent growth because the identification problems encountered in a contemporary cross-sectional sample is diminished to the

[3] Baumol (2002), p. 247.
[4] For a recent example, see Frankel and Romer (1999).

extent that the many persistent factors unique to Western Europe—such as geography, customs, intellectual and ethical tradition, or language are held constant.

The origin of modern growth goes back to the Industrial Revolution. A prevailing view is that the development of unusually well-functioning commodity markets in Western Europe did in fact predate subsequent economic growth. According to Douglas North and Robert Paul Thomas, the west succeeded in overcoming the institutional blockages, weak property rights, and other barriers that caused economies throughout history to become lodged in places where incentives could not flow towards specialization and division of labor.[5] Examples of early market improvements can be seen in the early modern era (1500-1700), when the growth of trade and commerce was critical to the advance of the Dutch economy. There, new arrangements in commercial activity was what made possible efficient business and flexible methods of innovation that were important to growth. Furthermore, it was the emergence of efficient markets that allowed the easy importation of raw materials and the sale of the final goods produced—which thus provided transparent incentives for turning production to profit. North also postulates that England's success followed the Dutch example; by the 1700's, the reduced cost of using the market was the main source of productivity gains in England. Eventually, the rest of Western Europe and the United States inherited these institutions from Great Britain.

Along similar lines, David Landes argues that the scope of private economic activity was far larger in Western Europe than it was in other parts of the world. According to Landes, societies which grew the fastest were also the free-est, where new areas of enterprise were untrammeled by "rule or custom".[6] Once the restrictive authoritative institutions and guilds that confined business activity with vested interested moved aside, competition was a self-reinforcing

[5] See North and Thomas (1973), especially pp. 134-142 on the role of markets.
[6] Landes (1989), p. 19.

process that also proved to be the better judge of allocation. In China, where traditional custom tended to elevate and thus preserve the social standing and views of the government literati rather than that of craftsmen, artisans, or merchants, there may be some truth to Landes' observation.

In contrast to the line of inquiry pursued by North and Thomas and Landes, we note that there are also some studies suggesting that English markets in earlier medieval times operated with a higher-than-expected degree of vibrancy and efficiency (Clark, 2002; Masschaele, 1993). The magnitude of the differences between the degree of market integration in medieval England and that in England some three later centuries later, however, remains to be seen. Finally, among those whose analysis has focused on non-European economies, Kenneth Pomeranz presents perhaps the most forceful summary of the view that Western European land, labor, and product markets were comparable to advanced areas in other parts of the world as of the late 18th century.[7]

Thus, while better markets or better market-supporting institutions may be a critical condition for growth, quantitative comparisons of how similar or how different markets really were across the pre-industrialized world at the point right before the industrialization of Western Europe are lacking. In this paper, we utilize a large comparative dataset consisting of European and Chinese price data, together with several empirical methodologies, to produce a much more comprehensive comparison of relative differences in market integration on the eve of the Industrial Revolution than is currently available. We do not attempt to explain the Industrial Revolution in its entirety, a question that still remains open to much speculation. Rather, we ask whether the degree to which the scope of economic incentives could be realized was different in Europe compared to China. If so, this would imply that underlying market-supporting institutions were indeed different as well. A comparison of these the scope of incentives should have more

[7] Pomeranz (2000), p. 17. Although they do not address North's thesis directly, one of the implications of the work of Wu (1983) and Xu and Wu (2000) and others on Chinese capitalism seems to be that the types of institutions described by North and Thomas were not entirely unique to the west. Huang (2002) critically reviews the thesis.

general implications for existing theories on long-run economic growth to the extent that these theories depend on efficiency considerations. More generally, the question of market functioning is also important in furthering understanding of the origins of modern growth, how it is sustained, and how it may be spread further across economies today.

INDUSTRIAL REVOLUTION AND MARKET INTEGRATION

Modern economic growth, as defined by a growth rate of 0.5 to 1 % per capita per year, occurred in Britain in the late 18th to early 19th century.[8] While growth started slowly, it also spread relatively rapidly to the United States and a narrow set of regions in Europe. Dates of the diffusion of technological mechanisms suggest that the innovations used for several of the key manufacturing sectors had spread from Britain to the United States and Western Europe by the early decades of the 19th century.[9] While cotton textiles, the energy generating industry (steam engine), and the iron and steel industry dominated the growth of manufactured output, there is also ample evidence suggesting that productivity growth occurred in the agricultural sector as well, albeit in a more broadly diffused manner. Modern growth is also different from everything that has come before in the sense that it was sustained. For the narrow set of countries that industrialized first, the result of two centuries of sustained growth was a rise in income of some 12-fold—a magnitude of unprecedented dimensions in all of world history.

To determine whether the level of market integration in Western Europe in the pre-industrial period might have caused the Industrial Revolution to take hold in the late 18th century, we need a pre-industrial economy against which a close comparison can be made. Our chosen economy is China. China, especially the Yangzi Delta area, was likely to have been one of the

[8] See Crafts (1994), p. 45.
[9] Clark (2002), Table 1 in Chapter 5, “The Spread of the Industrial Revolution, 1860-2000.”

more developed parts of the world outside of Western Europe in the 18th century. Overall comparisons of relative living standards in China versus those in Europe remain elusive. Studies differ depending on which population group is chosen, which region is studied (e.g. China in aggregate or only one part), and which measure of living standard (e.g. life expectancy, estimated grain wage, or consumption patterns of food and durable goods) is used. The lack of consensus indicates, among other things, that there is a lack of evidence showing average per capita incomes in China were much below or above those in Europe.[10]

While there seems little doubt that commodity markets existed in Europe, certainly some aspects of those markets existed in China as well (Marks, 1991; Wu, 1983; Shiue, 2002; Wong and Perdue, 1992). We do not know, however, how Chinese markets compare next to those in Western Europe on the eve of the Industrial Revolution. If the level of market development were an important factor in causing modern growth, then we should be able to confirm this hypothesis by comparing the performance of pre-industrial markets in Western Europe with markets in other parts of the world. If true, we expect to observe two things: First, if the markets in Western Europe were a pre-condition to subsequent growth, then we must be able to date this improvement in market functioning to a period before the emergence of the Industrial Revolution. Improvements in markets after the 18th century, once industrialization has started, may be attributed to factors responsible for industrialization, and, may therefore be endogenous. Second, market integration in Western Europe should be higher than in China, an advanced region of the world where industrialization would not take place. This finding would support conventional beliefs about the importance of market-supporting institutions. It would also support the idea that

[10] For living standard comparisons, see for instance Allen (2002, 2001) and Bairoch (1975), pp. 3-17. It has been difficult to obtain comparable wage data between China and Europe. If within-economy variations were significant, we would additionally need to know something about the population distribution of wages in order to make cross-economy comparisons.

one reason Europe industrialized first was because of more efficient markets. Alternatively, the finding of comparable levels of market operation in Western Europe and China tends to diminish the notion that markets are a key pre-condition to rapid subsequent growth.

APPROACH

Many variables may ultimately enhance or detract market function. Existing studies suggest that the list includes technological constraints, transport costs, institutions, information transmission, laws, regulation, political conflict, social customs, and the nature of property rights, among other variables. One approach is to check the direct evidence on each of these variables and try to conclude whether on balance, the end result was more or less favorable to market efficiency. For example, public intervention in grain markets was not uncommon, both in Europe as well as in China. To understand the effects of public intervention, we could review the regulations on private trade, and try to determine such factors as the government's official policy, the extent to which the state's actions were effective, how much of private actions escaped regulation, and how likely these effects on balance contributed to the effects of all the other factors that determine market integration apart from state regulation. Finally, we would have to compare how these different effects compare with that in different countries. In general, the task described is extremely difficult. Moreover, the size and sign of the impact of some variables on markets, such as social customs, cannot be simply assessed. Even the effects of the direct costs of transport, which can be more easily estimated, will still depend on relative factor and goods prices within each economy, and so the comparative impact is often unclear.

Rather than investigating those factors that might have constrained the scope of incentives, we take an alternative approach. We use various measures to assess the overall outcomes of market integration. To the extent that underlying market-supporting institutions indeed influence market outcomes, we can account for the impact of such factors as regulation or property rights as they might affect trade. This approach is based on the use of market prices, which are available for Western Europe and China. The next section discusses the data used.

DATA

The data set for Europe includes market samples from the 15th to the 19th century. The approach used in this paper requires that the price series that we use are free market prices. With the exception of the London series, the European sources employed in this paper are all records of *mercuriale* prices. Chinese markets of the 18th century are considered to be free markets. The government did attempt to regulate the supply of grain, with the hope of influencing prices. But these policies did not involve fixing prices at some official level for the common consumer. Table 1 ("Data Sources") is a summary of data from Chinese and European locations and data sources that are used in the analysis in this paper.

The prices for the European markets are for wheat, the dominant grain in most regions. The closest homogenous good that matches this characteristic in China is rice. Thus, while we do have some prices for wheat in the data set for comparison purposes (wheat was grown in some northern regions of China), the main commodity used for our analysis in China will be rice.

Figure 1 ("Data Availability") gives a graphical summary of the years of data available for each series. Note that the Chinese series of 121 locations, at 54 years of data, is relatively short compared to the time series availability of some European markets. However, it should be emphasized too that the geographical coverage of the Chinese price reports is much broader than it was in the European. The Chinese data captures 121 contiguous markets, a region comprising about 60 % of the empire and including the most commercialized areas as well as relatively remote regions. Many of the European price series, by contrast, have a longer time series, perhaps spanning over a century of time, but the geographical scope tends to be narrower. Another difference is that nearly all the European price data up to the 18th century are from regions that were fairly important markets. Only in the 19th century does more contiguous data become available, which, as in the case for France, begins to include records from small markets as well. The relatively small cities in the Grand Duchy of Mecklenburg (located in what was East Germany from 1949-1991), for which we also have 19th century price records, were not particularly central points of commerce either.

The sources for each series give quite detailed information on the method of collection of each series and the units of account. Due to changes in units of account, all nominal prices have been converted to common units of currency per volume (or weight) within a series. Additional details about these differences and references to units of each series used in this paper can be found in the Data Appendix.

The most important differences among the various price series have to do with the method of collection and the degree of aggregation in the price information. What allows us to measure the impact of differences in these respects is the fact that there are only a small number of different ways to collect market prices, and that there is enough data such that we can always find several markets sharing commonalities in their method of recording prices. The key differences are given in Table 1. The table also summarizes the data that we employ in the analysis. Columns I through III give information on the location of the region in today's country, the name of the location in historic times, and the source of the data. Columns IV through IX provide summaries of the differences among each series, which include the frequency of observation (IV), the years available (V), the method of collection (VI), whether minimum and maximum prices are recorded (VII), whether there is spatial aggregation in the method of collection (VIII), and whether quantity data is available as well (IX).

MEASURES OF INTEGRATION

Although foreign trade in the 18th century was not significant, China's expansive empire meant that even domestic trade involved large distances. Trade between the fertile agricultural areas in the upper reaches of the Yangzi River of Sichuan Province and the urban regions of Shanghai at the Yangzi Delta involved covering distances of at least 1700 kilometers. This is approximately the distance of the trade route between Antwerp and Lisbon. There are also comparable historical accounts of how grain was paid and transported along routes that connected the Yangzi Delta with Sichuan and Hunan, or, Amsterdam with Spain and France.

We may know about large specific transactions of grain, but trade volume statistics are spotty at best. In Europe, rough calculations suggest that 1 % of total consumption of the Mediterranean area was traded in the 16th century, and the situation may have remained much the same in the 17th century.[11] Much depends on whether one includes only the urban area importing the grain, or the entire population of potential exporters as well, but some kind of per capita weighting is essential. In China, the Yangzi Delta alone—with an area of 43,000 square kilometers and a population of approximately 20-36 million inhabitants in the 18th century—may have imported as much as one-quarter of its total grain consumption, but adding in the potential number of exporters supplying this grain, the relevant per capita trade statistic must be much smaller indeed.[12] Available estimates on disaggregated trade flows are also vague on

[11] Braudel (1992), p. 127.
[12] Population estimates are frequently imprecise. These estimates are reported in Li, B. (1998), p. 19.

considerations such as the date of purchase and delivery or the point of origin and destination of each shipment. Even if we had more detailed information on the volume of trade, however, this would not be enough to establish the efficiency of markets. On this question, other measures of integration are preferred.

Tests of market integration try to measure the extent to which there is an equilibrium relationship between two price series. Prices between two markets should not be too far apart in the long-run even if in the short term they may drift apart due to seasonal differences or other transitional forces. Free-market incentives, as well as some government interventions, under appropriate conditions tend to bring prices closer in line. However, there may be any number of reasons why the prices do not move to equilibrium, or tend to move only very slowly. Whether or not there is a long-run relationship between the prices of two regions is ultimately an empirical question.

ANALYSIS

In China in the 18th century, as in Europe, the labor force was predominately engaged in agriculture. The majority of the population was engaged in small-scale, producer-cum-consumer farming, and available estimates suggest that agricultural output made up at least 60 % of GNP in pre-industrial economies.[13] Grain was an important commodity, not only in overall output, but in consumption as well. Monotony in foodstuffs, with a large share of consumption being in cereals, was common in the lives of both European and Chinese. The share of cereals in the diet of urban dwelling northern Europeans, who it is said ate more meat and fish than their southern neighbors,

[13] See Chang (1962), pp. 291-325 for his estimate on the share of agriculture in China in the 18th century. Li, B. (1998) cites Qing observers who put the percent of the population engaged in agriculture in the Yangzi Delta at 50% during the late 17th century. In Britain in 1700, approximately 61.2% of male labor was employed in agriculture and 65% of total income (from industry and agriculture) was in agriculture; see Table 3.1 in Crafts (1994).

was still nearly 60%, a figure also likely to be significantly lower than for the average farmer.[14]

The pre-industrial agricultural economy may be modeled in the following simple terms. Consider an economy in which there is a single agricultural crop, i.e., rice or wheat, where there are a large number of agents who behave competitively and are risk-neutral. Aggregate harvest yields at time t, h_t, are a function of the amount of land T, and the current period weather, W_t :

(1) $$h_t = f(T, W_t).$$

Weather is a random shock that drives a wedge between the constant planned yield, H, and the actual yield at time t :

(2) $$h_t, = H(1+v_t),$$

where v_t is independently and identically distributed with E $[v_t] = 0$. Grain supply in period t, Q_t, will be a function of the carryover in supply from the previous period plus the new harvest, minus the amount put into storage. The grain price, P_t, in this economy is a function of Q_t:

(3) $$P_t = P\,[Q_t], \quad \text{with} \quad \partial P/\partial Q < 0.$$

Furthermore, a no-arbitrage condition applies when trade is allowed between two markets. When markets are fully efficient, the equilibrium relations of prices will satisfy

(4) $$\begin{aligned} &\left|P_t^a - P_t^b\right| \le z \quad \text{if } Z_t = 0. \\ &P_t^a + z = P_t^b \quad \text{if } Z_t > 0; \\ &P_t^a - z = P_t^b \quad \text{if } Z_t < 0; \end{aligned}$$

where $Z > 0$, a exports to b on net; and z are transport costs between a and b. The size of z does not alter the implications of the equilibrium conditions in (4). Thus, if prices in region b are higher than prices in region a for a certain commodity even after taking into account the cost of transport, there should be exports from a to b. This will tend to lower the price in region b. The

[14] Spooner (1961).

argument is analogous if prices in region *a* are higher than in region *b*. In equilibrium the price difference will be less than or equal to the cost of transport between the two regions.

The following sections employs a number of different methods to gauge the extent to which markets were integrated, ranging from largely descriptive analyses of price variability and cross-sectional bilateral correlations to the more powerful time-series analysis for cointegration of Engle and Granger (1987) and Johansen (1988).[15] Used for purposes of comparison across separate economies, the range of non-parametric and parametric methods allows us to assess with greater conclusiveness whether markets in China and Western Europe were truly different.

Price Volatility and the Random Walk Model

In general, volatility appears to be higher under situations of market segmentation. If fluctuations are smoothed, for example through trade, volatility decreases—price series of connected markets are less variable. The coefficient of variation of prices, taken at 20-year periods, suggests that volatility is lower in the 19th century than they were in the medieval times. McCloskey and Nash (1984) report that in Southern England in 1245-1350, standard deviations ranged from 0.2-0.43, averaging 0.26 in England in 1800-1825. By these standards, the coefficient of variation of prices, taken also at 20-year intervals, is relatively low across the ten provinces of the Chinese sample, ranging from 0.09 to 0.18 for the low price series and 0.20 to 0.38 for the high price series (See Table 2 "Mean Annual Prices and Coefficients of Variation").

An alternative way of measuring volatility in prices is to consider the standard deviation of the residual of the price difference between two periods (Engle and Granger, 1991). The random walk model also investigates the volatility of one price series at a time, but it is based on the

[15] For an early price history study, see Braudel and Spooner (1967). For more recent applications of market integration tests, see e.g. Ravallion (1986) and Persson (1999).

hypothesis that if markets are efficient, then the deviation of the past period's price, y_{t-1} , from the current price, y_t , cannot be forecasted beyond a random shock epsilon, ε_t , which is white noise. The reason is that prices are supposed to fully reflect all known information, so that the expectation on any future period's price, given what is known today, is no better than that which is reflected in prices today. Thus,

(5) $$y_t - y_{t-1} = \varepsilon_t \qquad \text{for } t = 1, \ldots T;$$

where ε_t is independent and identically distributed with zero mean and variance σ^2. The conditional mean corresponds to

(6) $$E\,(\,y_{t+1}\,|\,I_t\,) = y_t$$

where I_t is the information set at time t. Allowing for seasonal adjustment, the price difference is

(7) $$y_t - y_{t-1} = \psi' S(t) + \varepsilon_t \qquad \text{for } t = 1, \ldots T;$$

where S is a (1 x 2) vector allowing for semi-annual seasonal variation.

The parameters in the model are estimated with OLS. The average standard deviation of the residuals of a random walk model for twelve European markets over the period 1760-1785 is 13.6% (min = 11%, max = 15%). Average standard deviations for the 121 Chinese markets over the same period are 7.7% (min = 2.4%, max = 14.5%). Again, the volatility for the Chinese sample is relatively low in comparison to the European prices.

Bilateral Price and Distance Correlations

Price correlation of bilateral markets gives another measure of the extent to which markets are connected. Higher correlation suggests more trade links, all else equal. Distance conditioned mean bilateral correlations for markets selected for comparability and commonality of period is listed in Table 3a ("Price Correlations in China and Europe") and Table 3b. The most advanced regions of China include the Yangzi Delta and the Yangzi River prefectures. In addition, the table also gives the correlations for the provincial capital prefectures. This includes areas that are not as urbanized and well-connected via known trade routes. For Europe, the data includes 12 markets scattered across today's Germany, France, Belgium, Netherlands, Austria, Luxembourg, and England; and a more concentrated set of 10 regions in central France. According to Table 3a, mean price correlations in France, for distances of up to 450 km, were often higher than those of similar distance, even when compared to the region around the Yangzi Delta and the Yangzi River.

In general, price correlations between markets decline with higher distance. The distance between markets yields a rough approximation of the costs of transport, but distance is often also correlated with more abstract costs of trade. These include, for instance, uncertainty about what is happening in economies further away, greater differences in language, or the demarcation of political and administrative boundaries.

Distance conditioned regression slope coefficients, again for markets selected for comparability and commonality of period is given in Table 4 ("Distance Slope Coefficients in China and Europe"). Figure 2 ("Europe and China, Select Markets over 18th Century") summarizes the information in Tables 3a, 3b, and 4 by plotting the regression line of bilateral price correlation on bilateral distance of the 12 European markets against two regression lines. All samples are taken with a 25 year block of time, from 1770-1794. The lower represents the 10 Chinese provincial capital prefectures, while the upper represents the prefectures that lie close to (within 100 km) of the Yangzi River. We would expect that the river prefectures, which lie along a recognized trade route should show higher correlations at every distance, relative to the provincial capitals (which could not always access each other as easily), and this is confirmed in the figure. The European sample of market pairs lies somewhere within the two Chinese groups.

Figure 3 ("Europe and China, Select Markets over 17th-18th Century") shows the same figure as Figure 2, this time with an additional line that represents the regression in a sample of ten European markets for which we have data in the 17th century. The group of markets is not exactly the same as the group in the 18th century, but what is evident is that the estimated relation between price correlation and distance lies within the 99% confidence interval of the estimate for the 18th century. The scatter plot underlying the 17th century regressions suggest that with the exception of a handful of markets that were less than 200 kilometers from each other, there was relatively little integration over longer distances. On average, there was not too much change over the 17th to 18th centuries with respect to market integration. Although the group is somewhat different, the lack of apparent changes over the century prior to industrialization is not inconsistent with the idea that there was basically stagnation and zero average growth over the centuries of time up to the break into modern growth that occurred with the Industrial Revolution.

Figure 4 ("European Markets over 18th-19th Centuries") takes the comparison forward to a 25 year block of time from 1825 to 1849. In historical terms, just a short 55 years after the earlier sample (1770-1794) we viewed in Figure 2. But now the regression line now shows markedly higher average correlations for all distances, and the estimated relationship lies well above that of the 12 European markets in the 18th century, as well as both Chinese samples.

To compare this change to the entire Chinese sample of the 18th century, we plot the entire Chinese data sample against the European data of the late 18th century in Figure 5 ("China and 12 European cities, 1770-1794"), and then in Figure 6 ("China in 1770-1794 and 12 European cities in 1824-1849") against the 19th century European data. Figures 5 and 6 reinforce two observations. First, in the late 18th century, with the possible exception of short distance markets, Western European markets are not distinguishable from large parts of the Chinese sample, and especially they are not clearly ahead of the advanced regions in China. Second, it appears that Western Europe did make a significant step towards higher integration, but this step took place after a date when the beginnings of modern growth was likely already underway.

Cointegration Analysis

In this section, we examine the degree of market integration in China and Europe further by employing a number of relatively recent time series techniques. The concept of cointegration was introduced by Granger (1981), Engle and Granger (1987) as a way of characterizing the long-run relationship among a set of variables. Formally, cointegration refers to a situation in which a set of variables y_n, $n = 1,2,\ldots,N$, is each integrated of order $d > 0$ (or, $I(d)$), while a linear combination of the y_n variables is integrated of order $(d - b)$, ($I(d-b)$), with $b > 0$. Of particular interest is the case where $d = 1$ and $b = 1$, that is, where each variable by itself is non-stationary in that it has a unit root, while a linear combination of the variables is stationary; this case is denoted as $CI(1,1)$. In our context of prices in different grain markets, a linear combination of grain prices that is stationary when each individual price is not would support the idea that the grain prices evolve in a long-run relationship in which arbitrage (that is, trade) across markets prevents the prices to drift arbitrarily far apart. In this sense, testing for cointegration provides evidence on the degree of market integration.

Two different methods will be employed in the following. First, we conduct residual-based tests for cointegration proposed by Engle and Granger (1987), and second, we use the systems vector auto regression (VAR) method proposed by Johansen (1988). These two methods are complementary. On the one hand, Johansen's (1988) method is more powerful in that it allows one to estimate both the cointegrating rank and the model parameters simultaneously using a one-step maximum likelihood (MLE) procedure. Moreover, it also allows testing for restrictions on the long-run relationship and the speed of adjustment towards the equilibrium in the MLE framework. On the other hand, Engle and Granger's (1987) approach is simpler and more robust, both because it is based on least squares and because it makes fewer distributional assumptions.[16]

In section A, we will therefore start out our comparison of market integration in China and Europe using the Engle and Granger (1987) cointegration tests; the analysis based on Johansen's (1988) method can be found in section B below.

A. Engle and Granger (EG) Cointegration Results

The EG method may be described as follows. Consider the price series in location 1 and in location 2, y_{1t} and y_{2t}, $t=1,\ldots,T$, for which we would like to establish whether a long-run (cointegrating) relationship exists or not. We also assume that both y_{1t} and y_{2t} are known to be $I(1)$. Consider the following OLS regression:

(8) $$y_{1t} = \beta_0 + \beta_1 y_{2t} + e_t.$$

If y_{1t} and y_{2t} are co-integrated, there will be some β_1 and β_0 such that $y_{1t} - \beta_0 - \beta_1 y_{2t} = 0$ is satisfied. The error, e_t, is called the equilibrium error, and β is the cointegrating vector; β_0 is a constant capturing long-run price level differences (due for instance to transport costs). EG's approach of testing for cointegration among y_{1t} and y_{2t} relies on testing whether e_t is stationary or not, because e_t is stationary if and only if $y_{1t} - \beta_0 - \beta_1 y_{2t}$ is stationary. If this condition is satisfied, then y_{1t} and y_{2t} are cointegrated.

Let $\{\hat{e}_t\}$ be the sequence of residuals of regression (8); a Dickey-Fuller (1979) test of

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[16] See Maddala and Kim (1998) for further details and discussion.

whether $\hat{e}_t$ is *I(1)* or not can be based on

(9) $$\Delta\hat{e}_t = \delta_1\hat{e}_{t-1} + \varepsilon_t.$$

Under the null hypothesis that $\hat{e}_t$ is *I(1)*, the parameter δ_1 is equal to zero; failing to reject that $\delta_1 = 0$ provides evidence that $\hat{e}_t$ is *I(1)* and y_{1t} and y_{2t} are not cointegrated. Engle and Yoo (1987) tabulate the relevant critical values to be compared with the t-statistic of $\hat{\delta}_1$ for the test based on (9).[17] In general, the further $\hat{\delta}_1$ lies away from zero, or the lower is the t-statistic for $\hat{\delta}_1$, the stronger is the evidence that y_{1t} and y_{2t} are cointegrated.

For our analysis, we make the following modifications to this approach to improve the quality of our inferences. First, we include seasonal effects in the estimation of the long-run relationship (8). Second, we eliminate the effect from outliers in (8) by including indicator variables for periods with exceptionally strong price changes. Third, the dependent variable of (9) is lagged once and added as a regressor, turning this into an Augmented Dickey-Fuller (ADF) test.[18]

1) Results for European Markets

In Figure 7 ("Cointegration Comparison Europe versus China"), the average ADF t-statistic is shown by distance class. Eight non-overlapping distance classes are used. The European markets are summarized in the bold line of Figure 7. With 12 markets, there are a total of 132 bilateral relations. The ADF t-statistics are lowest for the smallest distance bracket (distances less than 150 kilometers), which is what one would expect: the evidence is strongest in support of cointegration of prices in relatively near-by markets. The evidence for cointegration among European markets

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[17] These critical values are not the standard Dickey and Fuller critical values because $\hat{e}_t$ is estimated.

[18] These changes imply that the Engle and Yoo (1987) critical values do not apply anymore (MacKinnon, 1991).

is strongest for the shortest bilateral distances, here less than 150 kilometers. As bilateral distance increases, the evidence for the existence of long-run relationships among markets falls, although there is a considerable amount of noise in that relationship, which is especially evident in the distance classes that are greater that 750 kilometers.

2) Chinese Markets

The results for the Chinese River prefectures are shown by the gray lines. For less than 150 kilometer distances, the evidence from cointegration suggests China is behind Europe, while for distances of 300-750 kilometers, market integration in China, at least among the Yangzi River prefectures, is ahead to that in Europe, on average. The Chinese provincial capitals are not as response to distance as the other groups (note that there are no markets in this group less than 150 kilometers in bilateral distance), but they also seem to reinforce the perception that long distance markets in Europe were not particularly well-integrated. Also included in Figure 7 are the prefectures of the expanded Yangzi delta (note that there are no markets in this group greater than 750 kilometers in bilateral distance). The overall conclusions are not greatly altered by Figure 8 ("Cointegration Comparison Europe versus China"), which recasts the detailed output of both Chinese and European markets in Figure 7 with smoothed (logarithmic) trend lines. Comparing the evidence for the expanded Yangzi Delta prefectures with the European markets (take the European trend line in Figure 8) suggests that market integration among these sets of markets was quite similar.

B. The Johansen (1988) method

The method developed by Johansen is based on systems vector autoregression (VAR) analysis. Consider the case of a first-order VAR:

$$(\mathbf{10}) \qquad y_t = A_1 y_{t-1} + \varepsilon_t,$$

where y_t is the $(n \times 1)$ vector $(y_{1t}, \ldots, y_{nt})'$, ε_t is the $(n \times 1)$ vector $(\varepsilon_{1t}, \ldots, \varepsilon_{nt})'$, and A_1 is a $(n \times n)$ matrix of parameters. Subtracting y_{t-1} from each side of equation (10) and letting I be an $(n \times n)$ identity matrix, we get

$$(\mathbf{11}) \qquad \begin{aligned} \Delta y_t &= -(I - A_1) y_{t-1} + \varepsilon_t \\ &= \pi\, y_{t-1} + \varepsilon_t \end{aligned}$$

Here π is the $(n \times n)$ matrix $-(I - A_1)$ and π_{ij} is the element in row i and column j of π.

Note that in this equation, Δy_t and ε_t are stationary while y_{t-1} is non-stationary (*I(1)*); for consistency, we therefore require the matrix π to be of less than full rank (denoted by r). In this paper, we will only consider the case of $n = 2$, which means that r is either of rank 0 or 1. If the rank of π is equal to zero, all elements π_{ij} are equal to zero and (11) becomes

$$(\mathbf{12}) \qquad \Delta y_t = \varepsilon_t \Leftrightarrow y_t = y_{t-1} + \varepsilon_t.$$

In this case, there is no linear combination of the elements of y_t that is stationary, or, y_{1t} and y_{2t} are not cointegrated. Alternatively, if $r = 1$, there is one cointegrating vector given by any row of the matrix π. Then, one can show that each sequence $\{y_{it}\}$ can be written in the error-correction form of (11) with non-zero parameters π_{ij} (Granger's representation theorem).

Normalizing with respect to y_{1t-1}, we set $\alpha_1 = \pi_{11}$ and $\beta_{ij} = \pi_{ij} / \pi_{11}$. Then we can write, for instance, Δy_{1t} as

$$(\mathbf{13}) \qquad \Delta y_{1t} = \alpha_1 \left(y_{1t-1} + \beta_{12} y_{2t-1} \right) + \varepsilon_{1t}.$$

In the long-run, the $\{y_{it}\}$ will satisfy the relationship

(14) $$y_{1t} + \beta_{12} y_{2t} = 0 \, .$$

This corresponds to the cointegrating relationship derived for the Engle and Granger (1987) method above. The β coefficients give the long-run (cointegrating) relationship, while the α coefficients govern the speed of adjustment to equilibrium. Johansen (1988) has shown how, under certain assumptions, these coefficients can be estimated by one-step MLE. The fact that the Johansen method uses both characteristics of the long-run relationship (i.e., the β) as well as the short-run adjustment to the equilibrium (i.e., the α) is an attractive feature of this method.

In summary, the Johansen method of testing for cointegration involves estimating the rank of the matrix π. If the rank of π is equal to 0, there is no cointegration, while if it is equal to 1, the two series are cointegrated. Consistency requires that this rank r should be lower than n (here: $n = 2$), so the approach is also called reduced rank regression.

Compared to the estimation methods considered so far, the Johansen method is the most restrictive, or, demanding, in terms of the conditions that must be holding in order for it to be appropriate; as an example, the errors must be Gaussian, whereas the Engle and Granger (1987) method does not rely on that. At the same time, Johansen's method is also the most powerful in the sense that when it is appropriate, it gives a number of economically interesting insights that the other methods do not provide. The following preliminary analysis provides a flavor of that by discussing an example, the relationship of grain prices between two Chinese prefectures during 1740-95. Future drafts of this paper will provide a more comprehensive picture of what can be said using Johansen's method on a comparison of market integration in Europe and China.

Johansen's Co-integration Analysis: An Example

Consider the prefectures Huizhou and Taicang, both located in the expanded Yangzi delta, China's most developed area in the 18th century. Huizhou is located in Anhwei province, and Taicang is located in Jiangsu province, with a distance of about 286 kilometers between them. Taicang is located right on the mouth of the Yangzi River, while Huizhou is further west, and although it is not located directly on the Yangzi River, it is not far from it.

Let the log rice price in Huizhou be denoted by y_{1t}, while Taicang's is given by y_{2t}. Figure 9 ("Huizhou Prefecture") and Figure 10 ("Taicang Prefecture") show these price series both in levels (on top) and in first differences. The plots suggest that the price levels are non-stationary while the first-differences are stationary, and formal tests confirm this. This means that there is reason to proceed. We are interested in whether the two prices appear to be in a long-run linear relationship, up to a constant:

$$B_1 y_{1t} + B_2 y_{2t} + \beta_3 = 0 \tag{15}$$

Johansen's method relies on the errors being Gaussian, and we perform a number of auxiliary tests that explore the price series for Huizhou and Taicang in this respect.[19] We also make a number of modifications to the base specification in equation (11) to improve our inferences. First, we add a seasonal effect that controls for price differences by month (spring or fall), and a number of indicator (dummy) variables that eliminate the effect of outliers. We denote these deterministic components by D_t. Second, we include the once-lagged differences of Δy_t, that is, Δy_{t-1}. Figure 11 ("Diagnostic Analysis for Differenced Taicang Price Series") shows one of the auxiliary data plots, here for the differenced Taicang series that helps to determine which

[19] These tests analyze in particular the degree of serial and cross-series correlation, whether the errors appear to be normally distributed, and whether there appears to be autoregressive conditional heteroskedasticity (ARCH) effects. The estimates were produced using the CATS module of the RATS regression package.

model should be estimated.[20] The resulting specification is given by

(16) $$\Delta y_t = \Pi y_{t-1} + \Gamma \Delta y_{t-1} + \Phi D_t + \varepsilon_t \, .$$

Recall that the rank of the Π matrix determines whether the price series are cointegrated or not. If this rank is equal to 0, there is no co-integration, whereas if it is equal to one, the series are co-integrated. The elements of the Π matrix are products of α's and β's, which are the short-run and long-run coefficients, respectively, of the price equilibrium.

The first step is to determine the rank of the Π matrix. We know that the rank of a matrix is equal to the number of its eigenvalues that are different from zero. Building on this result, Johansen has developed several statistical tests to determine whether, in our case with $n = 2$, one eigenvalue is sufficiently far away from zero so that one can conclude that it is not equal to zero. One of these tests is the so-called trace test. The larger eigenvalue of the matrix Π in equation (16) is estimated to be 0.254, with a trace test statistic of 52.51. The relevant critical value for the trace test is far lower than that (with a value of 17.79). This means that it is very likely that $r = 1$, that is, the two series are co-integrated.[21] Figure 12 ("The Estimated Cointegrating vector between the Huizhou and Taicang Price Series") shows the estimated cointegrating vector $B_1 y_{1t} + B_2 y_{2t}$. The difference between the top and the bottom part of the figure is that the bottom takes the deterministic components and the lagged difference Δy_{t-1} into account whereas the top does not. The plots suggest that at least for the larger parts of the time series, the estimated linear combination of the two prices is stationary.

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[20] There are a number of different criteria that we employ to determine (i) what lag length (the number of differenced lags on the right hand side) to use, (ii) whether to include seasonal effects, (iii) what constitutes an outlier, and other factors. See Maddala and Kim (1998) for a discussion.

[21] The exact critical value for this test might be somewhat different from 17.79, both because it is an asymptotic value, whereas we have only a time series length of T=108, and because we include some outlier dummies. In any case, the trace statistic of 52.51 is quite large, and it is unlikely that the true critical value would be close to that, so the qualitative finding would remain the same.

A second question that can be addressed with these data is whether an adjusted law of one price appears to be holding among these prefectures. Normalizing equation (15) by setting B_1 to 1—the parameter B_1 and B_2 are not separately identified—the question is whether in the long-run, the price in Huizhou is equal to the price in Taicang, up to a constant, or, whether B_2 is equal to minus one:

(17) $$y_{1t} = y_{2t} - \beta_3 .$$

In the unrestricted regression, we estimate B_2 to equal -0.989. It is thus not surprising that we cannot reject the hypothesis that $B_2 = -1$ at a 5% level in the restricted regression (p-value of 3%). Thus, we cannot reject the null hypothesis that the adjusted law of one price is holding here. Moreover, the cointegrating constant β_3 is estimated to equal 0.048. This suggests that the long-run price in Taicang, at the mouth of the Yangzi, is above the long-run price in Huizhou. The finding is quite plausible, because we know that on average, grain prices are increasing as we move from the inland regions of China's west down the river to the markets of the Yangzi Delta.

What happens if there is a shock to the long-run equilibrium? There are two questions of interest: first, do prices in both markets respond to the respective other price, or is it primarily the change in one price that brings the markets back to long-run equilibrium? The answer to question depends on the signs of the short-run adjustment coefficients α. Here, in the equation for Δy_{1t}, α_1 is estimated to be significantly negative, whereas α_2 in the Δy_{2t} equation is positive. This is plausible because the long-run equilibrium can be stable only if an above-long-run equilibrium value of y_{1t} triggers a subsequent decline of y_{1t} (or, $\Delta y_{1t} < 0$); the corresponding case for the Δy_{2t} equation also applies. Thus, adjustment towards the equilibrium works through both markets, or, put differently, neither of the market prices is weakly exogenous.

The second question is: how long does it take until a shock to the long-run equilibrium is absorbed? The answer is governed by the size of the adjustment coefficients. The point estimates for α_1 and α_2 are -0.228 and 0.291, respectively. These numbers, of around 0.25 in absolute value, translate into a half-life of a shock of about 1.75 years for these two markets. For comparison, Persson (1999) estimates comparable half-lives for a number of grain markets in Europe and finds that the duration in the 16^{th} to 18^{th} centuries was 1 ½ to 3 years; and the half life of a price deviation does not fall to 3 to 4 months until the mid-19th century.[22]

Clearly, these cointegration results for Chinese markets, coming from only one of $N(N-1)/2$, or 7260 bilateral market pairs—there is data on n = 121 prefectural markets—are preliminary, and more work needs to be done. The following section summarizes what we think can be said at this point.

CONCLUDING SUMMARY

The concept of market efficiency holds a prominent place in our understanding of economic growth, and it has also been offered as a leading explanation for why Western European markets industrialized in the late 18^{th} century. In this paper we examine in considerable detail the similarities and differences in markets in pre-industrial China and Western Europe from the 15^{th} to 19^{th} centuries. We use a range of descriptive (non-parametric) and more formal (parametric) methods to assess market efficiency in China and Western Europe in around 1770, to see whether we find one continent—specifically Western Europe—was clearly ahead. According to the evidence presented in this paper, as of the period right before the Industrial Revolution took place in Western Europe, long-distance markets were not uniformly better than they were elsewhere in

[22] Persson (1999), p. 98-100.

the world that did not eventually industrialize. Over relatively short distances of 150 km or less, however, there are indications that European markets were more integrated. This edge over other advanced parts of the world however, is relatively small when we consider what occurs right after the onset of industrialization. In the early 19th century, soon after the dates associated with industrialization, markets become, rather quickly, significantly more integrated than what had taken place over centuries prior. That the bulk of the market's improvement took place only once modern growth had started indicates that most of the improvements in the degree of market integration in the 19th century in Western Europe may be largely a consequence of industrialization rather than a cause.

Markets today in the United States and Western Europe are yet more integrated than they were in the 19th century. They are also more integrated than markets found in poor countries of today. But it would also be in part to confound cause and effect to conclude from this that markets must first be fixed before we can see modern growth. This, at least, according the findings in this paper, does not appear to be what happened in Western Europe before the onset of the Industrial Revolution. Even allowing that all other conditions in Western Europe were just right for modern growth, it is to be emphasized that the overall level of market integration was not exceptional. It is possible that a third factor is responsible for triggering improvements in both, and that market integration is a response to these changes. The findings in this paper provide new evidence on whether trade causes growth. Future research is necessary to better understand what factors facilitate market integration and how industrialization started to spread even without higher levels of long distance market integration.

DATA APPENDIX

This appendix provides additional details on the regions, cities, units of account, and frequency of price series used in this paper. Market prices are obtained whenever possible. London is the only non-retail market source. The European prices are for wheat and the Chinese prices are for rice. The time-length indicated for each series does not necessarily take into account gaps caused by missing data.

Methods of calculation differ on several dimensions, but there appear to be two major distinctions in methods of price collection. This distinction affects how one should interpret the price statistic. In column VI we distinguish between the categories with the denotations "First Market Day" and "Average". The distinction between the two depends on whether the indicated price (whether monthly or annually) has been arrived at through averaging over prices observed at smaller intervals of time (weekly for example, if prices are listed monthly). If this is the case, then we consider it an average. A major alternative method is to make observations at regular intervals. The monthly price is then the price that was observed on one day, typically the first market day of the month, although not necessarily so. The primary characteristic of this method is that there are regular intervals of observation, and the actual price recorded for an entry reflects relatively little in the way of temporal averaging on the part of the data collector.

The min/max criterion indicates whether the price series is recorded with a range, rather than as one figure. In terms of interpretation, the range could apply to a spatial property, if there has been significant spatial aggregation, as in the case of China. The spatial aggregation criterion refers to records of regions larger than a single town, city or urban center. In that case, the single price for that region refers to a type of average over the smaller markets of the area. In some sense, even the market for a single city must be composed of many smaller markets within different parts of the city, so the distinction here with respect to the spatial dimension is primarily a relative one. In particular, it is often more significant for the Chinese data, since the aggregation method used there selects the high and low prices across a group of city markets at the county level. The order of integration i.e., the I(d)-ness of a series, has been shown to be preserved under temporal aggregation. Thus if the series is generated over one time interval (daily) but recorded over a longer interval (monthly), the cointegration is not altered. With cross-sectional aggregation, cointegration at the micro level does not ensure cointegration at the macro level and vice versa. However, under certain conditions, different levels of aggregation will produce the same result. Gonzalo (1993) gives descriptions and conditions that ensure cointegration from different levels of aggregation.

Sometimes the average is arrived at through a further weighting of quantity sold. In the case of the French series in Drame et al. (1991), for instance, the prices are quantity weighted, and out of some 900 markets, the authors have selected the 50 markets where the greatest quantities were sold. This is likely to result in selection biases. This may be contrasted with the Chinese data, which includes data for all administrative regions, rather than only those markets where greater known quantities were sold.

For the late 18th century, conditional on a given series existing at all, there is a higher percentage of missing data in the Chinese records than in the European sample. Eventually some of the actual price records may be recovered from the Chinese statistics. At the moment, there is approximately 23 % missing in an average Chinese series; about 15 % missing on average in the European series. The TRAMO (Time Series Regression with ARIMA Noise, Missing Observations and Outliers) program was used to interpolate series for which there were not too many periods of consecutively missing data (See Gomez and Maravall, 1997).

Austria-Vienna (average monthly prices; monthly, 1792-1914).

Pribram, Alfred Francis. *Materialien zur Geschichte der Preise und Löhne in Österreich,* Volume I. Vienna: Carl Überreuters Verlag, 1938.

Average monthly prices are based on quantity-weighted units. Both quantity units and monetary units changed over this period quite a lot. Quantity Units: Wiener Metzen (1692-1752): for wheat, one n-oest. Land-Metzen is 39.375 Wiener Metzen (p. 96). Nieder-oesterreichischer Land-Metzen (1752-1875) being

61.48682 liter (p. 88) Kilogramm (1876- 1914). Wiener Metzen for wheat ("Traid" = wheat and corn) for years 1690-1752: 0.76069 Landmetzen or 46.41 Liter (p. 101); Landmetzen used between 1756-1875: 61.49 Liter; for 1688-1756 (i.e, 1752-56): 1 is 61.01 Liter. (p. 102).

Monetary Units: Kreuzer (1692-1752); Kreuzer Conventional Muenze (1752-1812); Kreuzer Wiener Waehrung (1812-1858); Kreuzer Oesterreichischer Waehrung (1858-1897); Heller Kronenwaehrung (1898-1914)

1 fl. (60kr) Konventionsmuenze = 2.5 fl. (150kr.) Wiener Waehrung = 1.05 fl. (105kr.) Oesterreichische Waehrung = 2.10 K (210 h) Kronenwaehrung. (p.196)
1 Krone (K) = 100 Heller (h); 1 fl = 1 Taler; kr stands for Kreuzer.

Belgium-Brussels (first market day of each month; monthly, 1568-1696, 1728-1795, 1800-1889).
For 1568-1696, 1728-1795,Verlinden, C. (ed.) *Dokumenten voor de Geschiedenis van Prijzen en Lonen in Vlaanderen en Brabant,* Vol. I. Bruges: De Tempel, 1959. For 1800-1889, Verlinden, C. (ed.) *Dokumenten voor de Geschiedenis van Prijzen en Lonen in Vlaanderen en Brabant,* Vol. III. Bruges: De Tempel, 1972. Quantity Units: Bruxelles setier; 1 setier = 48.76 liters (p. 6 in Verlinden, vol. XV-XVIII). These vary: from 1800-1871 prices are quoted for units of 100 liters. From 1872 on, they are per 100 kilogram. For wheat, 100 liters wheat = about 79 kilogram wheat (p. 291). Monetary Units are in Brabantse stuivers; 1 Brabantse denier of groot = 1/3 stuiver = 1/60 gulden, or, there are 20 stuivers in one gulden. The monetary units vary as well. From 1817-1832, they are Dutch guilders; 1800-1817 and 1833-end in French francs. Annual average prices in both guilders and francs for the harvest year series are available from the data source, so one can compute the exchange rates in 1816 and 1832 as follows: in 1816, 18.27 Dutch guilders are 38.10 French francs, or, 1 guilder = 2.085 French francs. In 1832, 18.59 francs were equal to 8.78 guilders. That means we have 2.117 francs per guilder.

Belgium-Brugge (first market day of each month; monthly, 1796-1914).
Verlinden, C. (ed.) *Dokumenten voor de Geschiedenis van Prijzen en Lonen in Vlaanderen en Brabant,* Vol. IV. Bruges: De Tempel, 1973. See notes above on Brussels.

China-121 Prefectures, consists of 10 Provinces (average monthly price; semi-annually, 1742-1795).
Original source: *Gongzhong liangjiadan* [Grain price lists in the palace archives]. Number One Historical Archives, Beijing. Data originally collected by C. H. Shiue; see Shiue (2002) and Roehner and Shiue (2000) for additional details.
Rice prices. Covers virtually all prefectures of the 10 provinces. Quantity units: shi; 1 shi = about 103 liters. Monetary units: liang (Chinese ounce of silver, also called the tael). The original government price reports lists the high and low prices culled from county level markets. These were recorded at 10 to 30 day intervals and aggregated up at the prefectural level government offices. Only the prefectural records are systematically available today, and these give the highest and lowest prices observed in the prefectural at monthly (lunar cyle) intervals. Location names are interpreted as the prefectural capital city.

China-13 Prefectures from Hunan province, (average monthly price; monthly, 1736-1856).
Original source: *Gongzhong liangjiadan* [Grain price lists in the palace archives]. Number One Historical Archives, Beijing. Data originally collected by P. Perdue; see Perdue (1987) and Wong and Perdue (1992) for additional findings on Hunan province.
Rice and wheat prices. Units of account same as above paragraph.

England-London (average monthly price; monthly, 1683-1801).
Beveridge, William H. B. *Prices and Wages in England from the Twelfth to the Nineteenth Century,* Volume 1, (Price Tables: Mercantile Era; first edition 1939). London: Frank Cass & Co. Ltd., 1965.

These series are conceptually different from the market prices of the other sources in this Data appendix. The original source of these prices was Victualling Board records. These are Navy procurement contract prices for grain. The prices given are monthly averages over prices for short-period wheat contracts, for delivery immediately or up to to one month, and occasionally longer (p. 535). The Victualling Board met daily to contract with dealers for the supply of provisions (method cited on p. 515). It was a public announcement, and the bidders were one-by-one asked to bid. Indications of collusion among bidders resulted in the postponement of procurement activity.

France-Paris (first market day of each month; monthly, 1520-1698).
Baulant, Micheline and Jean Meuvret. *Prix des céréales extraits de la mercuriale de Paris.* Paris: Ecole des Hautes Etudes, 1960.
In setier de Paris; 1 setier = 1.56 hectoliter (=156 liter). Monetary Units: Livres turnois

France-Toulouse (first market day of each month; monthly, 1486-1913).
Frêche, Georges and Geneviève Frêche. *Les prix des grains des vins et des legumes à Toulouse.* Paris:Presses Universitaires de France, 1967.
Hectoliter (100 liter) [one setier de Toulouse = 0.932 hectoliter]. Monetary Units: variously French francs and centimes. See below.

France-Alençon, Amiens, Bourges, Bourgogne, Bretagne, Caen, Lyon, Riom, Rouen, Tours (average price; annually, 1756-1790, 1806-1900).
Labrousse, C.E. *Esquisse du mouvement des prix et des revenus en France au 18e siècle.* Paris: Paris C. 1932. See Roehner and Shiue (2000) for additional details.
For 1756-1790, prices are in hundredth of livres per "setier de Paris" (a unit of volume equal to 156 liters and equivalent to about 120 kilograms). For the later period, prices are in centimes per hectoliter (a centime is one hundredth of a franc and throughout the 19th century one franc was effectively equivalent to one livre. Note that administrative boundaries were redefined during the Revolution. Here, location names are interpreted as the city center of the district.

France-50 cities, selected from 48 districts (bimonthly, 1825-1854).
Drame, Sylvie, Christian Gonfalone, Judith A. Miller, and Bertrand Roehner. *Un Siècle de Commerce du Blé en France, 1825-1913.* Paris: Economica, 1991.
Note that the state's requirements for nineteenth century price records became more demanding, relative to earlier periods. The original government record was collected by the mayor of every town twice a month, which they were supposed to weight by quantity. This was aggregated at the office of the departmental prefect. The markets selected represent the largest city in the department, or the city center with the largest quantity of sales. The markets covered include every part of France except the Alsace-Lorraine.

Germany-Cologne (averaged from weekly prices; monthly, 1368-1797).
Ebeling, Dietrich and Franz Irsigler. *Getreideumsatz, Getreide- und Brotpreise in Köln 1368-1797, Erster Teil: Getreideumsatz und Getreidepreise: Wochen-, Monats- und Jahrestabelle.* In H. Stehkämper (ed.) Mitteilungen aus dem Stadarchiv von Köln, Vol. 65-66. Köln-Wien: Böhlau-Verlag, 1976.
This has weekly, monthly, and annual prices for Köln for 1531-1797. Monthly prices are calculated by averaging over the weekly price tables. This is a simple average, unweighted by quantities. Quantity Units: Kölner Malter. Approximately 150 liters or about 117 kilograms of wheat. In the monthly tables the prices are given in Albus per one Malter. 1 Albus = 12 Heller; and 1 Gulden = 4 Mark = 24 Albus = 288 Heller.

Germany- Rostock, Schwerin, Wismar, Boizenburg, Parchim, and Grabow (monthly, 1771-1870).
Die Getreidepreise im Grossherzogthum Mecklenburg-Schwerin waehrend des Zeitraums von 1771 bis 1870, Beiträge zur Statistik Mecklenburgs. Schwerin: Mecklenburg-Schwerin Statistisches Landesamt, 1873.

This has monthly prices for 6 city-markets in the area.
Original source: “Mecklenburgische Anzeigen”. Quantity Units for Rostock and Schwerin: “Rostocker” or “Landesscheffel” (RS). One RS = 0.385371 Hecto Liter. Quantity in Wismar: “Wismarer Scheffel” (WS), 1 WS = 1.023331 RS. Quantity units in Grabow and Parchim: “Maass” (M), 1 M = 1.436 RS. Quantity units in Boizenburg: “Sack” (S); the prices are given for ¼ Sack; 1 Quarter-S = 1.077 RS. The prices are all given in “Ganzen und Zehntel-Schillingen Courant” (i.e., in decimal).

Germany-Munich (first market day of month; monthly, 1690-1779).
Elsas, Moritz John. *Umriss einer Geschichte der Preise und Löhne in Deutschland vom ausgehenden Mittelalter bis zum Beginn des neunzehnten Jahrhunderts.* Leiden: A.W. Sijthoff, 1936.
The price is the arithmetic mean of all prices on a given ‘Schrannen, or market, day (Saturday). Elsas’ monthly price is the price of the first market day of month. Quantity Units: in Scheffel; 1 Scheffel = 6 Metzen; 1 Metzen = just over 37 liters, i.e. 1 Scheffel = about 223 liter. Monetary Units: “alten (schwarzen) Rechnungspfennigen”; 1 Gulden = 60 Kreuzer; 1 Kreuzer = 3.5 “alte Rechnungspfennige”.

Germany-Munich, Erding, Landshut, Straubing, Regensburg, Bamberg, Bayreuth, Nürnberg, Würzburg, Augsburg, Kempten, Lindau, Memmingen, Nördlingen, Zweibrücken (average monthly prices; monthly, 1815-1855).
Seuffert, Georg Karl Leopold. *Statistik des Getreide- und Viktualien-Handels im Königreiche Bayern mit Berücksichtigung des Auslandes.* München: J.G. Weiss, 1857. Seuffert includes both weekly prices (4-5 per month) and monthly average prices for Munich only, from 1790-1855. Seuffert’s weekly prices for the first of the month are strictly comparable to Elsas’ data. Monetary units in Gulden and Kreuzer; to convert Seuffert into Elsas-comparable units we multiply Gulden times 60, add to that the Kreuzer, and take that times 3.5.

Italy-Siena (average monthly prices; monthly, 1546-1765).
Parente, Giuseppe. *Prezzi e Mercato del Grano Siena (1546-1765).* Florence: Carlo Cya, 1942.
Original source of prices from Archivio degli Esecutori della Gabella. Wheat prices in volume measure “Staio Senese”, equal to 22.84 liters. Monetary Units: Soldi. This was not the money in which all prices were expressed. For constant prices of grain in terms of silver, we take the following conversion units: 1542-1557: 0.23240; 1558-1676: 0.22288; 1677-1738: 0.21419; and 1739-1766: 0.18912;

Luxembourg (variable methods; monthly, 1722-1795)
Ruwet, Joseph. *Marché des céréales à Ruremonde, Luxembourg, Namur et Diest aux XVIIe et XVIIIe siècles.* Louvain: Bureau du recueil [de la] Bibiothèque de l'Université; Publications universitaires de Louvain, 1966.
Quantity units in “bichet”, which is the same as “le setier”, or Sester; one setier is 20.463 liters (p. 192) [1 setier is equal to 1/20 Luxembourg malter]. Monetary Units: In sous, which is the same as Stuber; one sous is 1/20 of a Luxembourg gulden (p. 189).

Netherlands-Utrecht (average monthly prices; monthly, 1393-1644).
Sillem, Jérome Alexandre. *Tabellen van Marktprijzen van Granen te Utrecht in de Jaren 1393 tot 1644, uit de rekeningen en weeklijsten der Domprossdij.* Amsterdam: Johannes Müller, 1901. Table II-VI. Average monthly market prices of wheat in Utrecht for 1534/1535 to 1643/44. Monetary units in Stuivers. Quantity units in Modius, or Utrechtsche mud. 1 Utrechtsche mud = 1.08 Amsterdamsch mud = (for wheat) 88.93 kilogram. Units of account: Stuivers per modius.

Netherlands-Nijmegen (first market day of month; monthly, 1558-1916).
Tijms, W. *Historia Agriculturae*. Groningen: Nederlands Agronomisch-Historisch Instituut, 1977.
Nijmegen: Malder 1558-1822; Hectoliter 1824-1916; 1 Malder = 166.88 liter = 5.89 cubic feet (p. 103); 1 Hectoliter = 100 liter. Monetary Units: Dutch Guilders (Guldens).

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Figure 1. Data Availability

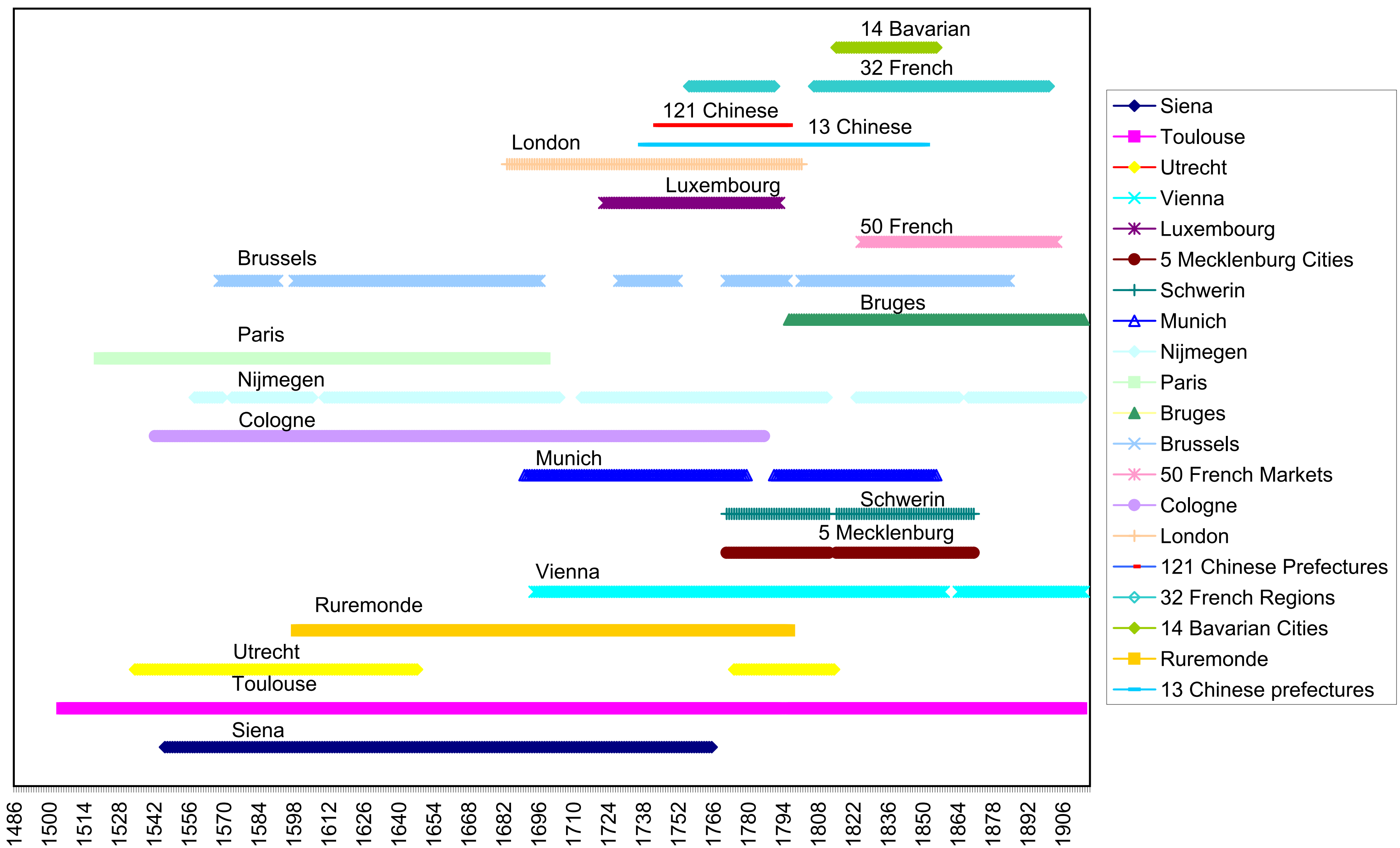

Table 1. Data Sources

I	II	III	IV	V	VI	VII	VIII	IX
Country	**Location**	**Source**	**Frequency**	**Years**	**Method**	**Max/Min Obs.**	**Spatial Aggregate**	**Quantity Weighted**
Austria	Vienna	Pribram (1938)	Monthly	1692-1914	Average	no	no	yes
Belgium	Brussels	Verlinden (1959)	Monthly	1568-1696	First day	no	no	no
		Verlinden (1972)	Monthly	1728-95,1800-89	First day	no	no	no
	Bruges	Verlinden (1973)	Monthly	1796-1914	First day	no	no	no
China	Hunan province (13 pref.)*	see Perdue (1987)	Monthly	1738-1858	First day	yes	yes	no
	121 Prefectures	see Shiue (2002)	Semi-annual	1742-1795	First day	yes	yes	no
	Anhwei province (13 pref.)		"					
	Fujian province (12 pref.)		"					
	Guangdong province (13 pref.)		"					
	Guangxi province (13 pref.)		"					
	Guizhou province (12 pref.)		"					
	Hubei province (10 pref.)		"					
	Hunan province (13 pref.)		"					
	Jiangsu province (10 pref.)		"					
	Jiangxi province (14 pref.)		"					
	Zhejiang province (11 pref.)		"					
England	London	Beveridge (1965)	Monthly	1683-1801	Average	no	no	no
France	Toulouse	Freche (1967)	Monthly	1486-1913	First day	no	no	in part
	Paris	Baulant (1960)	Monthly	1520-1698	First day	yes	no	no
	10 Generalite (Regions)	Labrousse (1932)	Annual	1756-90,1806-1900	Average	no	in part	in part
	50 Cities, 48 Departments	Drame (1991)	Bimonthly	1825-1903	First day	no	yes	yes
Germany	Cologne	Ebeling (1976)	Monthly	1531-1797	Average		no	
	6 Cities Mecklenburg-Schwerin	Beitrage (1873)	Monthly	1770-1870	Average	no	no	no
	14 Cities in Bavaria	Seuffert (1857)	Monthly	1815-1855	Average	no	no	no
	Munich	Elsas (1936)	Monthly	1790-1855	First day	no	no	no
Italy	Siena	Parenti (1942)	Monthly	1546-1765	Average	no	no	no
Luxembourg	Luxembourg	Ruwet (1966)	Monthly	1722-1795	variable	in part	no	no
Netherlands	Nijmegen	Tijms (1977)	Monthly	1558-1916	First day	start 1814	no	no
	Utrecht	Sillem (1901)	Monthly	1534-1647	Average	no	no	
		Posthumus (1964)	Monthly	1774-1814	Average	no	no	no
	Ruremonde	Ruwet (1966)	Monthly	1599-1796	First day	yes	no	in part

Notes:

Column VI indicates whether the prices were calculated from the first market day of the month or with a temporal averaging method.

Column VII indicates if the data records a range of prices, ie, typically the minimum and maximum prices observed.

Column VIII notes if spatial aggregation is involved; these cases are only relevant for regions larger than a city market, such as departments or prefectures.

Column IX indicates if price averages have been quantity-weighted in the original source.

*Hunan series of monthly prices for both rice and wheat.

Table 2.
Mean Annual Prices and Coefficients of Variation for 10 Provinces 1742-1795:
With the Low Price Series and High Price Series Compared.

Province	Geographic Location	Mean Price Low prices /High prices	Standard Deviation Low prices /High prices	Average and Maximum: Annual Coefficient Of Variation, 20-yr Periods Low prices /High prices
Anhwei	East	1.39/1.67	0.19/0.20	0.18/0.28
Jiangsu	East	1.62/1.94	0.20/0.18	0.16/0.31
Zhejiang	East	1.41/1.71	0.15/0.14	0.09/0.20
Fujian	Southeast	1.49/1.82	0.18/0.14	0.11/0.25
Guangdong	Southeast	1.30/1.67	0.22/0.20	0.13/0.31
Guangxi	Southeast	0.98/1.22	0.16/0.18	0.09/0.22
Hubei	Central	1.15/1.50	0.17/0.20	0.14/0.38
Hunan	Central	1.07/1.29	0.15/0.15	0.12/0.25
Jiangxi	Central	1.28/1.52	0.14/0.15	0.10/0.22
Guizhou	Southwest	0.84/1.11	0.21/0.18	0.09/0.29

Source: *Gongzhong liangjiadan,* No. 1 Archives, Beijing.
[Grain Price Lists in the Palace Archives] 1742-1795.

Table 3a. Price Correlations in China and Europe 1742-1794 in 25 year periods.

					1742-1766		1756-1780		1766-1790		1770-1794	
Country	Sample	N	Dist range	n	Mean	stdev	Mean	stdev	Mean	stdev	Mean	stdev
China	Yangzi Delta	9	<150	25	0.76	0.15	0.80	0.10	0.84	0.05	0.83	0.07
		9	150-300	11	0.73	0.13	0.74	0.08	0.81	0.04	0.81	0.06
	Yangzi D. expanded	26	<150	85	0.77	0.12	0.75	0.11	0.80	0.09	0.78	0.10
		26	150-300	138	0.67	0.15	0.68	0.11	0.71	0.11	0.70	0.12
		26	300-450	76	0.54	0.20	0.56	0.16	0.65	0.09	0.66	0.11
		26	>450	26	0.44	0.17	0.53	0.17	0.59	0.09	0.67	0.13
	Provincial Capitals	10	<150	0	---		---		---		---	
		10	150-300	8	0.58	0.11	0.49	0.24	0.64	0.26	0.59	0.24
		10	300-450	8	0.53	0.03	0.46	0.31	0.59	0.31	0.58	0.35
		10	450-600	7	0.53	0.07	0.27	0.20	0.37	0.32	0.38	0.34
		10	600-750	5	0.26	0.19	0.27	0.30	0.38	0.39	0.38	0.34
		10	750-900	7	0.42	0.18	0.17	0.22	0.08	0.30	0.12	0.32
		10	900-1050	2	0.35	0.17	0.03	0.17	-0.10	0.08	-0.14	0.15
		10	>1050	8	0.22	0.07	0.11	0.27	0.16	0.27	0.13	0.27
	Yangzi River	34	<150	68	0.78	0.12	0.77	0.11	0.82	0.07	0.81	0.09
		34	150-300	124	0.68	0.14	0.69	0.12	0.75	0.09	0.74	0.12
		34	300-450	146	0.58	0.16	0.60	0.13	0.68	0.10	0.68	0.10
		34	450-600	120	0.54	0.16	0.55	0.13	0.65	0.09	0.66	0.09
		34	600-750	57	0.51	0.15	0.45	0.14	0.64	0.12	0.64	0.10
		34	750-900	34	0.50	0.10	0.42	0.11	0.61	0.11	0.61	0.11
		34	900-1050	12	0.42	0.13	0.31	0.11	0.56	0.08	0.57	0.08
France	Central France	10	<150	10	---		0.88	0.04	0.80	0.09	0.80	0.09
		10	150-300	13	---		0.82	0.07	0.70	0.15	0.74	0.14
		10	300-450	14	---		0.74	0.07	0.58	0.09	0.65	0.09
		10	>450	8	---		0.74	0.07	0.55	0.08	0.63	0.08
Europe	{Mecklenburg(3),	12	<150	7	---		---		---		0.84	0.06
	Belgium(1),London,	12	150-300	6	---		---		---		0.58	0.11
	France(1),Austria(1),	12	300-450	10	---		---		---		0.60	0.24
	Germany(2),	12	450-600	14	---		---		---		0.58	0.14
	Luxembourg,	12	600-750	9	---		---		---		0.48	0.12
	Netherlands(1),	12	750-900	9	---		---		---		0.42	0.03
	Ruremonde}.	12	900-1050	6	---		---		---		0.31	0.10
		12	>1050	5	---		---		---		0.27	0.10

Table 3b. Price Correlation in Europe 1692-1716 and 1806-1855 in 25 year periods.

					1692-1716		1806-1830		1815-1834		1825-1849		1831-1855	
Country	Sample	N	Dist range	n	Mean	stdev	Mean	stdev	Mean	stdev	Mean	stdev	Mean	stdev
France	Central France	10	<150	10	---		0.96	0.02	0.97	0.02	0.96	0.02	0.98	0.01
		10	150-300	13	---		0.93	0.03	0.95	0.02	0.94	0.03	0.97	0.01
		10	300-450	14	---		0.90	0.02	0.91	0.03	0.89	0.04	0.95	0.02
		10	>450	8	---		0.87	0.04	0.88	0.03	0.84	0.03	0.94	0.01
	France	51	<150	140			---		---		0.91	0.07	0.94	0.05
		51	150-300	344	---		---		---		0.87	0.06	0.91	0.05
		51	300-450	321	---		---		---		0.82	0.07	0.88	0.05
		51	450-600	276	---		---		---		0.75	0.08	0.83	0.06
		51	600-750	155	---		---		---		0.71	0.08	0.81	0.06
		51	<750	39	---		---		---		0.70	0.05	0.79	0.03
Germany	Bavaria	13	<150	37	---		---		0.98	0.01	0.97	0.02	0.97	0.02
		13	150-300	41	---		---		0.97	0.02	0.93	0.03	0.95	0.02
	Bavaria &	20	<150	65	---		---		0.97	0.01	0.96	0.02	---	
	Mecklenburg	20	150-300	40	---		---		0.96	0.02	0.93	0.03	---	
		20	300-450	18	---		---		0.82	0.05	0.78	0.06	---	
		20	450-600	42	---		---		0.77	0.04	0.73	0.04	---	
		20	600-750	25	---		---		0.75	0.05	0.71	0.03	---	
Europe	{Belgium(2),	10	<150	2	---		---		---		0.97	0.01	---	
	France(4),	10	150-300	7	---		---		---		0.88	0.06	---	
	Germany(2),	10	300-450	5	---		---		---		0.77	0.09	---	
	Austria(1),	10	450-600	8	---		---		---		0.79	0.04	---	
	Netherlands(1)}	10	600-750	7	---		---		---		0.73	0.04	---	
		10	750-900	5	---		---		---		0.67	0.02	---	
		10	900-1050	7	---		---		---		0.68	0.06	---	
		10	1050-1200	4	---		---		---		0.43	0.02	---	
Europe	{Belgium(1),	9	<150	4	0.89	0.07	---		---		---		---	
	France(1),	9	150-300	2	0.88	0.06	---		---		---		---	
	London,Italy(1),	9	300-450	4	0.21	0.06	---		---		---		---	
	Austria(1),	9	450-600	5	0.43	0.30	---		---		---		---	
	Germany(2)	9	600-750	3	0.52	0.10	---		---		---		---	
	Netherlands(2)}	9	750-900	5	0.45	0.14	---		---		---		---	
		9	900-1050	10	0.55	0.23	---		---		---		---	
		9	1050-1200	3	0.22	0.19	---		---		---		---	

Table 4. Distance slope coefficients in China and Europe, 1742-1855 in 25 year periods.

					1742-1766		1756-1780		1766-1790		1770-1794	
Country	Sample	N	Distance range	n	Slope	R-sqr	Slope	R-sqr	Slope	R-sqr	Slope	R-sqr
			Shorter Distances									
China	Yangzi Delta	12	10 - 300	36	-0.06**	0.06	-0.06**	0.13	-0.03***	0.11	-0.03**	0.10
			Medium Distances									
China	Yangzi D. expanded	26	100 - 550	285	-0.20**	0.24	-0.16**	0.23	-0.13***	0.23	-0.10***	0.12
France	Central France	10	100 - 550	37	---		-0.15**	0.35	-0.26*	0.39	-0.17**	0.35
			Longer Distances									
China	Provincial Capitals	10	200 - 1400	45	-0.22**	0.37	-0.26*	0.26	-0.42*	0.38	-0.39*	0.34
Europe	{Mecklenburg(3), Belgium(1),London, France(1),Austria(1), Germany(2), Ruremonde, Luxembourg, Netherlands(1)}.	12	200 - 1400	54	---		---		---		-0.27**	0.29

					1806-1830		1815-1834		1825-1849		1831-1855	
Country	Sample	N	Distance range	n	Slope	R-sqr	Slope	R-sqr	Slope	R-sqr	Slope	R-sqr
			Shorter Distances									
Germany	Bavaria	13	10 - 300	37	---		-0.025***	0.37	-0.041**	0.50	-0.03**	0.43
			Medium Distances									
France	France	51	100 - 550	942	---		---		-0.10***	0.29	-0.06**	0.22
Germany	Bavaria & Mecklenburg	20	100 - 550	109	---		-0.14***	0.79	-0.16***	0.79	-0.12***	0.77
			Longer Distances									
Europe	{Belgium(2),France(4), Germany(2),Austria(1), Netherlands(1)}.	10	200 - 1400	41	---		---		-0.20**	0.60	-0.23**	0.70

Figure 2.

Europe and China, select markets over 18th century,

Bilateral Price Correlation on Distance.

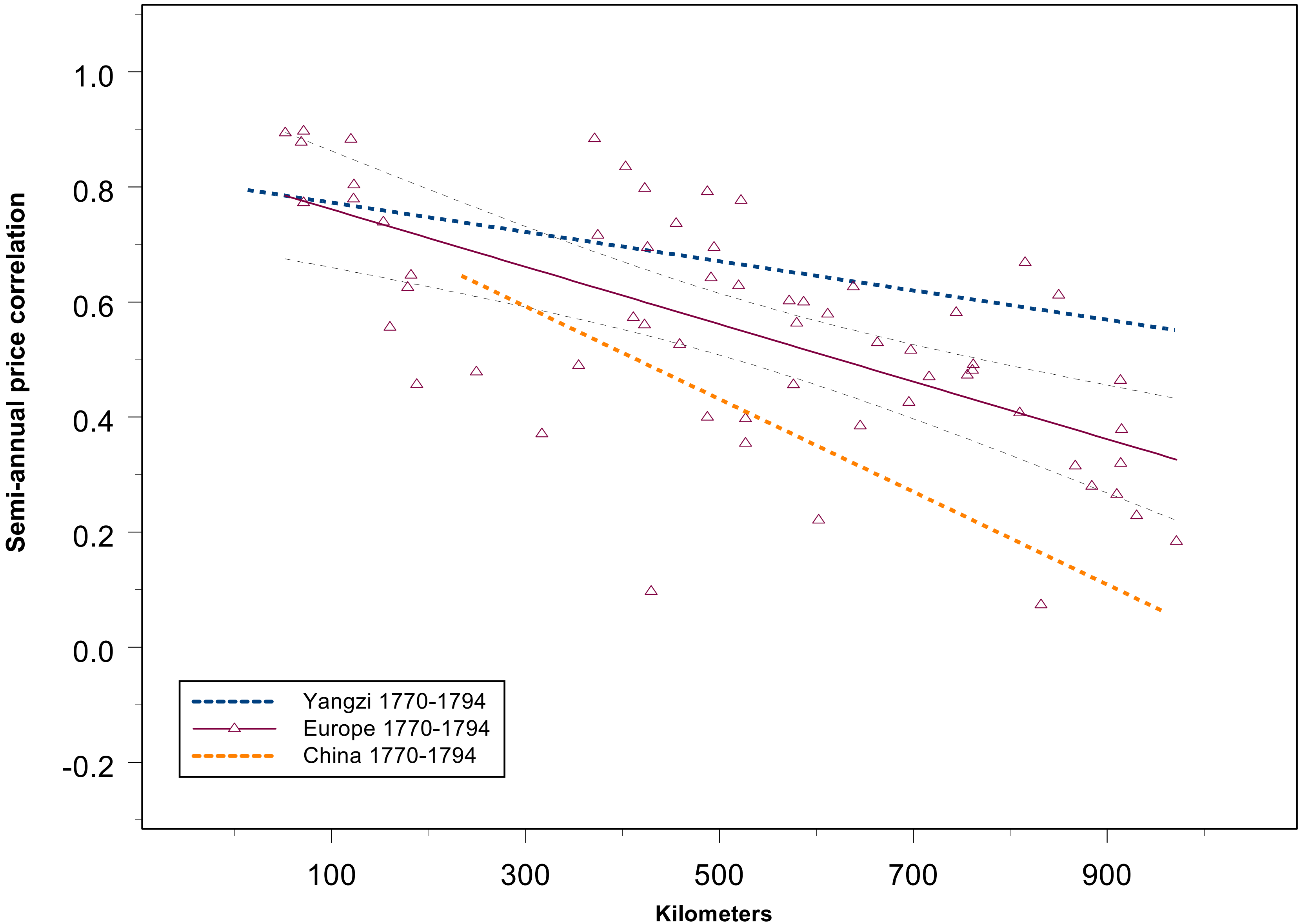

Figure 3.

Europe and China, select markets 17th-18th century

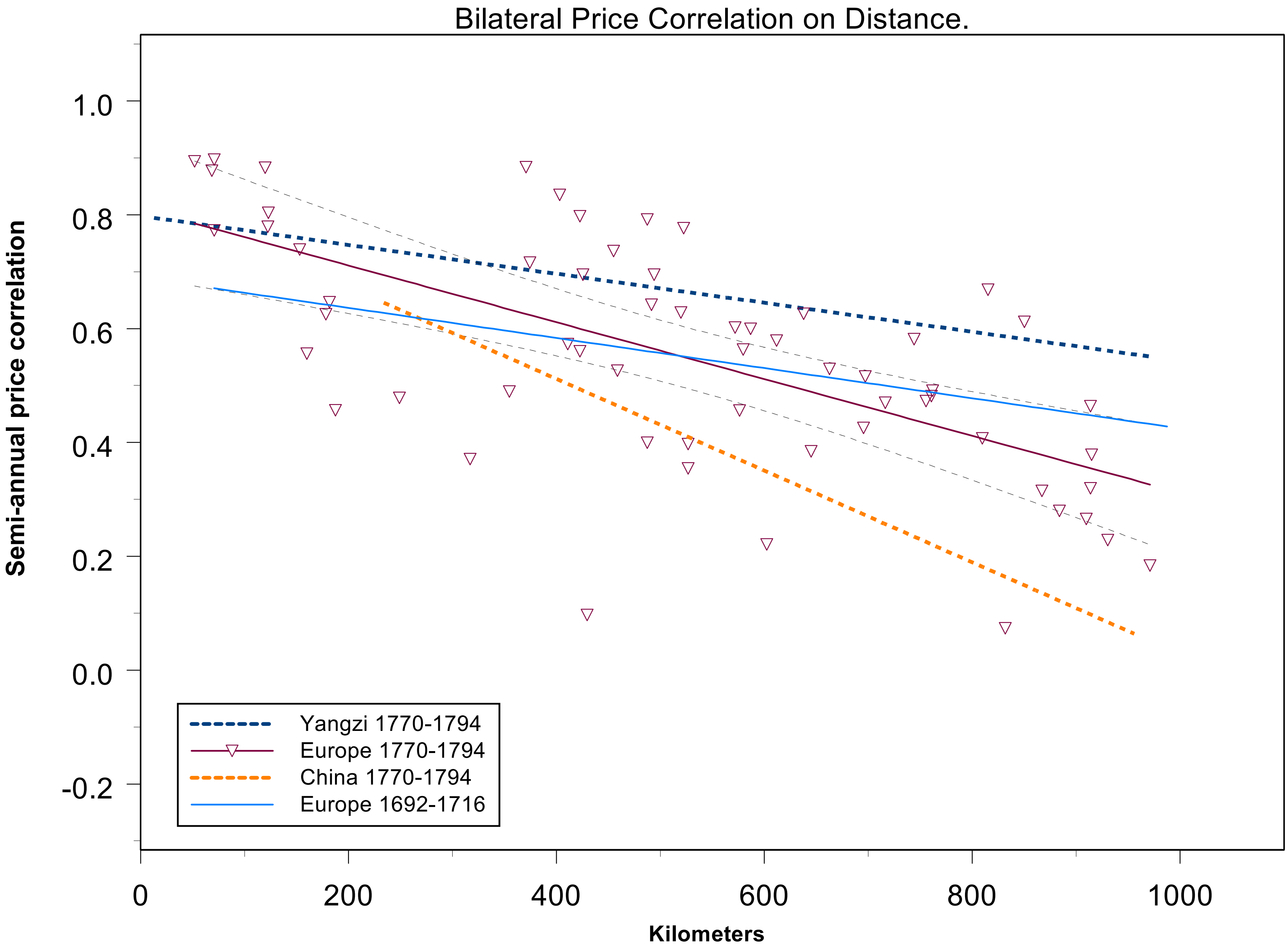

Figure 4.

European markets over 18th-19th centuries,

Select markets, Bilateral Price Correlation on Distance.

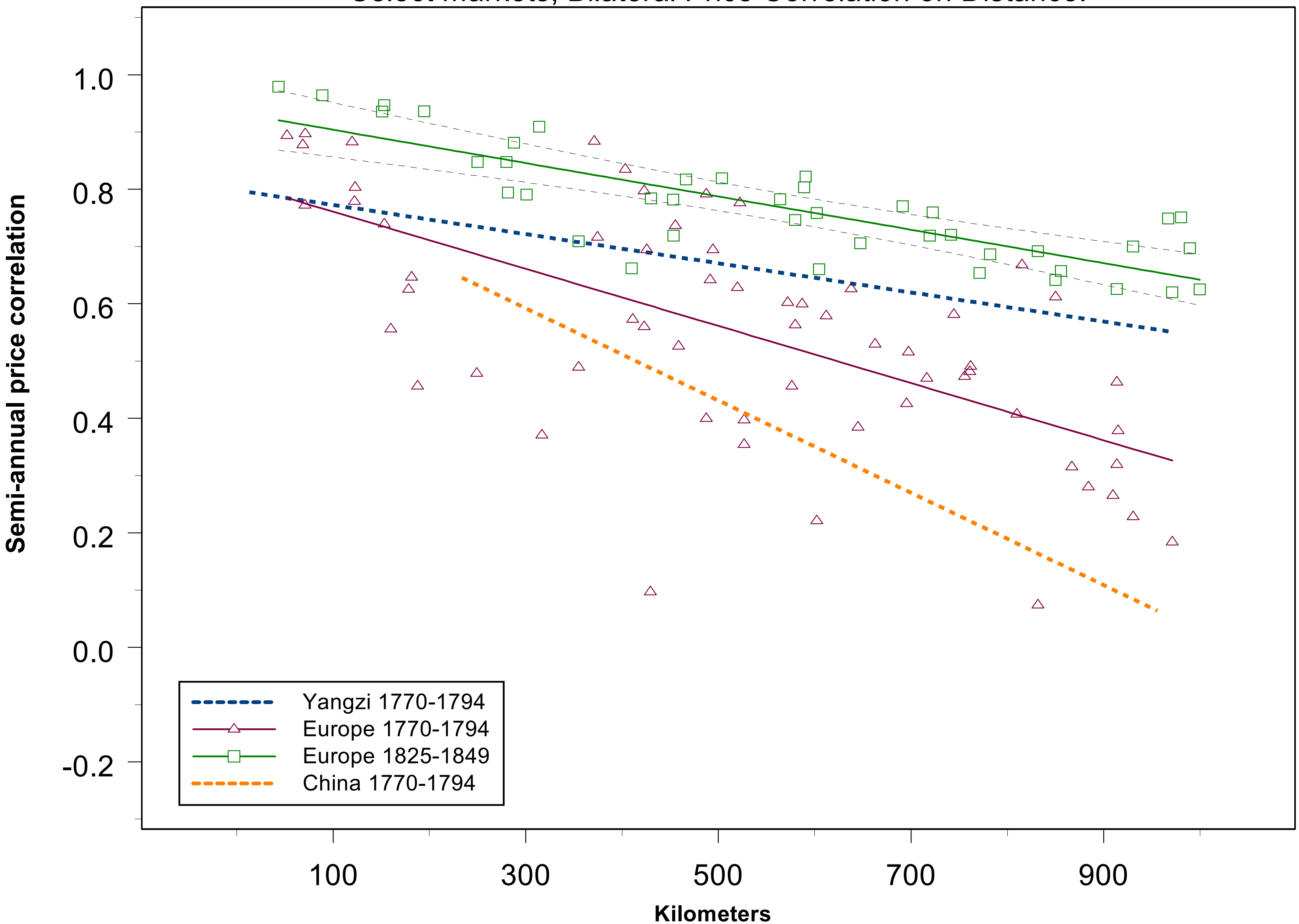

Figure 5.

China and 12 European cities, 1770-1794,

Bilateral correlation on bilateral distance.

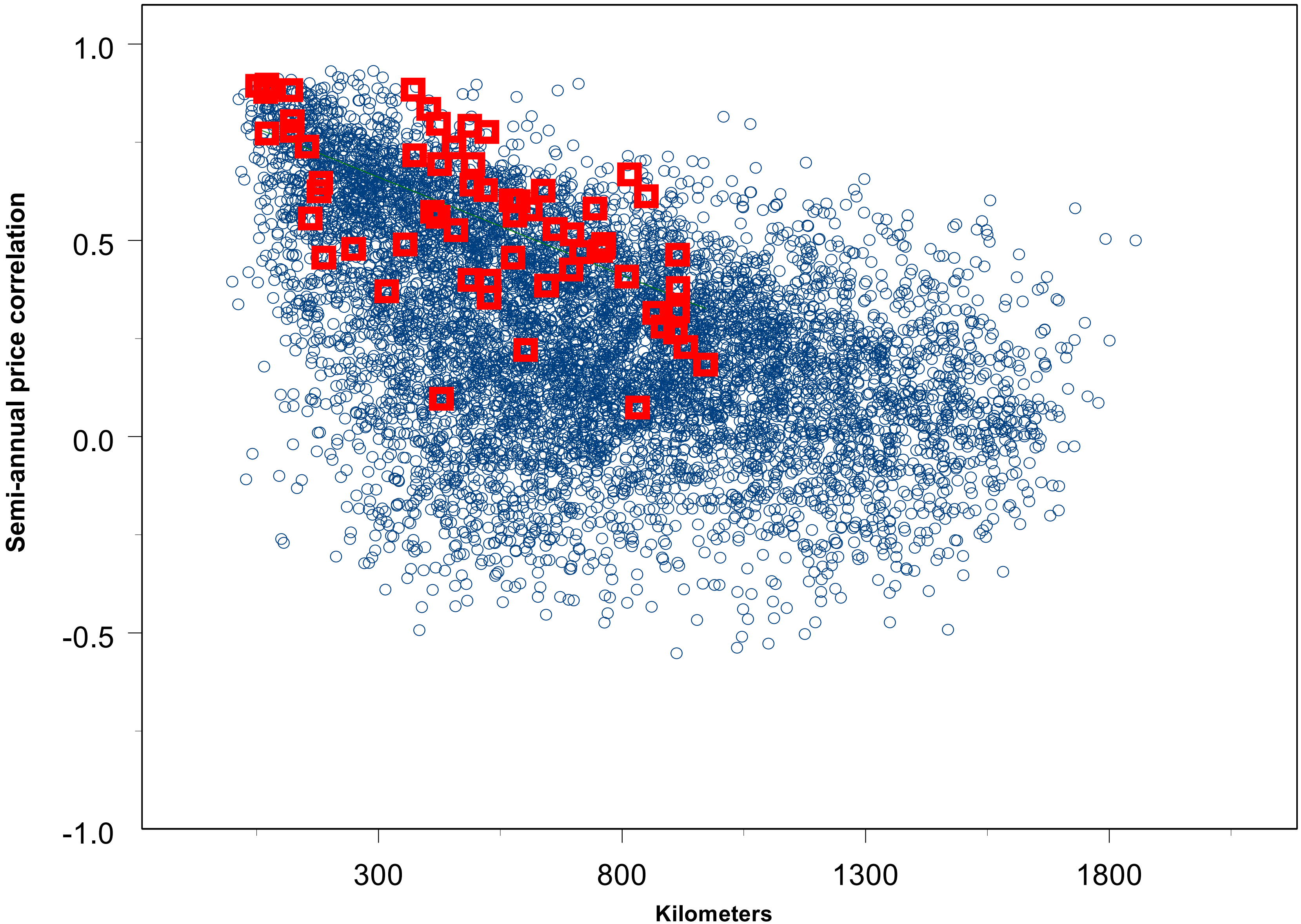

Figure 6.

China (1770-1794) and 12 European cities (1825-1849).

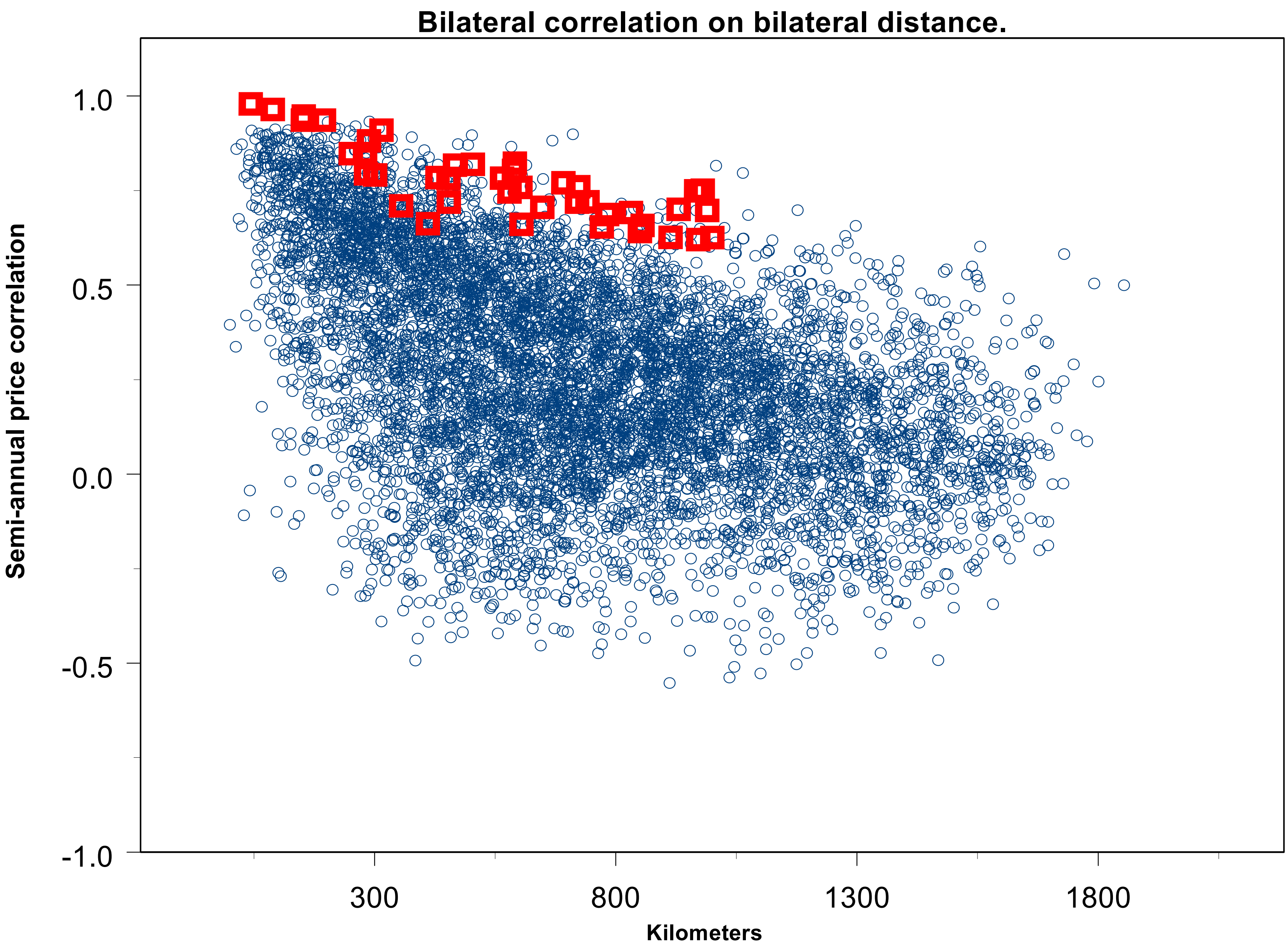

Figure 7. Co-integration Comparison Europe versus China.

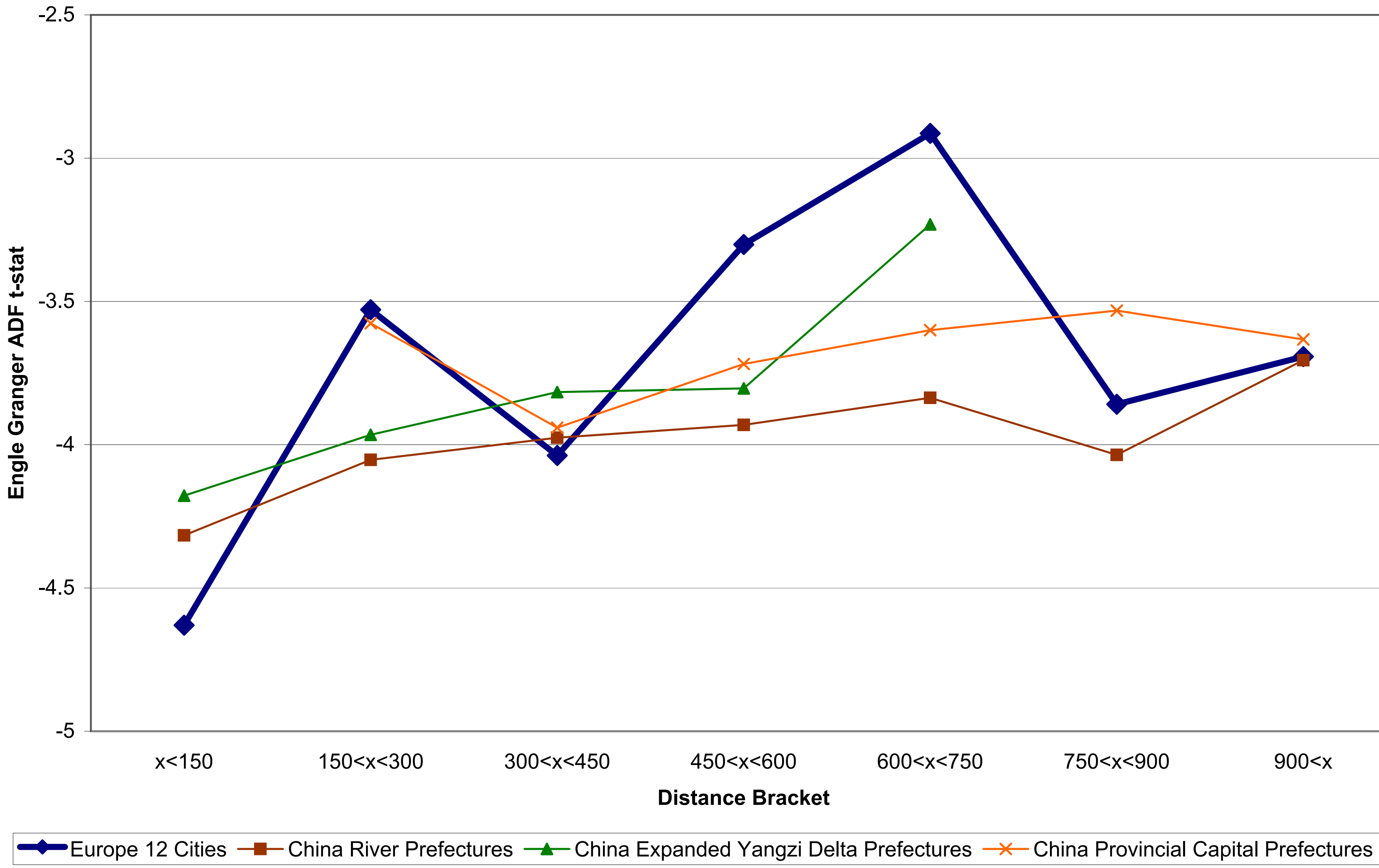

Figure 8. Co-integration Comparison Europe versus China.

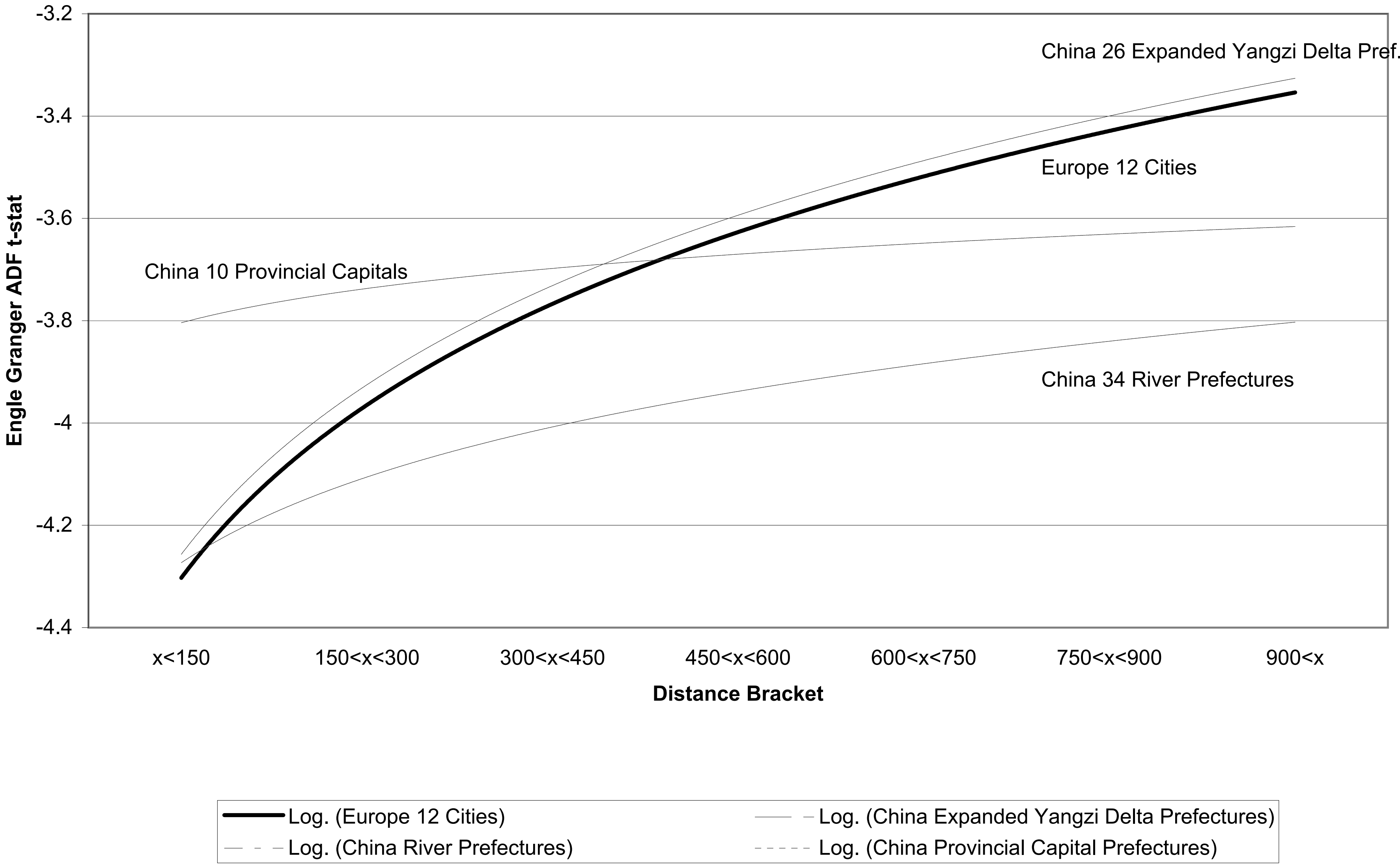

Figure 9. Huizhou Prefecture

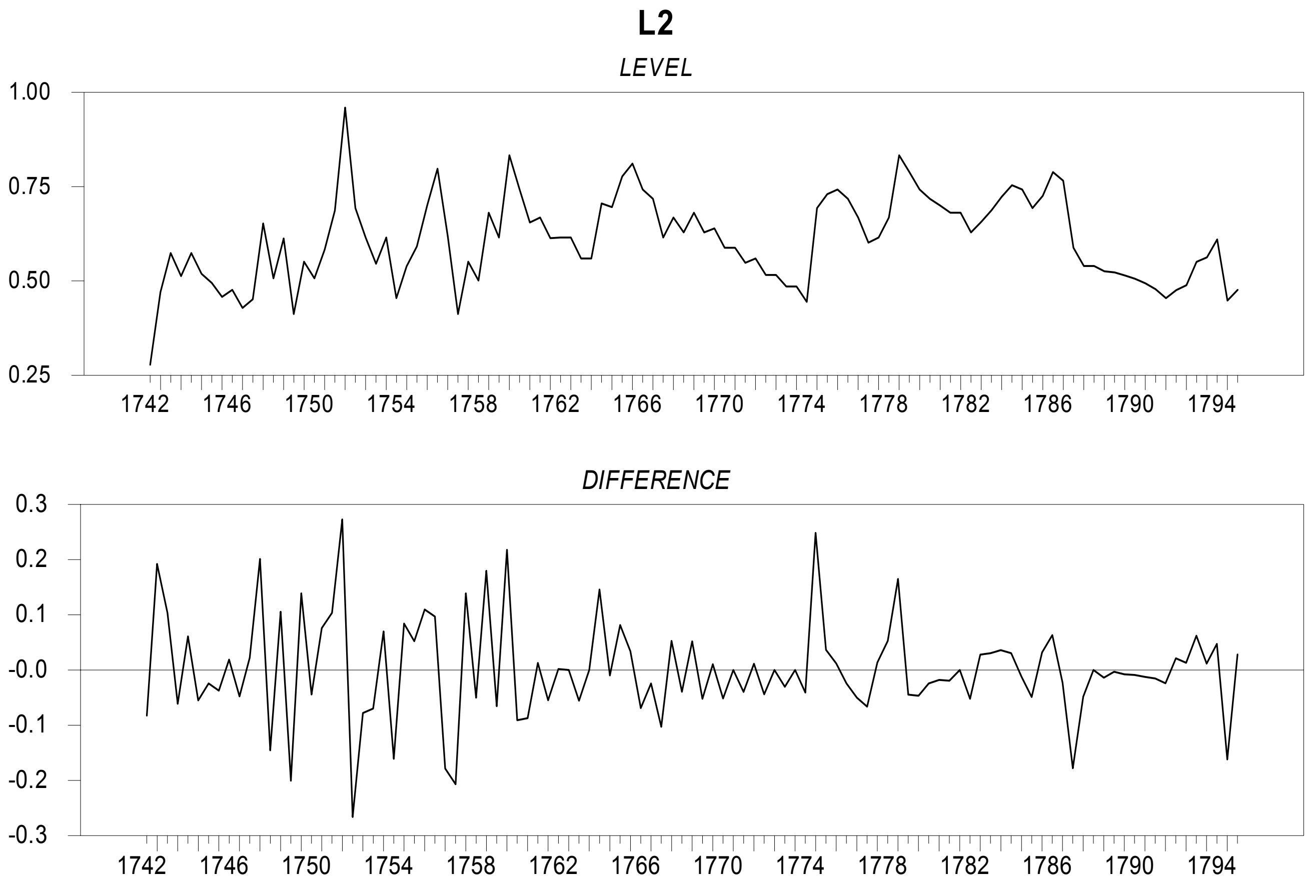

Figure 10. Taicang Prefecture

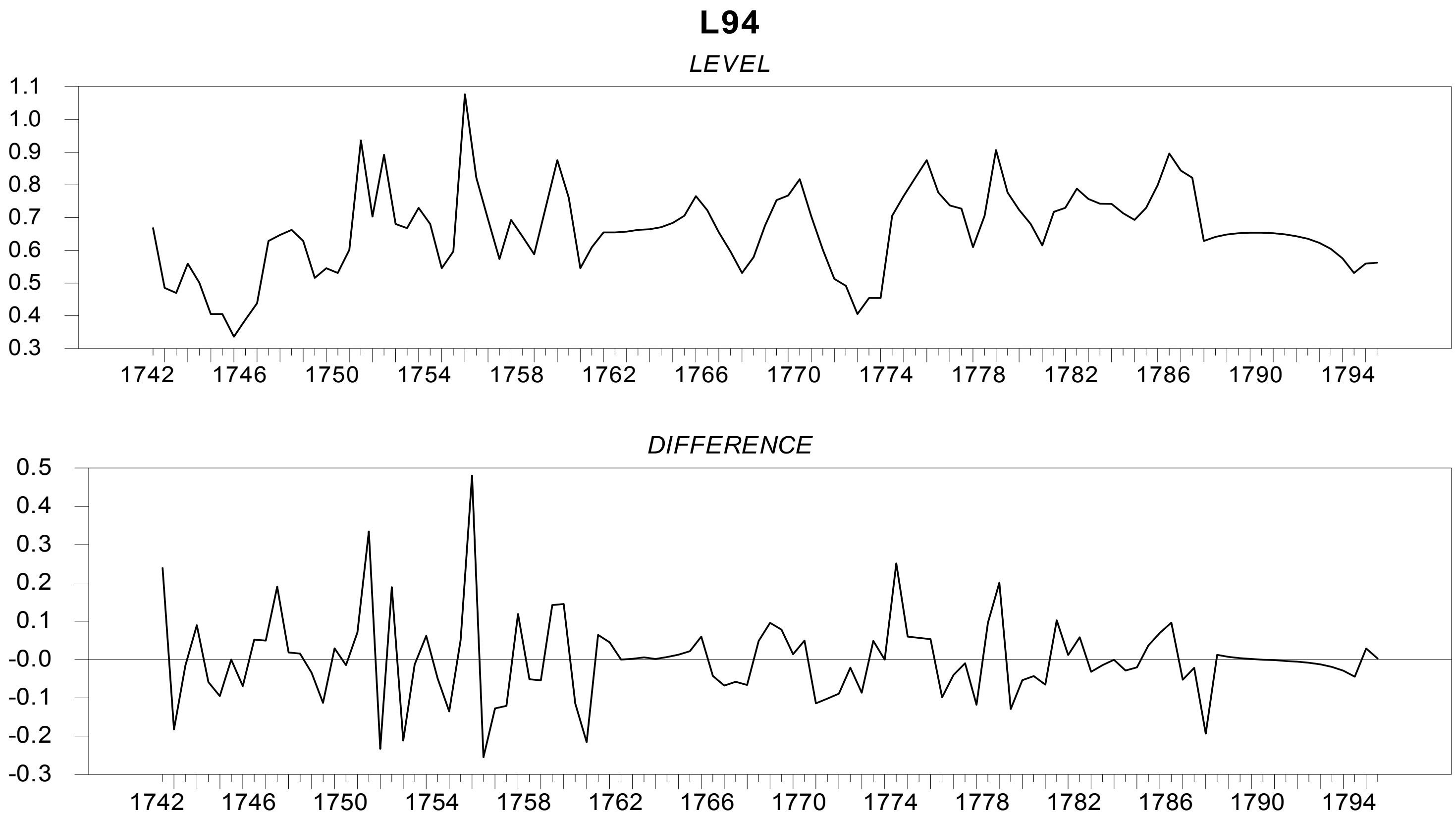

Figure 11. Diagnostic Analysis for Differenced Taicang Price Series

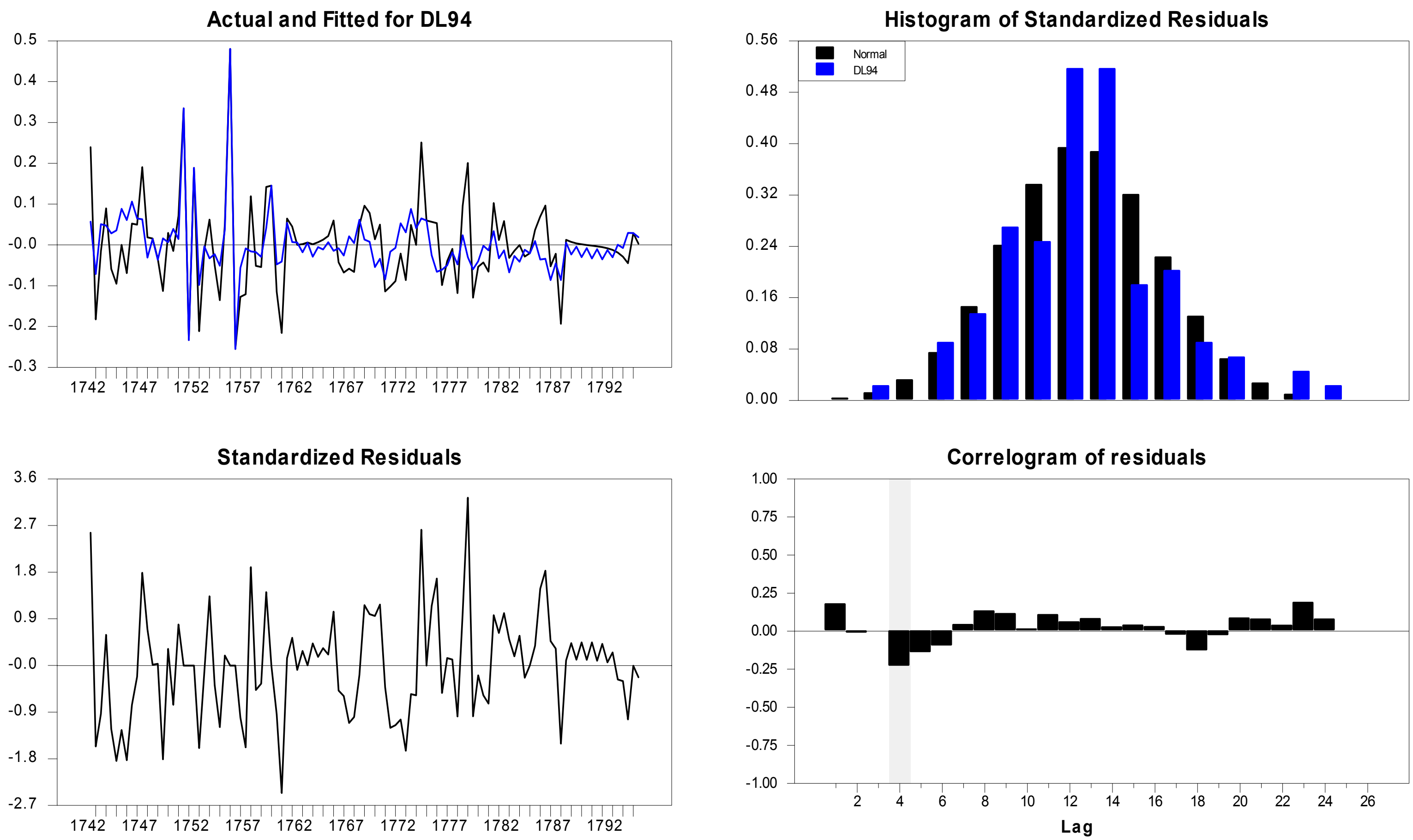

Figure 12. The Estimated Cointegrating Vector between the Huizhou and Taicang Price Series.