Web Appendix

1. A micro view of the organization of grain trade

The following section discusses major elements that had an influence on grain trade, with an emphasis on China where generally less is known. The references are to work cited in the main text.

(1) Actors: Most of the direct accounts of trade in 18th century China deal with government officials transporting rice. Far fewer records exist on the role of private merchant trade. In reality, the official shipments were only a minor component of total trade (Chuan and Kraus 1975, 56-58). In the mid-Qing, the official shipments—primarily tribute grain to Beijing and food for soldiers—were about 16.7% of China's total long distance trade (Xing et al. 2000, 170). Even on the Grand Canal, which was constructed, first and foremost, for the transport of tribute grain and other goods to the capital, the volume of private shipping probably outnumbered the official tonnage (Feuerwerker 1995, 31).

Who were the actors in this trade? In China, trade was a relatively specialized activity involving local (petty) traders, brokers, wholesale dealers, and itinerant (traveling) merchants. Petty traders worked on a small scale, usually with little capital, and were engaged in retail sales as well as carrying goods between urban centers and rural markets. Brokers (*yahang*) were middlemen engaged in a variety of roles, including supervising payment between buyers and sellers, overseeing delivery, providing information, inspecting for quality and quantity, and serving as guarantor on the exchange (Rowe 1984, 188-189; Mann 1987, 63-65). The broker was also responsible to the merchant for the safety of his goods during shipment, so that if the merchant was swindled, or incurred losses, the broker or shipping agent was obligated to pay compensation (Jing 1994, 59). In return, the brokers earned commission and rental fees for warehousing. Wholesale dealers typically specialized in a single item or a line of items and in some cases partially processed the merchandise.

Merchants varied greatly in the scale of operation. Some merchants formed networks that were typically identified by their common place of origin, such as the merchant networks from Huizhou or

Shaanxi. A particular merchant network was typically known for its trade in one commodity, such as the Fujian merchants' paper trade (Xing et al. 2000, 180) or the Yangzhou merchants' trade in salt (Ho 1954). Nevertheless, even these merchants frequently carried grain on the return trip, so that the development of long-distance grain trade was directly linked to the development of long-distance trade overall. For instance, a large percentage of the rice shipped downriver on the Yangzi River traveled on the ships of the salt merchants of Hankou, who would bring back salt from Yangzhou in Jiangsu (Rowe 1984, 55).

The largest fortunes in Ming-Qing times were as a rule built on domestic and international trade. Although formal Qing laws took a relatively hands-off approach to the daily affairs of trade, this did not mean that there was little interaction between merchants and the state. The distinction between merchants, gentry, and officials seems heavily blurred by the early 18th century. Many merchants purchased official titles or became officials of the state, and officials not only accepted but regularly solicited financial contributions from merchants for government projects. At the same time, the value of rich merchants to the government was enhanced by their large monetary contributions to the central treasury. The Liang-huai salt merchants contributed more than 36 million *taels* of silver to the government between 1738 and 1804, not counting the 4.6 million *taels* spent on the Qianlong emperor's southern tours and the numerous smaller contributions of salt officials (one *tael* of silver is about 37 gram). Although the merchant guilds authorized to trade out of Canton contributed only 3.95 million *taels* between 1773 and 1832, the Wu family alone contributed at least 10 million *taels* in 3 generations. For their contributions merchants were awarded with official titles and ranks, some as high as that of financial commissioner (Ho 1964, 82).

(2) Information: Information about prices, market conditions, and travel routes were transmitted in several key ways. First, teahouses and lodges formed meeting points at which merchants, gentry, and other members of the marketing community exchanged information, built up relationships, extended credit, coordinated actions, and negotiated over deals (Skinner 1964, 37). Second, merchant networks were an important means by which geographically dispersed groups cooperated and shared information about conditions in distant markets. Such groups were well-coordinated internally, and their spread over China amounted to networks of "commercial intelligence" about possibilities to produce and market various commodities. Merchant route books were practical manuals that laid out roads between market towns, giving distances that can be covered in a day, suggestions on where to stay overnight, as well as advice pertaining to commercial transactions (Brook 2002, 3). Third, the Qing state gathered information about agricultural practices, harvest outcomes, and market prices. In the case of agricultural technology, written treatises distributed among officials helped to spread information about agricultural techniques that could increase land productivity among farmers (Myers and Wang 2002, 599). Although information on harvests and prices were not widely distributed, local agents nevertheless knew official Qing harvest ratings; tenants, for instance, used the rating to reduce the amount of rent they expected to pay landlords (Marks 1998, 208). It is likely that merchants were aware of this information as well, and that it spread through market towns and networks quickly. The information flow between merchants and officials occurred in both directions—Qing government officials both imitated merchant trade practices and followed trade routes long established by merchants. As Chuan and Kraus note, if government officials thought about going to Shandong, for example, to buy grain, it was because they knew merchants frequently did it (1975, 66).

(3) Regulation, trade taxes, measurements and standards: At the local market town or community, itinerant merchants relied both on government-licensed brokers and on guilds (*huiguan*) to assess market prices (Mann 1987, 63-65; Xing et al. 2000, 180, respectively). The brokerage system allowed the state to have an official presence in certain wholesale transactions. The list of commodities subject to brokerage involvement varied from place to place, but in most central market towns it included grain. In Hankou in the mid-Qing, for instance, there were licensed brokers for 14 agricultural commodities, as well as cotton and silk cloth (Rowe 1984, 186). Although it was illegal to conduct any wholesale transaction without a licensed broker, the requirement was not fully enforced, resulting in a proliferation of unlicensed brokers and eventual protests calling for the removal of brokerage system altogether in the name of free trade.

Local guilds in China were corporate, self-governing organizations that were permitted a broad range of discretionary powers by the government (Mann 1987, 23). They provided lodging and services for merchants, helped calculating profit and loss, and they taught merchants bargaining techniques. Other functions included the establishment of dates that the market was open as well as regulations for sales, deliveries, and business conduct more generally (Xing et al. 2000, 180-183; Rowe 1984, 295-296). Unlike the guilds of Europe, where membership was based on residence, Chinese guild organizations were dominated by interregional merchant networks. Thus, while European guilds often would pitch residents (potential importers) against non-residents (potential exporters) and created a barrier to entry for new members, Chinese guilds typically did not keep out arriving merchants from membership (Rowe 1984, 297). One reason for this was that guilds operated on membership dues. Membership in the Hankou rice guild cost 15 *taels* up front and 0.8 percent of a member's annual gross receipts, for instance (Rowe 1984, 301-302).

Neither the government brokers nor the guilds ever came to dominate the marketplace. Whereas the Qing state saw monopolization and collusive behavior as a key reason for intervention in the marketplace, the guilds worked to oppose the state brokers and their high commissions (Xing et al. 2000, 180-182). If anything, the state relinquished the task of market regulation to the guilds, as the latter were delegated the unusual privilege of assessing and collecting trade taxes for the state (Mann 1987, 23-24).

The Chinese state also regulated the market directly. In addition to the brokerage tax, the state levied domestic customs, the Imperial maritime customs, and later, in the 19th century, the *likin* transit tax (Rowe 1984, 181). However, not only was the degree to which guilds restricted competition relatively low in China, but the amount of revenue the Chinese state received from trade taxes appears to have been lower than in Western Europe as well. With the notable exception of England, in Europe there were significant trade taxes within many countries at least through the 18th century, in addition to the tariffs between countries. For example, the trade of grain was highly regulated and restricted in 18th century

France, and there were also many tolls in the German areas.[1] Revenues from trade taxes were a higher fraction of total revenues in Europe even though over time, the Qing state came to rely relatively more on trade taxes.[2]

Relative to a situation where measures and monies are standardized, the different currencies and units of measurement used across Europe likely led to higher transactions costs and greater trade barriers. Even within countries, there were persistent variations in measurements. In England, for example, the final demise of local weights and measures did not occur until after 1850 (Mingay 1989, 226-227). Conversion rates into other units and currencies of (local) importance are occasionally available, but they tend to be subject to considerable uncertainties.

In the case of China, there was a consistent effort to ensure that the official units of accounting for rice prices in terms of *taels* of silver per *shi* was comparable across regions (Chuan and Kraus 1975, 12-14). Nevertheless, there were numerous local weights and measures under use. In addition, local exchange rates between copper cash and silver also varied across regions; see Vogel (1987, 30-31) who reports some local copper exchange rates for Jiangsu and Zhejiang provinces. Variation in local exchange rates may not have been as large as the variation in totally different currencies in Europe, but they may nevertheless have been an important trade barrier.

Overall, is difficult to say for certain whether the variations in the level of standardization presented a greater problem in China or in Europe since the issues were different. Merchants and other market participants were likely to be aware of and sensitive to variations in measurements and the value of the currency, so that the lack of standardization *per se* would not necessarily make trade impossible, but still, the variations had to be sorted out by local buyers and sellers. In this regard, guilds may have

[1] For example, see Kaplan (1984) on France, and Henderson (1939) on the pre-*Zollverein* situation in Germany. An analysis of the economic effects of the *Zollverein* can be found Shiue (2005b).

[2] One reason for this was that the state-licensed brokerage system was increasingly abolished in the 19th century (see above). At the same time, the Qing state's relatively stronger reliance on trade taxes during the 19th century may just have brought China to where the European countries already were. Consistent with this, the relative importance of land taxation in 18th century China was much higher than in England: by the year 1753, about three-quarters of the total state revenue came from the land tax, declining to 35% by 1908 (Wang Yeh-chien's estimate, reported in Rowe 1984, 181), whereas by 1750 in England, land, income, and property taxation accounted for only 29% (Mitchell 1988, 825).

reduced the transaction costs since common local units of measurement were chosen and partly enforced by the guilds. As an example for that, the 1678 Rice Market Guild of Hankou stated that “when any [guild member] acts as a wholesale rice broker for an itinerant merchant in the transactions of his business, the weights and measures employed in the transaction much first be submitted to the guild for approval, rather than adoption on an individual basis” (Rowe 1984, 295).

(4) Maintenance: The maintenance of transport routes was critical for the transport of grain. The Qing state devoted some 10 % of its total revenues to public projects, and also effectively supplied the necessary technology, especially for large scale projects such as flood control and maintenance of the passageability of the Yellow River and the Grand Canal. The state was also active in organizing local communities in the upkeep of transport routes, dykes, bridges, and roads (Naquin and Rawski 1987, 23; Myers and Wang 2002, 597). When provincial officials received an order to undertake a project, they called on local leaders to help finance the work. The costs of the repairs would usually come mainly from cash contributions of local landowners, gentry, and merchants, and labor contributions of tenant households. These efforts probably benefited the economies nearby to some extent, although it remains unclear whether public goods were still undersupplied.

Also in Europe, local authorities were initially responsible for maintaining transport infrastructure. In France, the central government finally assumed control over new investments along the major roads leading into Paris, but it did not improve secondary roads, leaving instead local governments responsible for them. After 1700 in England, however, the transport infrastructure was improved because maintenance was entrusted to private organizations created by Acts of Parliament (turnpike trusts, river navigation companies). More details on this in the case of England can be found in Jackman (1962) and in the more recent work of Bogart (2005).

(5) Security and property rights: Predation and extortion by bandits, pirates and governments alike threatened the trade of merchants both in China and in Europe. Some Chinese merchant route books note the locations of not only police stations en-route but also bandit hideouts (Tong 1991, 146). In England, farmers, millers and corn dealers at times of bad harvests in the late 18th century were often stopped and had their loads seized, in spite of significant penalties (Mingay 1989, 234-5), and arbitrary tolls imposed by local rulers in continental Europe were effectively another form of extortion. It is difficult, however, to assess how the overall security risks for traders in China compared with those in Europe. Qing laws sanctioned bandit activity with capital punishment, while predation and extortion of merchants by Qing officials or by local gentry was illegal and also subject to severe punishment. Nevertheless, capturing the bandits could be difficult, especially in harsh terrain. Complementing the Qing state, a variety of private activities emerged to provide security. For example, civilians joined forces with local military commanders, and local communities raised bounties to reward soldiers (Tong 1991, 85). Large merchants were also known to commission a merchant-militia for protection while traveling.

The Qing Code, the formal legal framework of Qing China, contains many articles related to property, such as on theft, sale of property belonging to others, or trespassing (Jing 1994, 43-44). Legal protection from acts of government officials as well as private agents was afforded to all privately owned property, regardless of whether it was held by individuals or lineages. The laws applied also to disputes among family members, so that intra-familial property disputes were not off-limits to the laws of the empire. Other laws forbid monopolization and price collusion, especially by government brokers, and prohibited counterfeiting and the use of fraudulent weights and measures in trade. It appears that the court system was widely used; for instance, civil cases accounted for about a third of the total case load of local courts in a study by Huang (1996, 11). Moreover, official arbitration of property disputes was apparently available for poor people as well (see Buxbaum 1971, 268, and Bernhardt and Huang 1994, 5).

Fundamentally, however, the Qing Code was not designed for the reconciliation of conflicting private economic interests. Rather, the emphasis was on maintaining public order by providing incentives for lawful behavior through the threat of punishment (also Huang 1996, 107). A good example of that is the law on bridge maintenance, which simply states:

"…If there is injury to the bridges and roads, and there is neglect in repairing them, hindering traffic along the routes, then the supervisory official and clerk will receive 30 strokes of the light bamboo." Board of Works Article 436 Repairing Bridges and Roads; in Qing Code (1994, 412).

Thus, there is little in Qing laws on what evidence is needed before judgment on guilt is parsed, and how the punishment is to be enforced, which in contrast with the written laws of the British Commonwealth,

With respect to the legal framework for trade, merchant guilds probably played a greater role than the Qing Code. They established rules for business conduct and means of contractual documentation (Rowe 1984, 295). Merchant guilds were also involved in adjudicating disputes (Mann 1987, 23). In short, the guilds supplied a wide range of legal functions—sometimes called "customary" or informal—both independently of the state and in parallel to official notions of justice.[3] Private (white) contracts were legally valid and eventually outnumbered official (red) contracts, which were stamped official versions registered for a fee with the local government headquarters. There does not appear to have been much of a contradiction or competition between the official and the customary laws since customary practice was judged within the official code, and conversely, private written contracts were enforced in the ruling of the Qing official's court when disputes arose. The system allowed legally recognized and enforced written commercial agreements to be routinely circulated, from shipping orders to bills of loading to promissory notes to contracts of sale (Rowe 1984, 75 and Chapter 5). In this sense, the legal framework for trade did not appear to be missing in China.

(6) Financial instruments: The involvement of the Qing state in financial institutions was relatively limited, but the state was not inactive: state controlled customs banks issued certain notes and stored customs revenue collected by the government. There were also government-owned pawnshops. Another important area controlled by the state was the bimetallic monetary system of the Qing, based on silver and copper cash, which produced some seigniorage revenue. There was, however, no formal regulatory agency responsible for overseeing financial administration and banking.

Many innovations in the area of credit and banking in the Qing can be traced to private merchant

[3] See Naquin and Rawski (1987, 102), and Jing (1994, 42) on the following.

activity. From the early Qing period, merchants purchased peasants' agricultural products and handiworks by paying money in advance, and it became an important method for purchasing commodities in rural areas. Financial institutions of various types often took deposits and made loans. Among the most important were the so-called *yinhao* ('native banks') and *piaohao* ('currency stores') (Zurndorfer 2004). During the Qianlong era (1736-95), native banks conducted local money exchange, accepted deposits, issued private banknotes, and lent money to partnerships in the local market (Zhou Yumin 2000, Rowe 1984, 161). There exist some similarities with early deposit banks in Europe (Mann Jones 1972, 47). In contrast to the local focus of the native banks, the currency stores dealt with interregional transactions, having often several branches all over the empire, and were related to the merchant networks. The *piaohao* were closer than the *yinhao* to being a state institution in banking since the government used these banks for deposit and required that companies desiring to found similar institutions be endorsed by the members of the established banks. (Mann Jones 1972, 50). These financial institutions issued promissory notes payable in the future, and facilitated the movement of goods and money over long-distances through innovations in credit.

It appears that some merchants entered the banking business as a means of capitalizing their commercial projects (Rowe 1984, 162). The private paper money issued by these banks may have constituted as much as 1/3 of total money in circulation in the mid-Qing. Thus, even though the Qing state did not issue paper notes, it permitted merchants to transform the monetary economy into one where paper notes circulated widely (Naquin and Rawski 1987, 101, 104-105).

That these banks developed relatively free from government involvement meant both little obstructionism and little constructive support. The establishment of ties and contract enforcement between creditors and debtors was mostly informal, and often based on kinship, common origin, or otherwise established through the merchant networks. This was especially true of the Shanxi merchants, for example, who relied on network connections to facilitate transactions between their operations in North China and the Yangzi Delta (Wong 2002). There were also Hunanese merchants that operated through an interlocked chain of banks at various points of their trade route (Rowe 1984, 162), and merchants from neighboring provinces to the north who dominated Sichuan's financial institutions for most of the Qing (Zelin 1993, 88). While we know that the interregional transactions were served by the *piaohao*, there is still the question of the extent of access to credit for non-members of the interregional networks. There is suggestive evidence that China's financial institutions were multi-faceted and extensive, but to date there is little quantitative evidence on the size and the performance of China's banking and credit sector during the 18th and 19th century in comparison to those in Europe.

2. Comparing market integration in China and Europe using bilateral price correlations

In Figure 2, we have shown that the degree of market integration for 15 West European cities in the late 18th century is comparable to that for certain markets in China during the same period. This section extends this analysis, thereby complementing the cointegration results shown in the main text. First of all, it appears that the degree of market integration attained in Europe as of the late 18th century had been roughly constant for some time. Figure A.1 compares the late 17th century (1692-1716) and the late 18th century (1770-1794), showing the regression lines for both samples together with the confidence bands of the earlier period. The estimated level and slope of the relationship between price correlation and distance for the 18th century lies fully within the confidence bands of the 17th century period. The lack of any dramatic shift in market integration between the late 17th and the late 18th century is in contrast to the changes that would be seen in Europe in the 50 years after 1770. Figure A.2 shows the price correlations for European cities for the years 1825-1849, together with the other samples shown in Figure 2. As the confidence bands indicate, the 19th century price correlations are above those in either 18th century Europe or China. It is apparent that the level of market integration in Europe has made dramatic improvements over a relatively short period of time.

If across-country market integration was not higher in Western Europe than in China on the eve of the Industrial Revolution, might within-country market integration have been? Figure A.3 compares the markets of the extended Yangzi Delta with those in England. The regression line for the English sample is located above that for the Yangzi Delta at virtually all distances. For distances below 400 kilometers, the confidence band of the Yangzi Delta sample is below the regression line for the English markets, indicating that the two sets of price correlations are also statistically different. This confirms the cointegration results from Figure 5. However, within-country market integration was not generally higher in Western Europe, as the comparison of the Yangzi Delta and regions in Central France in Figure A.4 shows: here, there is no statistical difference between price correlations in France and in China. Overall, our bilateral price correlation results confirm the cointegration results shown above.

3. Historical weather patterns in China and Europe

If weather patterns changed quite differently across geographic space in China compared to Europe, this could lead to substantial differences in the spatial price correlations, which could potentially cloud our inferences on market integration. We have thus collected and analyzed historical weather information for China and Europe to see whether such effects might be important.

For China, the weather data available to us is an indicator of rainfall and wetness in a given harvest year. Systematic rainfall recording began as early as the Tang Dynasty (618-907 A.D.), and from at least the 17th century the collection of rainfall and weather reports at the county level had become standard government practice (Wilkinson 1969). Our source for historical weather data are the weather maps in the State Meteorological Administration (1981). The maps give weather data throughout China for each year for 120 "stations", where one station corresponds to one or two of our prefectures. It is a discrete indicator of the degree of rainfall relative to what is considered normal for that region. The indicator, R_{nt}, ranges from 1 (severe droughts) to 5 (heavy rains and floods), and normal conditions are given by $R_{nt}=3$. The information is hand-coded from the weather maps to compute the weather correlations between any two prefectures.

For Western and Central Europe before 1300 A.D., there are reports of natural disasters, and by 1800 A.D. there are almost complete descriptions of monthly weather, although cross-border (international network) weather observations before 1860 were still rare (Pfister 2002). The exact relationship between climate and agricultural output is complicated, but it is clear that both extreme temperatures as well as extreme humidity tend to lead to bad harvests. Moreover, humidity and temperatures in different years or in different cities are correlated (Baten 2000 provides additional discussion). This means that we can employ the temperature data for 8 European cities available to us to compare the spatial weather patterns in Europe with those in China.[4] The cities are Paris, Vienna,

[4] The temperature data was provided by Rüdiger Glaser (see Glaser 2001); thanks to Jörg Baten for sharing the data with us.

Munich, De Bilt (the Netherlands), Nottingham (as Central England), Berlin, Basle (as Switzerland), and Stockholm (as Sweden). For each of the eight European cities, we have re-classified the weather data from temperature in degrees Celsius into five discrete classes, 1 to 5, and computed for each city pair the correlation of weather.[5]

The regressions presented in Table A.1 compare weather correlations in China and Europe as a function of distance. We see that throughout weather correlations in Europe were higher than they were in China, indicated by the higher intercepts for the former sample (China: 0.39 to 0.62, versus 0.83 to 1.17 for Europe). This in itself suggests that our evidence on price correlation might be affected by spatial patterns of weather (and not of arbitrage and trade) to a relatively greater extent in Europe, or put differently, without controlling for weather we have stacked the odds against finding China ahead in terms of market integration. However, it may be that the spatial correlation of humidity (used for China) and of temperature (used for Europe) are just different, and this may explain in part why we estimate a higher level of weather correlations for Europe.

Another question, thus, is how weather correlations changed with distance in the two continents. It turns out that there is no clear difference between China and Europe. In the preferred specification for the European sample (in terms of $\overline{R}^2$), we estimate a value of -0.243 on log distance for Europe, while for China it is smaller in absolute value (at -0.195). However, the 95% confidence interval of the estimate for Europe is (-0.310, -0.177), which covers the point estimate for China. Moreover, one may want to drop Stockholm from the sample because its location is substantially to the North of our core sample. That alone brings the distance coefficient to -0.186, less in absolute value than the estimate for China while at the same time increasing the $\overline{R}^2$ (see specifications III and VI, respectively). In addition, the preferred specification for the Chinese sample has both log distance and its square, and for this specification distance has the expected effects for China (linear: negative, squared: positive), while for Europe distance has no significant effect.

[5] We replicate the frequencies that are present in the data for China (1770-1794): R_{nt}=1, 2, 3, 4, and 5 with probabilities of 5.7%, 28.1%, 46.5%, 15.3%, and 4.5%, respectively.

On the bottom of the table, the predicted *level* of weather correlations in China and Europe is reported based on the OLS regressions. It is clear from these figures that the predicted weather correlation in Europe was higher than in China, while if one focuses on *changes* in weather correlation (moving from 300 km to 600 km e.g.), the magnitudes are roughly comparable. Finally, the remaining two specifications indicate that our results do not seem to be driven by the particulars of China's weather distribution during 1770-94 (specification V) or the fact that the minimum bilateral distance in our China is smaller than in our European sample (12 kilometers versus 265 kilometers; specification VI).

Overall, this analysis suggests that the influence of weather is unlikely to favor China over Europe in our comparison. First, the changes in weather accompanied by changes in distance were comparable in China and Europe. Second, we estimate that the level of weather correlations was substantially stronger in Europe than in China, and to the extent that this is not entirely due to differences in temperature versus humidity patterns, the analysis tends to favor Europe over China for finding relatively high price correlations.

4. A quantitative comparison of price behavior for rice and wheat

Our first approach is to employ additional price data on wheat in China. Wheat was an important crop in China primarily in the North. We have obtained a price series for Tianjin prefecture, near Beijing in Zhili province, for the 18th century, and this series can be compared to the 18th century European wheat price series. We also have obtained additional rice and wheat data for four major cities in Sichuan. Both crops are important in this province, which borders with the Guizhou, Hunan, and Hubei provinces in our sample.[6] Both the Tianjin wheat data as well as the rice and wheat data for the Sichuan cities originate from the empire-wide price reports that provide the data on the 121 prefectures used in the main text.

In Table A.2, we show summary statistics for 15 European wheat series and for Tianjin. The volatility of the Tianjin series is relatively low, with only Brussels having a lower standard deviation. The fact that storage cannot be negative creates an asymmetry that is typically reflected in the skewness of the price distribution (e.g. Deaton and Laroque 1992); here, both Tianjin and the average European series exhibit positive skewness, and this effect is stronger in Europe. If we focus on the years 1770-1781—a period with greater series overlap and before the turmoil of the French revolution—, the price volatility is still comparatively low in Tianjin, but its price distribution exhibits greater skewness than that of the average European market (on the right of Table A.2).

We have also examined the seasonal cycles in the two areas (Table A.2, bottom). In Europe, in two thirds of the cities the wheat price obtains its maximum in June to August and its minimum in January to April. In contrast, in Tianjin the maximum price is in March and the minimum in July; these results confirm the more extensive analysis by Li (1992). The price range within the harvest year is on average 7.2% in Europe, while it is 8.4% in Tianjin. This can be taken as an indicator of interest and other storage costs (McCloskey and Nash 1984, Shiue 2002). Thus, even though storage costs may have been higher in China, the lower volatility and possibly higher skewness in China may indicate somewhat

[6] We also have examined the price of wheat for a number of Hunan prefectures. However, the quality of the data is lower than for the Sichuan wheat price series. We suspect that it is related to the fact that wheat yields in Hunan were relative low compared to those in Sichuan (Bray 1984, 17-18).

more storage activity in China than in Europe. Note that the price volatility for Tianjin remains somewhat lower than for the average European city also if, alternatively, we (1) use seasonal controls and (2) employ first-differences instead of price levels. Overall, except for the timing of the seasonal cycle, the differences between wheat production in Europe and China as reflected in these statistics appear to be quite small.

A comparison of rice and wheat prices in four major cities of 18th century Sichuan—Chengdu, Chongqing, Nanchang, and Xichang—gives the following results (see Table A.3). In all cities, rice is more expensive than wheat, reflecting in part the fact that consumers preferred rice to wheat. The volatility for wheat is lower than for rice in three out of four cities. Wheat prices are also on average somewhat more skewed to the right than rice prices. Both of these findings are consistent with more wheat than rice storage. Given that storage and trade are substitutes, all else equal, this could mean less wheat trade than rice trade.

Other evidence we can bring to bear on this, however, does not support this hypothesis. First of all, the range of within-harvest year price fluctuations over the harvest cycle is on average higher for wheat than for rice in these markets (13.4% versus 10.8%, respectively). Moreover, wheat and rice tend to be both cheapest in the same month (the 8th lunar month). In addition, a computation of all six bilateral price correlations among these Sichuan cities shows that the rice price correlation is higher for three city pairs, while it is lower for the other three pairs, with the average price correlation for wheat actually exceeding that for rice (0.69 versus 0.66; see Table A.3, bottom). All in all, in this analysis for China, the similarities between rice and wheat outweigh the differences between the two crops.

Finally, we have examined grain prices in the United States to assess the likely impact that the difference in crops. While rice production in the United States likely differed from that in China, and the United States' wheat production differed from that in Europe, this comparison at least eliminates any bias coming from examining a few Chinese wheat price series so as to match European data when it is clear that rice was the more important crop in China.

For the period of 1749-74, we have examined monthly rice prices for Charleston and Philadelphia, and wheat prices for Boston, New York, and Philadelphia (source: Cole 1938). On average, rice prices are more volatile than wheat prices (standard deviation of log price 0.204 versus 0.176; see Table A.4), and the range of within-year fluctuations is larger for rice than for wheat as well (8.5% versus 6.8%). The difference between the two crops, while not large, may in fact be even smaller than what is implied by these figures, because Charleston appears to be an outlier; the within-year price range for rice in Philadelphia, for instance, is lower than for wheat in Philadelphia.

To shed additional light on the ease of rice versus wheat trade, we have also looked at how prices move with each other across markets. Computing all bilateral price correlations for these cities, we have found that conditional on geographic distance, rice price correlations are comparable to wheat price correlations in the United States. We note the small sample in this analysis of the US, and therefore have also extended the analysis of United States grain prices into the early 19th century, when price series for more cities become available; these results are similar to the results for the 18th century.

Overall, on the basis of this analysis, large biases in the comparison of market integration due to differences between rice and wheat appear to be unlikely.

Table A.1: The spatial correlation of weather in Europe and China, 1770 to 1794

Dependent variable: Bilateral weather correlation

	(I)		(II)		(III)		(IV)		(V)	(VI)
									Europe	Europe
	China	Europe	China	Europe	China	Europe	China	Europe	Alt. Dist'n***	w/o Stockholm
Intercept	0.390**	0.832**	0.588**	0.956**	0.535**	1.116**	0.618**	0.890*	1.166**	1.024**
	(0.007)	(0.034)	(0.013)	(0.095)	(0.008)	(0.065)	(0.010)	(0.387)	(0.071)	(0.068)
Distance	-0.029**	-0.025**	-0.096**	-0.048*						
	(0.001)	(0.004)	(0.003)	(0.020)						
Distance sq.			0.004**	0.001						
			(0.0001)	(0.001)						
Log Distance					-0.195**	-0.243**	-0.352**	-0.026	-0.260**	-0.186**
					(0.036)	(0.032)	(0.022)	(0.372)	(0.004)	(0.033)
Log Distance sq.							0.054**	-0.050		
							(0.007)	(0.085)		
Rbar-squared	0.158	0.616	0.218	0.637	0.234	0.626	0.251	0.630	0.586	0.648
# of obs.	7260	28	7260	28	7260	28	7260	28	28	21
Implied weather correlation at										
300 km	0.303	0.757	0.487	0.812	0.321	0.899	0.296	0.890	0.880	0.820
600 km	0.216	0.682	0.429	0.668	0.186	0.731	0.161	0.890	0.700	0.691
900 km	0.129	0.607	0.396	0.524	0.107	0.632	0.105	0.890	0.595	0.615

OLS regressions with heteroskedasticity-consistent standard errors in parentheses
Europe is the cities Paris, Vienna, Munich, De Bilt, Nottingham, Berlin, Basle, and Stockholm
China is 121 prefectures
**(*) indicates that a coefficient is significantly different from 0 at a 1% (5%) level
*** The European data is re-coded to match the distribution of weather in China during 1496-1916 (not 1770-94)

Table A.2: Comparison of wheat prices in Europe and Tianjin
(Monthly data, in logs)

	Years 1739 - 1794				Years 1770 - 1781			
	Std. Dev.	**Skewness**	**Kurtosis**	**n***	**Std. Dev.**	**Skewness**	**Kurtosis**	**n***
Aalst	0.184	-0.074	3.289	541	0.075	0.351	2.275	144
Antwerp	0.165	1.021	4.169	272	0.096	0.341	2.206	116
Boizenburg	0.183	0.453	3.180	293	0.198	0.214	1.832	137
Brussels	0.153	0.928	3.597	276	0.103	0.654	2.461	120
Cologne	0.233	0.242	3.129	672	0.207	0.207	2.397	144
London	0.271	-0.313	2.475	672	0.157	-0.580	2.538	144
Luxemburg	0.277	1.275	5.368	672	0.165	1.220	4.588	144
Munich	0.246	1.086	5.139	672	0.361	0.845	2.336	144
Nijmegen	0.220	0.347	3.060	672	0.184	0.330	1.909	144
Rostock	0.210	-0.034	2.473	293	0.227	0.139	1.617	137
Ruremonde	0.245	0.153	3.534	672	0.178	-0.029	1.887	144
Schwerin	0.185	0.120	3.153	293	0.196	-0.020	2.253	137
Toulouse	0.304	-0.240	2.499	648	0.150	0.295	2.653	144
Utrecht	0.191	0.330	2.925	420	0.174	0.463	1.986	144
Vienna	0.261	0.725	3.204	672	0.253	0.537	2.230	144
Average	0.222	0.401	3.413	516	0.182	0.331	2.345	139
Tianjin	0.162	0.058	2.876	509	0.156	0.581	2.321	137

* Number of observations varies by series

Seasonal Price Changes
(Log price, 1739-94)

	Minimum	**Maximum**	**Range**
Aalst	March	Oct	0.066
Antwerp	March	Aug	0.114
Boizenburg	Jun	Nov	0.065
Brussels	March	Aug	0.104
Cologne	Jan	July	0.068
London	Oct	July	0.051
Luxemburg	Sept	July	0.068
Munich	Feb	July	0.059
Nijmegen	March	Nov	0.069
Rostock	Jan	July	0.068
Ruremonde	Feb	July	0.066
Schwerin	Jan	July	0.086
Toulouse	Aug	March	0.052
Utrecht	Apr	Nov	0.107
Vienna	Oct	June	0.033
Average			0.072
Tianjin	July+	March+	0.084

+ These are the seventh and third lunar months; they differ from solar months by a relatively small but varying amount; see Perdue (1992)

Table A.3: Comparison of wheat and rice prices in Sichuan
(Monthly data)

Market		Mean	Std. Dev.	Skewness	Kurtosis	n*
		Years 1736 - 1782				
Chengdu	Rice	0.072	0.393	0.668	3.293	236
	Wheat	-0.094	0.360	0.578	2.794	210
Chongqing	Rice	0.063	0.311	0.563	3.106	222
	Wheat	-0.322	0.301	0.841	2.488	187
Nanchang	Rice	0.103	0.306	0.703	2.970	214
	Wheat	-0.278	0.309	0.845	2.455	182
Xichang	Rice	0.263	0.316	0.029	2.147	215
	Wheat	-0.074	0.281	0.022	2.921	174
Average	Rice	0.125	0.332	0.491	2.879	222
	Wheat	-0.192	0.313	0.572	2.665	188

Units: Price in silver taels per shi (about 103 liters); in logs

Bilateral price correlations between Sichuan markets
Common sample (T=104)

Bilateral pair	Rice	Wheat
Nanchang-Chengdu	0.862	0.846
Nanchang-Chongqing	0.877	0.930
Nanchang-Xichang	0.521	0.510
Chengdu-Chongqing	0.888	0.845
Chengdu-Xichang	0.498	0.572
Chungqing-Xichang	0.317	0.446
Average	0.661	0.691

Table A.4: Price data on rice and wheat in the 18th century United States
Common sample, years 1749-1774 (T=312); log price

	Standard deviation		**Within-year price variability** (Maximum-Minimum price)	
	Wheat	**Rice**	**Wheat**	**Rice**
Philadelphia	0.212	0.144	0.066	0.048
Boston	0.132		0.068	
New York	0.184		0.069	
Charleston		0.263		0.122
Average	0.176	0.204	0.068	0.085

Figure A.1 European locations, 17th and 18th century samples compared

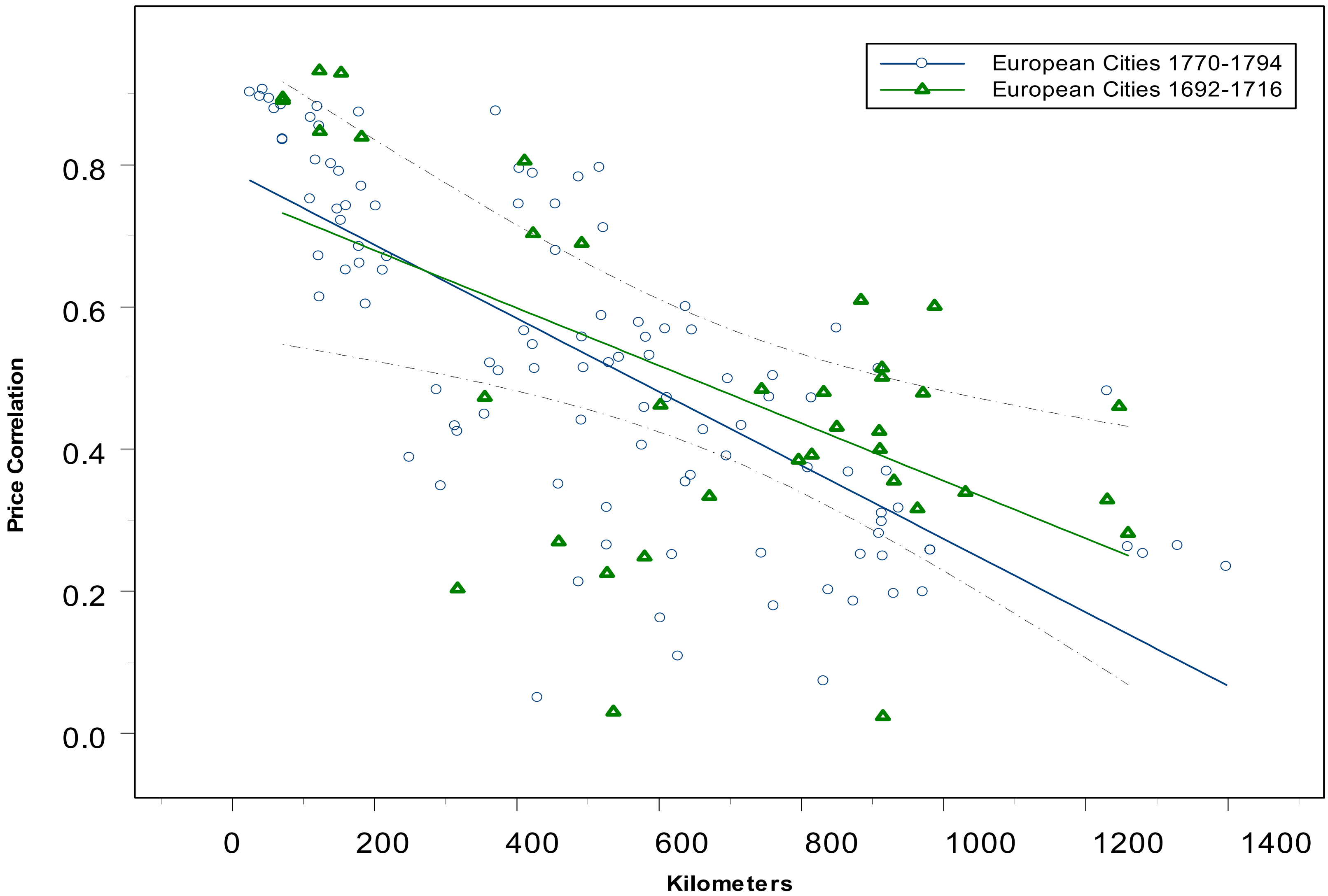


Figure A.2 China and Europe, selected markets over 18th and 19th centuries

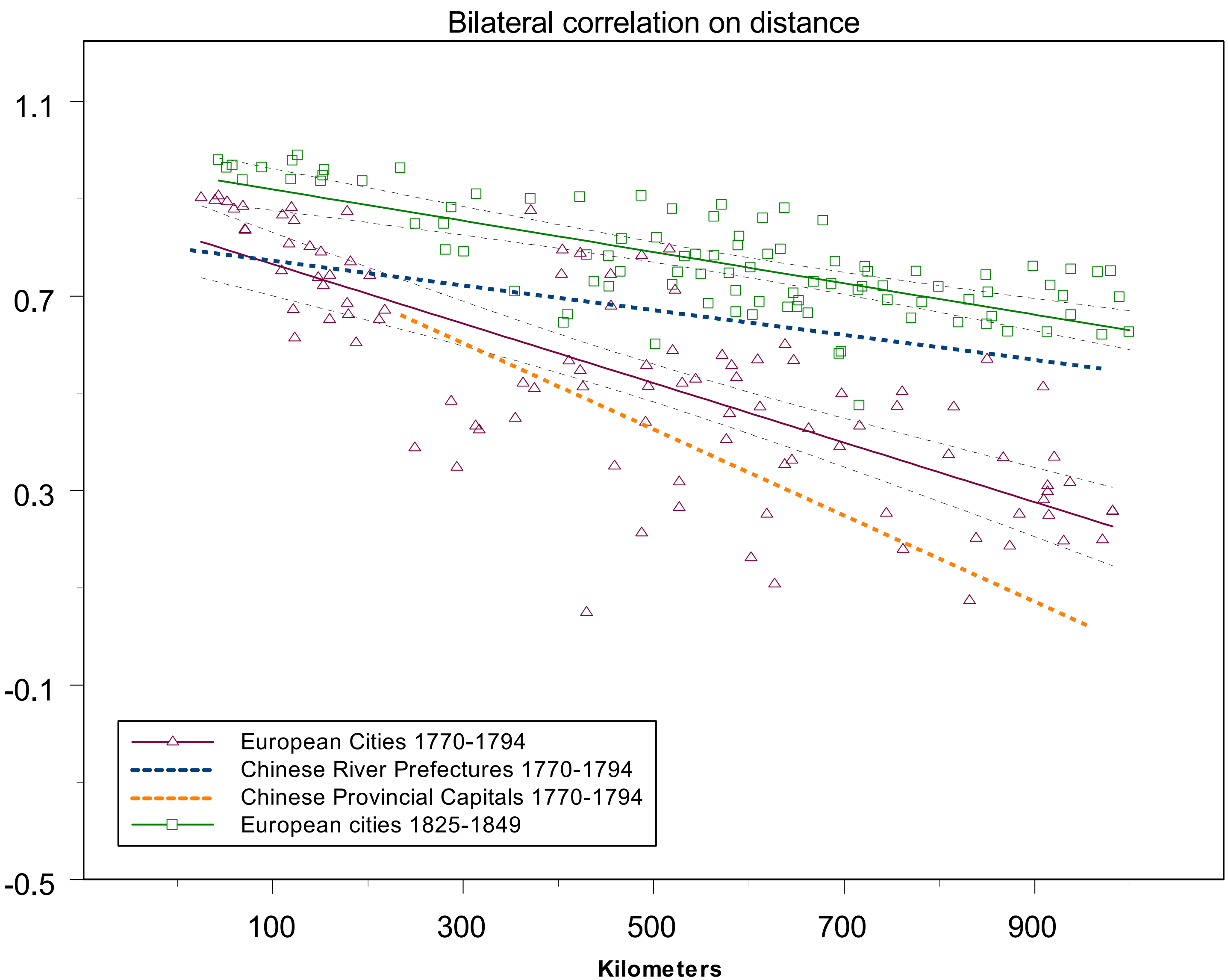


Figure A.3 England and the Yangzi Delta, 1770-1794

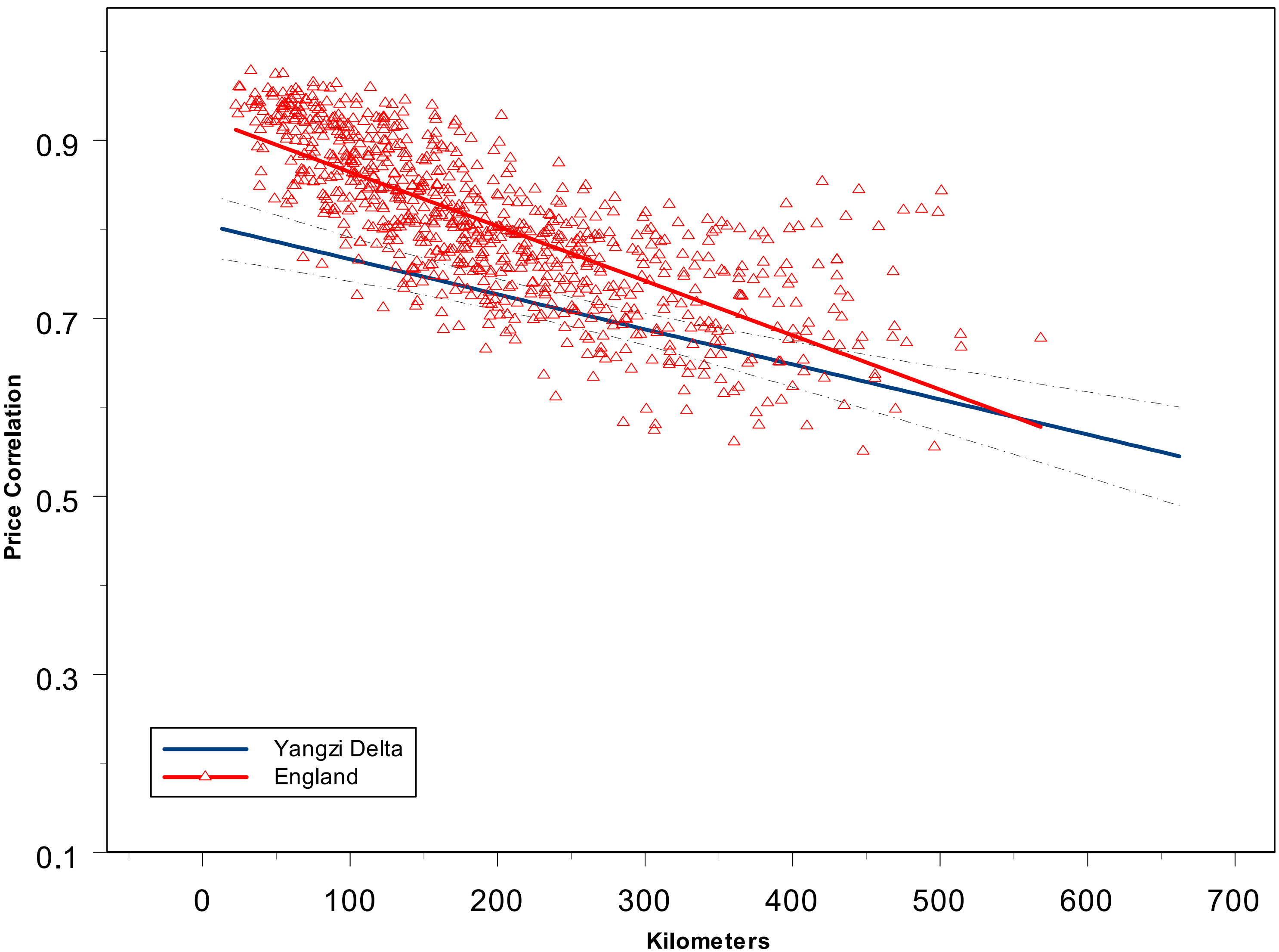
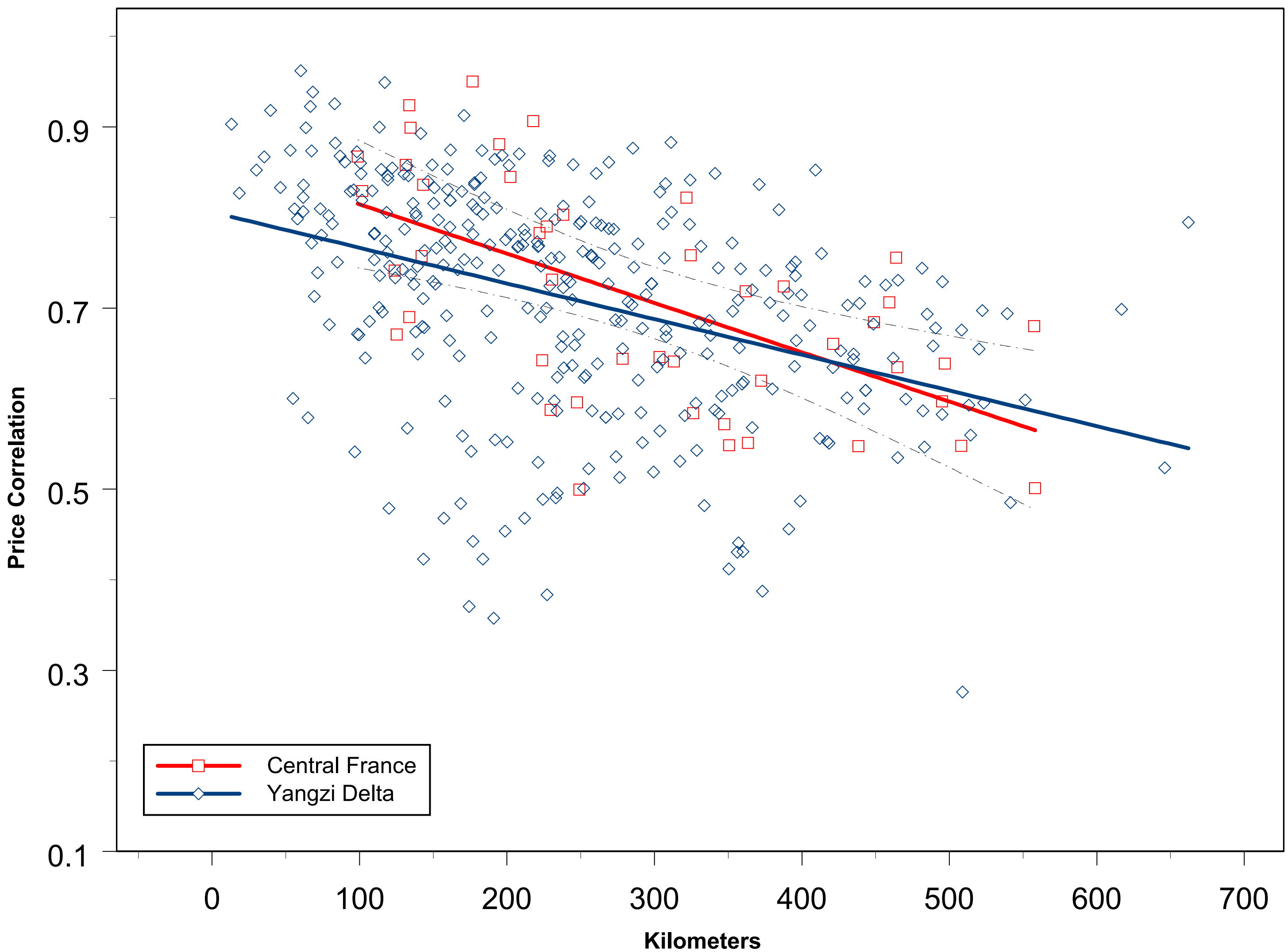
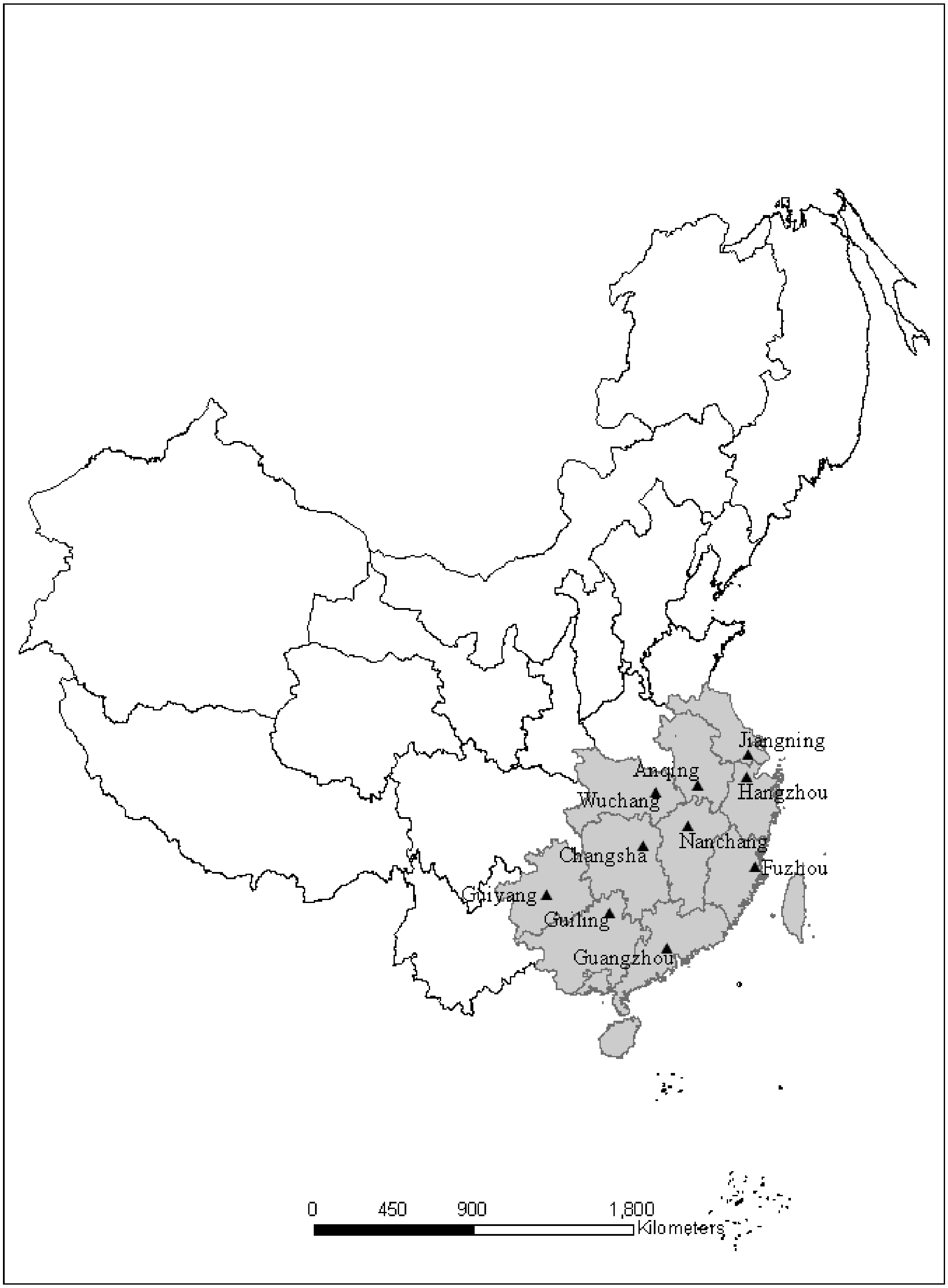


Figure A.4 Yangzi Delta and France, 1770-1794



Map 2


Jiangning
Anqing
Hangzhou
Wuchang
Nanchang
Changsha
Fuzhou
Guiyang
Guilin
Guangzhou
0
450
900
1,800
Kilometers

Map 3

1. Aalst
2. Antwerp
3. Boizenburg
4. Brussels
5. Cologne
6. London
7. Luxemburg
8. Munich
9. Nijmegen
10. Rostock
11. Ruremonde
12. Schwerin
13. Toulouse
14. Utrecht
15. Vienna
0
337.5
675
1,350
Kilometers