The Telegraph and Capital Market Integration in Late Imperial China, 1736–1911

Abstract

Exploiting quasi-exogenous variations in the timing of telegraph construction, the reduction of information costs promotes capital market integration in late imperial China. Employing a difference-in-differences strategy, we find that the telegraph connection within a prefecture pair reduced the difference in interest rate by 1.60 percentage points. Evidence from the textual analysis of historical documents suggests that the integration effect was driven by the information mechanism of the telegraph. In addition, the telegraph complements the institutional quality and transportation accessibility by enhancing capital market integration. Finally, nonlocal financial intermediaries have augmented the telegraph's effect on capital market integration. This augmenting effect of traditional banks (*piaohao*) on the capital market integration of the telegraph, however, only occurred within firm boundaries.

Keywords: Information friction, telegraph, capital market integration, financial intermediaries

JEL Classification: G14, G21, G23, N25, N75, O33

1 Introduction

Capital markets play a vital role in economic development by transferring current income to projects that incur future returns.[1] Therefore, capital market integration fosters economic growth by efficiently allocating capital surplus to those projects with the highest return (Gerschenkron, 1962; Goldsmith, 1962; Davis, 1965). However, this type of allocative efficiency cannot be achieved in a society with exorbitant information costs.[2] A vast body of literature has studied capital market integration in societies that possess modern information technology.[3] However, little is known about the effect of initially introducing modern information technology on capital market integration in premodern agrarian societies. This article fills this gap by directly investigating the effect of telegraph expansion on capital market integration in late 19th-century China. Specifically, we investigate whether the interest rates converged within the prefecture pairs that were connected by telegraph.

By the middle of 19th century, China had developed an inter-regional capital market that served a flourishing commodity market. Traditional financial intermediaries supplied funds to long-distance traders in interregional and intertemporal arbitrages in grains, textile, and other tradable (Pomeranz, 2000). While local money shops (*qianzhuang*) specialized in borrowing and lending at a local level, draft banks (*piaohao)* engaged in money remittance and capital arbitrage across regions, transmitting information along waterways and courier routes.[4] Prior to the arrival of the telegraph, however, the slow speed, instability, and limited coverage of information transmission impeded the integration of the capital market (Keller et al., 2021).

For military and administrative purposes, the Qing government began to construct telegraph lines in the 1880s. The construction plan for these telegraph lines and the timing

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[1]See Levine (2005) for a review of the vast literature on financial development and growth.

[2]According to Hayek (1945) and Stigler (1967). Information, by providing a price signal, serves as the foundation for a market, especially for a capital market.

[3]Studies cover the United States (Davis, 1965; James, 1967a,b; Sylla, 1969; Williamson, 1974; Smiley, 1975; Shuska and Barrett, 1984; Bodenhorn, 1992; Bodenhorn and Rockoff, 1992), Europe (Good, 1977; Brunt and Cannon, 2009; Keller et al., 2021), and Japan (Mitchener and Ohnuki, 2007, 2009)

[4]Modern banks emerged in the treaty ports of China following the 1840s under Western influence, but it took approximately another five decades for them to be established in a wider range of locations throughout the country (Lin et al., 2021).

of the construction were mostly driven by warfare and geopolitics rather than the need to facilitate trade and commerce (Gao and Lei, 2021; Hao et al., 2022). As shown in Figure 1, the telegraph spread so rapidly that 63.8% of the prefectures in China proper were connected to the telegraph network by the end of the Qing dynasty. The adoption of the telegraph enabled financial intermediaries to promptly track the capital market and communicate with their branches and customers in remote regions, thus promoting domestic capital market integration. In comparison, less than 10% of the prefectures were connected via railways, and less than 20% of the prefectures had become treaty ports by 1911, which makes it easier to disentangle the effects of information frictions from those of transportation and transaction costs.[5]

[**Figure 1** about here]

To evaluate the impact of telegraph connections on capital market integration, we construct a prefecture-pair × grain × year panel dataset that combines the yearly interest rate differences within prefecture pairs and their connection status via telegraphs. As there are not systematic interest rate records for a sufficiently large number of transactions (Chen et al., 2016), this study follows the work of Keller et al. (2020, 2021) and uses high-frequency (monthly) grain prices to calculate the annual interest rate. The intuition behind this method is that in an intertemporal arbitrage setting, the storing and selling of grain in the future should generate an equal return as that generated by investing in riskless assets. Hence, if the interest rate is higher within a harvest year, the grain price must rise faster to offset the higher opportunity cost of storing the grain. We use the monthly change in the price of rice, wheat and the six most widespread coarse cereals to calculate the annual interest rate at the prefecture level. Although these interest rates were extrapolated from grain prices, it does not mean that our calculated interest rates difference accurately captures grain market integration. As shown in Figure 2, the trend in nationwide average interest rates differences was uncorrelated to that in average grain price differences in the 19th century. The details of this method are shown in Appendix B.

[**Figure 2** about here]

[5] Generally, it is difficult to disentangle the effects of information frictions from those of transportation costs because telegraph poles were often built along railroads (Nonnenmacher, 2001).

We then exploit the exogenous variation in telegraph construction to identify its impact on capital market integration. Using a difference-in-differences (DID) model, we find that if two prefectures were connected by telegraph, the interest rate difference dropped by 1.60 percentage points (10% of the average interest rate difference). Exploring the dynamics of impacts, we find parallel trends between the treated and untreated groups before telegraph connection, suggesting that the timing of telegraph access was largely exogeneous to the capital arbitrage opportunities that existed between prefectures. We also find an increase in the magnitude of post-event impacts over time, amounting to 7.12 percentage points in more than 24 years after telegraph connection. Our results are robust to using a coarsened exact matched sample, to controlling grain market integration, railroad connections, spatial spillovers, and varying time trends between the treatment and control groups, and to the use of the staggered DID specification.

We further explore the mechanisms by which the telegraph affects capital market integration. First, we find that after the arrival of the telegraph, the connected prefectures were mentioned in the memorials submitted by departmental and provincial officials 0.87 more times per year (12.45% of the mean) than the unconnected prefectures, and they were mentioned 86.14 more times per year (81.48% of the mean) in *Shen Bao* (Shanghai News), which was the largest national newspaper in the late Qing period. These results suggest that the telegraph reduced information costs, increased information exposure, and in turn, enhanced capital market integration.

While telegraphs reduced information costs, financial players found engaging in capital arbitrage to be worthwhile only under sufficiently low transaction and transportation costs. We test whether the telegraph's impact was greater for those prefecture pairs that initially already had lower transaction and transportation costs when the telegraph arrived. Transaction costs were measured by treaty port status because defining property protection and enforcing contracts were less costly in treaty ports (Jia, 2014; Keller and Shiue, 2021). The results show that the telegraph's impact in those cases when both prefectures were treaty ports was approximately three times that when they were not. On the other hand, transportation costs were measured by dummies capturing waterway and one-day journeys because during this period, capital flows took physical form, including the shipping of silver ingots, metal coins, and paper money, and it was much cheaper to ship capital via waterways

(Chen, 1937). We find that the telegraph's impact if both prefectures were positioned along waterways was 3.75 times that if they were not. These findings support the view that the telegraph complements institutional quality and transportation accessibility in enhancing capital market integration, which reflects the importance of institutions and transportation in determining the extent of capital market integration (Stigler, 1965; Snowden, 1987; La Porta et al., 1997, 1998).

Finally, we investigate the role of the financial intermediaries that used vital information to engage in capital arbitrage. We focus on two types of players that engaged in cross-regional capital arbitrage: modern banks and *piaohao*. We find that the telegraph's impact on the interest rate difference was 216% greater in those prefecture pairs that both had a branch of the same bank in that year, and it was 158% greater in those prefecture pairs that both had a branch of the same *piaohao,* than it was in those cases where neither or only one prefecture possessed these financial intermediaries. As a placebo test, we find no such augmenting effect of *qianzhuang* (local money shops) and *shangbang* (long-distance commodity traders), because these players did not engage in long-distance capital arbitrage. A further comparison between *piaohao* and modern banks reveals the difference in scope of the augmenting effect between personal intermediaries and impersonal ones. In the case of *piaohao*, the augmenting effect is nonsignificant *unless* the prefecture pair is connected by branches of the *same piaohao* firm. In contrast, for modern banks, the augmenting effect is pronounced if the prefecture pair is connected by branches of any (different) modern banks. Together, these results suggest that relationship-based financial networks, unlike market-based ones, hindered the role of information technology in fostering capital market integration.

This paper contributes to the vast body of literature examining the impact of information technology on the development of the capital market. These studies involve the role of information technology in broadening banks' credit activities (Petersen and Rajan, 2002), promoting financial services competition (Hauswald and Marguez, 2003; Degryse and Ongena, 2005), lowering agency costs (Berger and DeYoung, 2006), shaping productivity and structural change (Wilhelm, 1999; Berger, 2003), fostering information exposure and banking development (Lin et al., 2021), and so on.[6] However, few studies have directly

[6]See Frame et al. (2018) for a review on the effect of information technology on capital market.

investigated the impact of information technology on capital market integration in pre-modern societies.[7] By focusing on an agrarian society, during which the modern banking system was in its initial stage and traditional financial institutions dominated, we can gauge the effect of information technology on capital market integration in quite a different environment from the modern societies used in all other related studies.

In addition, this paper complements the comparative studies of relationship-based financial institutions and market-based financial institutions. A recent work by Chen et al. (2022) investigated the substitution effect of a clan (a completely relationship-based institution) for modern banks (a completely market-based institution) and concluded that the Confucian clan impeded the development of modern financial markets in China. A case in point was the traditional *piaohao*, who used kin and countrymen networks to raise capital and expand operations. Rajan and Zingales (1998) have pointed out that a market-based system performs better than a relationship-based system, in which capital is relatively abundant when the contractual infrastructure is adequate.[8] We contribute to this literature by revealing that the augmenting effect of *piaohao* only occurred within firm boundaries, suggesting that personal financial networks hindered the role of the telegraph in capital market integration.

Broadly, this paper contributes to both the quantitative studies on capital market integration and the literature on the impacts of information technology (Brown and Goolsbee, 2002; Jensen, 2007; Aker, 2010; Ejrnæs and Persson, 2010; Goyal, 2010; Steinwender, 2018; Gao and Lei, 2021; Hao et al., 2021; Lin et al., 2021). By linking information technology progress and capital market integration, this study provides these two strands of literature with novel casual evidence from premodern China.

The remainder of the paper is organized as follows. In Section 2, a brief review of the historical background is provided. In Section 3, the dataset is introduced. In Section 4, the baseline results and the results of the robustness checks are presented. In Section 5, the informational mechanism and heterogeneities in the transaction and transportation costs are

[7] The only exception that we know of is Mitchener and Ohnuki (2009), who examined the effect of the telegraph on capital market integration in Japan over the period of 1882–1925, but they failed to disentangle the effects of information frictions from those of transportation costs.

[8] Relevant empirical evidence includes Hoshi et al. (1990), Petersen and Rajan (1995), Peek and Rosengren (1998), and Weinstein and Yafeh (1998).

examined. In Section 6, the roles played by different types of financial intermediaries are explored. In Section 7, the findings are summarized and the paper concludes.

2 Historical Background

2.1 Financial Market and Arbitrage

There has been a debate about the performance of the capital market in late imperial China relative to contemporary Europe. A few studies found extremely high pawnshop and usury rates in the Qing Dynasty and suggested that the farmers had to borrow at high rates because they usually made such loans for subsistence (Huang, 1985, 1990; Liu, 1995, 2000; Li and van Zanden, 2012). Rosenthal and Wong (2011) argued that pawnshop and usury rates were so limited and selective that these rates did not reflect the real condition of the financial market. They demonstrated that the interest rate differential between China and Western countries would be much smaller once they controlled the difference in borrowers, lenders, type of projects, maturity, risk, collateral and so on.[9] Using a newly validated method in which interest rates are calculated with grain prices, Keller et al. (2021) compared the capital markets in China and Britain from 1770 to 1860, and their findings were consistent with Rosenthal and Wong (2011). They found a relatively small gap between China and Britain in the average interest rate, although they found a sizable gap in capital market integration.

While a nationwide modern financial market was absent in late imperial China, traditional financial intermediaries such as *piaohao* played a key role in capital market integration. In 1880, 14.39% of prefectures had at least a branch of *piaohao,* whereas 4.68% of prefectures had at least a modern bank branch. *Piaohao* mainly conducted interregional remittances and served the needs of long-distance trade transfers (Zhang, 1957; Huang, 1990). With an extensive branch network, *piaohao* conducted financial arbitrage through branches in different regions. It was well documented that information was shared within a *piaohao*'s branch network and money was transferred from locations with lower interest rates to those with higher interests (Chen, 1937). In contrast, *qianzhuang*, a traditional local

[9]Using scattered interest rate data from various sources, Chen et al. (2016) finds a relation between interest rate and the lender type, collateral type, and loan amount before 1937.

money shop, generally provides small loans and money exchange services only for local clients (Yang, 2018).[10]

Unlike modern banks, however, *piaohao* relied on both informal institutions (client-patronage network) and formal institutions (impersonal market rules) in their operations (Chen, 1937). A piece of evidence is that remittance fees were usually negotiated by the *piaohao* and remitter. Although transaction costs and transportation costs were important in determining the remittance fees of *piaohao*[11], the fees largely depended on the relationship between the *piaohao* and the remitter: if the remitters had a close tie with the *piaohao*'s manager, remittance fees tended to be low. In light of these features, we suspect that information would be shared effectively only within firm boundaries, i.e., among branches of the same firm of *piaohao*. Information about arbitrate opportunities would meet barriers when it flows beyond firm boundaries.

2.2 Telegraph Construction in China

Telegraph spread to China in the early 1860s, shortly after it was invented by Morse in 1844. In the following two decades, the Qing government prohibited the construction of telegraph lines and poles on a large scale, while the Western powers tried hard to lobby for it.[12] However, the Qing government began to develop a telegraph network in the 1880s to efficiently transmit military information. In 1881, the Qing authorities laid the first north–south telegraph line to link Shanghai and Tianjin to coordinate defense works. The next two decades saw a rapid expansion of the telegraph across the country. Figure 1 shows that no prefectures had telegraph stations before 1881. The speed of telegraph construction surged in the 1880s because of the outbreak of the Sino-French War (1883–1885), then

[10]Modern banks emerged in China after the 1840s under Western influence. After the Oriental Bank, a British-Indian joint venture, opened a branch in Hong Kong in 1845 (Chen, 2011), foreign banks emerged in the treaty ports, and gradually spread to the inland.

[11]Averagely, the remittance fees were only 0.2–0.3 percentage points within large cities with convenient transportation, while it could reach 2–3, even 7–8, percentage points within remote regions with inconvenient transportation.

[12]Initially, the Qing government refused to establish a nationwide telegraph network mainly for three reasons (Xia, 2012). First, the Qing government considered that it might lose the control of the information system, which would threaten to its sovereignty. Once an important message had reached Western counties (via telegraph) before it reached Beijing (via imperial routes), the Qing government would be situated in a weak strategic position. Second, allowing foreigners to build telegraph lines was likely to cause disputes between China and foreign countries. Third, telegraph lines might have disturbed houses and tombs when going across mountains and fields, which might lead to mass uprisings.

slowed down in the 1890s, and finally speeded up again following the Boxer Uprising in 1900. By 1911, approximately 50,000 kilometers of telegraph lines had been laid, and 503 telegraph stations were established, covering 63.8% prefectures in China Proper (Traffic History Compilation Committee, 1936). [13]

Telegraph construction in the late Qing Dynasty provides an ideal setting for our empirical analysis for the following reasons. First and foremost, the spread of telegraphs can be viewed as a quasi-experiment. The Qing authorities generally chose the location of the major telegraph station for military and administrative purposes and linked them in a straight line to save cost (Xia, 2012).[14] As shown in Figure 3, telegraphs were constructed earlier on the eastern coast, the southwestern frontier, and the northwestern frontier but much later in populous provinces with prosperous traditional trading networks, such as Henan, Shanxi, Anhui, Jiangxi, and Hunan. Moreover, the timing of the telegraph's arrival in a given prefecture was quite random because it greatly depended on geographic and weather conditions (Gao and Lei, 2021). Second, the reduction in information cost induced by the telegraph provided vast spatial and temporal variations in information cost, which were necessary for identifying the effect of information friction. Third, we can disentangle the effects of information costs from those of transportation costs because the telegraph system expanded rapidly across the country before most regions were connected by railroads.

[**Figure 3** about here]

Telegraph networks substantially lowered information costs in long-distance trade and communication in China. Previously, messages were delivered by boats or horses. It usually took 40 to 50 days to make the round trip from Chongqing to Yichang, although the bilateral distance is only 650 kilometers (Peng, 2015). The adoption of the telegraph shortened the delivery time of messages to a few hours. In addition, telegram fees were affordable for most financial intermediaries. According to the unified pricing rules in 1894, telegram fees

[13]China Proper refers to the territory which was under the county-province administration; it excludes peripheral provinces, such as Manchuria, Tibet, Xinjiang, Mongolia, and Qinghai. This paper focuses on China Proper because the peripheral areas had very different population density, agriculture production and administration form.

[14]Of the 67 telegraph lines built between 1882–1896, only 1 was built for commercial purposes. Although the telegraph lines were initially constructed for military or administrative purposes, they were widely used in business communications for two main reasons. First, the merchants contributed a lot to the construction of the telegraph. Second, the Qing government could earn profits and maintain operations by providing private telegram services (Xia, 2012).

were 0.05 silver dollars per character within a prefecture, 0.1 silver dollars per character within a province, and 0.02 silver dollars per character for each additional province (Traffic History Compilation Committee, 1936). Although telegraph fees were higher in imperial China than in contemporary Europe and the U.S., they were generally much lower than the cost of urgent letters delivered manually (Huang, 2002). Moreover, financial intermediaries (e.g., *piaohao*) were willing to pay a relatively high price for timely information to seize business opportunities and improve business efficiency (Peng, 2015). The efficiency and affordability of using the telegraph to transfer information made private telegrams very popular in business, especially in financial arbitrage.[15] Anecdotal evidence shows the wide use of the telegraph in financial arbitrage (Chen, 1937):[16]

> *The local interest rates of each piaohao branch should be transferred to all other branches of the same piaohao every day. If the local interest rates are stable, the message will be transferred by ordinary letters. Once the interest rates sharply fluctuate, the messages will be communicated by urgent letters to all directly related branches before the introduction of the telegraph. However, all the urgent messages would be transferred by telegrams after the construction of telegraph.*

3 Data and Variables

To investigate the effect of telegraph connection on capital market integration, we construct a prefecture-pair × grain × year panel dataset combining yearly interest rate difference within prefecture pairs, which is calculated with prices of grain, and their connection via telegraph. In Section 3.1, we discuss how we construct the interest rate difference within a prefecture pair; in Section 3.2, we describe the measure of our treatment variable—telegraph connection between prefectures; in Section 3.3, we demonstrate how we collected data on the information exposure from textual analysis; in Section 3.4, we present the measures and sources of variables used for the heterogeneity analysis. We show the sources of variables on four types of financial intermediaries and those used for coarsened exact matching in Section 3.5 and Section 3.6, respectively. The summary statistics are presented in Table 1.

[15]For example, almost all the telegrams on the Yangtze River Basin were to communicate business message (Tongling Gazetteer, 1993). In 1912, approximately 88% of the sent telegrams were private (Traffic History Compilation Committee, 1936).

[16]See Song (2014) for more examples on the use of telegraph in financial arbitrage by banks.

[**Table 1** about here]

3.1 Interest Rates

As asset prices ought to obey the law of one price in a perfect capital market, we measure capital market integration with the absolute value of the interest rate difference within each prefecture pair. However, there are no interest rate records for a sufficiently large number of transactions for which rigorous empirical analysis can be conducted (Chen et al., 2016). Therefore, this study follows Keller et al. (2020, 2021) and Keller and Shiue (2021) and uses the grain price to calculate interest rates.[17] The intuition of this method is that in an intertemporal arbitrage setting, storing and selling grain in the future should generate equal returns with investing in riskless assets. Hence, if the interest rate is higher, the grain price must rise faster to offset the higher opportunity cost of storing grain. Keller et al. (2020) validated this method by showing the similarity between bank interest rates and interest rates calculated using grain prices in the 19th United States. They used this approach to study the capital market in premodern China (Keller et al., 2021; Keller and Shiue, 2021).

Appendix B1 gives a brief demonstration of the storage cost method. To further validate the method, Appendix B2 provides a formal test showing that the time trends in calculated interest rates in this paper are positively correlated with that in documented interest rates collected from historical account books. In addition, although yearly interest rates were extrapolated from monthly change in grain prices, it does not mean that the calculated interest rates difference captures grain market integration. Appendix B2 provides formal test showing that the time trends in calculated interest rate (and its difference) are not correlated with that in grain price (and its difference).

The grain price data used for the calculation are obtained from the Grain Price Database of Qing Dynasty (Institute of Modern History, Academia Sinica (Taiwan), 2014), which is derived from a long-standing grain price recording system in China. A countrywide grain price reporting system established in the reign of Qianlong (1736–1795) required that local

[17] Although there are several scattered records of interest rates in historical sources for China, they are not proper for rigorous empirical analysis because vital transaction details, such as the borrower, the lender, the type of project and so on, are missing (Pomeranz, 1993). Chinese economic historians have been trying to collect systematic records of interest rates in historical sources for China (Chen et al., 2016). Although they have made some progress, their data are not enough for constructing a panel of nationwide interest rates for a long period.

governments at all levels should report the monthly prices of the main types of grain within their jurisdiction. This system worked until 1911 and collected prefecture-month panel grain price data across 319 prefectures and 20 provinces for approximately 200 years. In addition to such abundant details and high frequency, the Qing grain price dataset is generally considered of high quality because the meticulously designed bottom-up reporting system made the manipulation difficult; hence, it has been widely used in many empirical studies (e.g., Shiue, 2002; Shiue and Keller, 2007; Gao and Lei, 2021; Hao et al., 2021; Keller et al., 2021; Keller and Shiue, 2021). In this study, we selected rice, wheat and the six most widespread coarse cereals (millet, sorghum, black soybean, pea, red rice and soybean) for the sample.[18]

3.2 Telegraph Construction

Data on telegraph construction were collected from *Jiaotongshi Dianzhengbian* (Traffic History: Telecommunications) and local gazetteers from the sample prefectures (see Appendix C for details of these sources).[19] We started by obtaining a list of prefectures in which the telegraph was constructed before 1913 from *Jiaotongshi Dianzhengbian*. From local gazetteers, we then pinned down the dates when these telegraph stations successfully operated. We restrict our analysis to the prefectures that belong to China Proper and are available to telegraph construction information (276 prefectures, 18 provinces). The time trend and spatial distribution of the telegraph network are shown in Figures 1 and 3.

3.3 Information Exposure

We collected data on information exposure from two sources. First, we collected the data on official information exposure from the First Historical Archives of China, where digitized memorials in the Qing Dynasty are available. Memorial refers to a wide range of official documents addressed to the emperor (handled by his consulting board). Hence, the

[18]To filter the influences of climate, interregional trade and cropping pattern on interest rates, we calculate the adjusted interest rate using information of rainfall, waterway, and harvest pattern. The data on historical rainfall are collected from the State Meteorological Society (1981). We categorize the climate conditions at prefecture-year level into five levels ranging from 1 (very wet) to 5 (very dry), with 3 being the normal level of rainfall. The data on waterway come from the China Historical Geographic Information System (CHGIS), and the data on cropping pattern come from Keller et al. (2021). The waterway dummy equals 1 if the prefecture has an access to water transport, i.e., the Yangzi, the Pearl River, the Grand Canal or costal. The cropping pattern dummy equals 1 if the rice can be harvested twice each year in the province.

[19]Local gazetteers were widely used as sources for the study on Chinese history (Lin et al., 2021).

frequency of the prefecture names mentioned in the memorials can be viewed as a good proxy for the frequency of the exposure in the official information system. We performed textual analysis on the titles of the memorials to count the yearly frequency of the prefecture names and obtained a prefecture-year panel of information frequency for 276 prefectures from 1633 to 1911.

Second, following Lin et al. (2021), we gauge private information exposure by using the frequency of the prefecture being reported in *Shen Bao* (Shanghai News). *Shen Bao*, which started publication in 1872 and stopped publication in 1949, was the most influential national daily newspaper in modern China. Because of its long publication period and broad influence, it has been widely used in research on modern Chinese history. In addition, it played a vital part in transferring business information, which made it especially suitable for our study. For instance, financial market information in Shanghai has been published in *Shen Bao* every day since 1872, and key information could widely spread across the country through water transportation, (land) postal delivery, and, later, telegraph networks (Peng 2015). We conducted textual analysis on *Shen Bao*, the full text of which was digitized by the Green Apple Center in 2010. Specifically, we counted the yearly frequency of the prefecture names from 1872 to 1911.

3.4 Data for Heterogeneity Analysis

To study the heterogeneity in transaction cost and transportation cost, we employ data on treaty ports from Yan (2012), waterways from the China Historical Geographic Information System (CHGIS) and inter-prefecture distance from Playfair (1965). We measure the treaty port (or waterway) connection with dummies that indicate whether both prefectures were treaty ports (or along waterways) before 1881, the year when the first telegraph was established in China. The one-day journey indicator equals 1 if the distance within the prefecture pair is less than 25 kilometers, the upper bound of the average daily travel distance on waterways (Peng, 2015).

3.5 Financial Intermediaries

To investigate the role of different types of financial intermediaries in capital market integration, we collected data on the distribution of modern banks, *piaohao*, *qianzhuang*, and *shangbang*. First, the data on *piaohao* were hand-collected from *Shanxi Piaohao Shiliao*

(Historical Data of Shanxi *Piaohao*), which was edited by Jianhui Huang in 2002. We mainly use the information on the setup of branches of each *piaohao*.[20] Second, we employed Jiang (2014), who reports the opening and closing of the business of banks and *qianzhuang* in China, to pin down 33 bank branches (from 10 firms of banks) and 65 *qianzhuang* that were established before the arrival of the local telegraph and still on operation when the telegraph was adopted. Finally, we use the data on *shangbang* from Liu et al. (2021). They collect information on whether each county established *shangbang* before 1911. We aggregate the data to produce an indicator of *shangbang* for each prefecture.

3.6 Data for Coarsened Exact Matching

As the introduction of telegraph is initially for military and administrative purpose, we collect information on the prefecture's military and political importance to construct the coarsened exact matched (CEM) sample. We first collect the numbers of foreign intrusions on prefecture-decade level from *Zhongguo Lidai Zhanzheng Nianbiao* (A Chronology of Warfare in Dynastic China), which was compiled by China's Military History Editorial Committee.[21] The Taiping Rebellion (1851-1872) caused serious threat to the sovereignty of the Qing Dynasty, so we also record the regions affected by the rebellion from the National Defense University (2013) to measure the military importance. Moreover, naval warfare plays an important part in national defense, so we construct a coast dummy using CHGIS data. For the political importance, we use two proxy variables: a dummy of province capital from Zhao (1998), and the official ratings of prefectures from Bai and Jia (2016).[22]

[20] We only select *piaohao* with branches established in more than five prefectures *before* the arrival of the local telegraph because they were more likely to play a part in integrating the capital market. The 16 *piaohao* in our samplele are *Rishengchang, Weitaihou, Weifenghou, Weishengchang, Xintaihou, Xietongqing, Baichuantong, Qianjisheng, Weichanghou, Qidechang, Yunfengtai, Songshengchang, Heshengyuan, Sanjinyuan, Xiechengqian and Hutongyu*. These *piaohao* belong to four guilds (*bang)*: Pingyao guild, Qixian guild, Taigu guild and South guild. And the Pinghyao guild is the largest guild among them.

[21] We also collected information on the battlefields of the First Opium War, the Second Opium War, and the Sino-French War.

[22] These ratings are based on a prefecture's accessibility by transport (*chong*), amount of administrative work (*fan*), taxation difficulty (*pi*), and crime rate (*nan*). For each prefecture, the official system assigned 0-4 features by which to describe a prefecture; more features indicate greater importance. There, prefectures are divided into four types: the most important (*zui yao que*), with four features; the second-most important (*yao que*), with three features; the third-most important (*zhong que*), with two features; and the least important (*jian que*), with one or no features.

4 Telegraph Connection and Capital Market Integration

In this section, we examine the impact of telegraph connections on the absolute value of the interest rate difference. We present the baseline results in Section 4.1. Section 4.2 illustrates the dynamic effect of telegraph adoption over time and tests the parallel trend assumption for the DID strategy. Section 4.3 shows robustness checks, including addressing the potential confounders (i.e., grain price difference, wireless telegraph, railroad, and various time trends across the treatment and control groups), excluding spillover effects, applying a CEM sample, and using two-way clustered standard errors. Last, we tackle the possible estimation bias caused by the heterogeneous treatment effects in staggered DID designs.

4.1 The Baseline Results

Our baseline specification employs a DID strategy that compares the interest rate difference in telegraph-connected prefecture pairs to those without telegraph connections before and after both prefectures gained access to telegraphs. The regression equation is as follows:

$$IRD_{ijkt} = \alpha + \beta Tel\_connection_{ijt} + \gamma_{ij} + \theta_{kt} + \varepsilon_{ijkt} \tag{1}$$

where IRD_{ijkt} denotes the absolute value of the interest rate difference between prefecture i and prefecture j in year t, with the interest rates being calculated using the prices of grain k. The variable $Tel\_connection_{ijt}$ is a dummy that indicates whether prefectures i and j were connected by telegraphs in year t, which equals 1 from the year in which both prefectures had access to telegraphs and onward. In the preferred specification, we control for all the time-invariant characteristics of the prefecture pair (e.g., geographical features of prefectures i and j) by adding the prefecture-pair fixed effects, γ_{ij}, and grain-year fixed effects, θ_{kt}. All standard errors are clustered at the province-pair × grain level.

Table 2 presents the baseline results. Column 1 shows that the telegraph connection within a prefecture pair significantly reduced the interest rate difference by 1.39 percentage points (8.55 percent of the mean of the interest rate difference) when we control for year, grain and prefecture-pair fixed effects. In our preferred specification, we more strictly control for prefecture-pair fixed effects and grain × year fixed effects. The corresponding results in column 2 show that the telegraph's presence in both prefectures narrowed the interest rate gap by 1.60 percentage points (9.85 percent of its mean). In short, the telegraph connection reduced the interest rate difference across markets linked to the telegraph network and significantly improved capital market integration.

[**Table 2** about here]

4.2 The Dynamic Impacts of the Telegraph Connection

To investigate the effect of the telegraph connection over time and check the parallel trend assumption for the DID strategy, we allow for a more flexible specification and conduct a dynamic analysis where we replace $\beta Tel\_connection_{ijt}$ with $\sum_{m=-G}^{M} \beta_m D_{ij,t+m}$, where $D_{ij,t+m}$ is an indicator that equals 1 if prefecture i and prefecture j were connected by telegraph m periods before time t; and β_m captures telegraph's effect of m periods after time t. We set the preevent period bin as 45 years and the postevent period bin as 6 years to obtain a "symmetric" plot (i.e., both G and M equal 4). In doing so, we could directly test the parallel trend assumption for the DID design ($\beta_m = 0, \forall m < 0$) and observe the pattern of the telegraph's dynamic impacts on capital market integration.

Figure 4 presents the differences in the absolute value of the interest rate difference between telegraph-connected prefecture pairs and those without telegraph connections over 9 periods: 4 periods before, 1 period during, and 4 periods after. It is clear that the decline in the interest rate difference did not occur over the 4 periods before the telegraph's arrival. There is a sharp decline in the interest rate difference once the telegraph was introduced, and the downward trend was persistent and increased over time. The short-term effect (in period 0 and 1) of telegraph connection on the interest rate difference was approximately 1 percentage point (6.15 percent of the mean of interest rate difference); the mid-term effect (in period 2 and 3) rose to over 2 percentage points; the long-term effect (in period 4, 24 or more years after telegraph connection) finally reached 7.12 percentage points (42.21 percent of its mean). The results of dynamic effects enhance our confidence in the baseline results because the discontinuous and persistent reduction in the interest rate difference following telegraph connections was unlikely to be driven by unobserved confounders.

[**Figure 4** about here]

4.3 Robustness Checks

4.3.1 Grain Price Difference

Because we use grain prices to calculate interest rates, a major concern is that the effect of telegraphs on interest rate differences may be driven by the effect of telegraphs on grain price differences. We address this concern from three aspects. First, as discussed in Section 3.1, we calculate the interest rate using the growth of grain price instead of the level of grain price, so the calculated interest rate difference is the first order difference in the grain price difference than the grain price difference itself. We indeed find insignificant correlations between the calculated interest rate (difference) and the grain price (difference) in Appendix B2.2. In addition, Shiue and Keller (2007) find a small gap in the integration of China's commodity markets (measured by grain price) relative to those in Western Europe, while Keller et al. (2021) find a sizable gap in capital market integration (measured by interest rates calculated with grain price).

Although the mathematical relationship between the interest rate and grain prices can greatly dispel our concerns, we try to further address the concern with two empirical tests. We start by controlling for the grain price difference.[23] As the result shows in column 2 of Table 3, the negative and significant effect of telegraph connection remains stable, with a slight reduction in the magnitude.[24]

[**Table 3** about here]

Third, we replicate our baseline regression in two subsamples in which the interest rate is calculated separately with the price of rice and the price of wheat. Hao et al. (2021) find that telegraph construction has a much smaller impact on wheat market integration (the price difference of wheat) than on rice market integration (the price difference of rice) because of the lower commercialization of wheat. If the telegraph's effect on interest rate difference is mainly driven by its effect on grain price difference, the effect of telegraph on the interest rate difference would be larger when we calculate the interest rate with rice price than with

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[23] $\text{price\_difference}_{ijkt} = \left|\frac{2(price_{ikt} - price_{jkt})}{price_{ikt} + price_{jkt}}\right| \times 100$

[24] We should be cautious of the causality in this specification because grain price difference is not a predetermined variable and may be a "bad control" when we are estimating the effect of telegraph connection. This is the main reason why we prefer not to control grain price difference in our baseline.

wheat price. However, columns 3 and 4 of Table 3 show the opposite effect. The impact of telegraph connections on the interest rate difference is larger in the wheat subsample (-2.65) than in the rice subsample (-1.17). Together, these results indicate that the telegraph's impact on capital market integration is not driven by its impact on commodity market integration.

4.3.2 Contemporaneous Technology Changes

We then controlled the impacts of the contemporaneous changes in information and transportation technology. To eliminate the potential confounding impacts of the *wireless* telegraph, which was first employed by the Qing government in 1905, we followed Gao and Lei (2021) to restrict our sample to the period before 1905. As shown in column 5, the negative effect of telegraph connections on interest rate differences remains almost unchanged, indicating that our baseline result is unlikely to be driven by the introduction of wireless telegraphs. In addition, we added an indicator that equals 1 if both prefectures are along railroads, and the results in column 6 show that our main result remains stable.[25]

4.3.3 Various Time Trends between Control and Treated Group

Moreover, we allow for different time trends between prefecture pairs with and without telegraph connections by adding the interactive term of the treatment indicator and linear time trend. Column 7 shows that the effect of telegraph connections on interest rate differences is similar to the baseline result in both magnitude and significance levels. This result addresses the concern that the assignment of the treatment status may be endogenous and promotes the reliability of the parallel trend assumption.

4.3.4 Spillover Effect

In addition, to capture a possible spillover effect, we create a control variable—nearby telegraph connection dummy, which equals 1 if the nearby (within 100 km) prefectures i and j were connected by telegraph. Column 8 shows that the effect of telegraph connections remains almost unchanged, and the impact of nearby telegraph connections is

[25]As there was no railroad in China before 1881, the dummy of both railroads is not a predetermined variable and may be a "bad control". Therefore, we should be cautious of the causality in this specification.

statistically insignificant.[26] The results assure us that the spillover effects of telegraph connections beyond prefectural borders are at most limited; any bias in the baseline results from spillover effects is negligible.

4.3.5 Coarsened Exact Matched (CEM) Sample

Although the negative effect of telegraph connection on capital market integration is robust to controlling a series of fixed effects and time-variant variables above, we further adopt a CEM approach to improve comparability. This approach was introduced by Iacus et al. (2012) and has been gradually applied in recent economics studies (e.g., Jaravel et al., 2018; Azoulay et al., 2019; Aneja and Xu, 2022; Bo et al., 2022). Compared with controlling confounders, the CEM method can reduce statistical bias with less model dependence (Ho et al., 2007). Moreover, the CEM method dominates commonly used existing matching methods (e.g., propensity score matching and Mahalanobis matching) in its ability to reduce imbalance, model dependence and estimation error (Iacus et al., 2009, 2011).

We match prefectures according to the eight variables which can determine the construction of telegraph: three binary variables indicating whether a prefecture was province capital, coast, and the battlefield against the Taiping Rebellion, and five numerical variables measuring the prefecture's official ratings and the numbers of foreign intrusions in four different periods. For the first three dummies, we apply the default binning algorithm (the Sturges automatic rule), which yields an exactly balanced matching. We coarsen the other four numerical variables according to their ranges by setting different bins. Using this matching rule, we find matches for 2938 out of 3066 treated events. Our matches come from 36 different strata. We evaluate the matching quality using L1 distance (Iacus et al., 2012), which measures multivariate differences between the treated and untreated groups. Before the matching, the multivariate L1 distance is 0.34; afterwards it decreased sharply to 0.02, indicating that our matching quality is high. Balance check results in Table A2 show that the treatment group are more important in military and politics than the control group before the matching. However, in the CEM sample, both the mean difference and the L1 distance of each covariate greatly declined. Using the CEM sample to replicate the baseline regression, we find that the negative effect of telegraph connection on interest rate difference

[26] We define the threshold of "nearby prefectures" as prefectures within 50 km, 150 km and 200 km and replicate the regression in appendix Table A1. This has little influence on the main results.

remains almost unchanged (column 9, Table 3), suggesting our main result are robust to the confounders that may determine the assignment of the treatment.[27]

4.3.6 Two-way Clustered Standard Errors

For each column, we also two-way cluster the standard errors at the level of province-pair × grain and year, as reported in the brackets. Although the estimates become noisier when we use the two-way clustered standard errors, the results across all columns show that almost all the negative coefficients on telegraph connection remain statistically significant. One exception is that the effect of the telegraph on interest rate differences becomes insignificant, perhaps because of the reduction in sample size (Column 3). However, this result, along with the result in column 4, further dispels the concern that our baseline result might be driven by the change in the grain price difference within prefecture pairs.[28]

4.3.7 Robustness Estimators for Staggered DID

A common concern of the conventional two-way fixed effect (TWFE) estimation in a staggered DID setting is that treatment effects may be heterogeneous across time periods or across agents within a time period. In such cases, some units might receive negative weights when their outcomes are aggregated to form treatment effects, which could bias the TWFE estimate (De Chaisemartin and d'Haultfoeuille, 2020; Goodman-Bacon, 2021; Sun and Abaham, 2021; Borusyak et al., 2022; Callaway and Sant'Anna, 2022). We address this concern in two steps. First, we examine the distribution of yearly treatment status over time. The possibility of a negative weight, the cause of bias, would be low if there is a large proportion of units that are never treated or treated late in the sample period ("clean controls"). As shown in Appendix Figure A1, a considerable portion (36.3%) of prefectures were never treated, and all the other prefectures were treated after 1880, a very late timing

[27]Using the CEM sample to replicate the dynamic analysis in Section 4.2 also barely changes the results (Figure A2, Appendix A).

[28]Another noteworthy change is that the coefficient on the interactive of treatment dummy and linear time trend becomes statistically insignificant when we use the two-way clustered standard error, which enhances our confidence that our result is not driven by the various time trend between treated and untreated group.

in our sample period (1736–1911). The substantial share of "clean controls" greatly dispels concerns about the potential bias of TWFE estimates in staggered DID.[29]

To further check for the possibility of such bias, we replicate our results on dynamic effects using the estimation method proposed by Cengiz et al. (2019). This approach consists of the following steps. 1. We create cohort-specific panel datasets, where each dataset contains a single treated cohort along with all never treated units. These never treated units make up the "clean controls". 2. We stack these datasets and line them up according to the relative time indicators. 3. We conduct a dynamic analysis on this stacked dataset, interacting fixed effects with dataset indicators. Standard errors are clustered two-way at the province-pair × grain and dataset indicator levels. Figure 5 shows that these estimates are similar in size to our standard TWFE estimates. Thus, we use standard TWFE estimates in the remainder of the article.

[**Figure 5** about here]

5 Mechanism and Heterogeneity

The results in Section 4 suggest a causal impact of the telegraph on capital market integration. Why and how? An obvious answer might be that the telegraph reduced information friction and promoted information exchange. In Section 5.1, we directly investigate the impact of telegraph construction on information exposure. In Section 5.2, we proceed to see if a reduction in information cost induced arbitrage to a larger extent in an area with lower transaction and transportation costs.

5.1 Information Exposure as the Mechanism

Traditionally, information is transmitted via (land) postal routes or waterways, which are characterized by low speed and high cost and are subjected to weather changes and topographic conditions. With the arrival of the telegraph, information could be delivered instantly at a relatively low cost, which might promote more efficient financial arbitrage and

[29]This is the main reason why we prefer to use so many years of data before the introduction of the telegraph. Our main results keep almost unchanged if we use the data beginning in 1800, 1810, 1820, 1830, 1840, or 1850. Moreover, a long-run perspective is a natural choice to capture the nature of the market integration process.

integrate the capital market. With the data on information frequency and telegraph construction at the prefecture-year level, we employ a DID strategy that compares information frequency in prefectures with telegraphs to those without telegraphs before and after the prefecture gained access to the telegraph. The regression equation is as follows:

$$IF_{it} = \alpha + \beta Tel_{it} + \gamma_i + \theta_t + \varepsilon_{it} \quad (2)$$

where IF_{it} denotes the information frequency of prefecture i year t. Tel_{it} is a dummy that indicates whether prefecture i gained the arrival of the telegraph in year t, which equals 1 from the year in which prefecture i had the arrival of the telegraph onward. We control for all the time-invariant characteristics of the prefecture by adding the prefecture fixed effects, γ_i, and control for the common time trend by adding the year fixed effects, θ_t. All standard errors are clustered at the province × half-decade level.

We first estimate the regression with official information exposure from the First Historical Archives of China. Column 1 in Table 4 shows that the effect of the telegraph on official information frequency is 0.87 and statistically significant. This means that after the arrival of the telegraph, the names of the prefectures with telegraphs appeared in the titles of the memorials 0.87 more times per year (12.45% of the mean of the dependent variable) than those without telegraphs. Constraining the sample to the memorials whose titles contained military keywords, such as *jun* (army), *bing* (soldier), *di* (enemy), *zhan* (war), *gong* (attack) and *shou* (defense), we replicated the estimation and obtained similar results. As shown in column 2, the introduction of the telegraph increased the frequency of prefecture names in the titles of military-related memorials by 0.27 times per year (55.30% of the mean of the dependent variable), which is consistent with the fact that the telegraph lines were built mainly for military purposes.

We then investigate the relationship between telegraph connections and private information exposure in *Shen Bao,* the most influential national newspaper. Column 3 shows that after the arrival of the telegraph, the names of the prefectures with telegraphs were reported in *Shen Bao* 86.14 more times per year (81.48% of the mean of the dependent variable) than those without telegraphs. More specifically, the telegraph increased the frequency of being reported in the news by 24.36 times per year, 54.63% of its mean

(Column 4), and that in advertisements by 60.81 times per year, 102% of its mean (Column 5).

Taken together, these results indicate that telegraph construction promoted both official and private information exposure and, in turn, improved capital market integration in prefectures connected by telegraph networks.

[**Table 4** about here]

5.2 Heterogeneity in Transaction Cost and Transportation Cost

Timely information is undoubtedly essential to financial arbitrage, but the effect of telegraph connections would not be realized unless the financial intermediaries found it worthwhile to utilize the information and engage in arbitrage. In consideration of the important role of transaction costs and transportation costs in the capital market (Stigler, 1967; Snowden, 1987; La Porta et al., 1997, 1998; Rosenthal and Wong, 2011), we further investigate whether the effect of telegraph connections was greater within prefecture pairs that enjoyed lower transaction costs and transportation costs, that is, if a reduction in information costs induced arbitrage to a larger extent in an area with lower transaction costs and transportation costs.

Transaction cost is a broad concept, and we only focus on contracting cost in our empirical analysis. We suspect that even with a reduction in information cost, financial arbitrage would be much less likely to take place if such costs were too high. We use an indicator of treaty port to proxy transaction cost because Jia (2014) and Keller and Shiue (2021) find that treaty port could reduce contracting costs by introducing impersonal solutions to business disputes. The treaty port indicator of a prefecture pair equals 1 if both prefectures were treaty ports in 1880.

The transportation costs were particularly vital in financial arbitrage in the late Qing because financial players still needed to fiscally transport metal and paper money across regions.[30] We suspect that even with a reduction in information cost, financial arbitration would be much less likely to take place if transportation costs were too high. We use a

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[30]Although the adoption of telegraph made it possible to conduct telegraphic transfer, the transportation costs still played an important role in financial arbitrage because the scale of telegraphic transfer indeed kept at a very low level before 1933 (Xia and Xia, 2016).

waterway dummy and a one-day journey dummy to measure transportation costs. The waterway dummy equals 1 if both prefectures in the prefecture pair were located along a waterway; the one-day journey dummy equals 1 if the distance within the prefecture pair was less than 25 kilometers, the upper bound of average daily travel distance on a waterway (Peng, 2015).

We test the heterogeneity in costs by adding the interactive terms of the telegraph indicator and the cost dummies, and the results are presented in Table 5. Column 1 shows that the telegraph reduced the interest rate difference by 4.87 percentage points $(1.58 + 3.29)$ if both prefectures were treaty ports, approximately triple the baseline effect (1.60). Column 2 shows that the telegraph's effect on capital market integration is larger within prefecture pairs along waterways. The telegraph connection reduced the interest rate difference by 4.55 percentage points $(1.21 + 3.34)$ if both prefectures were located along the waterway, and by three times otherwise. Column 3 shows that the telegraph connection reduced the interest rate difference by 2.43 percentage points $(1.47 + 0.96)$ if one spent less than one day traveling from one prefecture to another prefecture in the prefecture pairs, and by 1.65 times otherwise. Taken together, these findings support the view that the telegraph complemented institutional change and transportation technological change in enhancing capital market integration.

[**Table 5** about here]

6 The Role of Financial Intermediaries

We proceed to investigate the role of various types of financial intermediaries that were likely to use timely information to engage in capital arbitrage. We first focus on the role of nonlocal financial intermediaries (i.e., modern banks and *piaohao*) that engaged in interregional remittance services. Then, we investigate the effects of *qianzhuang* (financial but local) and *shangbang* (nonlocal but nonfinancial) as placebo tests. Finally, we discuss the difference between the personal (or relationship-based) financial network of *piaohao* and the impersonal (or market-based) financial network of modern banks in improving capital market integration.

6.1 The Role of Nonlocal Financial Intermediaries

To explore the role of different financial intermediaries, we add the interaction of the telegraph indicator and the dummies of these intermediaries. As shown in Table 6, modern banks and *piaohao* strengthened the telegraph's effect on capital market integration (Columns 1 and 2). Specifically, the telegraph connection reduced the interest rate difference by 3.44 percentage points ($1.59 + 1.85$) if the prefecture pair was connected by branches of the same firm of modern banks, and by 2.16 times otherwise. It reduced the interest rate difference by 2.51 percentage points ($1.59 + 0.92$) if the prefecture pair was connected by branches of the same firm of *piaohao*, and by 1.58 times otherwise. As placebo tests, we find that such an augmenting effect disappeared for *qianzhuang*–local money shops and *shangbang*–nonfinancial merchant groups. As *qianzhuang* mainly provided local financial services, few *qianzhuan*g operated branches in different prefectures. These results indicate that both players did not engage in cross-regional capital arbitrage, and thus, their existence did not help the telegraph facilitate capital arbitrage.[31]

[**Table 6** about here]

6.2 The Limitation of the Personal Financial Network

Since the *piaohao* network was largely personal, we suspect that information would be shared effectively only within firm boundaries, i.e., among branches of the same firm of *piaohao*. Information about arbitrate opportunities would meet barriers when it flows beyond firm boundaries. In light of these features, we explored, step by step, whether the augmenting effect of the *piaohao* network on the telegraph's impact on capital market integration was limited to the branches of the same firm of *piaohao*.

In column 1 of Table 7, we replicate the result from column 2 of Table 6, where the *piaohao* connection dummy equals 1 if both prefectures have branches of the same firm of *piaohao*. In column 2, we redefine the *piaohao* connection dummy as being connected by *piaohao* from the same guild or not. In column 3, the *piaohao* connection dummy equals 1

[31]We also use the dummy that indicates whether the ratio of counties with *shangbang* in a prefecture is more than its median (12.5%) to construct the *shangbang* dummy. The results obtained using this new *shangbang* measure (not reported) are similar to those reported in this paper. However, the results for the heterogeneity in *shangbang* should be explained with caution in the sense that the nonpredetermined *shangbang* dummy could bias the estimates.

as long as both prefectures have branches of any firm of *piaohao*. The insignificant coefficients of the interaction terms in columns 2 and 3 indicate that the augmenting effect of the *piaohao* network on the telegraph's impact on capital market integration was limited to the branches of the same firm of *piaohao*. Once the branches in the two prefectures were from different firms of *piaohao*, the augmenting effect disappeared. These results suggest that a personal and closed-form financial network hindered the role of telegraphs in market integration.

In contrast, in the case of modern banks, branches from *any* firm could promote the effect of telegraphs on capital market integration (Column 4, Table 7), and the magnitude of the coefficient on the interaction term is no different from the case where the bank connection dummy equals 1 if both prefectures have branches of the same firm of modern banks (Column 1, Table 6). In summary, the augmenting effect of modern bank networks on the telegraph's impact on capital market integration was *not* limited by firm boundaries. These results indicate that in the case of modern banks, there were fewer barriers to information flow relative to the case of *piaohao*, from one branch of a modern bank to another branch of a different modern bank. Therefore, the telegraph better facilitated capital market arbitrage with the help of a larger, more open, and impersonal financial network.[32]

[**Table 7** about here]

7 Conclusions

This paper investigates the effect of telegraph-induced information flows on cross-prefectural interest rate differences by exploiting a quasi-experiment—the construction of the telegraph in the late Qing Dynasty. The military and administrative purpose of the telegraph introduction provides an ideal setting for identifying the impact of information friction on capital market integration. The extensive distribution of the telegraph network allows us to explore the heterogeneous effects of the telegraph in markets with various characteristics.

[32]These results are consistent with the argument that an impersonal financial network was more likely to adapt to a modern financial market in which many arms-length financial transactions occur (Rajan and Zingales, 1998). With the development of property rights, laws, and institutions that facilitate transactions, the relative value of relationships would gradually decline.

The main findings of this paper are as follows: (i) the lower information cost induced by the telegraph connection promoted capital market integration; (ii) the impact of the telegraph on capital market integration was achieved by greater information exposure; (iii) the telegraph's effect on capital market integration was stronger when transaction and transportation costs were relatively low; (iv) nonlocal financial intermediaries, e.g., bank and *piaohao,* played an important part in integrating the capital market; and (v) the augmenting effect of the *piaohao* network on the telegraph's impact on capital market integration was only pronounced within firm boundaries.

This paper sheds new light on the Great Convergence in an era of globalization when modern information technology was introduced to agrarian societies such as China (Baldwin, 2016). Although the telegraph narrowed the gap between China and the West in capital market integration, such an impact was subject to institutional barriers such as personal financial intermediaries. Since capital market integration can foster economic growth by efficiently allocating capital surplus to the projects with the highest return (Gerschenkron, 1962; Goldsmith, 1962; Davis, 1965), the gap between China and the West in capital market integration may have partially contributed to the relatively slower growth rate of China in the first wave of globalization.

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Figures and tables

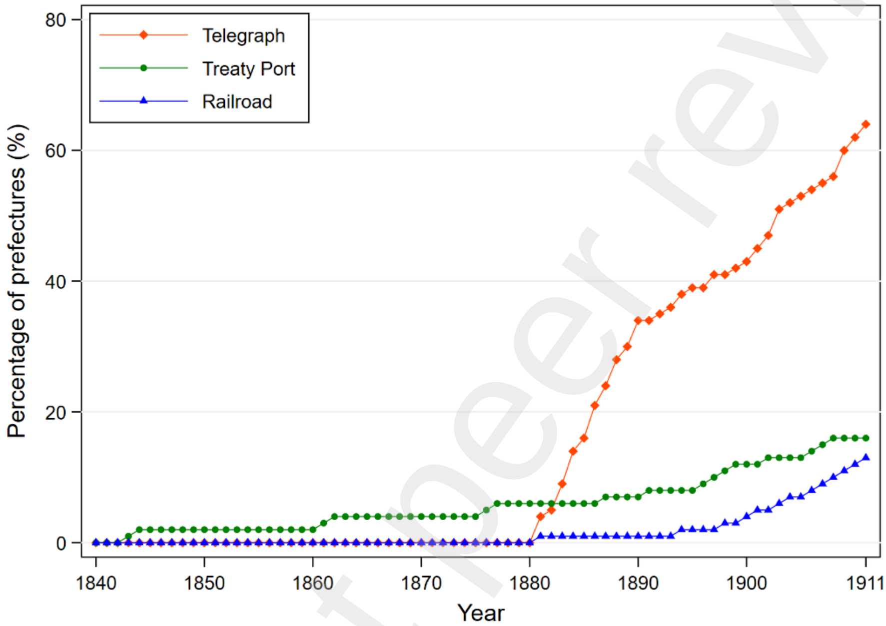


Figure 1: The spread of telegraph, treaty ports, and railroad in the late Qing period

Notes: See the text for data source. The square, point and triangle lines plot the percentage of prefectures with telegraph stations, the percentage of prefectures being treaty ports, and the percentage of prefectures connected via railroads, respectively.

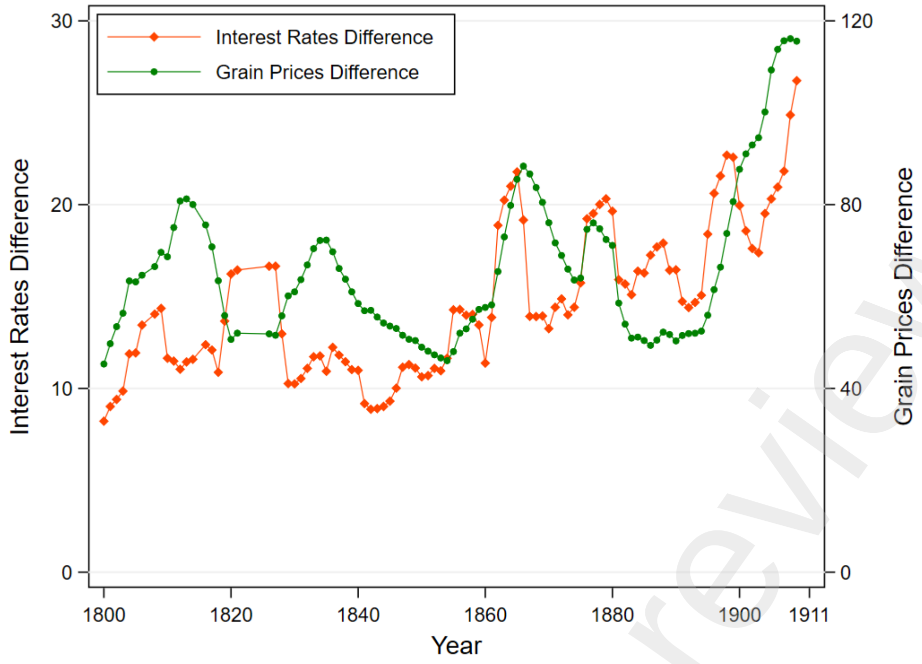


Figure 2: Interest rates difference and grain price difference

Notes: See the text for data source. The square lines and point lines plot the nationwide interest rates difference and grain prices difference across prefectures. The interest rates differences are calculated using grain price using the storage cost approach.

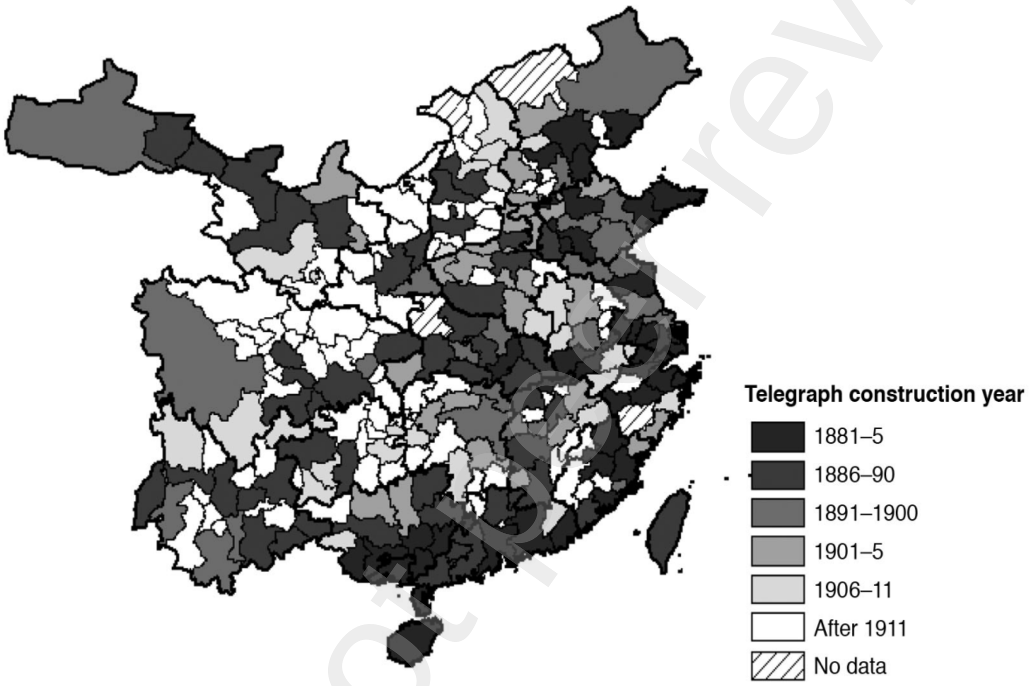


Figure 3: The evolution of telegraph in China proper, 1881-1911.

Source: Traffic History Compilation Committee, *Jiaotongshi Dianzhengbian*; local gazetteers.

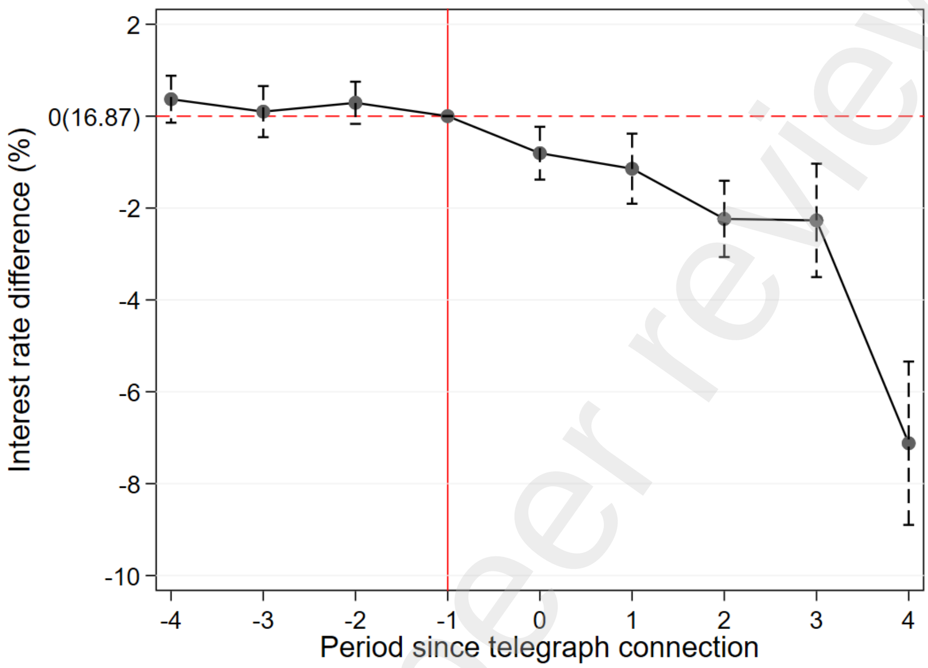


Figure 4: The dynamic impacts of telegraph connection on interest rate difference

Notes: Estimated coefficients and 95% confidence intervals from a regression of the absolute value of interest rate difference on the interactives of treat group dummy and event periods from -4 to 4. Generally, the span of one negative period and nonnegative period is respectively 45 years and 6 years (for example, $t = -1$ indicates 1-45 years before telegraph connection; $t = 1$ indicates 6-11 years after telegraph connection), except that $t = -4$ is 135 or more years before telegraph connection and $t = 4$ is 24 or more years after telegraph connection, which consider long-term effects. One period before the prefecture pair is connected through telegraph ($t = -1$) is the base period. The mean of absolute value of interest rate difference one period before telegraph connection is given in the parenthesis for reference.

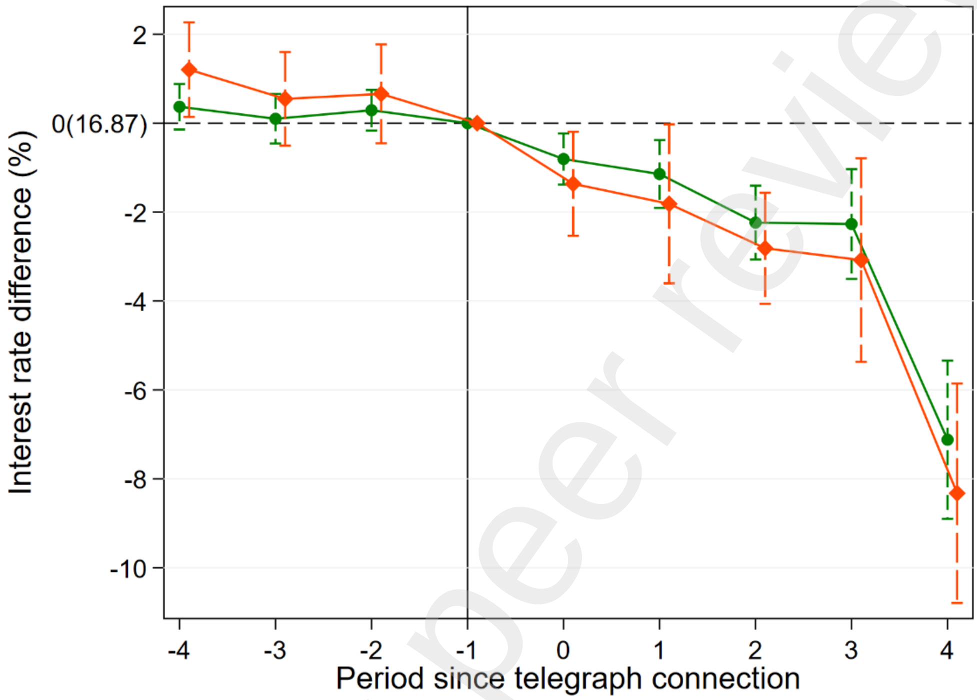


Figure5: The dynamic impacts of telegraph connection on interest rate difference-Cengiz et al. (2019) approach

Notes: Estimated coefficients and 95% confidence intervals from a regression of the absolute value of interest rate difference on the interactives of treat group dummy and event periods from −4 to 4. The circle lines and square lines plot standard TWFE estimates and the robust estimates in Cengiz et al. (2019). TWFE standard errors are clustered at the province-pair × grain level; standard errors in Cengiz et al. (2019) are two-way clustered at the province-pair × grain and dataset indicator level.

Table 1 Summary statistics

Variables	Mean	SD	Min	Max	N	Source
Sample A: prefecture pair × year						
Telegraph connection	0.046	0.209	0	1	1930956	1
Both *piaohao*	0.007	0.086	0	1	2159567	2
Both bank	0.002	0.045	0	1	2365595	3
Distance (100km)	8.635	5.922	0	49.59	2280132	4
Sample B: prefecture pair × grain × year						
Interest rate difference (%)	16.008	20.189	0	564.82	3186030	5,6,7
Grain price difference (%)	0.321	0.435	0	14.998	3186030	5
Sample C: prefecture × year						
Telegraph	0.081	0.272	0	1	33444	1
Waterway	0.177	0.382	0	1	35461	6
Railroad	0.006	0.080	0	1	35947	7
Rain	2.893	1.039	1	5	27475	8
Treaty port	0.042	0.201	0	1	35974	9
Qianzhuang	0.074	0.262	0	1	27149	3
Shangbang	0.621	0.485	0	1	26185	10
Information frequency in memorials	6.965	10.650	0	95	64141	11
Military info. frequency in memorial	0.481	1.904	0	16	53899	11
Information frequency in *Shen Bao*	105.724	280.750	0	2707	10296	12
News frequency in *Shen Bao*	44.593	93.702	0	681	10296	12
Advertisement frequency in *Shen Bao*	59.620	202.468	0	2015	10289	12
Outward conflicts (of decade)	0.079	0.501	0	8	44707	13
Taiping Rebellion	0.065	0.257	0	1	44707	14
Coast	0.134	0.304	0	1	44707	6
Province capital	0.065	0.246	0	1	44707	15
Official ratings	2.352	1.125	0	4	44707	16
Sample D: year						
Documented interest rates of China (%)	43.205	25.484	16	120	176	17
Documented interest rates of Shanghai (%)	6.597	2.570	1.095	12.41	40	18

Sources: 1: Traffic History Compilation Committee (1936); 2: Huang (2002); 3: Jiang (2014); 4: Playfair (1965); 5: Institute of Modern History, Academia Sinica (Taiwan) (2014); 6: Harvard Yenching Institution (2007); 7: Ma (1983); 8: State Meteorological Society (1981); 9: Yan (2012); 10: Liu et al. (2021); 11: The First Historical Archives of China; 12: The Green Apple Data Center (2010); 13: China's Military History Editorial Committee (2003); 14: National Defense University (2013); 15: Zhao (1998); 16: Bai and Jia (2016); 17: Tang (2016); 18: Financial Research Center of Shanghai Branch of The People's Bank of China (1978).

Table 2 Baseline results: the impact of telegraph on interest rate difference

	(1)	(2)
	|Interest rate difference|	
Telegraph connection	-1.386***	-1.603***
	(0.435)	(0.329)
Year FE	Yes	
Grain FE	Yes	
Prefecture-pair FE	Yes	Yes
Grain × Year FE		Yes
Adjusted R^2	0.131	0.232
N	3028170	3028163

Notes: Standard errors in parentheses are clustered at the province-pair × grain level. *significant at 10%; **significant at 5%; ***significant at 1%

Table 3 Robustness checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All Sample		Rice Price	Wheat Price	Before 1905	All Sample			CEM Sample
	|Interest rate difference|								
Telegraph connection	-1.603 (0.329)*** [0.585]***	-1.337 (0.310)*** [0.593]***	-1.169 (0.416)*** [0.769]	-2.649 (0.651)*** [1.113]***	-1.692 (0.336)*** [0.597]***	-1.610 (0.329)*** [0.577]***	-1.306 (0.284)*** [0.524]***	-1.61 (0.328)*** [0.576]***	-1.431 (0.330)*** [0.611]**
Grain price difference		8.887 (0.414)*** [1.591] ***							
Both railroad						0.628 (0.959) [1.445]			
Treat × Time trend							-0.005 (0.002)** [0.004]		
Nearby telegraph connection								0.147 (0.288) [0.483]	
Prefecture-pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Grain × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.232	0.259	0.215	0.184	0.230	0.232	0.232	0.232	0.232
N	3028163	3028163	1648691	966560	2890106	3028163	3028163	3028163	266909

Notes: Column 1 reports the baseline results as a reference. All columns except columns 3 and 4 use the prices of all types of grain to calculate interest rate; column 3 and 4 separately use rice prices and wheat prices to calculate interest rate. Column 5 drops the observations after 1904 to eliminate the potential impact of wireless telegraph. Column 9 only uses CEM sample. Standard errors reported in the parentheses are clustered at the province-pair × grain level; standard errors reported in the brackets are two-way clustered at the province-pair × grain and year level. *significant at 10%; **significant at 5%; ***significant at 1%

Table 4 Information mechanism: the impact of telegraph on information exposure

	(1)	(2)	(3)	(4)	(5)
	Memorial		*Shen Bao*		
	Total	Military	Total	News	Advertisement
	Information frequency				
Telegraph connection	0.867**	0.266***	86.139***	24.360***	60.812***
	(0.407)	(0.063)	(15.082)	(4.575)	(10.606)
Prefecture FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Mean	6.965	0.481	105.724	44.593	59.620
Adjusted R^2	0.560	0.251	0.776	0.799	0.731
N	63825	53623	10082	10083	10075

Notes: Columns 1 and 2 report the results of the memorial data; columns 3-5 report the results of the *Shen Bao* data. Observations that had an outlier number of information frequency (top 1% tail) were dropped. Standard errors in parentheses are clustered at the province × half-decade level. *significant at 10%; **significant at 5%; ***significant at 1%.

Table 5 Heterogeneity in transaction cost and transportation cost

	(1)	(2)	(3)
	|Interest rate difference|		
Telegraph connection	-1.575***	-1.212***	-1.467***
	(0.328)	(0.336)	(0.342)
Telegraph connection × Both treaty port	-3.294***		
	(0.846)		
Telegraph connection × Both waterway		-3.335***	
		(0.523)	
Telegraph connection × One-day journey			-0.960*
			(0.555)
Prefecture-pair FE	Yes	Yes	Yes
Grain × Year FE	Yes	Yes	Yes
Adjusted R^2	0.232	0.232	0.232
N	3028163	3028163	3028163

Notes: Standard errors in parentheses are clustered at the province-pair × grain level. *significant at 10%; **significant at 5%; ***significant at 1%.

Table 6 The role of financial intermediaries

	(1)	(2)	(3)	(4)
	|Interest rate difference|			
Telegraph connection	-1.584***	-1.587***	-1.579***	-1.512***
	(0.329)	(0.330)	(0.330)	(0.376)
Telegraph connection × Both bank	-1.846***			
	(0.655)			
Telegraph connection × Both *piaohao*		-0.922*		
		(0.543)		
Telegraph connection × Both *qianzhuang*			-1.251	
			(0.856)	
Telegraph connection × Both *shangbang*				-0.126
				(0.311)
Prefecture-pair FE	Yes	Yes	Yes	Yes
Grain × Year FE	Yes	Yes	Yes	Yes
Adjusted R^2	0.232	0.232	0.232	0.233
N	3028163	3028163	3028163	2934777

Notes: Standard errors in parentheses are clustered at the province-pair × grain level. *significant at 10%; **significant at 5%; ***significant at 1%.

Table 7 Personal p*iaohao* versus impersonal bank

	(1)	(2)	(3)	(4)
	Same firm of *piaohao*	Same guild of *piaohao*	Any *piaohao*	Any modern bank
	|Interest rate difference|			
Telegraph connection	-1.587***	-1.613***	-1.609***	-1.574***
	(0.330)	(0.331)	(0.332)	(0.330)
Telegraph connection	-0.922*	0.435	0.195	
× Both *piaohao*	(0.543)	(0.585)	(0.528)	
Telegraph connection				-2.265***
× Both bank				(0.633)
Prefecture-pair FE	Yes	Yes	Yes	Yes
Grain × Year FE	Yes	Yes	Yes	Yes
Adjusted R^2	0.232	0.232	0.232	0.232
N	3028163	3028163	3028163	3028163

Notes: Column 1 is for reference, where *piaohao* connection dummy equals 1 only when the prefecture pair is connected by the same firm of *piaohao*. In column 2, *piaohao* connection dummy equals 1 when the prefecture pair is connected by *piaohao* from the same guild; in column 3, *piaohao* connection dummy equals 1 as long as both prefectures have a branch of any *piaohao*. In column 4, bank connection dummy equals 1 when the prefecture pair is connected by bank branches from any bank. Standard errors in parentheses are clustered at the province-pair × grain level. *significant at 10%; **significant at 5%; ***significant at 1%.

Appendix

A. Supplementary Figures and Tables

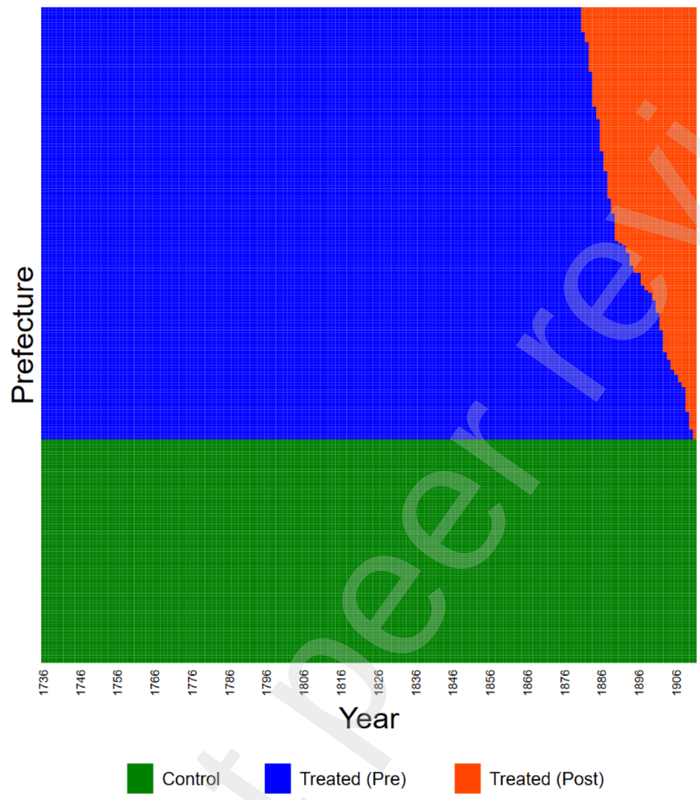


Figure A1: The yearly treatment status of prefectures

Notes: This figure shows the yearly treatment status of the prefectures in our sample. Each grid represents an observation of prefecture-year level.

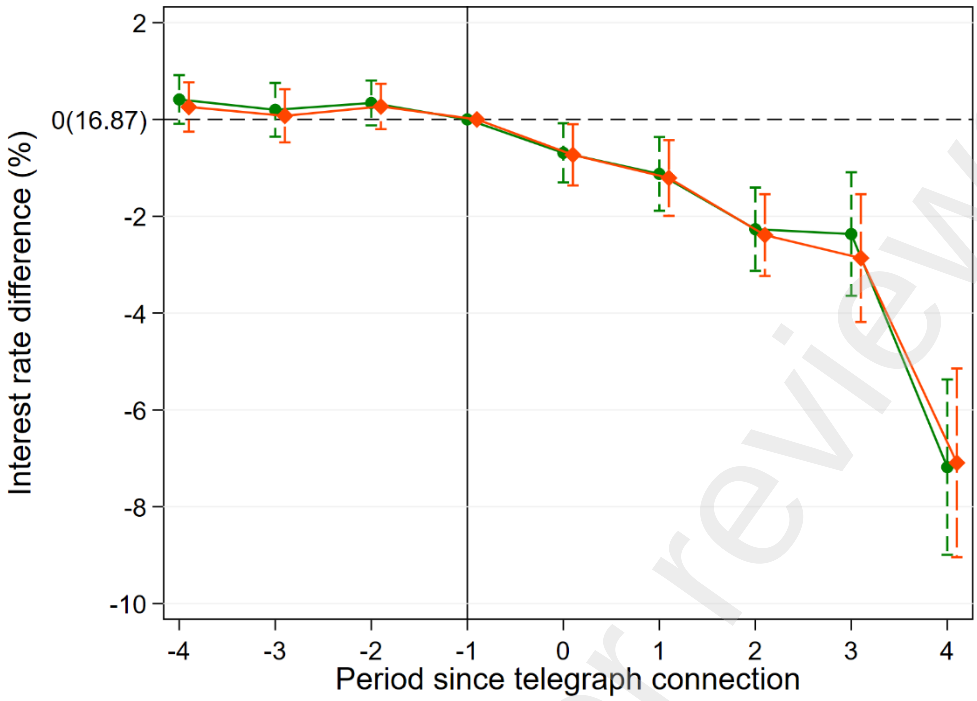


Figure A2: The dynamic impacts of telegraph connection on interest rate difference- CEM sample

Notes: Estimated coefficients and 95% confidence intervals from a regression of the absolute value of interest rate difference on the interactives of treat group dummy and event periods from -4 to 4. The circle lines and square lines plot the baseline results and the estimates when we use CEM sample.

Table A1 Spillover effect checks on different spatial scope

	(1)	(2)	(3)	(4)
	<=50km	<=100km	<=150km	<=200km
	|Interest rate difference|			
Telegraph connection	-1.600	-1.610	-1.590	-1.600
	(0.328) ***	(0.328) ***	(0.325) ***	(0.324) ***
	[0,583] ***	[0.576] ***	[0.572] ***	[0.574] ***
Nearby telegraph connection	-0.725	0.147	-0.105	-0.040
	(0.576)	(0.288)	(0.267)	(0.289)
	[1.218]	[0.483]	[0.391]	[0.424]
Prefecture-pair FE	Yes	Yes	Yes	Yes
Grain × Year FE	Yes	Yes	Yes	Yes
Adjusted R^2	0.232	0.232	0.232	0.232
N	3028163	3028163	3028163	3028163

Notes: The scopes of nearby prefectures are 50, 100, 150, and 200km from column 1 to column 4. Standard errors reported in the parentheses are clustered at the province-pair × grain level; standard errors reported in the brackets are two-way clustered at the province-pair × grain and year level. *significant at 10%; **significant at 5%; ***significant at 1%.

Table A2 Balance Checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Full sample				CEM sample			
	Control group	Treated group	Difference	L1 distance	Control group	Treated group	Difference	L1 distance
Outward conflicts	0.011	0.030	0.019***	0.015	0.020	0.020	0.001	0.003
(1 decade before)	(0.145)	(0.215)	(0.004)		(0.179)	(0.176)	(0.004)	
Outward conflicts	0.009	0.024	0.015***	0.015	0.004	0.004	0.000	0
(2 decades before)	(0.139)	(0.182)	(0.003)		(0.066)	(0.066)	(0.001)	
Outward conflicts	0.007	0.032	0.024***	0.022	0.010	0.010	0.000	0
(3 decades before)	(0.131)	(0.208)	(0.004)		(0.127)	(0.127)	(0.005)	
Outward conflicts	0.027	0.166	0.139***	0.066	0.087	0.089	0.001	0.001
(4+ decades before)	(0.279)	(0.732)	(0.013)		(0.451)	(0.455)	(0.018)	
Taiping Rebellion	0.051	0.259	0.208***	0.208	0.252	0.251	0.000	0
	(0.220)	(0.438)	(0.008)		(0.434)	(0.434)	(0.014)	
Coast	0.125	0.245	0.119***	0.119	0.233	0.233	0.000	0
	(0.331)	(0.430)	(0.008)		(0.423)	(0.423)	(0.010)	
Province capital	0.060	0.125	0.065***	0.065	0.116	0.116	0.000	0
	(0.238)	(0.331)	(0.006)		(0.321)	(0.321)	(0.010)	
Political	2.325	2.718	0.392***	0.160	2.721	2.709	-0.012	0.012
importance	(1.128)	(1.010)	(0.019)		(0.992)	(1.019)	(0.029)	
N	41641	3066	44707	44707	41056	2938	43994	43994

Notes: This table reports the balance checks of our treatment and control sample. The results in columns 1–4 use the full sample, whereas those in columns 5–8 use the CEM sample. Smaller L1 distance represents that the treatment and control sample are more balanced.

B. The Storage Cost Approach (SCA) of Calculating Interest Rates

B1. The Outline of the SCA

The core idea of the SCA is that we can derive the interest rate in a specific region and year from the slope of the grain price change over the harvesting cycle. The slope is informative because the equilibrium of storage level requires that the price change offsets the opportunity costs of storing grain, which include the interest rate. The SCA is theoretically founded in asset pricing (Working, 1933, 1949; Kaldor, 1939) and in the analysis of commodity storage (Hotelling, 1931; Williams and Wright, 1991), and has been widely employed in empirical studies (e.g., McCloskey and Nash, 1984; Taub, 1987; Pomeranz, 1993; Brunt and Cannon, 1999, 2009; Clark, 2001; Shiue, 2002).

Since Keller et al. (2020) validated the SCA by showing the similarity between bank interest rates and interest rates calculated using grain prices in the 19th United States, more recent literature has been using this approach in their empirical researches to analyze *the capital market in China.* (e.g., Keller et al., 2021; Keller and Shiue, 2021). We give an outline of the SCA in the following, with more details given in Keller et al. (2020, 2021).

Consider a merchant in region i at time t can purchase Q_{it} units of grain from a farmer at price P_{it}. The grain can be stored for one period and sold at time $t+1$ at price P_{it+1}. Otherwise, she can invest in a risk-free asset with the rate of return at time $t+1$ equal to ρ_{it}. The merchant and farmer would make a contract on P_{it} and F^j_{it}, where F^j_{it} is the price at which the farmer buys back the grain from the merchant in transaction j. The resale price F^j_{it} depends on the costs and benefits of grain storage.

For the merchant there were two types of costs. First, there is the opportunity cost induced by a risk-inclusive interest rate r^j_{it}, where $r^j_{it} \geq \rho_{it}$. It captures the fact that no interest will be earned if the merchant stores the grain for one period and that the grain market between t and $t+1$ may not perform as expected. Second, the per-unit storage costs caused by spoilage are denoted as c_{it}. In addition, holding grain gives the merchant a convenience yield, denoted by b_{it} per-unit.

In the clearing of grain storage market, if capital moves freely between grain storage market and capital market, the cost and benefit must equalize:

$$F_{it}^{j} - P_{it} + P_{it}b_{it} = P_{it}(r_{it}^{j} + c_{it}),\ \forall i,t,j$$

So, the price F_{it}^{j} has to be:

$$F_{it}^{j} = P_{it}(1 + r_{it}^{j} + c_{it} - b_{it}),\ \forall i,t,j \qquad \text{(B1)}$$

To apply this approach empirically we make some assumptions. First, we use the average level of risk, r_{it} (with $r_{it} > \rho_{it}$) because we do not observe the transaction-specific risk for each contract, r_{it}^{j}. Second, we let $F_{it}^{j} = P_{it+1}$ as we do not observe the price F_{it}^{j}. Finally, we assume that b_{it} equals zero.

With the assumptions above, equation (B1) can be converted to

$$\hat{p}_{it} \equiv \frac{P_{it+1} - P_{it}}{P_{it}} = r_{it} + c_{it},\ \forall i,t \qquad \text{(B2)}$$

Equation (B2) shows that in a storage equilibrium the slope of grain movement equals the sum of the risk-inclusive interest rate r_{it} and grain-specific storage costs c_{it}. The term $\hat{p}_{it}$ refers to the **carry benefit of grain**, which should be equal to the **carry cost of grain** in the equilibrium.

To derive interest rate, one has to deduct storage cost from price rise. Given that one cannot directly observe storage costs across regions and time, Keller et al. (2021) develop a regression approach to purge trade-related and weather-related costs from carrying costs. Specifically, assume that storage costs largely depend on climate (measured by rainfall) and access to interregional trade (measured by waterway access to river, canal, and coast):

$$c_{it} = \beta_0 + \beta_1 climate_{it} + \beta_2 trade_i + u_{it}$$

Together with equation (B2):

$$r_{it} = \hat{p}_{it} - c_{it} = \hat{p}_{it} - \beta_0 - \beta_1 climate_{it} - \beta_2 trade_i - u_{it},\ \forall i,t \qquad \text{(B3)}$$

Estimating equation (B3) using monthly grain price data yields interest rates.

It is crucial to notice that the storage approach only applies to the price change during storage months. After a harvest, grain price started to fall. But storage won't take place until the price reaches the bottom when merchants start to buy in grain and store. As demand rises and supply falls, grain price rises. In a place with higher interest rate, the rise in grain price must be greater to offset the opportunity cost of buying and storing. Merchants will gradually sell grain until the next harvest when grain price started to fall. In a nutshell, only during storage months can one estimate underlying interest rates.

In this paper, we use code provided by Keller et al. (2021) and the procedures can be summarized as follows:

(1) Take monthly grain price data for a specific region *i* and apply time-series filter such as Butterworth (1930).

(2) Compute mean of one-month differences during storage months for each calendar year with equation (B2), under certain assumption on storage months and with adjustment for missing values and lower quality data. These yield carrying costs for region *i* and year *t.*

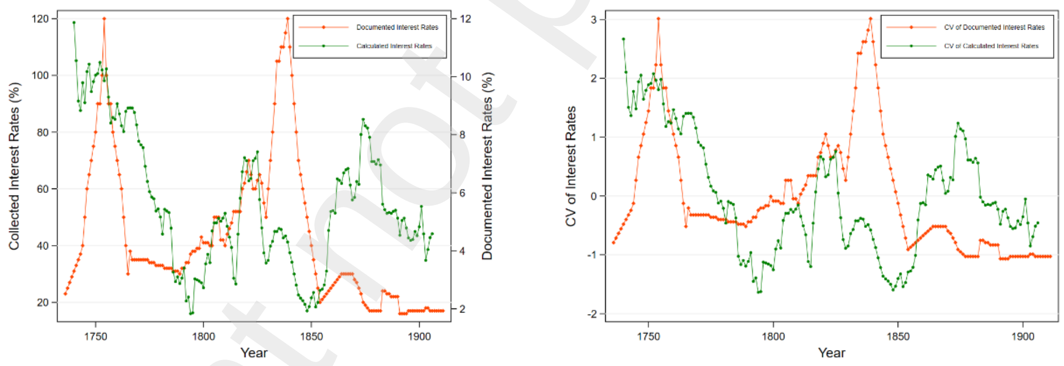
(3) Use equation (B3), to purge trade-related and weather-related costs from carrying costs. These give estimated interest rates for region i and year t.

B2. The Validation of the SCA in the Qing Dynasty

Although the SCA has been validated with the historical data from the United States (Keller et al., 2020), and used in the recent empirical studies of the Qing dynasty (Keller et al., 2021; Keller and Shiue, 2021), we further validate the SCA in the Qing dynasty by showing (i) the high correlation between the calculated interest rates and the documented interest rates collected from different historical sources, and (ii) the significant difference between the calculated interest rates (capital market) and the grain prices (commodity market).

B2.1. Correlation between the Calculated Interest Rates and the Documented Interest Rates

We first collect the data of documented historical interest rates from Tang (2016) and *Shanghai Qianzhuang Shiliao* (Historical Materials of the Money shops in Shanghai). The former contains the ten-year moving average of the interest rates in China from 1736 to 1911, and the latter compiles the annual average interest rates in Shanghai from 1872 to 1911. Figure B1 shows a similar dynamic pattern between the calculated interest rates and the documented interest rates, which suggests that our calculated interest rates are good proxies of the real interest rates.



Panel a Panel b

Figure B1: The calculated interest rates and observed interest rates

Notes: See the text for data source. This figure compares the annual calculated interest rates with the annual collected interest rates at the national average level. The square lines and circle lines plot documented interest rates and calculated interest rates. Ten-year moving average interest rates are used in accordance with Tang (2016). The panel a show the results of the interest rates; the panel b shows the results of the coefficient of variation of the interest rates.

Their positive correlation remains when we conduct a formal empirical test. Table B1 shows significantly positive correlations between the calculated and the documented interest rates either in China or in Shanghai. Thus, these findings ensure that we can use the SCA to calculate the interest rates in the Qing dynasty.

Table B1 Calculated interest rates and documented interest rates

	(1)	(2)	(3)	(4)
	China		Shanghai	
	Documented interest rate			
Calculated interest rate	1.812**	0.0166**	0.066**	0.310**
	(0.854)	(0.078)	(0.032)	(0.149)
Adjusted R^2	0.027	0.027	0.091	0.091
N	167	167	37	37

Notes: This table reports the correlations between the calculated interest rates and the documented interest rates in China (1736-1911, column 1 and 2) and in Shanghai (1872-1911, column 3 and 4). The column 1 and 3 show the results of the interest rates; the column 2 and 4 show the results of the coefficient of variation of the interest rates. Robust standard errors are reported in the parentheses. *significant at 10%; **significant at 5%; ***significant at 1%.

B2.2. Comparison of Interest Rates and Grain Prices

Existing literature has shown that the performances of capital market and the commodity market in a specific region can be different. For example, Shiue and Keller (2007) find a small gap in the integration of commodity markets (measured by grain price) between China and Western Europe, while Keller et al. (2021) find a sizable gap in capital market integration (measured by interest rates calculated with grain prices) between them.

We further certify the difference between the grain prices and the interest rates calculated with grain price. Figure B2 provides the suggestive evidence on the different dynamic trends between the interest rates and the grain prices. We then regress the interest rate (difference) on the grain price (difference). Table B2 reveals that there are no significant correlations between the interest rate (difference) and the grain price (difference).

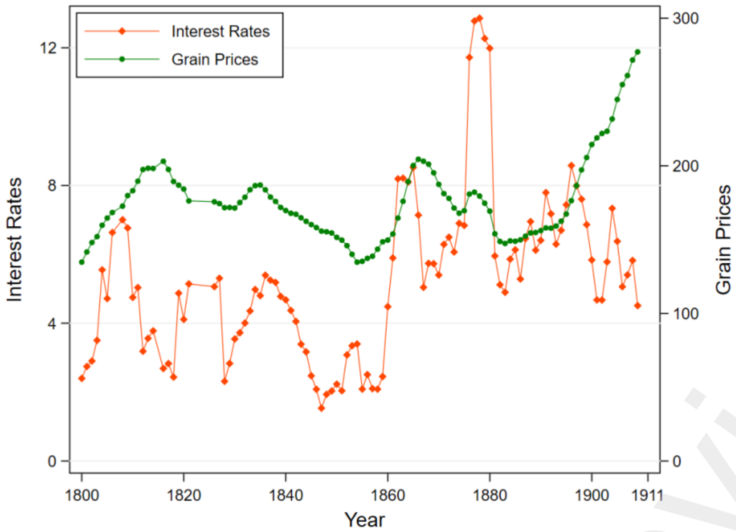


Figure B2: The comparison of calculated interest rates and grain prices

Notes: See the text for data source. The square lines and circle lines plot the trend of the calculated interest rates and the trend of the grain prices. Five-year moving averages are used to smooth the fluctuations.

Table B2 Interest rates and grain prices

	(1)	(2)	(3)	(4)
	Interest rate		Interest rate difference	
Grain price	-0.002	0.004		
	(0.006)	(0.006)		
Grain price difference			0.002	-0.001
			(0.002)	(0.002)
Prefecture (pair) FE	Yes	Yes	Yes	Yes
Grain × Year FE	Yes	Yes	Yes	Yes
Adjusted R^2	0.130	0.134	0.081	0..085
N	84217	79786	3199935	3031413

Notes: This table compares the calculated interest rates and grain prices. Column 1 and 2 report the correlations between interest rates and grain price; column 3 and 4 report the correlations between interest rate difference and grain price difference. Prefecture fixed effects are controlled in column 1 and 2, and prefecture-pair fixed effects are controlled in column 3 and 4. All the columns control grain × year fixed effects. Column 1 and 3 drop the two-tailed 2.5% outliers of the dependent variables; column 2 and 4 drop the two-tailed 5% outliers of the dependent variables. Standard errors are clustered at the province level in column 1 and 2, and at the province-pair level in column 3 and 4. *significant at 10%; **significant at 5%; ***significant at 1%.

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