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Wolfgang Keller
Carol H. Shiue
Xin Wang

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ABSTRACT

Does the difference in capital market development between major advanced economies during the 18th and 19th centuries explain the subsequent divergence in their income levels? We employ a storage model to obtain regional interest rates from monthly grain price changes, and we compare the integration of capital markets in Britain and China. The first step is to validate the approach by showing that grain price-based interest rates match salient features of the 19th century U.S. capital market. Our analysis using almost 20,000 new interest rates reveals that Britain's rates were lower than China's, even compared to China's more developed areas, although not by a large margin. The regional integration of capital markets in Britain was substantially higher than in China, however, indicating lower barriers to capital flows than in China. At distances above 200 kilometers regional interest rates in British regions are about three times as strongly correlated as interest rates in China. Our results show that while China appears not to have been as capital-scarce as generally presumed, it had a strong disadvantage relative to Britain in its ability to allocate capital to the location of efficient use. Overall these results suggest that capital market performance may have been an important reason behind the divergence in incomes across countries in the 18th and 19th century.

Wolfgang Keller
Department of Economics
University of Colorado at Boulder
Boulder, CO 80309-0256
and NBER
Wolfgang.Keller@colorado.edu

Carol H. Shiue
Department of Economics
University of Colorado at Boulder
Boulder, CO 80309
and NBER
carol.shiue@colorado.edu

Xin Wang
University of Colorado Boulder
Room 307, Economics Building
256 UCB
Boulder, CO 80309-0256
xin.wang-2@colorado.edu

I. Introduction

All societies, past and present, are faced with the problem of how to allocate capital in ways conducive to economic growth. Capital markets are essential--in their absence the surplus income of the savers cannot be easily matched to the productivity-enhancing projects of the investors.[1] Even as it is widely recognized that the financial development of a country is important for economic growth, it has been difficult to distinguish historically decisive differences between capital markets in different countries.

In this paper, we turn the focus towards two prominent economies, China and Britain, and ask whether there were significant differences in the interest rates and the integration of capital markets over the 18th and 19th centuries that can inform the very different growth trajectories the two regions experienced in the 20th century. While a considerable amount of new data has been brought to bear recently on the question of the timing of the worldwide divergence in incomes between Northwest Europe and China (Allen et al. 2011, Broadberry et al. 2014), determining the cause of this divergence has proved to be a much greater challenge (Needham 1969, Pomeranz 2000, Lin 2014). The answer to this question, however, has broad significance for microeconomic and macroeconomic factors, and goes to the heart of the role of the financial system for growth (Bagehot 1873, Schumpeter 1911, Levine 2005), as well as its relation to the political environment (Rajan and Zingales 2003, Rosenthal and Wong 2011) and social organization (Greif 1989).

By the 18th century in China, historical evidence indicates that farmers moved their assets back and forth between cash and grain by trading with merchants or by bringing the grain to local markets.[2] There is evidence that

[1] The link between financial development and growth has long been emphasized (Bagehot 1873, Schumpeter 1911, Gurley and Shaw 1955). Rousseau (1999), Mitchener and Ohnuki (2007) and Rosenthal and Wong (2011) provide discussions, and Levine (2005) a broader review.
[2] Described in a memorial from the 18th century by a Qing official named Tang Pin in *Da Qing li chao shilu* (1964), Gaozong (Qianlong) reign 286: 24b-25a (4154-55); see Pomeranz (1993, p. 32). Agriculture's intertemporal aspects and the link to other parts of the capital market are also illustrated in the following description of the Xu family (Fujian, 19th century): "Except for the import and export trade of the Chunsheng and Qianhe shops, the Xu's had quite a few storefronts and much arable land for renting in Taiwan. Their real estate was mainly distributed in towns of Lugang, Fuxing

merchants and farmers in Britain had been engaged in this type of trade as well from the late-Middle Ages onwards.[3] Based on these facts, we employ a storage model as the framework with which to estimate regional interest rates from monthly grain prices. Since stored grain is an asset and competes with other assets to convert current into future consumption, regional grain price movements will necessarily reflect interest rates (Working 1933, Kaldor 1939). As grain is being bought and sold over time this activity between buyers and sellers establishes a connection between the grain price and the capital market.

Much of the analysis on capital markets in the existing literature has been on the level of interest rates (Rosenthal and Wong 2011 review comparative work on China and Europe, Ch. 5). A relatively low interest rate, or price of capital, indicates not only that the economy is not constrained by the lack of capital, but it also points to relatively low levels of risk in capital market transactions. North and Weingast (1989) for example argue that institutional improvements resulted in a capital response; specifically, the level of interest rates on government loans declined. Low interest rates may also affect the rate of technological change by giving relatively strong incentives to mechanize and invest in machinery, thereby--as has been argued--pulling Europe ahead of other parts of the world (Allen 2009). A common basis for obtaining a comparison of interest rates is crucial. It turns out that it is not too difficult to find evidence depicting interest rates in Europe as being relatively low and Chinese interest rates as being fairly high; however, because numerous aspects of these transactions are often unobserved, it is typically not possible to compare a given contracted interest rate with another one. Pomeranz (1993), for example, notes that while there are many interest rates for China's Shandong

and Xiushui in Zhanghua County, collecting more than 2,000 *dan* of grain as rent per year.... Not only selling to rice-purchasers, the Xu's also processed the grain themselves and transported it to the mainland for sale. In addition, they even set foot in loaning business, often lending money and grain to other firms and people with interest.... In the operation of their businesses, they adopted diversified investment strategies: managing Chunsheng and Qianhe shops, investing extra capital in other firms and directly doing business in partnership with others." (Chen 2010, p. 433, based on Lin and Liu 2006). Also see Zhang (1996), Pan (1996) on rural borrowing and merchant credit.

[3] Everitt (1967) describes the private trading in England, which arose to supplement the town markets and fairs that had been in operation already over the 16th and 17th centuries. These private traders consisted of travelling merchants and salesmen who purchased in advance grains and other goods, connecting the village peasant to the wider intertemporal market.

province, "most cannot be used in systematic comparisons… because they omit information about who was charged a particular rate, what security there was, how interest was paid, and so forth" (1993, p.32). Thus, selection biases and other issues preclude a simple comparison of interest rates and offer at face value little certainty to the question of whether China was capital strapped while Britain was capital abundant (Rosenthal and Wong 2011).

We tackle the issue of comparability with a framework that provides a common foundation across different economies. To confirm the method is sound, we choose our approach by calibrating the storage model to key features of U.S. capital markets in the early 19th century and comparing the estimated results with actual bank interest rates (source: Bodenhorn and Rokoff 1992). In addition, we account for variation in storage and other grain-specific costs by using information on historical climate, transport routes, and cropping patterns in our comparison of Britain and China.

Our estimated interest rates go a long way towards overcoming the main limitations in reported rates from individual written contracts. Our main focus, however, is not the level of the interest rate but the integration of the capital market and a comparison thereof across regions. Although the literature has generally given most emphasis to interest rate levels, it is well known that even in highly developed capital markets regional interest rate levels vary due to various observed and unobserved factors. Thus, our preferred measure of capital market performance is the integration of capital markets. Analogous to the analysis of commodity markets and the so-called "law of one price", the emphasis is not on price (i.e. interest rate) levels but on barriers to arbitrage in the capital market.

Low capital market integration is a sign of high barriers to the division of labor, to the allocation of investment as well as high levels of risk, whereas highly integrated markets ensure that capital can flow to the location of efficient use. Studies of early capital markets, for example Mitchener and Ohnuki (2007) in the case of Japan, often focus on the integration of the market. After we calculate regional interest rates in Britain and China in the period of 1770 to 1860, we compare the integration of capital markets by examining the correlation of interest rates across regions within each country.

Most of what we know about early financial integration is based on the 19th century U.S.[4] We provide, to our knowledge, the first study of financial market integration using interest rates for the 18th century.[5] In the main empirical section of the paper, we show results from assessing the most comprehensive set of grain prices available for China and Britain—a data set with nearly 20,000 interest rates—which we use to evaluate the performance of capital markets. In addition to presenting comprehensive new interest rates for large parts of China and Britain, we also show how grain price interest rates can be employed for studying capital markets in other countries where information on regional interest rates is scarce. A better understanding of the divergence between China and Europe can distill lessons on the causes of economic development more broadly. Our paper thus extends studies on the historical role of financial development on countries in Europe and North America (Davis 1965, Sylla 1969, Rousseau 2003, Hoffman, Postel-Vinay, and Rosenthal 2011), and the case of Japan (Mitchener and Ohnuki 2007, 2009).

We find typical annual rates in China of about 7.5% compared to about 5.4% in Britain, and that storage costs are important for applying this grain price approach to interest rates. Without netting out storage costs our estimates would be about 40% higher.[6] Our findings show that although interest rates were lower in Britain than in China, the difference is not so large as to be wholly consistent with the often-drawn picture of a highly capital-strapped Chinese economy. The

[4] Good (1977) and Brunt and Cannon (2009) study 19th century Austria and England, respectively.
[5] Other evidence on China's capital market development includes Zelin (2006) who shows that salt merchants were able to raise substantial funds in southern Sichuan during the late 19th to early 20th centuries, and Pomeranz (1993) who discusses the variation in 20th century regional interest rates in Shandong province. Li and van Zanden (2013) discuss interest rates in China's Yangzi Delta and the Netherlands. Before the 19th century, work on capital market integration has typically relied on interest rate proxies, e.g. the number of real property transactions (Buchinsky and Polak 1993).
[6] These figures are nominal; interest net of inflation would be preferred. We could obtain real interest rates by deflating with the regional price of grain. We have not done so here to maintain comparability with the literature, which focuses on nominal rates.

implication is that any weakness of the Chinese financial system does not center on interest rate levels.

Comparing the performance of British versus Chinese capital markets, we find that the spatial correlation of regional interest rates in British capital markets was substantially greater than regional integration in China. Integration levels for the Yangzi Delta come close to the British average at distances below 200 kilometers, while at larger distances interest rate correlations in Britain are twice those of the Delta, and three or more times higher than elsewhere in China. Notably, the advantage that England had over China in the late 18th century with respect to the integration of commodity markets (Shiue and Keller 2007) appears to be small when compared to the British advantage in terms of capital markets. Thus, even though China might not have been as capital scarce as generally thought, the lower integration of capital markets means that capital was not flowing to the location of efficient use. Our results suggest that in this respect capital market development might have been a critical factor in explaining the divergence in income that becomes apparent by late 18th century.

The remainder of the paper is as follows. Motivating our approach, the following section reviews the existing direct evidence on interest rates in China. We then introduce and calibrate a simple storage model to infer interest rates from monthly grain price changes. We describe the data in section 3. Our empirical results on comparative interest rates and capital market integration are given in section 4, which also discusses the influence of a number of factors on the results. We return to the question of why capital market performance, in light of our results, may have led to the income divergence between Northwest Europe and China in the concluding section 5.

2. The grain price approach to capital markets

2.1 Early modern interest rates in China: what do we know

There are numerous but scattered interest rates that can be found for China. These sources provide support for the notion that the riskiness of the loan affected the reported interest rates charged, and also that credit was used regularly by farmers to purchase fertilizer or consumption goods (Pan 1996, Huang 1990). We know that entrepreneurs invested in large commercial ventures (Zelin 2006), and that merchants involved in long-distance trade in grain acted as intermediaries between farmers and brokers in physically carrying the grain to market. Most of the long-distance trade in China consisted of grain and textiles, and merchants were able to secure loans from domestic banks at just 10% per year in some places prior to the 19th century (Zhang 1996, p. 127). Recorded information about rates for more rural areas tends to be much more sparse and limited. Anecdotally, Qing official Chen Hongmou claimed that private loans taken in the spring for grain and repaid in the fall had interest of 30-40% (Rowe 2001, p. 285).[7] Another Qing contemporary, Wei Jurui, observed that peasants borrowing 20-30 *taels* were required to pay as much as 200-300 *taels* at the end of a year (cited in Zhang 1996, pp. 102-3), an example that suggests how interest rates might become worthy of official record once they reached especially high levels.

Although direct interest rates can be useful, the main concern is the limited and possibly distorting information contained in them because of selection biases. First, many available sources are for the late 19th century, with much fewer observations available for the 18th century.[8] Second, the spread of the rates that are available tends to be fairly large, reflecting the fact that the terms of loans are highly

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[7] The Qing dynasty was in place between the years 1644 and 1911.

[8] Lieu (1937) and Chao (1977) cite interest rates in the silk and cotton industries in the Yangzi Delta during the 20th century; see also Shiroyama (2004). Dyke (2011) cites interest rates concerning traders in Canton. Interest rates for areas outside of major urban trading centers can also be found. Pomeranz (1993) studies interest rates from Shandong province, while Li and van Zanden (2013) report figures for the Lower Yangzi area. In 1890, rates on short-term loans in the cotton industry reportedly varied from 6 to 14.6%. Rates on long-term loans in Shanghai were around 10.5%. In the Canton trade, short-term loans in the 1880s averaged between 12 and 15%, while government loans in the 1910 period ranged between 5.3 and 7%. See also the Discussion in subsection 4.1 below.

variable and not specifically observed.[9] In addition, the relative riskiness of the borrower and the relationship between the borrower and lender is often unknown to an outside observer, but likely would have been known to the lender and therefore incorporated into the rate on the loan. Therefore, from these scattered sources or records that have survived we cannot learn much about the mean or the overall distribution of the rates. Furthermore, the rates may be subject to potentially serious biases resulting from selection and unobserved idiosyncratic factors. Given that, it would be challenging to attempt to conduct a comparative study based on available transactions of interest rates from China and Britain.

There are other reasons why one needs to use caution in assuming the rates are representative. Most importantly, if China had had extremely high interest rates it would have had to be a highly capital-strapped economy. Pomeranz (2000), however, largely dismisses the capital market hypothesis by noting that capital surplus was unlikely to have been a constraint given that China had a similar fraction of high-status individuals in its population as England, and that the savings rate, even for low-income farmers, was substantial (pp. 178-188). In addition, not only were groups of individuals able to amass large sums of capital for trade or for joint projects (Zelin 2006), these groups did not seem to be extraordinarily rare. To the contrary, not only did family lineages mobilize capital but also groups of individuals who were not blood relatives adopted the social and communal organizations set up by family lineages to maintain cooperation in the business shareholding unit (Faure 1995, Chung 2010).

In light of these concerns we use a storage model and within-harvest year grain price variation to comparatively study capital markets. This allows us to address many factors that induce biases when using observed interest rates. One might be concerned that by focusing on borrowing and lending in agricultural markets we could miss some part of the overall capital market. Three observations reduce our concerns that this is the case. First, while not all grain entered the market for intertemporal trades, agriculture was by far the largest part of China's

[9] Although the Qing state prohibited high interest rates of above 3% per month and total interest that exceeded the loan, officials were unable to enforce the statute (Isett 2006, pp. 362-3).

economy for the period examined, and it remained an important sector in Britain, especially in the earlier part of our sample. Second, not only were grain producers connected to the market through merchants, but merchants also arbitraged across goods, trading grain for non-agricultural products. Although we are focusing on grain prices, general equilibrium effects mean we are also capturing aspects of the economy at large. Finally, below we examine whether grain price variation is informative for the performance of early capital market at large in an instance where this performance is known: the case of 19th century U.S. capital markets. As we will see, the grain price approach captures several salient features of capital market performance.

2.2 Theoretical framework

What would a grain storage model imply about the rates of interest in the economy? Consider a merchant living in region *i* at time *t* who can buy Q_{it} units of grain from a farmer at price P_{it}. The merchant can store the grain for one period and sell it at time *t+1* at a price P_{it+1}. Instead of buying the grain, the merchant can also invest the costs of buying the grain ($P_{it}\,Q_{it}$) in a risk-free asset and receive (1+ ρ_{it}) times $P_{it}Q_{it}$ at time *t+1*, where ρ_{it} is the rate of return on a risk-free asset. The merchant and farmer would contract on an agreement that specifies the merchant's purchase price from the farmer (P_{it}) as well as the price at which the farmer buys back the grain from the merchant, F^j_{it+1}, where *j* denotes the particular transaction.

At what price F^j_{it+1} will the merchant store the grain? This depends on the costs and benefits of grain storage. We distinguish three types of costs. First, there is the opportunity cost related to the risk-free rate, which captures the fact that if the merchant does not buy grain from the farmer he has an income of no less than $(1+\rho_{it})P_{it}\,Q_{it}$ at time *t+1*, whereas if he stores the grain for one period, then no interest is earned. Second, when the merchant stores the grain the potential income is tied up in the granary and subject to risk. In particular, by storing grain the merchant faces the risk that the grain market between *t* and *t+1* does not perform as expected. We denote the interest rate inclusive of risk factors by r^j_{it}, where $r^j_{it} \geq \rho_{it}$.

Third, grain does not store perfectly but is subject to spoilage (mold, mice, etc.). Per-unit storage costs are denoted as c_{it}. The benefit of storage is the value of the marginal unit of grain storage, which is usually referred to as convenience yield.[10] We denote the convenience yield by b_{it}.

Given r_{it}^{j} , c_{it}, and b_{it} as well as the current price P_{it}, for the merchant to be indifferent between storing and the alternative investment, the price F_{it+1}^{j} in the contract between merchant and farmer would have to be

$$(1) \qquad F_{it+1}^{j} = P_{it}\left(1 + r_{it}^{j} + c_{it}\right) - \ b_{it},$$

or, in other words the price specified in the contract, F_{it+1}^{j}, has to be such that risk-inclusive interest and storage costs net of the convenience yield are covered.

To apply this approach empirically we make a number of assumptions. First, we do not observe the transaction-specific risk for each contract; consequently, the superscript *j* is dropped and it is assumed that we capture the average level of risk, r_{it} (with $r_{it} \geq \rho_{it}$). Second, since we do not observe the price F_{it+1}^{j} in the contract we assume that it is equal to the spot price of grain in period *t+1*, that is $F_{it+1}^{j} = P_{it+1}$.[11] Finally, we do not observe the convenience yield; in most applications, b_{it} is inferred from an asset-pricing equation with data on forward price, expected spot price, storage costs, and the riskless interest rate. Here, we set b_{it} equal to zero and assess the role of the convenience yield for the results by building on the evidence that convenience yields are inversely related to inventory levels. While we do not observe inventories, in section 4.2 we employ information on the level and the volatility of regional grain prices to identify periods in which inventories were likely to be high and, correspondingly, convenience yields low, and contrast these results with our main findings.

[10] The convenience yield exists because positive grain inventories may allow meeting unexpected demand, for example.

[11] With a positive risk premium, the forward price will be lower than the expected future spot price. We assume that there is no difference in risk, as well as tolerance of risk, in the inter-temporal trade of grain in China and Britain. Regarding temporal variation, see the analysis of time-varying convenience yields in section 4.2.

Under these assumptions equation (1) can be rewritten as

$$(2) \qquad \hat{p}_{it} \equiv \frac{P_{it+1} - P_{it}}{P_{it}} = r_{it} + c_{it}.$$

Equation (2) shows that in a storage equilibrium the rate of grain price change is equal to the risk-inclusive interest rate r_{it} plus grain-specific factors c_{it}. We will refer to $\hat{p}_{it}$ as the carry cost of grain.

To characterize the relationship between grain storage and interest rates we employ a standard model of commodity storage along the lines of Williams and Wright (1991). The equilibrium storage and pricing behavior of our model is shown in Figure 1. Beginning with the first price (solid line) we see that upon arrival of the new grain from the harvest, the price falls, reaching a first minimum in period 8. This is the beginning of the new harvest year. The price rises until period 18 when the maximum is reached, and the cycle repeats itself.

Between period 8 and period 12, storage level and price rise together, while after period 12 the price increase is accompanied by declining storage. The last unit of stored grain is withdrawn just before the new harvest arrives. The new grain supply causes a fall in price; in this way, storage has the consequence of dampening price fluctuations.

Figure 1 shows a second price series, denoted with a dotted line. Notice that it has lower amplitude and is flatter than our earlier price series. This second equilibrium price is computed for a lower interest rate than in the first case, with all else equal. The key finding is that the steeper the increase of the price within the harvest year, the higher is the interest rate that agents face. This is the basis for the approach of inferring interest rates from grain prices. In principle, the approach can be applied to other storable commodities. What makes grain particularly attractive in this context is that the see-saw price pattern of Figure 1 is more discernable for grain than for other commodities given that grain is typically harvested only once per year; furthermore, grain price data (but not prices of other commodities) is available regionally for our sample at a high-frequency level.

2.3 Capital market performance: interest rates and market integration

This section describes our implementation of equation (2) to estimate interest rates. We also discuss why the integration of capital markets, rather than interest rate levels, is our preferred measure of capital market performance.

Equation (2) implies that differences in interest rates between two economies are equal to differences in their carry costs only if storage costs are the same. Therefore, we adopt two approaches to comparing interest rates. The first is to make certain assumptions on *average* storage costs in China and Britain, and the second is to model storage costs in terms of observables.

First, if storage costs over all regions and years in China are no different from those in Britain, equation (2) implies that the difference between the average Chinese carry costs, $\hat{p}_{it}$, over all regions and years minus the average British carry costs is equal to the difference in their interest rates. Thus, as our first comparison of interest rate levels, we will compare average carry costs across countries while assuming that storage costs are the same on average.

Second, we account for differences in storage costs using climatic data. It is well known that climate greatly influences storage costs. This is true particularly for the extent of rainfall and wetness, which, for example, influences the presence of mold and pests. Furthermore, interregional trade can affect within harvest-year price fluctuations and therefore measured interest rates.[12] Therefore, we also adjust for differential access to trade that regions within each country would have had.

To capture the roles of climate and interregional trade we adopt the following regression approach:

$$(3) \qquad c_{it} = \beta_0 + \beta_1 climate_{it} + \beta_2 trade_i + u_{it},$$

[12] Shiue (2002) presents evidence from 18th century China.

where u_{it} is assumed to be a well-behaved mean-zero error term. $Climate_{it}$ is a measure of wetness in region *i* at time *t*, as detailed in the appendix. Since the strongest determinant of low cost transportation prior to steam technology was whether or not shipping was feasible by water, our measure of trade is waterway access to rivers, canals, and the coast.

Using equations (2) and (3) the influence of interregional trade, storage, and other weather-related costs can be purged from carry costs using a regression approach:[13]

(4) $$r_{it} = \hat{p}_{it} - c_{it} = \hat{p}_{it} - \beta_0 - \beta_1 climate_{it} - \beta_2 trade_i - u_{it}, \forall i, t.$$

Estimating equation (4) yields our grain interest rates.

To see the advantage of evaluating capital market performance by examining market integration instead of interest rate levels, suppose that instead of being mean-zero, u_{it} contains systematic but unobserved components, denoted by x_{it},

(5) $$u_{it} = x_{it} + e_{it},$$

and e_{it} is a well-behaved mean-zero error term. To the extent that over some period x_{it} does not change, $x_{it} = x_i, \forall i, t$, the correlation in the adjusted carry costs (equation 4) of two regions *i* and *i'* is equal to the correlation in their interest rates because time-invariant factors drop out.[14] Plausibly, there are many factors that differ across regions but do not change differentially over (parts of the) sample period. An example is storage technologies: as long as storage technologies do not change differentially over some period, the correlation of the adjusted carry costs in two regions provides valid information on their capital market integration. In contrast, interest rate level-comparisons are not identified under these conditions.

We are not the first to shed light on historical capital markets by examining the behavior of grain prices (Working 1933, 1949, Kaldor 1939, McCloskey and Nash 1984, Taub 1987, Pomeranz 1993, Brunt and Cannon 1999, 2009, Clark 2001, and Shiue 2002). While we find the approach appealing, one might be concerned

[13] Extending this approach below we also account for the effect of multiple harvests per year.
[14] It is sufficient that there is no differential change in x_{it}.

about how much of capital market development can be captured through this approach. Given that we are resorting to the method in the absence of consistent interest rates, what can we say about the accuracy of the approach in the context of economies in which markets may not have been perfect?[15] Furthermore, even if one accepts that high-frequency price changes of stored commodities provide information on interest rates, to what extent does intertemporal trade in grain provide information on the capital market at large? We contend that while the model may be misspecified it can still provide new insights, and furthermore we provide to the best of our knowledge the first comparison between grain price interest rates and bank interest rates for any economy: in our case, for the early 19th century U.S., a context in which both grain prices and bank rates are to some degree available. In addition to a new form of validation of the grain price approach to studying capital markets, this yields information about both the potential and limitations of this approach, arguably important for studying capital markets in historical and contemporary economies where consistent interest rates are unavailable.

As we will see in the next section, the grain price approach captures some of the major features of early U.S. capital markets.

2.4 The grain price approach to capital markets: A calibration to U.S. data

This section evaluates the predictions of the storage model we have laid out above by comparing capital market performance based on grain price data according to the storage model with actual bank interest rates.[16] Using wheat prices for five U.S. cities (Indianapolis, New Orleans, New York, Philadelphia, and Richmond), we ask whether the grain price approach captures key aspects of the early 19th century U.S.

[15] A critique of the approach along these lines is Komlos and Landes (1991).

[16] The bank interest rates are shown in the Appendix, Table A.1. The Richmond and Indianapolis figures are for entire states, Virginia and Indianapolis, respectively, implying a varying degree of spatial aggregation. See section 4.2 on the influence of region size for the results.

capital market.[17] If it does, there is reason to believe that our grain price approach is also informative for comparing capital markets in Britain and China.

Recall that our grain price approach utilizes the within-harvest year price gradient during periods of storage (see Figure 1). The (log) price of a bushel of wheat in Philadelphia for the years 1836 to 1840 is shown in Figure 2. In addition to the see-saw pattern of the harvest cycle, the Philadelphia wheat price seems to also be affected by shocks and stochastic trends. Therefore, in addition to the raw price series we employ filtered grain price series, where the filters are designed to bring out the cyclical, twelve-month harvest pattern and suppress other influences. We perform a grid search over time-series filters (and their parameters) to choose the filtering technique that yields the closest possible match between the capital market performance based on the grain price approach and that implied by the observed bank interest rates. For this analysis we have considered all major time series filtering techniques (see Canova 2007, Ch. 3 for an introduction). The results for several key filters are reported in Table 1.[18]

Column 1 of Table 1 shows several measures of 19th century U.S. capital market performance based on Bodenhorn and Rokoff's (1992) bank interest rates. Panel A is based on the interest rates themselves. Results in Panel B are based on characteristics of the integration of the U.S. 19th century capital market. We begin in the upper left corner of Table 1, which shows that the average of the bank interest rates in the five cities between 1815 and 1855 (as shown in Table A.1) was 5.8%, with a standard deviation of 0.018. In the lower part of column 1 of the table, we report results on bilateral interest rate correlations, a standard measure of capital market integration. For this we compute the bilateral correlation between any city pair (with n = 5, there are n(n-1)/2 = 10 bilateral correlations). The average bilateral correlation based on the bank interest rates in these cities is equal to 0.25 (row (iii), column 1).

[17] The U.S. grain price data is from Jacks (2005, 2006).

[18] We have also considered exponential, Holt-Winters, Kalman and Hodrick-Prescott filters, among others, finding that they do not perform as well as those shown in Table 1.

We are interested in whether the grain price approach to capital markets succeeds in capturing major features of the U.S. capital market. Columns 2 to 6 of Table 1 report results for five alternative grain price models. For each of the five models the gradient of the within-harvest year price cycle is computed as the average price change in the months of August through December. Given that for these months we typically see month-to-month price increases, these months are taken to be the storage periods in the analysis.[19]

Employing the grain price approach with simply log price, we compute a mean interest rate of 7.4% (row (i), column 2). This is not too different from what we find using bank interest rates (5.8%, column 1). Furthermore, for the two most important markets, New York and Philadelphia, the grain price approach comes even closer to the bank interest rates (6.1% versus 5.3%, respectively). The grain price approach captures the average bank rate quite well, but the standard deviation is much larger than that of the bank interest rates. One reason for this may be that strong price shocks are picked up as very high or low interest rates (see Figure 2).

Next, we examine the degree to which the grain price approach matches the time series variation of bank interest rates. For example, Philadelphia bank interest rates were 6.5%, 3.4%, and 6.1% in the years 1833, 1834, and 1835, respectively (Table A.1). Does the grain price approach pick up these types of swings in interest rates? To find out we run, city-by-city, simple OLS regressions of the grain price interest rate on the bank interest rate.[20] There is generally a positive correlation between bank and grain price rates in the time series. We report the average t-statistic of this regression across five cities in row (ii) of Table 1. Employing the log wheat price, the average t-statistic is equal to 1.6. This is based on a relatively small number of observations, the years between 1815 and 1855 for which we have bank interest rates for each of the cities.

[19] Figure 1 indicates that the interest rate affects price gradients in all periods between low and high price. The focus on periods with consistent price increases despite shocks and stochastic trends improves the performance of the grain price approach.
[20] To do so we have linearly interpolated the small number of missing values for New Orleans and Indianapolis; see Table A.1.

The main reason for preferring market integration as the measure of capital market performance is time invariant determinants of price changes. In Panel B we compare the grain price approach to the bank interest data in this respect. Employing the log wheat price the grain price approach yields interest rates that across all n(n-1)/2 = 10 city pairs have an average correlation of 0.73 (row (iii)), which is higher than the average bilateral correlation of bank interest rates (see row (iii), column 1).

Arguably the most important of the four criteria reported in Table 1 is given in row (iv). Here we ask whether the grain price approach accurately reflects *differences* in the strength of capital market integration. Does the grain price approach match the relatively high capital market integration between New York and Philadelphia, for example, when this is compared to New York's lower capital market integration with New Orleans? To see this, we take the 10 bilateral interest rate correlations implied by the bank interest rates as well as the 10 bilateral interest rate correlations based on the grain prices, and evaluate how strongly the two sets of capital market integration measures are correlated with each other. Table 1 reports a correlation of 0.72 when grain interest rates are based on the log grain price (column 2, row (iv)).

The remaining columns of Table 1 report results for the same criteria of capital market performance using alternatively filtered grain prices. These are a moving average (column 3) as well as the filters proposed by Baxter and King (1999), Christiano and Fitzgerald (2003), and Butterworth (1930) (columns 4, 5, and 6, respectively). The results in column 6 employ the Butterworth filter as a bandpass filter which suppresses stochastic cycles both at high and low frequencies to emphasize the harvest cycle in grain prices.[21]

We see that except for the Butterworth-filtered figure the filtered interest rates tend to be higher than the bank rates (Table 1, row (i)). The time-series

[21] See the notes of Table 1 for information on the parameters chosen for each filter; we set the parameters so as to match the capital market performance implied by the observed bank rates as closely as possible.

movements of the interest rates are best described by the grain rates based on the Butterworth filter, where the regression on the observed bank rates city-by-city yields a t-statistic of about 2.2 (Table 1, row (ii), column 6).

Turning to the analysis of capital market integration in Panel B of Table 1, we find that just as in the case of the raw grain prices of column 2, interest rates based on filtered grain price series imply a higher level of capital market integration than implied by the bank interest rates (row (iii)).[22] Finally, we find that the correlation between the capital market integration implied by the bank interest rates and that based on filtered grain interest rates is between 0.6 and 0.75 (row (iv)). The highest figures are obtained for the Baxter and King filter, followed by the Butterworth filter. The fact that these models, as well as the raw grain prices of column 2, yield correlations of about 0.75 indicates that differences in capital market integration across regions are picked up well by the grain price approach to capital markets. To keep the number of reported results manageable we will focus below on the raw grain prices as well as the Butterworth filter (columns 2 and 6). Among the filtered series the Butterworth filtered series has the best all-around performance: not only does it exhibit a high correlation with observed capital market integration (row (iv)) and matches the time series (row (ii)) but it also predicts a variability of capital market integration that is close to that implied by the bank rates (see the standard deviation of the bilateral interest correlations, row (iii)).

Overall this analysis has shown that the grain price approach captures key features of the performance of the early U.S. capital market. It is therefore reasonable to assume that within-harvest year grain price changes also contain information on capital markets in Britain and China. Furthermore, given that the correlation between regional market integration based on bank interest rates and grain interest rates is about 0.75, it must be the case that capital markets in agriculture are quite closely related to other, non-agricultural capital markets.

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[22] This may be in part due to weather shocks affecting regional grain prices; in the comparison of China and Britain below this will be addressed by employing historical weather data.

Having validated the approach, the following section introduces our data on Britain and China.

3. Data

The source of the grain prices for Britain is the British government's Corn Returns, which were printed in the *London Gazette* newspaper. The Corn Returns were created to provide a reference market price of domestically-produced wheat that would inform taxation and the regulation of international trade of wheat. Our sample consists of the average monthly price of wheat for the period 1770 to 1860, in up to 52 counties (see Appendix Table A.2 for a list). The sample of British prices consists of around 48,000 monthly grain price observations, which are quoted in shillings per bushel.

The Chinese grain prices are administrative records from the Qing grain price recording system, which covered each of the 28 provinces from 1662 to 1911. We focus on prices for the years 1770 to 1860 in up to 252 regions (prefectures) located in 20 provinces (see Appendix Table A.3 for a list of prefectural markets and provinces). We focus on the crops with the most wide-spread coverage in China: rice in two different qualities (first-grade [*shangmi*] and second-grade [*zhongmi*]), wheat (*xiaomai*), and millet (*sumi*) (see Table A.4 for summary statistics). Wheat accounts for one-third of the observations in China, as climatic conditions in a large part of China are conducive to growing wheat. There are more than 318,000 monthly grain price observations, which are quoted in *tael* per *shi*.

Historical weather data for China and Britain used to account for climatic influences on prices are constructed from State Meteorological Society (1981) and Pauling et al. (2006), respectively. The data for China comes from 120 weather stations, which allows drawing contour maps with climate ranging from 1 (a lot of rainfall leading to very wet conditions) to 5 (little rainfall leading to very dry conditions), with 3 being the normal level of rainfall in that region. The climate in each prefecture is equal to that at the geographically closest weather station. Figure

A.1 summarizes this data on climate over time across the Chinese prefectures. We have employed the precipitation reconstructions of Pauling et al. (2006) to calculate five climate categories in Britain analogous to the Chinese data; see Figure A.2.

The influence of inter-regional trade on grain price behavior is accounted for by employing information on the ease of waterway transport: regions with access to navigable rivers, canals, or coastline had substantially lower transport costs and more trade.[23] Finally, we address differences in cropping patterns in China, most importantly the possibility of having multiple harvests per year in certain Southern areas.

The Appendix provides more details on the sources and construction of these data. In some key dimensions there existed similar patterns in Britain and China. First, the variability of (log) grain prices in the two countries is very similar, with coefficients of variation of about 0.35 in both areas (see Table A.4). Second, the variability of the weather in a given region is similar in Britain and China as well, with a standard deviation of wetness of 1.16 in Britain, compared to 0.98 in China.

While it was our goal to ensure the highest possible level of comparability of the British and Chinese data, some differences remain that we note here. One difference is the British grain price information tends to be highly complete for a given year; sample size variations tend to be due to political considerations and macro policies such as the Corn Laws (1815 to 1846). In contrast, the Chinese data is less complete, but it is also less subject to changes in the sample composition for systematic reasons. Another difference is that the Chinese administrative region (the prefecture) corresponding to the price reports is typically larger than the British administrative region. We conduct a number of robustness checks below that confirm that this and other differences do not determine our main findings.

We now turn to the empirical results.

[23] Our analysis abstracts from overland transport; on England's turnpikes, see Bogart (2005).

4. Empirical results

4.1 Preliminaries: Carry costs and interest rates

We begin by computing the carry costs of grain, $\hat{p}_{it}$, which is equal to the risk-inclusive interest rate plus the storage cost (equation 2). As in the analysis of the U.S. capital market we focus on price changes during storage months, as the price gradients are more informative compared to periods of flat or falling prices.[24] Furthermore, we give greater weight in the analysis to years, regions, and grains for which more high-frequency changes are recorded because these data tend to be of higher quality.[25]

The results are shown in Table 2, column 1. The mean monthly carry cost for British counties based on the log wheat price series is about 0.85%, or 10.2% per year.[26] In contrast, across all Chinese regions and based on all grains, the mean is about 13.7% annually. If we assume that the broadly defined storage costs in China and Britain were the same on average across all years and all regions, then British interest rates were substantially lower than China's during the sample period.

Results based on bandpass filtered price series using the Butterworth filter are shown in the lower part of column 1. These carry costs are generally lower than for those based on the unfiltered time series, consistent with the idea that time series filtering succeeds in removing stochastic trends. According to the filtered series, British carry costs average around 8.2% per year while Chinese carry costs are around 9.6%.

Additional analysis for China shows that the difference in carry costs by grain is small, which is plausible because storage costs are unlikely to vary greatly across grains. We also find that the British advantage of lower carry costs holds not only

[24] Storage months are defined as months when carry costs are typically 5% or more per year; we also show that a broader criterion, all months of price increases, yields the same qualitative results.
[25] Specifically, the weight is the share of non-zero month-to-month changes in a given year, so that if for one year 10 monthly changes are non-zero and in another only 6, for example, the observations receive weights of 10/12 and 6/12, respectively. We also focus on the central 95% carry costs for each grain by discarding values below percentile 2.5 and above percentile 97.5.
[26] We compute annual rates in this paper as 12 times the monthly rate.

across all grains but also specifically for wheat. These results are shown in Table A.5.

Grain interest rates

This section calculates our regional interest rates by purging from the carry costs the influences of weather shocks, inter-regional trade, and harvest differences, as described in section 2.3 above. The analysis is performed separately for the (log) price series and the Butterworth-filtered series. Results are shown in columns 2 to 5 of Table 2, Panels A and B, respectively.

In the first step we consider the influence of climate by adjusting for differences in rainfall. In line with other evidence, our results indicate that climate has a substantial influence on carry costs. Our climate-adjusted carry costs, which would hold had the climate been the best possible in every year, are around 4 to 5 percentage points lower than before (column 2, Panel A). Because Britain and China are similarly affected, however, adjusting for climate does not change the ranking between Britain and China.

Next, we turn to the additional influences of interregional trade (column 3). In comparison to climate, interregional trade turns out to matter less. Our results imply that if no region had waterway access, carry costs would be higher by only 0.07 percentage points in either Britain or China (column 3, Panel A). Adjusting for multiple harvests in China has a relatively small effect as well (compare columns 3 and 4, Panel A).

Column 4 presents our grain price interest rates. Annually for the years 1770 to 1860, we obtain about 15,000 rates for Chinese prefectures and about 4,000 rates for British counties. The mean for Britain in Panel A is about 5.3%, compared to a mean for China of about 9.2%. Adjusting the bandpass filtered carry costs for climate, interregional trade, and harvest differences yields a broadly similar picture (Panel B). In particular, adjusting for climate differences has a larger effect than inter-regional trade and harvest patterns. The average interest rate for Britain now is about 5.4%, compared to 7.5% for China. Whether we remove stochastic trends by filtering the grain prices or not, the typical interest rate for Britain was substantially lower than in China according to our analysis, with an order of magnitude of around 30 to 40%.

In addition, we note that even when the analysis is based on all months that typically see price increases (instead of a smaller set of storage months), British interest rates are found to be lower than China's (see column 5). This does not substantially change when we adjust carry costs for climate, inter-regional trade, and harvest patterns in one step instead of sequentially (not reported). Neither does the finding of lower British interest rates disappear when we account for the unobserved convenience yields in a number of different ways.[27]

If China's interest rates are higher on average than Britain's, how about interest rates in China's more highly developed areas, such as Jiangsu province at the mouth of the Yangzi river, or Guangdong province in the South? Our average unfiltered interest rate for Jiangsu and Guangdong provinces is 8.2%, compared to 9.3% in China outside of Jiangsu and Guangdong provinces. While these figures confirm what is known about comparative development within China, the implied heterogeneity is not large enough to bring about parity of interest rates in Britain and China's more developed areas.

Discussion

Employing a standard commodity storage model we estimate typical interest rates for China between 7.5 and 9.2%, with a midpoint of about 8.35% (Table 2, column 4). How does this figure compare to other estimates? For the Yangzi Delta, Li and van Zanden's (2013) report figures for the 18th and early 19th century which imply annual rates between roughly 5 to 25%. For the late 19th century, annual interest rates faced by trading firms and cotton factories in Canton and Shanghai

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[27] For example, we have computed interest rates during years of low volatility, with volatility of year t measured by the average of the variation in year $t-1$, t, and $t+1$ prices, for each month. Convenience yields will tend to be low at times of low volatility, and indeed we estimate lower rates with the lower 75 percent of times in terms of volatility. At the same time, the convenience yield adjustment does not change the finding that British rates are lower than China's (3.9% versus 6.2%, both for wheat, not filtered). Section 4.2 below reports additional results on the role of convenience yields.

ranged between 6 and 15% (Shiroyama 2004, Dyke 2011). The midpoint of these estimates is about 13%. This is higher than our estimate of about 8.35%, and a natural question is what might explain the difference between the two sets of estimates.

First, all interest rates include the risk associated with that particular transaction. In the case of the grain interest rates the risk concerns transactions *within* harvest years rather than the risk involved in the harvest for any particular year, which may in turn be attributed to climatic variations. Thus, our relatively low interest rates may be consistent with the prevailing idea that "agricultural risk" is high because, in fact, these are two different concepts. Agricultural risk typically refers to the risk of the failure of the harvest, not the risk of asset movements once the harvest has arrived.

Our analysis captures the average riskiness of the grain asset, and this risk is relatively low not only because the market is quite thick—and buyers and sellers are relatively easy to find—but also because the risk of holding grain is low given it can be consumed. In comparison, the risk of a Canton trading company is likely to be substantially higher.[28] Higher risk will be naturally compensated for by a higher rate of interest.

The second issue is selection. Our analysis is based on market prices for grain in a given region, implying that the grain interest rates reflect the activity of *all* farmers, merchants, government officials, and others that were buying and selling grain in a given prefecture and year. While not all of China's grain supply entered the market (perhaps a quarter of the total), enough of it did that not a single seller or buyer, including the government, could monopolize the market. Grain interest rates reflect activities from a far larger set of the population than most other interest rates that we know of. To the extent that our rates differ from historically available rates, and tend to be lower than memorialized interest rates, this is not surprising. Interest rates charged by pawnshops such as those noted by Li and van Zanden (2013) were, given the low credit rating of the borrower, notoriously high,

[28] The enforcement (credit) risk could also be different.

and officially memorialized interest rates would be selected because a high rate would have a higher chance to be memorialized in the first place.

Third, while it is useful to compare the grain interest rates to other rates, our primary goal is to compare capital markets in China and Britain. So far we have shown that based on the same methods and assets, Britain had interest rates that were 30 to 40 percent lower than China's. While one might consider this figure to be too small (or too large) we believe that this evidence is important as it can be argued that a reliable set of comparable interest rates did not exist in this setting. At the same time, our goal is to compare capital market performance by studying market integration. The reason for this as noted above is that interest rates can differ across regions even with virtually perfect markets, while factors determining interest rate differentials often do not affect the extent of market integration.

4.2 Comparison of capital market performance in Britain and China

This section presents our analysis of capital market performance in Britain and China by comparing the extent of regional market integration in the two countries. We begin by contrasting capital markets in Britain with those of China overall before narrowing the analysis down to China's Yangzi Delta, one of China's most developed regions. We then turn to the question of timing by asking whether capital market development was already different by the late 18th century, or only later. The section concludes with examining the influence of a number of factors such as temporal changes (e.g., the British Corn Laws), region size, as well as other issues for our results.

We compare the capital market performance in Britain and China in terms of bilateral correlations between regional interest rates over time. A high level of bilateral correlation indicates that the forces that integrate capital markets in the two regions are strong.[29] Furthermore, because early capital market participants

[29] Instead of bilateral correlations, more sophisticated techniques can be employed to study market integration (see, e.g., Shiue and Keller 2004, Mitchener and Ohnuki 2007). Doing so here does not change our main findings.

typically had to meet in person to trade, given some cost of moving in geographic space, bilateral correlations will tend to fall with distance.

Bilateral interest rate correlations for each pair of regions in a given country are computed over all years (1770 to 1860) based on the grain interest rates derived above (Table 2, column 4). The degree of capital market integration in the two countries is summarized in Figure 3. There are six distance bins in steps of one hundred kilometers, from 0-100 kilometers to 500-600 kilometers.[30] For each country and each distance bracket, Figure 3 shows the average bilateral interest rate correlation based on both filtered and unfiltered price series.

Notice that the lines for Britain lie well above those for China in Figure 3. In particular, the bilateral correlations based on raw (unfiltered) grain prices for distances below 100 kilometers are typically around 0.8 while in China they are less than 0.6. Even more striking is the difference in the decline of capital market integration with distance. In Britain, an increase in distance from 100 to 600 kilometers is associated with a fall in the average bilateral correlation from 0.8 to 0.7; in China over the same distances, the fall is quite a bit larger, from 0.6 to 0.1.

We find somewhat lower correlations when interest rates are based on the filtered grain prices, in line with the idea that filtering removes common shocks. Nonetheless, the comparison between Britain and China yields a very similar finding: bilateral correlations are higher in Britain than in China, especially at greater distances.

A more detailed picture can be drawn with interest correlations based on different types of grain for China (see Tables 3 and 4). We see that irrespective of the type of grain underlying the interest rate, bilateral correlations fall with distance, which is what we would expect. Distinguishing among the different grains is also informative because millet is grown mostly in Northern China and rice mostly in Central and Southern China, implying that these results shed light on within-China heterogeneity. The results turn out to be not too different across grains. For example, Table 4 reports correlations for 300-400 kilometers ranging from 0.12

[30] The maximum distance between any two British county capitals in our sample is 638 kilometers.

(millet) to 0.17 (second-grade rice). With a value of 0.13, interest rate correlations based on wheat at this geographic distance are in between these two values. In contrast, wheat interest rate correlations in Britain are around 0.65 for distances between 300 and 400 kilometers (Table 4, first column). The highest average interest rate correlation in China is found for distances below 100 kilometers based on first-grade rice, with a value of 0.65 (Table 3). This type of rice in our sample is grown mostly in the relatively urban and commercialized central-southern areas of China, where one would expect capital market integration to be relatively high.

In sum, comparing the average interest rate correlations at a given geographic distance provides evidence that Britain's capital market integration was considerably higher than China's at this time. To be sure, the degree of variation in interest rate correlations at a given distance is substantial, as the standard deviations show. While it is possible to observe comparable levels of capital market integration in Britain and China, typical levels are always lower in China than in Britain as a cell-by-cell comparison of the means in Tables 3 and 4 shows.

There may be no better way of making this comparison than by visually examining the entire distributions of bilateral interest rate correlations. In Figure 4 we show those distributions plotted against bilateral geographic distance based on the filtered interest rates. The circles are bilateral interest rate correlations in Britain, while the crosses are observations for China. The British circles fill up the upper part of the figure, indicating high levels of capital market integration for a given distance. The figure also shows the smoothed mean correlation for China (dashed line). The observations for Britain are positioned almost entirely above the dashed line for China. The evidence in Figure 4 strongly supports the hypothesis that the degree of integration in British capital markets exceeded that of Chinese capital markets over 1770-1860.

Capital market integration in China's Yangzi delta in comparison

Pomeranz (2000) emphasized that a comparison of other parts of the world with China should account for China's large size. To be specific, in the present analysis we do not want to make the mistake of comparing capital markets in the relatively underdeveloped regions of China's southwestern Yunnan province with capital markets in Lancashire, where the world's first factory-based textile industry emerged.

In this section we focus on China's Yangzi Delta as an example of a relatively highly developed area.[31] Results are shown in Table 5. We find an average interest rate correlation for all grains in China's Yangzi Delta of 0.47 at distances below 100 kilometers, which is higher than at these distances outside of the Delta (0.42, last row). There is also evidence for relatively high capital market integration in the Delta at distances above 100 kilometers (column 2 and 3). Our analysis yields results in line with other evidence that the Yangzi Delta was more developed than other parts of China.

Next, we focus on capital market integration based on rice prices, because rice was the Yangzi Delta's most important grain and rice quotations might be more reliable than those for other grains. Bilateral correlations with rice-based interest rates show figures of around 0.6 for distances below 200 kilometers (row 2). Note that a correlation of around 0.6 is also obtained at these distances for Britain (range from 0.59 to 0.62, see row 1). Beyond 200 kilometers, however, correlations in Britain are almost twice as high as in the Yangzi Delta (0.55 versus 0.30).

Together with the previous results indicating grain type does not give rise to very different estimates within regions, we conclude that while the Yangzi Delta's capital market integration over short distances was high by most standards, the Delta's capital market integration above 200 kilometers was considerably lower than in Britain.[32] In sum, capital market integration in Britain exceeded the integration of capital markets even of China's most developed areas.

[31] The seven Yangzi Delta prefectures in our data set are marked in Table A.3.
[32] Larger geographic distance is an important margin of market integration (Keller and Shiue 2007).

The timing of capital market development and industrialization

An important question on which we can provide insight is whether our findings hold already for the late 18th century, or only for the entire sample period of 1770 to 1860. This speaks to simultaneity and reverse causation concerns. Regarding the latter, if capital market development is an outcome of industrialization, it should not come as a surprise that Britain was ahead of China in the 19th century, because after all, Britain industrialized first. As for simultaneity, it would still be impossible to establish a causal effect from capital market development on modern economic growth using only data for the 19th century if capital market development and the take-off into modern economic growth went hand in hand.

In order to shed some light on this question we compare capital market integration in China and Britain in the late 18th century. Figure 5 shows the entire distribution of bilateral interest rate correlations in China and Britain for the years 1770 to 1794. Figure 5 can be compared with Figure 4, which shows the correlations for the entire sample period of 1770 to 1860. While the advantage of Britain grew somewhat over time, the most striking finding from comparing Figures 4 and 5 is how large Britain's advantage over China already was by the late 18th century. If we were to follow convention and use 1770 as the start date of British industrialization, the findings are consistent with capital market development being an important factor in explaining why Britain industrialized first. Britain had an advantage in terms of capital markets not only in comparison to China during the sample period, but given the stark difference shown in Figure 5, we can conclude that a large gap existed well before the onset of Britain's own higher rate of technological change.

Robustness analysis

Region size and the role of spatial aggregation

Chinese prefectures are on average roughly twice as large as British counties. To see the implications of this for our study of capital market performance, we have paired up the 52 British counties into 26 regions of roughly similar size. Taking the same steps as before for these larger British regions, we compare bilateral interest rate correlations resulting from this set of 26 regions with the results from before based on the 52 counties. In Table A.6, the latter are denoted by "Baseline" (left two columns) while the former are denoted by "Aggregated".

We see that for both interest rates based on the filtered and on the unfiltered data series, aggregation increases the correlations somewhat. Furthermore, it does so for all geographic distance categories. This implies that our findings are not driven by the relatively small size of the regions in Britain. If anything, the difference in average region size has put Britain at a disadvantage relative to China.

The role of the choice of storage months

Recall that interest rates are estimated to be lower if we were to include the less steep parts of the price curve over the harvest cycle in the analysis (Table 2, column 5). To see the influence of this for our comparison of capital market integration, Figure A.3 shows results on bilateral correlations based on filtered grain prices, where the solid lines are based on our preferred interest rates while the dashed lines are for the broader interest rates. Generally, the broader interest rates imply a relatively low degree of capital market integration. For China, the difference between the preferred and the broader definition is increasing in distance. The results suggest that including additional storage months makes the grain interest rate a relatively noisy measure. At the same time, irrespective of whether we adopt the preferred or the broader storage month criterion, we find evidence that the integration of capital markets in Britain was higher than in China.

Convenience yields, volatility, and inventories

This section examines the possible influence of convenience yields on our capital market performance analysis. Since the convenience yield is unobserved we employ price information to predict periods of high inventory, exploiting the well-established negative relationship between inventories and convenience yields. Table A.7 provides results for three alternative criteria that yield periods of low convenience yields, based on current and past price levels as well as price volatility. These criteria are detailed in the notes to Table A.7.

Each of these criteria is applied in the same way to both Chinese and British regions, and Table A.7 reports average bilateral interest rate correlations across distance bins based on the subsamples that satisfy the particular low convenience yield criteria. We see throughout that the result of the main analysis that capital market integration in Britain was higher than in China is upheld. Based on these results, it is very unlikely that variation in convenience yields over time and across regions is important for explaining the finding that Britain's capital markets performed better than China's during the sample period.

Sample composition before and after the year 1820

There are on average more than 170 Chinese prefectures in the sample for a given year, with just under 150 from 1770 to 1820, after which the number jumps to around 215 prefectures. The increase in the number of regions is due to the publication of a reprint of these price data that starts in the year 1820. In Britain, the number of counties in the sample is on average 45. There is information for almost all counties between 1790 and 1820, while during the 1820s the number of counties is only around 35. The change in regional coverage in Britain reflects in part in the influence of certain groups upon British legislation (see Brunt and Cannon 2013).

Because such changes might affect our comparison of capital market performance, we have conducted the analysis of capital market integration for the period before and after 1820 separately. Results are shown in Table A.8. Even though the change in the number of regions from one period to the other is at times substantial, we do not see evidence that this systematically affects the results for Britain. For China, there is some evidence for lower levels of integration after the year 1820 for short distances. This finding, however, is to some extent reversed at higher distances. Overall, we do not find evidence that changes in the sample composition have a major impact on our results.

Capital market integration and time series length

A related concern is that we calculate the bilateral correlations for interest rates that are based on different numbers of annual observations. For some pairs we have interest rates over the entire sample period 1770 to 1860, while for others only for a subset of years. Because the degree of bilateral correlation might be affected by the time series length, if there were differences between China and Britain this could affect our results. We analyze this issue by contrasting the results when using all region pairs with results that employ data for 50 to 70 years.

The results in Table A.9 show that the time series length has some effects on the estimates of capital market integration. In particular, when focusing on pairs with data for 50 to 70 years, the average interest rate correlations for China increase. For example, at distances between 200 and 300 kilometers, the mean correlation increases from 0.25 to 0.36. Based on these figures, China's capital market integration appears to have been not far behind Britain's at distances below 100 kilometers (mean correlation of 0.61 versus 0.68, respectively). At distances above 300 kilometers, however, interest rate correlations between British regions are typically still at least twice as high as those in China.

Overall, the shorter average time series length together with the larger regional units in China does not clearly raise or lower the rates estimated. Taken together, there is no evidence that would overturn our finding of a British lead in capital market performance over China.

5. Conclusions

The problem of the role of financial development for growth in China is not that researchers have been unaware of deficiencies in China's capital markets. Rather, it has never been quite clear what these deficiencies were, and why they could possibly have been so critical to China's long-run development relative to Britain and other countries of Northwestern Europe. To some extent this has been due to scarce information on early capital markets. Avoiding the potential biases inherent in the scattered existing information, our analysis is based on a large new set of interest rates not only for China but also for Britain. To be sure, our grain price approach to capital markets has its own limitations; at the same time, the method is based on an externally validated approach using U.S. data. We provide a new empirical grounding for future research—a consistent set of annual and regional interest rates for most of the geographical area of Britain and China over a critical century in world history.

We estimate interest rates that average between 7.5 and 9% for China, and somewhat lower in China's most-developed areas. These rates are higher than our estimate for Britain of about 5.5%. While it is possible to develop a threshold model of development in which the difference between 5.5% and 7.5% interest is crucial, we think the difference is relatively small and that surplus as such was probably not the main constraint in China.

Rather, our finding that capital market integration in China was relatively low points to questions of the allocation of capital. Markets generally facilitate the division of labor, allowing gains from specialization to be reaped. We know that commodity markets in China worked quite well in the 18th century—and were not much less integrated than British markets (Shiue and Keller 2007); however, in terms of capital market integration, China was further behind Britain. Why does this matter?

Commodity markets match buyers and sellers, as in an endowment economy model in which lychees and apples fall from trees and are traded for other consumption goods. In contrast, capital markets channel resources from individuals willing to postpone consumption to others with productivity-enhancing projects that pay off only in the future. The finding of low regional capital market integration provides evidence that the search for good matches between savers and investors in China was mostly a local process, thereby reducing the allocative efficiency of capital.

Further research is needed to determine what explains the lower regional capital market integration in China compared to Britain. Some accounts suggest that the wealthy in China in the 18th and 19th centuries did not conduct much capital accumulation. The salt merchants of Yangzhou, for example, the wealthiest merchants of this time, saw their wealth dissipate in a few generations (Ho 1954). Investments flowed into political connections or for the grooming of sons to enter the civil service examinations and a career in officialdom, rather than towards the preservation or expansion of family wealth. While this might lead to low levels of capital market integration, much work remains to be done on the returns to different investments in China to substantiate these accounts.[33]

Another possible explanation is that the Chinese empire, up until the Taiping Rebellion of the 19th century, was a balanced budget state, meaning that it never borrowed, and therefore had no experience with bonds and other financial instruments. The first stock market in China was introduced by foreigners (Goetzmann et al. 2007). In England, by contrast, it was not only the state but also state-backed ventures such as the East India Company that created wealth for nationals, giving investors new opportunities and investment strategies with financial innovations such as limited liability joint stock companies. There is probably some truth to this state finance hypothesis, although very little is known at this point on its quantitative importance.

Further on the role of the state, our finding of low capital market integration over long distances in China is consistent with the hypothesis that borrowing and lending is segmented geographically because of the importance of local lineages (common descent groups). Along these lines, China's relatively low capital market integration would reflect the delayed transition in China from kinship-based financial transactions to impersonal transactions, especially those involving banks.

In sum, we have shown that Britain had a lead in capital market development not only in comparison to most areas of China, but also at a date well before the onset of technological change in Britain (ca. 1770). While this is consistent with accounts that have emphasized capital market development as an important factor in explaining income divergence in these parts of the world, future research is needed to address a number of important remaining questions.

[33] For an analysis of the changing returns to human capital accumulation in China, see Shiue (2016).

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Table 1. Capital market performance in 19th century United States using bank interest rates vs. grain interest rates

	Bank interest rates	Grain price interest rates				
		Grain price (log)	Moving average	Baxter-King	Christiano-Fitzgerald	Butterworth
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Interest rates						
(i) Mean	0.058	0.074	0.269	0.197	0.127	0.029
	(0.018)	(0.507)	(1.802)	(1.113)	(0.337)	(0.241)
(ii) Mean of t-statistic of OLS on bank rate		1.63	1.05	1.98	1.91	2.17
		(1.40)	(1.52)	(0.65)	(0.46)	(0.57)
Panel B: Capital market integration						
Bilateral interest rate correlations						
(iii) Mean	0.25	0.73	0.80	0.72	0.54	0.46
	(0.33)	(0.16)	(0.09)	(0.15)	(0.28)	(0.30)
(iv) Correlation w/ capital market integration pattern based on (1)		0.72	0.61	0.75	0.69	0.72

Notes: Bank interest rates in column 1 are from Bodenhorn and Rokoff (1992); Grain price is one-month change of log grain price in August, September, October, November, and December. Moving average using 2 lags, the month itself, and 2 leads; Baxter-King filters below 4 months, above 12 months, moving average of order 10; Christiano- Fitzgerald filters below 3 months, above 12 months; Butterworth filters below 3 months (order 8), and above 12 months (order 2). Standard deviation in parentheses.

Table 2. Grain interest rates: the influence of weather, trade, and harvest patterns

		Carry costs			Interest rate	Interest rate broad
Adjustments		None (1)	Climate (2)	Climate & Waterway (3)	Climate & Waterway & Harvest Patterns (4)	Climate & Waterway & Harvest Patterns (5)
Panel A. Unfiltered data						
Britain	Mean in %	10.248	5.271	5.348	5.348	5.348
		(30.924)	(30.804)	(30.795)	(30.795)	(30.795)
	n	4,074	4,074	4,074	4,074	4,074
China	Mean in %	13.732	9.374	9.440	9.200	6.258
		(29.350)	(29.040)	(29.088)	(29.077)	(24.544)
	n	15,152	15,152	15,152	15,152	18,586
Panel B. Bandpass-filtered data						
Britain	Mean in %	8.209	4.891	5.415	5.415	3.204
		(26.868)	(26.808)	(26.772)	(26.772)	(15.684)
	n	4,102	4,102	4,102	4,102	4,115
China	Mean in %	9.612	7.616	7.482	7.501	4.023
		(26.064)	(25.800)	(25.934)	(25.814)	(15.946)
	n	13,403	13,403	13,403	13,403	19,736

Notes: Table shows statistics for the carry costs of grain with various adjustments in columns (1) to (3); statistics for the preferred grain interest rates are shown in column (4). "Interest rate broad" is calculated using grain price gradient in all months that typically exhibit price increases. Standard deviation given in parentheses.

Table 3. Capital market integration in comparison
Based on log grain price data

	Britain	China			
	Wheat	Wheat	Rice 1st quality	Rice 2nd quality	Millet
0-100km	0.80 (0.16) [n = 350]	0.53 (0.38) [n = 186]	0.65 (1.18) [n=196]	0.56 (0.62) [n=202]	0.54 (0.36) [n=152]
100-200km	0.77 (0.16) [n = 788]	0.41 (0.55) [n = 566]	0.45 (1.37) [n=602]	0.40 (0.69) [n=628]	0.44 (0.38) [n=484]
200-300km	0.74 (0.17) [n = 720]	0.30 (0.43) [n=730]	0.39 (1.43) [n=758]	0.36 (0.72) [n=840]	0.35 (0.45) [n=616]
300-400km	0.73 (0.18) [n = 476]	0.21 (0.39) [n=786]	0.20 (0.80) [n=802]	0.22 (1.01) [n=902]	0.25 (0.43) [n=684]
400-500km	0.70 (0.18) [n = 246]	0.11 (0.49) [n = 886]	0.20 (2.07) [n=908]	0.14 (0.88) [n=1,108]	0.17 (0.38) [n=568]
500-600km	0.70 (0.19) [n = 64]	0.07 (0.48) [n=1,002]	0.11 (2.04) [n=1,018]	0.11 (1.22) (n=1,184)	0.12 (0.27) [n=548]

Notes: Entries are average correlations over period 1770 to 1860. Interest rates as underlying Table 2, Panel A, column 4. Standard deviations in parentheses.

Table 4. Capital market integration in comparison II
Based on filtered price data

	Britain	China			
	Wheat	Wheat	Rice 1st quality	Rice 2nd quality	Millet
0-100km	0.71	0.35	0.44	0.51	0.29
	(0.17)	(0.28)	(0.50)	(0.46)	(0.34)
	[n = 350]	[n = 138]	[n=166]	[n=158]	[n=134]
100-200km	0.68	0.26	0.34	0.35	0.24
	(0.18)	(0.30)	(0.56)	(0.54)	(0.35)
	[n = 788]	[n = 424]	[n=500]	[n=494]	[n=390]
200-300km	0.66	0.21	0.23	0.25	0.16
	(0.17)	(0.33)	(0.62)	(0.58)	(0.35)
	[n = 720]	[n=556]	[n=620]	[n=612]	[n=482]
300-400km	0.65	0.13	0.16	0.17	0.12
	(0.16)	(0.31)	(0.73)	(0.56)	(0.34)
	[n = 476]	[n=560]	[n=628]	[n=660]	[n=514]
400-500km	0.63	0.10	0.15	0.10	0.07
	(0.19)	(0.34)	(0.78)	(0.55)	(0.33)
	[n = 246]	[n = 630]	[n=658]	[n=804]	[n=398]
500-600km	0.62	0.07	0.07	0.08	0.03
	(0.23)	(0.34)	(0.75)	(0.62]	(0.29)
	[n = 64]	[n=706]	[n=682]	(n=802)	[n=374]

Notes: Entries are average correlations over period 1770 to 1860. Interest rates as underlying Table 2, Panel B, column 4. Standard deviations in parentheses.

Table 5. Capital market performance: the Yangzi Delta and beyond

		Distance		
		0-100km	100-200km	200-300km
Britain	Mean	0.621	0.592	0.552
	n	350	788	720
Yangzi Delta Rice	Mean	0.598	0.618	0.300
	n	36	28	20
Yangzi Delta All Grains	Mean	0.468	0.242	0.115
	n	66	68	36
China outside Yangzi Delta, All Grains	Mean	0.416	0.238	0.086
	n	704	2,364	3,194

Notes: Interest rates based on time-series filtered data (Table 2, Panel B, column 5). "Yangzi Delta" prefectures are particular prefectures that are listed in Table A.3. "Rice" is first-grade and second-grade rice. "All Grains" here is rice plus wheat.

Figure 1. Interest rate and price in a model of storage

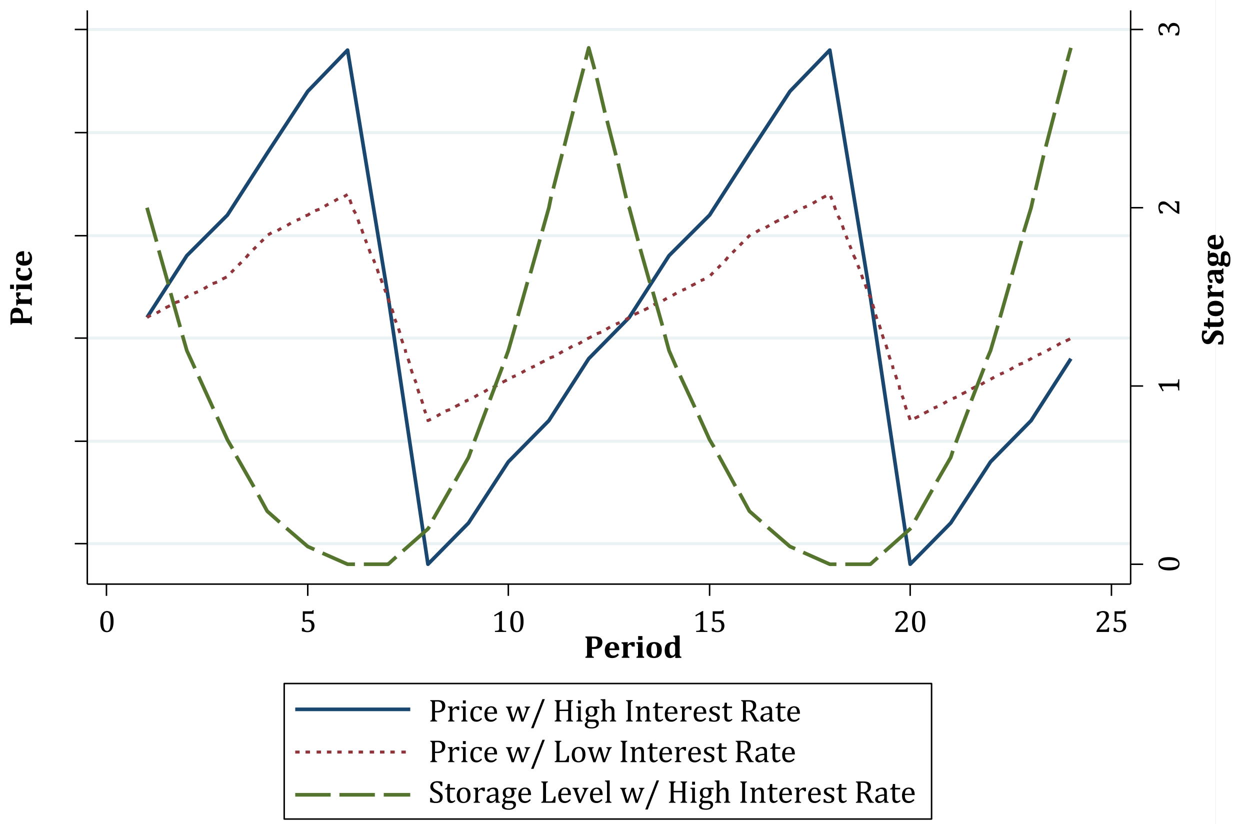
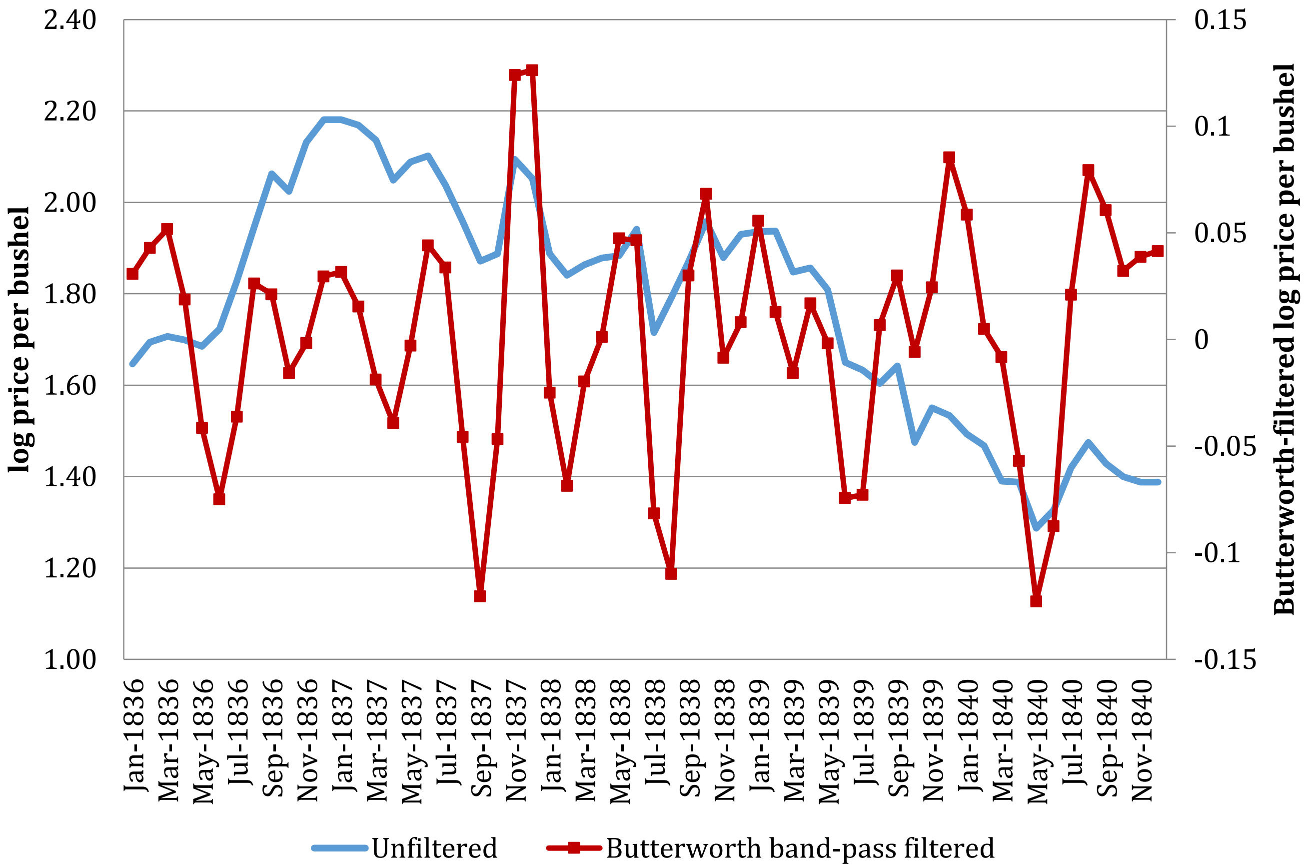


Figure 2. Filtered vs. unfiltered Philadelphia wheat prices, 1836-40



Sources: Jacks (2006) and own calculations.

Figure 3. Capital market integration in Britain and China, 1770-1860

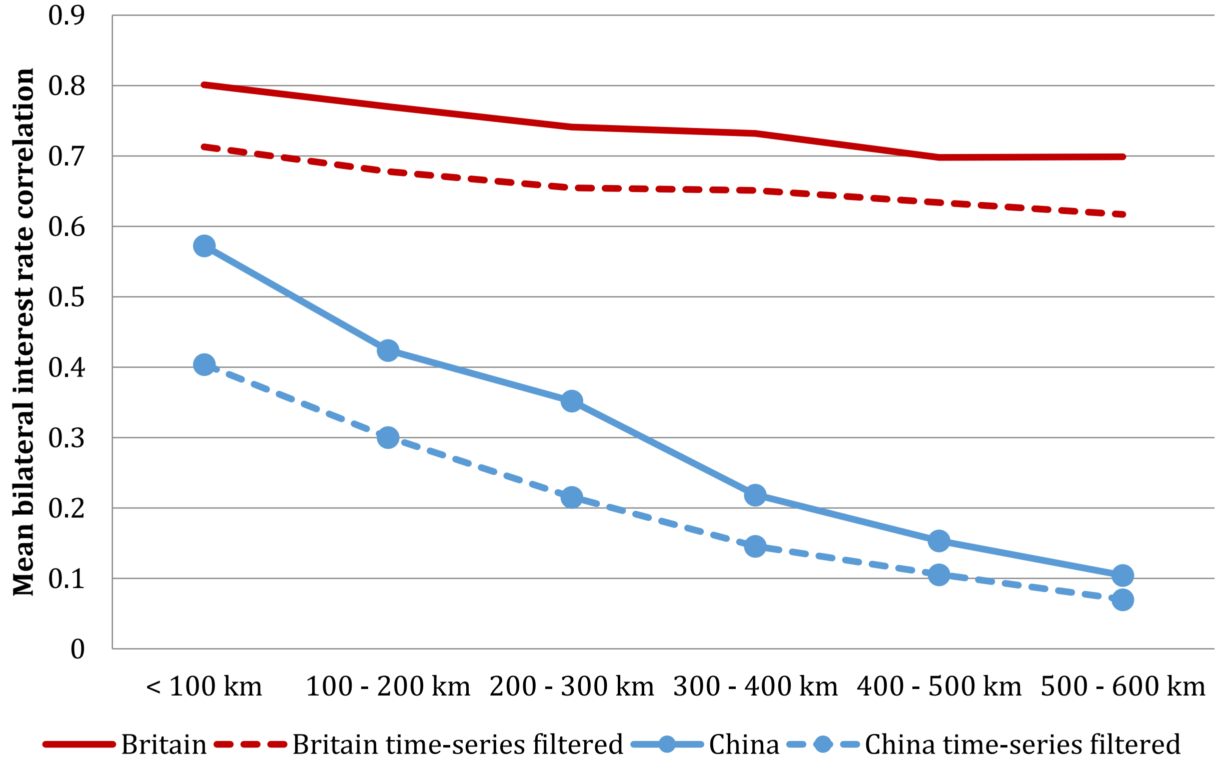


Figure 4. Bilateral interest rate correlations versus distance, 1770-1860

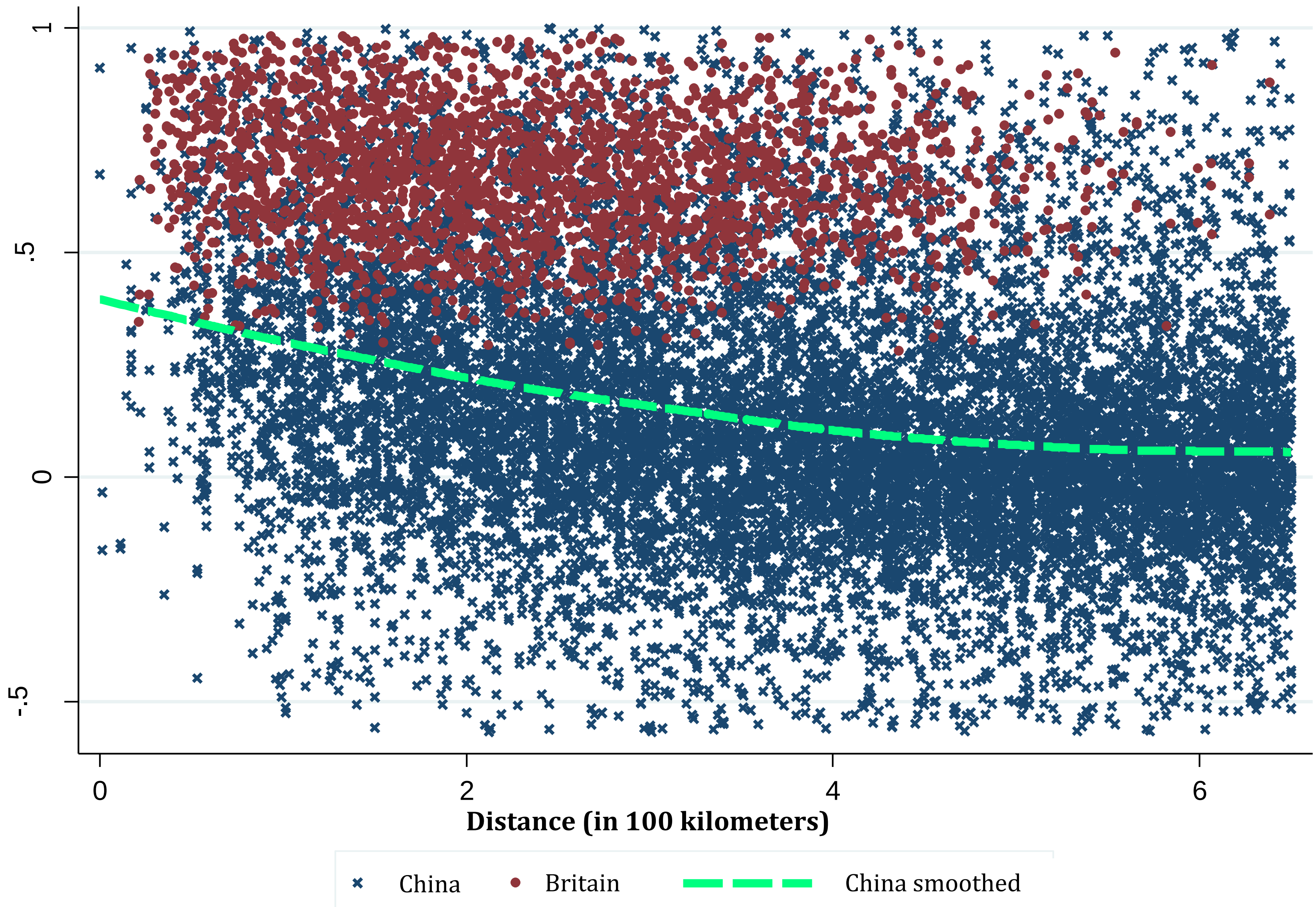
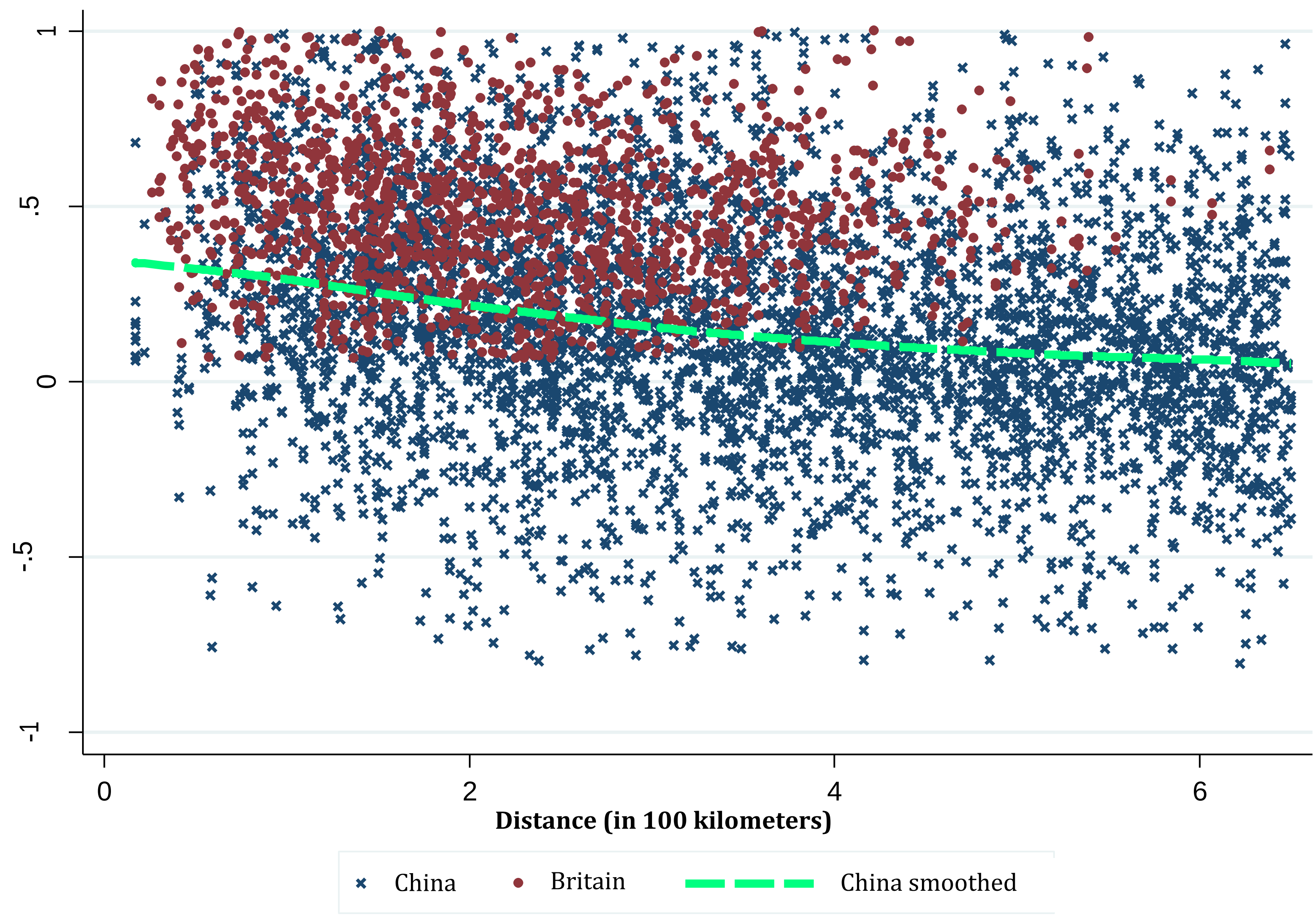


Figure 5. Bilateral interest rate correlations, 1770-1794



Appendix

I. Grain price data

China The price reports are originally from the *Gongzhong zhupi zouzhe, nongye lei, liangjia qingdan* [Grain Price Lists in the Agricultural Section of the Vermilion Rescripts in the Palace Archives], which records prices for each lunar month during the sample period of 1770 to 1860. These data exist on microfilm (Yishiguan 1990) and in published volumes from the Daoguang reign onwards (after the year 1820; Chinese Academy of Social Sciences 2009). The price quotes are at for each prefecture, a unit that is one level below the provincial level.

The sources give the prefectural high price, which is for the market with the highest price in the prefecture, as well as the prefectural low price, which is for the market with the lowest price in the prefecture. The analysis uses the mid-point price, defined as the average of the high price and low price of the prefecture, which is mapped to the location of the prefectural capital. Quantity units are in units of *shi*, where 1 *shi* = 103 liters. The original monetary units are in *liang*, or the Chinese silver *tael*. We focus on the four most prevalent grains as reported in the sources, wheat, millet, and 1st and 2nd quality rice. As a consequence, we do not cover some areas where particular grains were grown, perhaps most importantly Zhejiang province where particular types of rice were grown. We have confirmed that this does not drive the main findings of the analysis.

Britain Wheat prices for British counties for our sample period come from the British government's Corn Returns, which were published weekly in the London Gazette (a newspaper). Before 1820 there is information on the weighted average of the grain price in the county, while after October 1820, prices and quantities for all market towns within each county are available (Adrian 1977). We construct the weighted monthly price at the level of the county for the period 1770 to 1860 as our British grain data. The difference between the mid-point price (for China) and the weighted average price (for Britain) does not drive our main findings. Thanks to Edmund Cannon who provided to us the data for 1770 to 1820, see Brunt and Cannon (2013). Data for the later years were obtained from www.cornreturnsonline.org

II. Weather data

China The Chinese rainfall data comes from the compilation published by the State Meteorological Administration (1981) from a variety of historical sources, including local histories and gazetteers. A ranking of one to five is used to summarize the "wetness and dryness" of weather for each year during the sample period at 120 "stations", a regional designation that serves one or two prefectures, throughout the sample area. The weather categories are defined as follows:

- Level 1 represents years in which there have been exceptional rainfall, leading to major floods, typhoons, water related disasters, and the destruction of all crops.
- Level 2 encompasses cases where there is heavy rainfall, but limited in scope and/or resulting in only minor flooding.
- Level 3 should be interpreted as normal weather, neither very wet nor very dry, and therefore the most favorable weather for that locality.
- Level 4 indicates minor droughts of limited consequences.
- Level 5 denotes the years of greatest drought, lasting two or more seasons of the year, and leading to major harvest failures.

Over all years and all regions considered, the five categories are classified by the authors such that years and regions ranking level 1 and 5 in severity each appears with a frequency of 10 percent, ranks of level 2 and 4 each appears with a frequency between 20-30 percent, and the rank of level 3 accounts for 30-40 percent of the total distribution. In particular, the scale of rainfall is classified as follows:

Level 1: $R_i > (\overline{R} + 1.17\tilde{\sigma})$

Level 2: $(\overline{R} + 0.33\tilde{\sigma}) < R_i \leq (\overline{R} + 1.17\tilde{\sigma})$

Level 3: $(\overline{R} - 0.33\tilde{\sigma}) < R_i \leq (\overline{R} + 0.33\tilde{\sigma})$

Level 4: $(\overline{R} - 1.17\tilde{\sigma}) < R_i \leq (\overline{R} - 0.33\tilde{\sigma})$

Level 5: $R_i \leq (\overline{R} - 1.17\tilde{\sigma})$

where,

R_i = relative wetness of year *i,* between the months of 5-9.

$\overline{R}$ = average wetness between the months 5-9 over all years.

$\tilde{\sigma}$ = standard deviation.

The weather for each prefecture in the sample is determined by the weather at the weather station that is closest in terms of geographic distance to the prefectural capital. To adjust carry costs for weather effects and storage cost differences, we include indicator variables for each of the five wetness levels to determine the weather during which carry costs were on average lowest during the sample period; this wetness level is defined as the best possible weather in the sense that it is associated with the on average lowest carry costs. We adjust the carry costs using the difference of the OLS estimates for the best possible and the actual climate in each region and year in our interest rate calculation.

Britain We use the precipitation reconstructions from Pauling et al. (2006) as our rainfall data to adjust the British carry costs for weather and storage effects. Pauling et al. (2006) present seasonal precipitation reconstructions for European land areas on a 0.5 by 0.5 grid for each year of our sample period. We aggregate the seasonal data to obtain total seasonal precipitation. The weather in a given county and year is the geographically closest data point from Pauling et al. (2006). We normalize the British weather data according to the methodology for China from above to the same 1 to 5 scale and the same aggregate frequencies that are in the Chinese data.

III. Other data

Location of regions and geographic distance

The latitude and longitude measurements of the prefectural cities in China come from Playfair (1965), which are based on their historical locations. The data for Britain is based on the maps with historical information at http://www.cornreturnsonline.org/analysis/map-of-grain-markets together with distances between counties calculated using http://www.distancesfrom.com/Latitude-Longitude.aspx

Inter-regional trade and waterways

We construct indicator variables for the location of a region on a major waterway, accounting for

- Rivers: Yangzi and Pearl rivers in China, and the Thames, Trent, Severn, and Lea in Britain
- Canals: Grand Canal in China and the Bridgewater Canal in Britain.
- Coastal location: In China we employ three indicator variables, for North and South of the Yangzi Delta, as well as the Yangzi Delta itself.

The selection of these waterways is based on Watson (1972), Paget-Tomlinson (1993), and the sources given in Shiue and Keller (2007).

Differences in harvest patterns

In creating the indicator for particular harvest patterns we focus on the possibility that in certain parts of Southern China it was possible to harvest rice twice in a given year (Chuan and Kraus 1975, LeClerc 1927). Perkins (1969) reports that double-cropping with wheat and barley in the winter, followed by millet and rice in the summer in certain areas of China was also significant (1969, p. 46). There is little data on the extent of this double-cropping during the years 1770 to 1860, though we know it became more important over time; by the 1930s the increase in output due to double-cropped wheat and barley was about 14 million tons, compared to a total output of about 33 million tons of wheat and barley (Perkins 1969, p.47, Table D.5, Table D.7). During our sample period double-cropped wheat is unlikely to account for more than one third of all of wheat production. Based on the relatively small effect of double-cropping on our rice interest rates, and the fact that we find similar grain interest rates across grain types, accounting for double-cropping in millet, wheat, and barley is very unlikely to affect our main findings.

Table A.1. United States Regional Interest Rates, 1815-1859

Year	New York City	Philadelphia	Richmond	New Orleans	Indianapolis
1815		4.62			
1816		5.70			
1817		3.69			
1818		5.55			
1819		3.84			
1820		5.60			
1821		4.78			
1822		5.65	4.08		
1823		3.42	3.81		
1824		5.21	4.14		
1825		4.24	4.61		
1826		5.86	3.97		
1827		4.95	4.97		
1828		5.82	3.97		
1829		4.58	4.23		
1830		4.97	4.45		
1831		5.15	4.84		
1832		4.48	6.28		
1833	5.03	6.54	8.02		
1834	5.69	3.41	3.75	6.82	
1835	5.11	6.12	4.43	7.54	7.97
1836	6.82	5.74	7.22	7.16	7.60
1837	5.91	4.75	5.70	11.28	8.50
1838	5.33	5.47	4.41	7.68	8.35
1839	4.24	3.44	6.78	10.15	
1840	5.57	5.73	5.43	9.01	
1841	5.27	4.41	4.21	8.86	7.65
1842	3.95	2.50	4.20	8.85	5.05
1843	5.37	3.72	4.12		2.85
1844	5.80	5.18	4.15		5.74
1845	5.21	4.20	5.10		7.86
1846	4.69	6.39	3.95		
1847	5.04	5.21	4.99		6.32
1848	5.32	4.83	4.43	7.73	8.36
1849	7.17	6.35	4.19	4.84	7.77
1850	5.62	6.47	4.53	7.42	9.45
1851	6.32	4.69	4.72	7.79	5.95
1852	7.23	5.56	5.53	7.91	6.81
1853	4.99	5.10	4.46	7.38	6.37
1854	4.98	5.31	5.04	8.50	7.70
1855	5.87	5.70	5.18	12.81	10.89
1856	6.09	4.45	4.29		9.25
1857	5.45	3.16	3.88		
1858	4.95	6.46	2.92		
1859	4.62	4.32	5.96		

Source: Bodenhorn and Rokoff (1992). "Richmond" rates are for Virginia, "Indianapolis" rates are for Indiana.

Table A.2. British regions

Region No.	County name	Region No.	County name
1	Anglesey	27	Lancashire
2	Bedfordshire	28	Leicestershire
3	Berkshire	29	Lincolnshire
4	Brecknockshire	30	Merionethshire
5	Buckinghamshire	31	Middlesex
9	Caernarfonshire	32	Monmouthshire
6	Cambridgeshire	33	Montgomeryshire
7	Cardiganshire	34	Norfolk
8	Carmarthenshire	35	Northamptonshire
10	Cheshire	36	Northumberland
11	Cornwall	37	Nottinghamshire
12	Cumberland	38	Oxfordshire
13	Denbighshire	39	Pembrokeshire
14	Derbyshire	40	Radnorshire
15	Devon	41	Rutland
16	Dorset	42	Shropshire
17	Durham	43	Somerset
18	Essex	44	Staffordshire
19	Flintshire	45	Suffolk
20	Glamorgan	46	Surrey
21	Gloucestershire	47	Sussex
22	Hampshire	48	Warwickshire
23	Herefordshire	49	Westmorland
24	Hertfordshire	50	Wiltshire
25	Huntingdonshire	51	Worcestershire
26	Kent	52	Yorkshire

Table A.3. Chinese regions

Region No.	Name	Prefecture name in pinyin	Province	Province in pinyin	Yangzi Delta	Region No.	Name	Prefecture name in pinyin	Province	Province in pinyin	Yangzi Delta
1	奉天府	Fengtian Fu	奉天	Fengtian		46	绛州	Jiangzhou Zhilizhou	山西	Shanxi	
2	錦州府	Jingzhou Fu	奉天	Fengtian		47	隰州直隶州	Xizhou Zhilizhou	山西	Shanxi	
3	承德府	Chengde Fu	热河	Rehe		48	朔平府	Shuoping Fu	山西	Shanxi	
4	济南府	Jinan Fu	山东	Shandong		49	宁武府	Ningwu Fu	山西	Shanxi	
5	兖州府	Yanzhou Fu	山东	Shandong		50	霍州直隶州	Huozhou Zhilizhou	山西	Shanxi	
6	东昌府	Dongchang Fu	山东	Shandong		51	归绥道	Guisui Dao	山西	Shanxi	
7	青州府	Qingzhou Fu	山东	Shandong		52	开封府	Kaifeng Fu	河南	Henan	
8	登州府	Dengzhou Fu	山东	Shandong		53	归德府	Guide Fu	河南	Henan	
9	莱州府	Laizhou Fu	山东	Shandong		54	彰德府	Zhangde Fu	河南	Henan	
10	泰安府	Taian Fu	山东	Shandong		55	卫辉府	Weihui Fu	河南	Henan	
11	武定府	Wuding Fu	山东	Shandong		56	怀庆府	Huaiqing Fu	河南	Henan	
12	曹州府	Caozhou Fu	山东	Shandong		57	河南府	Henan Fu	河南	Henan	
13	济宁直隶州	Jining Zhilizhou	山东	Shandong		58	南阳府	Nanyang Fu	河南	Henan	
14	沂州府	Yizhou Fu	山东	Shandong		59	汝宁府	Runing Fu	河南	Henan	
15	临清直隶州	Linqing Zhilizhou	山东	Shandong		60	汝州	Ruzhou Zhilizhou	河南	Henan	
16	顺天府	Shuntian Fu	直隶	Zhili		61	陈州府	Chenzhou Fu	河南	Henan	
17	保定府	Baoding Fu	直隶	Zhili		62	许州直隶州	Xuzhou Zhilizhou	河南	Henan	
18	永平府	Yongping Fu	直隶	Zhili		63	陕州直隶州	Shaanzhou Zhilizhou	河南	Henan	
19	河间府	Hejian Fu	直隶	Zhili		64	光州直隶州	Guangzhou Zhilizhou	河南	Henan	
20	正定府	Zhengding Fu	直隶	Zhili		65	西安府	Xi'an Fu	陕西	Shaanxi	
21	顺德府	Shunde Fu	直隶	Zhili		66	延安府	Yan'an Fu	陕西	Shaanxi	
22	广平府	Guangping Fu	直隶	Zhili		67	凤翔府	Fengxiang Fu	陕西	Shaanxi	
23	大名府	Daming Fu	直隶	Zhili		68	汉中府	Hanzhong Fu	陕西	Shaanxi	
24	冀州直隶州	Jizhou Zhilizhou	直隶	Zhili		69	兴安府	Xing'an Fu	陕西	Shaanxi	
25	赵州直隶州	Zhaozhou Zhilizhou	直隶	Zhili		70	商州	Shangzhou Zhilizhou	陕西	Shaanxi	
26	深州直隶州	Shenzhou Zhilizhou	直隶	Zhili		71	同州府	Tongzhou Fu	陕西	Shaanxi	
27	定州直隶州	Dingzhou Zhilizhou	直隶	Zhili		72	乾州厅	Qianzhou Zhilizhou	陕西	Shaanxi	
28	天津府	Tianjin Fu	直隶	Zhili		73	邠州	Binzhou Zhilizhou	陕西	Shaanxi	
29	易州直隶州	Yizhou Zhilizhou	直隶	Zhili		74	鄜州	Fuzhou Zhilizhou	陕西	Shaanxi	
30	遵化州直隶州	Zunhua Zhilizhou	直隶	Zhili		75	绥德州	Suide Zhilizhou	陕西	Shaanxi	
31	宣化府	Xuanhua Fu	直隶	Zhili		76	榆林府	Yulin Fu	陕西	Shaanxi	
32	太原府	Taiyuan Fu	山西	Shanxi		77	兰州府	Lanzhou Fu	甘肃	Gansu	
33	平阳府	Pingyang Fu	山西	Shanxi		78	平凉府	Pingliang Fu	甘肃	Gansu	
34	大同府	Datong Fu	山西	Shanxi		79	巩昌府	Gongchang Fu	甘肃	Gansu	
35	潞安府	Luan Fu	山西	Shanxi		80	庆阳府	Qingyang Fu	甘肃	Gansu	
36	汾州府	Fenzhou Fu	山西	Shanxi		81	宁夏府	Ningxia Fu	甘肃	Gansu	
37	辽州直隶州	Liaozhou Zhilizhou	山西	Shanxi		82	西宁府	Xining Fu	甘肃	Gansu	
38	沁州直隶州	Qinzhou Zhilizhou	山西	Shanxi		83	安西直隶州	Anxi Zhilizhou	甘肃	Gansu	
39	泽州府	Zezhou Fu	山西	Shanxi		84	凉州府	Liangzhou Fu	甘肃	Gansu	
40	平定州	Pingding Zhilizhou	山西	Shanxi		85	甘州府	Ganzhou Fu	甘肃	Gansu	
41	忻州直隶州	Xinzhou Zhilizhou	山西	Shanxi		86	秦州直隶州	Qinzhou Zhilizhou	甘肃	Gansu	
42	代州直隶州	Daizhou Zhilizhou	山西	Shanxi		87	阶州直隶州	Jiezhou Zhilizhou	甘肃	Gansu	
43	保德州	Baode Zhilizhou	山西	Shanxi		88	肃州直隶州	Suzhou Zhilizhou	甘肃	Gansu	
44	蒲州府	Puzhou Fu	山西	Shanxi		89	泾州直隶州	Jingzhou Zhilizhou	甘肃	Gansu	
45	解州	Jiezhou Zhilizhou	山西	Shanxi		90	江宁府	Jiangning Fu	江苏	Jiangsu	1

Region No.	Name	Prefecture name in pinyin	Province	Province in pinyin	Yangzi Delta	Region No.	Name	Prefecture name in pinyin	Province	Province in pinyin	Yangzi Delta
91	苏州府	Suzhou Fu	江苏	Jiangsu	1	136	福宁府	Funing Fu	福建	Fujian	
92	松江府	Songjiang Fu	江苏	Jiangsu	1	137	永春州	Yongchun Zhilizhou	福建	Fujian	
93	常州府	Changzhou Fu	江苏	Jiangsu	1	138	龙岩州	Longyan Zhilizhou	福建	Fujian	
94	镇江府	Zhenjiang Fu	江苏	Jiangsu	1	139	台湾府	Taiwan Fu	福建	Fujian	
95	淮安府	Huaian Fu	江苏	Jiangsu		140	武昌府	Wuchang Fu	湖北	Hubei	
96	扬州府	Yangzhou Fu	江苏	Jiangsu		141	汉阳府	Hanyang Fu	湖北	Hubei	
97	徐州府	Xuzhou Fu	江苏	Jiangsu		142	安陆府	Anlu Fu	湖北	Hubei	
98	太仓直隶州	Taicang Zhilizhou	江苏	Jiangsu	1	143	襄阳府	Xiangyang Fu	湖北	Hubei	
99	海州直隶州	Haizhou Zhilizhou	江苏	Jiangsu		144	郧阳府	Yunyang Fu	湖北	Hubei	
100	通州直隶州	Tongzhou Zhilizhou	江苏	Jiangsu	1	145	德安府	De'an Fu	湖北	Hubei	
101	安庆府	Anqing Fu	安徽	Anhui		146	黄州府	Huangzhou Fu	湖北	Hubei	
102	徽州府	Huizhou Fu	安徽	Anhui		147	荆州府	Jingzhou Fu	湖北	Hubei	
103	宁国府	Ningguo Fu	安徽	Anhui		148	宜昌府	Yichang Fu	湖北	Hubei	
104	池州府	Chizhou Fu	安徽	Anhui		149	施南府	Shinan Fu	湖北	Hubei	
105	太平府	Taiping Fu	安徽	Anhui		150	荆门直隶州	Jingmen Zhilizhou	湖北	Hubei	
106	庐州府	Luzhou Fu	安徽	Anhui		151	长沙府	Changsha Fu	湖南	Hunan	
107	凤阳府	Fengyang Fu	安徽	Anhui		152	岳州府	Yuezhou Fu	湖南	Hunan	
108	广德直隶州	Guangde Zhilizhou	安徽	Anhui		153	宝庆府	Baoqing Fu	湖南	Hunan	
109	和州直隶州	Hezhou Zhilizhou	安徽	Anhui		154	衡州府	Hengzhou Fu	湖南	Hunan	
110	滁州直隶州	Chuzhou Zhilizhou	安徽	Anhui		155	常德府	Changde Fu	湖南	Hunan	
111	六安州直隶州	Liu'an Zhilizhou	安徽	Anhui		156	辰州府	Chenzhou Fu	湖南	Hunan	
112	泗州直隶州	Sizhou Zhilizhou	安徽	Anhui		157	永州府	Yongzhou Fu	湖南	Hunan	
113	颍州府	Yingzhou Fu	安徽	Anhui		158	靖州	Jingzhou Zhilizhou	湖南	Hunan	
114	南昌府	Nanchang Fu	江西	Jiangxi		159	郴州直隶州	Chenzhou Zhilizhou	湖南	Hunan	
115	饶州府	Raozhou Fu	江西	Jiangxi		160	永顺府	Yongshun Fu	湖南	Hunan	
116	广信府	Guangxin Fu	江西	Jiangxi		161	澧州直隶州	Lizhou Zhilizhou	湖南	Hunan	
117	南康府	Nankang Fu	江西	Jiangxi		162	沅州府	Yuanzhou Fu	湖南	Hunan	
118	九江府	Jiujiang Fu	江西	Jiangxi		163	桂阳州	Guiyang Zhilizhou	湖南	Hunan	
119	建昌府	Jianchang Fu	江西	Jiangxi		164	广州府	Guangzhou Fu	广东	Guangdong	
120	抚州府	Fuzhou Fu	江西	Jiangxi		165	韶州府	Shaozhou Fu	广东	Guangdong	
121	临江府	Linjiang Fu	江西	Jiangxi		166	南雄直隶州	Nanxiong Zhilizhou	广东	Guangdong	
122	吉安府	Ji'an Fu	江西	Jiangxi		167	惠州府	Huizhou Fu	广东	Guangdong	
123	瑞州府	Ruizhou Fu	江西	Jiangxi		168	潮州府	Chaozhou Fu	广东	Guangdong	
124	袁州府	Yuanzhou Fu	江西	Jiangxi		169	肇庆府	Zhaoqing Fu	广东	Guangdong	
125	赣州府	Ganzhou Fu	江西	Jiangxi		170	高州府	Gaozhou Fu	广东	Guangdong	
126	南安府	Nan'an Fu	江西	Jiangxi		171	廉州府	Lianzhou Fu	广东	Guangdong	
127	宁都直隶州	Ningdu Zhilizhou	江西	Jiangxi		172	雷州府	Leizhou Fu	广东	Guangdong	
128	福州府	Fuzhou Fu	福建	Fujian		173	琼州府	Qiongzhou Fu	广东	Guangdong	
129	泉州府	Quanzhou Fu	福建	Fujian		174	罗定直隶州	Luoding Zhilizhou	广东	Guangdong	
130	建宁府	Jianning Fu	福建	Fujian		175	连州直隶州	Lianzhou Zhilizhou	广东	Guangdong	
131	延平府	Yanping Fu	福建	Fujian		176	嘉应直隶州	Jiaying Zhilizhou	广东	Guangdong	
132	汀州府	Tingzhou Fu	福建	Fujian		177	佛冈直隶厅	Fogang Zhiliting	广东	Guangdong	
133	兴化府	Xinghua Fu	福建	Fujian		178	连山直隶厅	Lianshan Zhiliting	广东	Guangdong	
134	邵武府	Shaowu Fu	福建	Fujian		179	桂林府	Guilin Fu	广西	Guangxi	
135	漳州府	Zhangzhou Fu	福建	Fujian		180	柳州府	Liuzhou Fu	广西	Guangxi	

Region No.	Name	Prefecture name in pinyin	Province	Province in pinyin	Yangzi Delta
182	思恩府	Si'en Fu	广西	Guangxi	
183	平乐府	Pingle Fu	广西	Guangxi	
184	梧州府	Wuzhou Fu	广西	Guangxi	
185	浔州府	Xunzhou Fu	广西	Guangxi	
186	南宁府	Nanning Fu	广西	Guangxi	
187	太平府	Taiping Fu	广西	Guangxi	
188	郁林直隶州	Yulin Zhilizhou	广西	Guangxi	
189	泗城府	Sicheng Fu	广西	Guangxi	
190	镇安府	Zhenan Fu	广西	Guangxi	
191	成都府	Chengdu Fu	四川	Sichuan	
192	保宁府	Baoning Fu	四川	Sichuan	
193	顺庆府	Shunqing Fu	四川	Sichuan	
194	叙州府	Xuzhou Fu	四川	Sichuan	
195	重庆府	Zhongqing Fu	四川	Sichuan	
196	夔州府	Kuizhou Fu	四川	Sichuan	
197	龙安府	Longan Fu	四川	Sichuan	
198	潼川府	Tongchuan Fu	四川	Sichuan	
199	嘉定府	Jiading Fu	四川	Sichuan	
200	雅州府	Yazhou Fu	四川	Sichuan	
201	眉州	Meizhou Zhilizhou	四川	Sichuan	
202	邛州	Qiongzhou Zhilizhou	四川	Sichuan	
203	泸州直隶州	Luzhou Zhilizhou	四川	Sichuan	
204	资州	Zizhou Zhilizhou	四川	Sichuan	
205	绵州	Mianzhou Zhilizhou	四川	Sichuan	
206	茂州	Maozhou Zhilizhou	四川	Sichuan	
207	叙永厅	Xuyong Zhilizhou	四川	Sichuan	
208	绥定府	Suiding Fu	四川	Sichuan	
209	宁远府	Ningyuan Fu	四川	Sichuan	
210	酉阳州	Youyang Zhilizhou	四川	Sichuan	
211	忠州	Zhongzhou Zhilizhou	四川	Sichuan	
212	松潘厅	Songpan Zhiliting	四川	Sichuan	
213	石砫厅	Shizhu Zhiliting	四川	Sichuan	
214	太平厅	Taiping Zhiliting	四川	Sichuan	
215	云南府	Yunnan Fu	云南	Yunan	
216	大理府	Dali Fu	云南	Yunan	
217	临安府	Lin'an Fu	云南	Yunan	
218	楚雄府	Chuxiong Fu	云南	Yunan	
219	澂江府	Chengjiang Fu	云南	Yunan	
220	广西直隶州	Guangxi Zhilizhou	云南	Yunan	
221	顺宁府	Shunning Fu	云南	Yunan	
222	曲靖府	Qujing Fu	云南	Yunan	
223	武定直隶州	Wuding Zhilizhou	云南	Yunan	
224	永昌府	Yongchang Fu	云南	Yunan	
225	永北直隶厅	Yongbei Zhiliting	云南	Yunan	
226	元江直隶州	Yuanjiang Zhilizhou	云南	Yunan	
227	广南府	Guangnan Fu	云南	Yunan	
228	蒙化直隶厅	Menghua Zhiliting	云南	Yunan	
229	景东直隶厅	Jingdong Zhiliting	云南	Yunan	
230	开化府	Kaihua Fu	云南	Yunan	
231	丽江府	Lijiang Fu	云南	Yunan	
232	东川府	Dongchuan Fu	云南	Yunan	
233	镇沅直隶州	Zhenyuan Zhiliting	云南	Yunan	
234	昭通府	Zhaotong Fu	云南	Yunan	
235	普洱府	Puer Fu	云南	Yunan	
236	镇雄直隶州	Zhenxiong Zhilizhou	云南	Yunan	
237	贵阳府	Guiyang Fu	贵州	Guizhou	
238	思州府	Sizhou Fu	贵州	Guizhou	
239	思南府	Sinan Fu	贵州	Guizhou	
240	镇远府	Zhenyuan Fu	贵州	Guizhou	
241	石阡府	Shiqian Fu	贵州	Guizhou	
242	铜仁府	Tongren Fu	贵州	Guizhou	
243	黎平府	Liping Fu	贵州	Guizhou	
244	安顺府	Anshun Fu	贵州	Guizhou	
245	都匀府	Duyun Fu	贵州	Guizhou	
246	平越直隶州	Pingyue Zhilizhou	贵州	Guizhou	
247	大定府	Dading Fu	贵州	Guizhou	
248	兴义府	Xingyi Fu	贵州	Guizhou	
249	遵义府	Zunyi Fu	贵州	Guizhou	
250	仁怀直隶厅	Renhuai Zhiliting	贵州	Guizhou	
251	松桃直隶厅	Songtao Zhiliting	贵州	Guizhou	
252	普安直隶厅	Pu'an Zhiliting	贵州	Guizhou	

Table A.4. Summary statistics for grain prices

					One-month Δ non-zero
	n	Mean	Std. Dev.	Coeff. Var.	Mean
Britain					
Wheat	48,314	7.732	2.696	0.349	0.994
Bandpass filtered					
Wheat	48,314	1.001	0.049	0.048	0.994
China					
Wheat	107,069	1.466	0.521	0.355	0.344
Millet	52,947	1.601	0.558	0.348	0.456
Rice 1st quality	74,282	1.798	0.603	0.336	0.517
Rice 2nd quality	84,458	1.694	0.572	0.338	0.464
Bandpass filtered					
Wheat	107,069	1.000	0.020	0.020	0.344
Millet	52,947	1.000	0.022	0.022	0.456
Rice 1st quality	74,231	1.000	0.018	0.018	0.517
Rice 2nd quality	84,374	1.000	0.020	0.020	0.464

Notes: Source of data, see text. Last column gives the fraction of one-month price changes that is non-zero in the original data source.

Table A.5. Carry costs of grain, 1770 to 1860

			Monthly rate		Annualized
		n	Mean (%)	Std. dev.	(%)
Britain	Wheat	4,074	0.854	2.577	10.248
China	All grains	15,152	1.144	2.446	13.732
China	Wheat	4,930	1.124	2.577	13.488
	Millet	3,973	1.020	2.598	12.242
	Rice 1st quality	5,135	1.071	1.978	12.854
	Rice 2nd quality	5,384	1.074	2.133	12.883
Bandpass filtered					
Britain	Wheat	4,102	0.684	2.239	8.209
China	All grains	13,403	0.801	2.172	9.612
China	Wheat	4,221	0.774	1.886	9.284
	Millet	3,314	0.684	2.000	8.210
	Rice 1st quality	4,366	0.761	2.048	9.131
	Rice 2nd quality	4,794	0.781	2.054	9.376

Notes: Means are weighted by the fraction of month-to-month prices changes that are non-zero as shown in Table A.4. Annual rates are computed as 12 times the monthly rate.

Table A.6. Spatial Aggregation and capital market integration

	Baseline		Aggregated	
	Unfiltered	Filtered	Unfiltered	Filtered
0-100 km	0.80	0.71	0.85	0.81
	(0.16)	(0.17)	(0.10)	(0.11)
	[n = 350]	[n = 350]	[n = 42]	[n = 42]
100-200km	0.77	0.68	0.82	0.74
	(0.16)	(0.18)	(0.13)	(0.13)
	[n = 788]	[n = 788]	[n = 162]	[n = 162]
200-300km	0.74	0.66	0.81	0.71
	(0.17)	(0.17)	(0.12)	(0.11)
	[n = 720]	[n = 720]	[n = 170]	[n = 170]
300-400km	0.73	0.65	0.80	0.70
	(0.18)	(0.16)	(0.12)	(0.11)
	[n = 476]	[n = 476]	[n = 132]	[n = 132]
400-500km	0.70	0.63	0.78	0.69
	(0.18)	(0.19)	(0.13)	(0.11)
	[n = 246]	[n = 246]	[n = 74]	[n = 74]
500-600km	0.70	0.62	0.79	0.67
	(0.19)	(0.23)	(0.19)	(0.15)
	[n = 64]	[n = 64]	[n = 20]	[n = 20]

Notes: All results are for Britain. Shown in the Baseline columns are results for 52 counties. In the Aggregated columns, the 52 counties are aggregated to 26 regions that on average closely resemble the size of a Chinese prefecture.

Table A.7. Convenience yields and capital market performance

	Less than 10% above price trend		No consecutive price increases		Low volatility	
	Britain	China	Britain	China	Britain	China
0 to 200 km	0.776	0.438	0.782	0.441	0.732	0.388
	(1,138)	(748)	(1,128)	(738)	(1,128)	(712)
200 to 400 km	0.734	0.252	0.748	0.264	0.677	0.193
	(1,196)	(1,482)	(1,176)	(1,412)	(1,174)	(1,320)
400 to 600 km	0.722	0.124	0.727	0.145	0.631	0.086
	(310)	(1,780)	(298)	(1,626)	(298)	(1,384)

Notes: Entries give average bilateral interest rate correlation; number of observations given in parentheses. Results for three different subsamples during which convenience yields are expected to be low are shown.

Less than 10% above price trend: Compute 5 period moving average trend based on annual average grain prices; identify all years in which actual price is less than 10% above this moving average trend.

No consecutive price increases: Construct indicator variable equal to 1 if region has seen three or more consecutive price increases leading up to year t; results based on data for which indicator is 0.

Low volatility: For year t and month m, compute price volatility as the standard deviation of prices in years t-1, t, and t+1. Take the average of these twelve month-specific standard deviations as the volatility of year t.

Analysis is based on the lower 75 percent of observations in terms of volatility.

Table A.8 : The role of sample composition before and after 1820

	Britain		China	
	Before 1820	After 1820	Before 1820	After 1820
0-100 km	0.73	0.72	0.38	0.29
	(0.20)	(0.23)	(0.32)	(0.32)
	[n = 350]	[n = 314]	[n = 116]	[n = 108]
100-200km	0.69	0.71	0.28	0.23
	(0.22)	(0.23)	(0.40)	(0.30)
	[n = 788]	[n = 724]	[n = 380]	[n = 274]
200-300km	0.66	0.69	0.21	0.22
	(0.21)	(0.26)	(0.42)	(0.35)
	[n = 720]	[n = 660]	[n = 472]	[n = 380]
300-400km	0.66	0.68	0.15	0.14
	(0.22)	(0.24)	(0.36)	(0.36)
	[n = 476]	[n = 430]	[n = 474]	[n = 288]
400-500km	0.64	0.66	0.10	0.09
	(0.28)	(0.21)	(0.33)	(0.43)
	[n = 246]	[n = 216]	[n = 478]	[n = 276]
500-600km	0.56	0.67	0.06	0.09
	(0.42)	(0.24)	(0.34)	(0.39)
	[n = 64]	[n = 58]	[n = 530]	[n = 278]

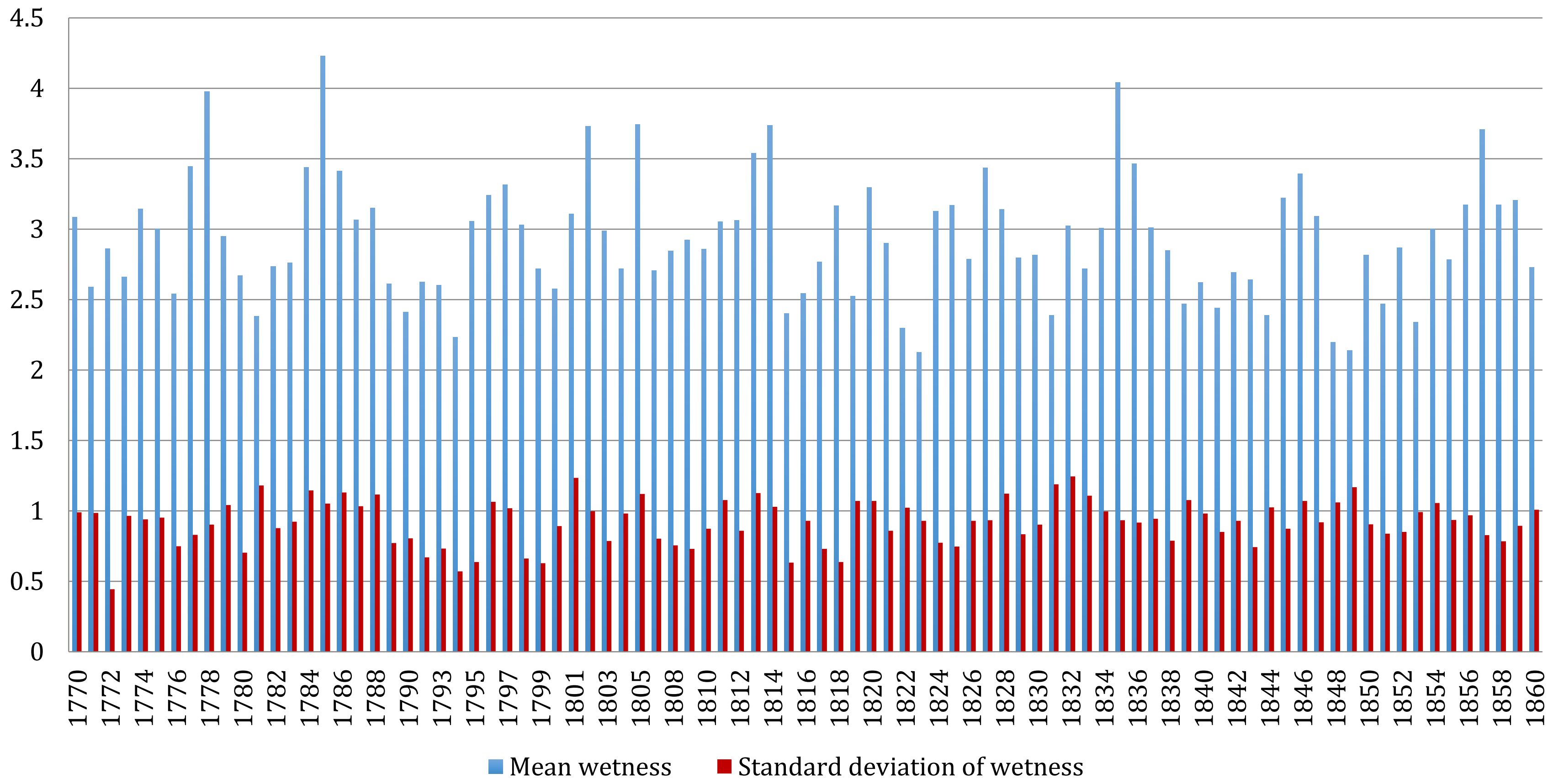
Notes: Results for mean bilateral correlations of interest rates based on filtered wheat prices. Standard deviation in parentheses.

Table A.9. Capital market integration and time series length

	Britain		China	
	All	50 < x < 70	All	50 < x < 70
0-100 km	0.71	0.68	0.51	0.61
	(0.17)	(0.18)	(0.46)	(0.50)
	[n = 350]	[n = 92]	[n = 158]	[n = 56]
100-200km	0.68	0.67	0.35	0.46
	(0.18)	(0.18)	(0.54)	(0.61)
	[n = 788]	[n = 222]	[n = 494]	[n = 164]
200-300km	0.66	0.67	0.25	0.36
	(0.17)	(0.16)	(0.58)	(0.49)
	[n = 720]	[n = 224]	[n = 612]	[n = 118]
300-400km	0.65	0.65	0.17	0.33
	(0.16)	(0.13)	(0.56)	(0.23)
	[n = 476]	[n = 136]	[n = 660]	[n = 66]
400-500km	0.63	0.65	0.10	0.22
	(0.19)	(0.14)	(0.55)	(0.29)
	[n = 246]	[n = 80]	[n = 804]	[n = 48]
500-600km	0.62	0.66	0.08	0.19
	(0.23)	(0.12)	(0.62)	(0.55)
	[n = 64]	[n = 28]	[n = 802]	[n = 108]

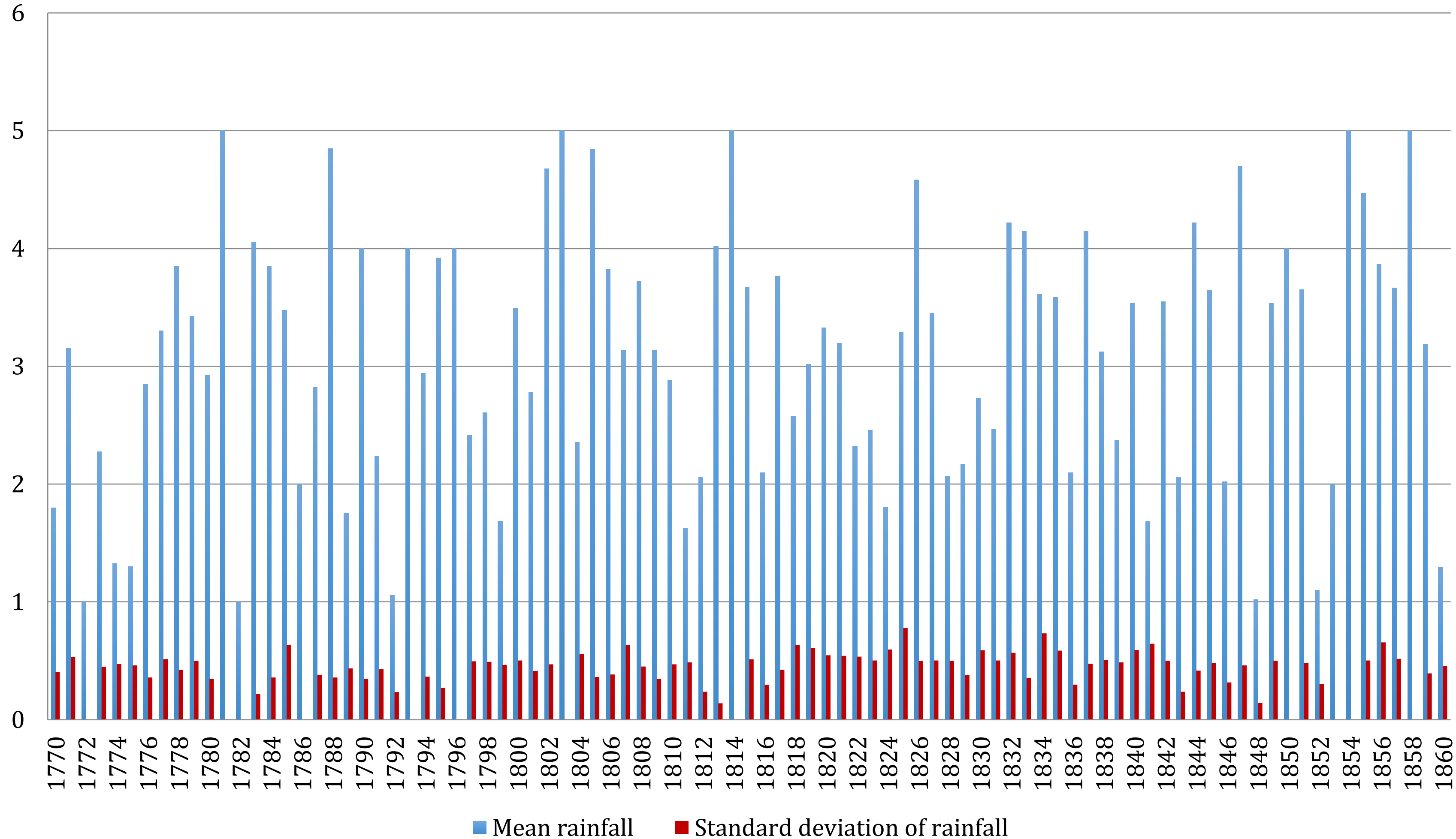
Notes: Results for mean bilateral correlations of interest rates based on filtered wheat prices for Britain and based on filtered second-grade rice prices for China. Results for columns "All" are for interest rate correlations using all data, from Table 4. Results for columns "50 < x < 70" are for pairs of regions with 50 to 70 years of data in the period 1770 to 1860. Standard deviation in parentheses, and number of observations in brackets.

Figure A.1. Climate in China: Annual wetness, 1770-1860



Source: State Meteorological Society (1981)

Figure A.2. Climate in Britain: Annual rainfall, 1770-1860



Source: Pauling, Luterbacher, Casty, and Wanner (2006)

Figure A.3: Capital market integration comparison and storage months