Selective Technology Importation and the Convergence in the Late Qing Dynasty: Evidence from Wired Telegraph

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Abstract: *Using the adoption and expansion of wired telegraph in China during the late 19th century, this paper investigates the effect of cost reductions for knowledge exchange on China's industrial growth before the outbreak of the War of Resistance Against Japanese Aggression (1931-1945), thus testing Baldwin's theory of "the Great Convergence" in which developing countries are empowered by information and communication technologies. Based on panel data of 1858-1937, we found that wired telegraph access had a significantly positive effect, as well as a long-term growth effect, on the entry of industrial enterprises. Our mechanism analysis indicates that wired telegraph access accelerated early-stage industrialization in localities by encouraging market integration, human capital accumulation, and auxiliary commercial organizations. Only a few countries firmly asserted their telegraph sovereignty and set up their own workforce educational system during telegraph adoption. This explains why the Great Convergence arising from technology importation only occurred in a small number of countries. Our findings contribute to understanding the source of China's modern industrial progress, as well as why global inequities remain.*

Keywords: *wired telegraph, entry of industrial enterprises, the Great Convergence, human capital*

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1. Introduction

Economic historians have long debated "the Great Divergence" and "the Great Convergence" that occurred in global economic development, particularly between the East and West (Pomeranz, 2000; Brandt et al., 2014). Existing research has discussed the causes of the Great Divergence in terms of factor endowment allocation (Allen, 2009) and institutional structure (Ma, 2020), with less attention to the Great Convergence. Baldwin (2016) posited that the three-tiered cost constraints of commodity trade, information transmission, and human mobility, driven by technological advancements that reduce transaction costs, are crucial factors shaping "the Great Divergence" and "the Great Convergence".[1] According to him, the information technology revolution that began in the 1980s combined low labor

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[1] Baldwin (2016) posited that the geographical relationship between production and consumption had been unwound as a result of the First Industrial Revolution. Because the cost of intellectual exchange remained constant, industrial innovation was limited to the developed world, resulting in the Great Divergence. However, as information and communication technologies (ICTs) advanced, knowledge spread, resulting in "the Great Convergence" of certain countries (such as China). We are now faced with the third constraint, namely the cost of the flow of people.

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costs with high technology, thereby stimulating rapid industrialization in some developing countries (Great Convergence). However, there still lacks effective explanations why the Great Convergence has occurred in just a few developing nations. This paper attempts to study China's Great Convergence from the perspective of selective technology importation, aiming to provide academic annotations for this issue.

China provides an important and distinctive case study for late-movers seeking to capitalize on the Great Convergence by importing and deploying new technology. China's nominal GDP accounted for 18% of the world total in 2022, which is close to its proportion during the Great Divergence in 1840[2]. China completed its shift from the Great Divergence to the Great Convergence over a 180-year period of economic development. In terms of trends, China has experienced two significant rounds of the Great Convergence. The first one lasted from the start of the Self-Strengthening Movement (1860s to 1890s) to the eve of the War of Resistance Against Japanese Aggression (1931-1945), which Rawski (1986) referred to as "China's prewar economic growth". The second one occurred after the reform and opening up started in 1978, corresponding to China's rapid economic growth, which has been referred to as "China's economic growth miracle" by Justin Yifu Lin (1999). Numerous literature has explored the sources of this "economic growth miracle", with representative explanations including "growing out of the plan" (Norton, 1996) and "championship for promotions" (Zhou, 2007).

However, these two "Great Convergences" occurred during distinctive historical circumstances. During the first Great Convergence, China had very weak national strength and industrial fundamentals, and barely any modern science and educational systems. Its economic development was frequently disrupted by wars and turmoils. Some literature studied China's early-stage industrial growth from various angles, including transportation improvements (Liang, 2015), trade openness (Jia, 2014; Yang et al., 2023), the spread of Protestant knowledge (Bai and Kung, 2014), the abolition of the imperial exam system (Bai and Jia, 2016), and military investment (Bo et al., 2023). In this paper, we expect to extend Baldwin's (2016) theory forward to the early stages of the communications technology revolution, with a focus on measuring the impact of the Qing government's ((1840-1912) proactive and selective access to and expansion of the wired telegraph network on China's early industrialization. This research design is advantageous in at least two aspects. First, the wired telegraph represents an initial transition from traditional to modern means of communication, thereby avoiding the confusion of multiple communication technologies. Second, China's introduction of wired telegraph technology is relatively exogenous.

In ancient China, official information was delivered by a network of relay courier stations, while private messages were generally sent along with freight transportation, the carriers of which included horses, camels, and boats. Information transmission was time-consuming and susceptible to adverse weather and other uncertainties. Since the 1840s, frequent internal strife and external invasions raised concerns among some officials about the value of timely communication of military information to national security. Between 1879 and 1904, 147 Chinese prefectures were connected to the telegraph network (Wang, 1988). The installation of a telegraph network, while initially intended to improve national security, had significant spillover effects on other industrial sectors. First, the construction of the telegraph network introduced Western engineers, establishment of telegraph schools, and translation of electrical engineering textbooks, all of which accelerated the influx of modern science and technology from the West. Second, the telegraph network was predominantly utilized for commercial purposes, which facilitated information transmission between enterprises as well as market integration.

As such, we sorted out the new data of China's industrial sectors from 1858 to 1937 in order to assess the effect of telegraph network expansion on industrial growth and to explain how the

[2] Liu (2009) estimated that China accounted for less than 1/5 of the global GDP in 1840.

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communications technology revolution pushed modern China into a brief and weak "the Great Convergence" with the Western world. Using a staggered DID identification approach based on panel data of China's modern industrial enterprises with telegraph access, we discovered a 5.7% increase in the entry of enterprises in the prefectures with telegraph network access. Our event study results confirmed a similar trend, revealing that the treatment effect was modest during the early stages of telegraph construction, but increased gradually over time. Based on recent concerns about the "bad control group" in staggered DID, we presented event study results with multiple alternative estimators that yielded consistent conclusions.

We also investigated the channels via which the early-stage communications technology revolution spurred the growth of modern industrial enterprises. Based on Wang Yejian's grain price database of the Qing Dynasty (1616-1912), the telegraph network improved commercial information transmission, which helped reduce commodity price volatility and promote market integration. Price stability in a market based on the supply-demand relationship, as well as the formation of a unified market, would foster the development of modern industrial enterprises. We also looked at other continuous growth mechanisms frequently mentioned in the literature, such as human capital accumulation and the development of commercial organizations and financial markets. Our research discovered that access to the telegraph network stimulated human capital accumulation in science and specialized technology, as well as the creation of commercial organizations and modern banks represented by chambers of commerce. Human capital accumulation mechanism not only addresses the conditions that unleashed "the Great Convergence" posited by Baldwin's (2016), namely, access to wired telegraph reduced the cost for Western science and technology to be introduced and widely disseminated in China, but it also explains why the Great Convergence occurred only in a few developing countries.

This paper's marginal contributions might include: First, it empirically verified Baldwin's (2016) theory that advances in communications technology could catapult a few developing countries into "the Great Convergence". In reality, the majority of developing countries did not experience the Great Convergence. By 2021, the Group of Seven (G7) accounted for 44% of the global economy, with only a few emerging economies showing signs of convergence. As a result, understanding the mechanism of the Great Convergence in its early stage can shed insight on the causes of persistent global inequalities. Second, this paper adds to the academic literature on early industrialization in modern China. While most previous research has focused on military investment, trade openness, and the abolition of the imperial civil service exam system, this paper emphasizes the role of communications technology in lowering the cost of knowledge flow and advancing early-stage industrialization through its effect on industrial enterprise site selection. Third, this paper examines the underlying process by which access to communication infrastructure fosters long-term industrial growth through three channels: market integration, the formation of commercial organizations and bank subsidiaries, and human capital accumulation.

2. Research Background

2.1 Introduction and Expansion of Wired Telegraph

In ancient China, the central and local governments relied on an efficient network of courier stations for political communications, and the speed of correspondence was determined by the level of emergency. According to Stephen (2015), this network of information transmission was still more advanced than most countries up until 1800. By the 1850s, however, institutional corruption had seriously weakened the capacity of this national communications infrastructure. The purpose of courier stations was limited to the transmission of official information, which was conducted without adequate monitoring. As a result, authorities routinely embezzled courier stations' special funds and subtracted messenger supplies and courier horse feed (Editorial Office of Postal and Telecom History, 1984). Furthermore, the sweeping Taiping Heavenly Kingdom Movement (1851-1864) destroyed roads, canals,

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and courier stations, which further damaged the courier station network's transmission efficiency. The average time it took to send a memorial from Guangzhou to Beijing increased from 32 days in 1838 to 55 days in 1861, while official communications from Guiyang to Beijing took 117 days with a reply message expected in more than 7.5 months (Yoon, 2008). "Documents were arbitrarily delayed", claimed Feng Guifen, a famous Chinese philosopher. "Only after a certain amount had accumulated would a groom be sent to deliver them. Documents were frequently delayed for more than ten days over distances as short as a few hundred miles". (Editorial Office of Postal and Telecom History, 1984)

In 1844, American inventor Samuel Morse built a telegraph line and sent the first telegraph message between Washington and Baltimore. This invention radically changed long-distance communications. Human communication has entered the era of photoelectric transmission from the era of acoustic-physical transmission (Xia, 2012). However, the spread of wired telegraphs was not without obstacles. With the construction of the first underwater cable between Hong Kong and Shanghai in 1871, external information could be quickly communicated to concessions in Shanghai. Unfortunately, the Qing Dynasty government refused to permit the construction of land lines, citing a variety of plausible reasons. For example, it was concerned that the telegraph might facilitate political and economic infiltrations by foreign powers, disturb the landscape, or *Fengshui*, and fuel social unrest. For example, Chen Yi, the Ministry of Works' supervising secretary, wrote a memorial noting that "the installation of electric wires goes deep underground and runs through in all directions. With this, the earth's veins are severed. Wind and water will eventually intrude. How can folks who are concerned about their descendants feel at ease?" (Chinese Historical Association, 2000). With Western powers' increasingly frequent invasions of China's coastline and border regions after the 1870s, Qing government officials began to recognize the importance of telegraph in updating border situations, transmitting military information, and strengthening national security. In dealing with the Taiwan Strait crisis of 1874, Shen Baozhen, a Qing government bureaucrat, suggested that a telegraph line be set up between Fuzhou and Taiwan, which did not materialize due to popular opposition. This instance shows how the Qing administration began to accept telegraph technology. In 1879, the first telegraph line on the Chinese mainland was completed between Tianjin and Dagu Fortress, allowing for swift exchange of time-sensitive military information during China-Russia border conflict negotiations. The construction of a long-distance telegraph link between Shanghai and Tianjin, which was sanctioned at the request of Viceroy Li Hongzhang, enabled external information to be instantly delivered to Tianjin and relayed to Beijing. Over the subsequent two decades, the late Qing Dynasty's government rapidly built telegraph lines across the country. By 1911, the coverage of telegraph service was extended to 176 prefectures in China, accounting for 64.5% of all prefectures. By the time of the sample period in this paper, the majority of prefectures in China had access to telegraph.

The mode of telegraph access in the late Qing Dynasty allows us to investigate how communications technology facilitated early-stage industrialization. First, the adoption of telegraph technology and the expansion of the telegraph network were driven by wartime demands rather than endogenous to economic development in modern China. Viceroy Li Hongzhang, for example, requested the installation of the first cross-provincial Beijing-Shanghai telegraph line in 1880, emphasizing the necessity of telegraphy in modern warfare. "In the art of war, swiftness is of utmost importance". In addition to rifles and cannons, Western nations were able to deploy their troops at incredible speeds using ships and trains. Military communications spanned tens of thousands of kilometers of ocean (Chinese Historical Association, 2000). On the eve of the Sino-French war, the Office of Foreign Affairs sent a message to Viceroy Li Hongzhang, requesting that he connect the capital Beijing to telegraph due to serious border and coastline defense situations. "Telegraph is relied upon for the dispatch of troops to avoid delays in military operations" (Chinese Historical Association, 2000). Second, even if the construction of one telegraph line was put on the agenda, it was impossible to predict when each station would be connected to the telegraph network (Baark, 1997). The line could be suspended or opened in sections according

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to the needs of the war. In his report to He Jing, Governor-General of Fujian and Zhejiang provinces, in 1883, Sheng Xuanhuai stated: "If circumstances emerge at the southern border, I'm concerned that electricians will need to be dispatched to operate on different routes. Now, I've pushed for material procurement". ("Institute of Modern History, Academia Sinica", 1957). Finally, the government controlled the planning and installation of telegraph lines, with commercial groups having minimal say in routing design; as a result, political centers such as provincial capitals were frequently connected along straight lines (Yoon, 2008). Aside from key political centers and frontier cities, cities between two sites on a telegraph line could be chosen at random.

2.2 Early-stage Great Convergence

Driven by the First Industrial Revolution, the Western civilization overtook the East Asian civilization in the late 18th and early 19th centuries, eclipsing its long-held economic preeminence. Economic historians refer to this phenomenon as "the Great Divergence". In recent decades, however, such divergence has begun to reverse for the first time in nearly two centuries. As of 2021, the G7 countries' proportion of world GDP has fallen to less than 44.6%, similar to their early 20th century level. Almost all of the lost share was transferred to newly industrialized nations. Baldwin (2016) described this phenomenon as "the Great Convergence". For some countries, the Great Convergence occurred shortly after the Great Divergence. For instance, Japan enjoyed an economic boom during the Meiji Restoration, accounting for 4% of global GDP as the sixth largest economy in the world on the eve of World War II. Most scholars believed that contemporary China had been trapped in a protracted period of stagnation due to foreign invasion and persistent conflicts. Contrary to this view, Rawski (1986) discovered, based on extensive historical data and comparative research, that China approached the levels of industrialized nations such as Japan and the Soviet Union in terms of the speed of manufacturing development and achieved a certain level of economic growth preceding the War Against Japanese Aggression (1931-1945). Structure-wise, China's manufacturing industry was neither dependent on international market demand nor controlled by foreign capital; around three-quarters of the industry was still owned by Chinese private entrepreneurs (Rawski, 1986). These evidence indicate that modern China had already experienced a brief and modest wave of convergence.

2.3 Wired Telegraph Technology and Modern Industrial Enterprises

Prior to the adoption of wired telegraph, self-sufficient smallholder economy and small-scale artisanal industry were the predominant forms of economic organization in modern China. After the two opium wars, China was forced to open a few treaty ports, but most of its regions were barren of advanced science and technology, philosophy, and industrial goods. To some extent, such isolation came to an end as a result of the Self-strengthening Movement (1861-1895) and the development of modern industry and wired telegraph network. The self-strengtheners called for "learning from the advanced technologies in the West in order to resist the invasion of the Western powers". Adopting modern Western industrial technology, they created 35 military-industrial enterprises, which exerted a major spillover effect on the subsequent growth of industrial enterprises (Bo et al., 2023). Unlike other developing countries, Chinese self-strengtheners took firm control of telegraph interests and human resources, following a similar mode in establishing its military industry. In comparison, Western colonialists built telegraph networks and monopolized telegraph equipment and technicians in India and Africa, using wired telegraph communications to increase colonial exploitation (Beauchamp, 2008). As another legacy of the Self-strengthening Movement, the selective importation of wired telegraph technology could influence the siting of industrial enterprises via various channels.

First, wired telegraph considerably reduced the cost of sharing information, which is important both internationally and domestically. On a global scale, the Great Divergence between the East and West that followed Europe's technological and industrial revolutions is largely attributed to

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geographical limits and self-seclusion policies (Pomeranz, 2000; Baldwin, 2016). In the modern era, China's access to telegraph allowed for more efficient and extensive understanding of the Western world. Telegraphy symbolizes a reversal in the Great Divergence between the East and West, which had lasted two centuries, by facilitating the accumulation of advanced scientific knowledge, hence creating intellectual and technological conditions for the early-stage Great Convergence. At home, telegraphy ended the Qing government's monopoly on the information transmission network, which facilitated faster and cheaper commercial information communication and market integration (Lin et al., 2021; Gao and Lei, 2021; Hao et al., 2022). The establishment of a unified market ensured the price stability of raw materials, allowing firms to respond quickly to price volatility. Jing Yuanshan, a renowned industrialist from the gentry class in the late Qing Dynasty, commented on the benefits of telegraph: "without telegraph installations, it would be too difficult to ask whether goods such as coal and steel distributed to various treaty ports are in undersupply or oversupply and too late to increase or reduce supplies accordingly" (Yu, 2011). Flour mills, a representative national industry in modern China, used telegraph to transmit wheat price changes. For example, Fuxin Flour Mill, founded by renowned industrialists Rong Desheng and Rong Zongjing, known as the "Rong Brothers", frequently communicated with wheat shops across the country via telegraph: "local wheat shops all followed the instructions of the Shanghai headquarters' wheat division on the price, quantity, and timing of wheat purchase". "If the price of wheat flour was preferential, a buy order would be sent by telegraph; if the price of wheat flour was unfavorable, or if the intention was to bring down wheat price, a stop purchase order would be sent by telegraph (Economic History Group of the Institute of Economics at the Shanghai Academy of Social Sciences, 1962)". Obviously, telegraphs became a key managerial tool for organizations in modern China.

Second, the Qing Dynasty government accumulated human capital by sending overseas students and building schools as wired telegraph expanded. In addition to emphasizing telegraph sovereignty, self-strengtheners placed a high value on cultivating local talent throughout the creation of telegraph networks. Altogether, they opened six telegraph academies, accounting for one-fifth of all Western academies in the country. According to Xia (2012), the Qing Dynasty government constructed at least 10 telegraph academies before its fall, and some comprehensive academies offered electronics and telegraphy majors. These early academies translated Western theories of electricity, cultivated talent in the field of electrical engineering, and accelerated the development of vocational education in modern China, providing industrial enterprises with a qualified workforce. Furthermore, the Qing Dynasty government dispatched 120 students to the United States in four waves, and at least 23 of the 94 returnees had attended a telegraph academy or worked in telegraphy. Many of them made significant contributions to modern Chinese education. For example, Cai Shaoji became president of Beiyang University (now Tianjin University), while Fang Boliang became superintendent of Tangshan Railway Academy (now Southwest Jiaotong University).

Finally, wired telegraph increased the service margins of commercial organizations and banks, facilitating the growth of modern industrial enterprises. Wired telegraph improved the environment for bank development in at least three ways: First, prompt information transmission reduced the uncertainty in cross-regional financial markets. According to historical information about merchants from Shanxi Province, money shops used telegraph to share information: "When the flow of money was stable, associated money shops were informed by correspondence", and in case of a sudden change in market situations, various branches were notified by emergency correspondence"; after telegraphy was established, "such notification were sent by telegraph" (Research Institute of Shanxi Merchants, Shanxi University of Finance, 2008). Second, telegraphy improved information interchange and business interactions between the bank's headquarters and its local offices. If a money shop had a bank run, "upon receiving the telegraph message, all other money shops promptly pooled an enormous sum of money to cover any shortfall". (Research Institute of Shanxi Merchants, Shanxi University of Finance,

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2008). Third, telegraphy addressed principal-agent issues in bank management. The Imperial Bank of China, China's first bank, prescribed the following rules in its Constitution: "If a payment made by a branch bank to the head office does not exceed 100,000 taels, such fund may be withdrawn upon the branch bank's discretion; if it exceeds 100,000 taels, the branch bank shall consult the head office by telegraph for its consideration". To avoid inefficient competition, the Constitution requires branch banks to evaluate market conditions and take care of one another in their money order business. "For large transactions, they must consult the head office by telegraph to avoid a squeeze" (Xie, 2016).

3. Data and Descriptive Statistics

In this study, multiple historical datasets are used to investigate how the phased deployment of wired telegraphy in the late Qing Dynasty (1840-1911) influenced the entry of industrial enterprises in modern China. Our outcome variable is the entry of industrial enterprises in each prefecture, as measured by the number of newly founded industrial enterprises. We obtained a list of newly founded enterprises in each prefecture between 1857 and 1937 from Du Xuncheng (2014, 2019). These two monographs provide extensive and reliable data on the registration information of national capitalist enterprises in modern China. This data collection includes the date of founding, name, location, type of ownership (commercial, government-run, or government-supervised commercial enterprises), and registered capital of large enterprises from 1857 to 1937. The registered capital of industrial, mining and shipping enterprises all exceeded 10,000 yuan, while that of new financial enterprises all exceeded 50,000 yuan. Based on this data collection, we calculated the number of new enterprises at the prefecture and year levels.

Our core explanatory variable is the connection to wired telegraph in each prefecture. The location and connection time of each telegraph line were determined with three separate data sources. To begin, we conducted a cross-verification using the *Postal Album of the Great Qing*, compiled by the Statistical Department of the Imperial Maritime Customs Service, and the *Postal, Telecom, and Aviation Histories of China*, written by Xie Bin, to outline the basic framework of China's telecom network at that time. Second, we obtained the launch dates for each telegraph line in China from Wang Ermin's paper, "Sheng Xuanhuai and Telegraph Operations in China". Wang (1988) gathered information about each telegraph line prior to 1904, including its route, telecom bureau, founder, date of telecom access, and funding source. Finally, we supplemented the missing information for specific telegraph lines with local chronicles and other materials.

In order to mitigate the potential omitted variable bias in the model, we selected control variables from six aspects: telegraph siting conditions, local conditions, Western influence, transportation conditions, trade convenience, and political importance. The study uses four indicators to control telegraph siting conditions. First, information transmission was critical for national defense and military operations, particularly maritime defense[3]. Using CHGIS, we estimated the distance between each prefecture and the coastline to represent the importance of the coastal defense strategy. Second, it was critical for the government to maintain social stability, particularly to monitor and quell social disturbances (uprisings). Between 1839 and 1870, China experienced at least 132 wars of various sizes, devastating two-thirds of its administrative regions. We compiled a complete record of conflicts between 1840 and 1870 from the *Chronology of Wars in China Through Successive Dynasties (1840-1870)*, and then aggregated the number of internal and external wars at the prefecture level between those years. Finally, the distance between each prefecture and the provincial capital. Political and military communications were frequent between provincial capitals, which served as political centers, and

[3] From the late years of Tongzhi Emperor' (1861-1875) to the early years of Emperor Guangxu (1875-1908), the Qing Dynasty government held a vital discussion on the most urgent strategic orientation of national defense, which is referred to by historians as the debate between "maritime defense" and "frontier defense".

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between provincial capitals and central administrations. As a result, provincial capitals and surrounding regions were more likely to be linked by the telegraph network.

We also controlled variables that could influence the development of industrial enterprises in the late 19th and early 20th centuries. These characteristics may be related to both telegraph access and the entry of industrial enterprises. First, we controlled each prefecture's longitude and latitude to represent its geographical characteristics. Second, Western influence. We measured Western influence using two indicators: the number of treaty ports and foreign-funded enterprises in modern China. According to Jia (2014) and Yang et al. (2023), treaty ports had a significantly positive effect on urbanization, population growth, and entrepreneurial culture, all of which were factors that support the growth of industrial enterprises. Foreign-funded enterprises could contribute technology and managerial expertise while involved in market competition. Yan (1955) reported the number of treaty ports, while Zhang (1987) reported the number of foreign-funded businesses in modern China. Third, controlling transportation conditions. The convenience of freight transportation was a key concern for business, and river transportation served as a traditional means of transit. Furthermore, railway transportation has been proved to have a significant effect on business development and modernization. As a result, we further controlled the information about each prefecture's river transportation and railway access, such as river density, distance to port, and railway opening. Waterway density and distance to port data are from the China Historical Geographic Information System (CHGIS), while railway opening data are from Ma et al.'s *Chronicle of Railway Construction in China (1881-1981)*. Fourth, the regional importance of each prefecture varies depending on local fiscal and development policies, which might influence firm entry and development. As a result, we used four dummy variables derived from the *Draft History of the Qing Dynasty* to control the central government's political rating of each prefecture.

Except for railway opening and establishment of treaty ports, all other variables are constant over time. In the panel data regression, we introduced an interaction term between those variables and the dummy variable of time. Table 1 presents the descriptive statistics and data sources for the variables in the baseline regression. "Commercial enterprises" and "government-supervised commercial enterprises" refer to the numbers of newly founded enterprises classified by category. Government-supervised commercial enterprises include government-run enterprises. All the explained variables are logarithmically transformed.

Table 1: Descriptive Statistics

	Variable	Sample Size	Mean Value	Standard Deviation	Data Source
Explained variable	Number of newly established enterprises	16415	0.123	0.398	A, B
	Number of newly established enterprises (excluding the financial sector)	16415	0.119	0.383	A, B
	Commercial enterprises	16415	0.101	0.365	A, B
	Government-supervised commercial enterprises	16415	0.031	0.166	A, B
Explanatory variable	Telegraph access	16415	0.296	0.456	C, D
Control variables	Number of conflicts before 1870 (civil disturbance)	16415	1.404	1.801	F
	Number of conflicts before 1870 (external conflicts)	16415	0.11	0.535	F
	Distance to provincial capital	16415	157.96	107.47	E
	Distance to coastline	16415	453.71	411.21	E
	Longitude	16415	114.35	6.996	E
	Latitude	16415	32.519	6.52	E
	Treaty ports	16415	0.172	0.378	G
	Number of foreign-funded enterprises before 1870	16415	1.837	11.304	H
	Access to railway	16415	0.14	0.347	I

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Table 1 Continued

	Variable	Sample Size	Mean Value	Standard Deviation	Data Source
	River density (km/km^2)	16415	0.246	0.074	E
	Distance to port	16415	530.13	429.27	E
	Geographical importance	16415	0.531	0.499	J
	Frequent communications	16415	0.616	0.486	J
	Local burden	16415	0.229	0.42	J
	Difficulty of governance	16415	0.559	0.497	J
	Number of courier stations in the Ming Dynasty	16415	1.074	0.89	K

Sources: A: Du Xuncheng (2014); B: Du Xuncheng (2019); C: Wang Ermin (1988); D: Xie Bin (1928); E: CHGIS; F: Compilation Group of Chinese Military History (2003); G: Yan Zhongping et al. (1955); H: Zhang Yufa (1987); I: Ma Qianli et al. (1988); J: Zhao Erxun (1977); K: Yang Zhengtai (2006).

4. Effect of Telegraph Network on the Rise of Modern Enterprises

4.1 Identification Strategy and Baseline Estimation

In this paper, the following difference-in-differences (DID) identification strategy is adopted:

$$firms_{ct}=\alpha+\beta Telegraph_{ct}+Controls\times Time_t+\gamma_c+\omega_t+\delta_{pt}+\varepsilon_{ct} \quad (1)$$

In equation (1), $firms_{ct}$ is the number of newly established enterprises in prefecture c and year t, which is logarithmically transformed. $Telegraph_{ct}$ is the dummy variable that represents whether prefecture c was connected to wired telegraph in year t, i.e., the value is 1 if it was connected to telegraph; otherwise, it was 0. *Controls* is a set of prefecture-level control variables. Aside from the two variables of treaty ports and access to railway, all other control variables are based on cross-sectional data. Therefore, we introduced an interaction term between each of them and the dummy variable of time $Time_t$. γ_c is the prefecture FEs to capture unobservable factors of each prefecture that do not change over time. ω_t controls factors with the same pattern of shock to all prefectures but change over time. We also use δ_{pt} to capture the unobservable shock at the level of province that change over time.

Table 2 shows the regression results for equation (1). In equation (1), we solely controlled the fixed effects of prefecture and year, as well as the Provincial FEs-year interaction. The estimated coefficient is 0.099 and significant at the 1% level, indicating that access to wired telegraph is significantly positively linked with industrial enterprise entry. Regressions of columns (2) through (4) gradually control the siting conditions of telegraph, the geographical conditions of each prefecture, and Western influence. The estimated coefficient of connection to wired telegraph continued to decrease, but remained significant at the 1% level. After incorporating mixed factors such as transportation conditions, trade convenience, and political importance into columns (5) and (6), the estimated coefficient and statistical significance remained unchanged. The estimated coefficient in column (6) indicates that after accounting for all control variables, there was a 5.7% increase in the number of enterprises in prefectures with wired telegraph compared to other prefectures without telegraph access. The effect is statistically significant at the 1% level. Finally, we removed samples after 1911 from our regression analysis, as shown in column (7), to account for the adoption of wireless telegraphy, telephones, and other new modes of communication, the enormous impact of the 1911 Revolution on China's political system, and our concern about the modest volatility in telegraph connections after 1911. Compared with the baseline regression result, the regression coefficient decreased but remained significant at the 5% level. Overall, the regression results in Table 2 indicate that the advent of telegraphy in the late Qing Dynasty had a significantly positive effect on China's early industrialization. This conclusion serves as our baseline evidence to support our assertion that communications technology influenced China's Great Convergence in its early stage.

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Table 2: Effect of Telegraph Access on the Establishment of New Enterprises

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Firms						
	Total Samples						Before 1911
Telegraph	0.099***	0.089***	0.086***	0.060***	0.058***	0.057***	0.036**
	(0.024)	(0.023)	(0.023)	(0.020)	(0.018)	(0.019)	(0.015)
Prefecture FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province-year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Siting conditions	No	Yes	Yes	Yes	Yes	Yes	Yes
Corporate conditions	No	No	Yes	Yes	Yes	Yes	Yes
Western influence	No	No	No	Yes	Yes	Yes	Yes
Transportation conditions	No	No	No	No	Yes	Yes	Yes
Trade convenience	No	No	No	No	Yes	Yes	Yes
Political significance	No	No	No	No	No	Yes	Yes
R^2	0.333	0.361	0.361	0.396	0.403	0.401	0.339
N	15879	15879	15879	15879	15879	15879	9717

Note: Numbers in parenthesis represent standard errors clustered at the prefecture level; ***, **, and * indicate significance at 1%, 5%, and 10%, respectively. The same applies below.

Table 3 provides the estimation strategy for the instrumental variable in the cross-sectional data. Specifically, the following regression models are estimated:

$$firms_c=\alpha+\beta_1 Telegraph_c+Controls_c+\delta_p+\varepsilon_c \quad (2)$$

$$Telegraph_c=\alpha+\beta_2 yizhan_c+Controls_c+\delta_p+\varepsilon_c \quad (3)$$

In equation (2), $firms_c$ is the number of newly founded enterprises in prefecture c between 1858 and 1937, and $Telegraph_c$ is a dummy variable with a value of 1 if prefecture c was connected to wired telegraph; otherwise, it is 0. The set of control variables contained in $Controls_c$ is consistent with equation (1). Instrumental variable $yizhan_c$ is the number of courier stations in each prefecture during the Ming Dynasty based on data from *A Survey of Courier Stations in the Ming Dynasty* compiled by Yang Zhengtai.

Courier stations were network nodes for official information transmission in ancient China, providing accommodations for couriers of government documents and traveling officials. The number of courier stations was determined by a locality's strategic position and the frequency of government communications, which was consistent with telegraph siting requirements. In other words, the number of courier stations correlates with telegraph availability. Furthermore, the number of courier stations fits the instrumental variable's exclusivity condition: in ancient China, courier stations were largely used to send governmental information, not business information. For example, Zhu Yuanzhang, the Ming Dynasty's founding emperor, issued the *Rules on the Eligibility for Using Courier Stations*, which stated that "under no circumstances should a courier station be used for matters other than important military and state affairs". The number of courier stations cannot, therefore, have a direct influence on the development of national capitalist enterprises in modern China. Second, courier stations created during the Ming Dynasty are unlikely to be influenced by corporate development in modern China.

Columns (1) and (2) of Table 3 present the first-stage regression results for the instrumental variable. The results show that telegraph-connected prefectures had more courier stations, indicating a correlation between telegraphy and courier stations. Both infrastructures were positioned along key routes or nodes for military information transmission. Various statistics in Table 2 further prove that the

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number of courier stations during the Ming Dynasty serves as a valid instrumental variable for modern telegraphy adoption[4]. The instrumental variable results in columns (3) and (4) reveal that access to telegraphy significantly increased the number of industrial enterprises in each prefecture. Due to the use of cross-sectional data and measures to mitigate endogeneity, however, the estimated coefficient of the instrumental variable is larger than that of the DID coefficient.

Table 3: Instrumental Variable Regression for Cross-Sectional Data

Variable	(1)	(2)	(3)	(4)
	Stage 1		Stage 2	
	Telegraph	Telegraph	firms	firms
yizhan	0.259***	0.267***		
	(0.061)	(0.065)		
Telegraph			2.411***	1.350***
			(0.692)	(0.450)
Provincial FEs	Yes	Yes	Yes	Yes
Baseline control	No	Yes	No	Yes
N	241	241	241	241
R^2	0.236	0.250		
Under-identification test			17.04	15.91
Weak instrumental variable test			15.2	14.93

4.2 Robustness Test

4.2.1 Test of sub-samples

To address the concerns about the comparability between treatment and control groups, we restricted our regression to several sub-samples. First, approximately 8.5% of Du's (2014, 2019) dataset consists of financial enterprises. While the rise of the modern banking industry is a key indicator of the Great Convergence, it may introduce deviations in our specification of early industrialization. Therefore, we excluded financial enterprises from the regression in column (1) of Table 4. The results show only a limited difference from the baseline, suggesting that the baseline results are largely driven by industrial enterprises. Second, we categorized the samples based on ownership structure into two groups: commercial enterprises and government-supervised commercial enterprises (including government-run enterprises). In column (2), the estimated coefficient for commercial enterprises is slightly smaller than the baseline estimate, while the coefficient for government-supervised commercial enterprises in column (3) is only 0.012, which is significantly lower than that of commercial enterprises. These results indicate that commercial enterprises were the main drivers of industrial growth in modern China. Third, as the new government established in 1927 implemented various economic reforms, corporate development faced mixed influences. Thus, we excluded post-1927 samples in column (4) of Table 4. Fourth, we removed samples from Jiangsu Province in column (5). Jiangsu played a crucial role in modern China's industrial development, accounting for nearly half of the country's industrial enterprises and over half of its industrial output. After excluding Jiangsu, the estimated coefficient increased, indicating that other provinces still contributed significantly to industrial enterprise growth. Fifth, we removed provincial capitals from the sample. As noted in the background section, the transmission of military and official

[4] Referring to Yang et al. (2023), we utilized Anderson canon. LM statistic to reject the under-identification hypothesis, and Cragg-Donald Wald F statistic to reject the weak instrumental variable hypothesis.

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information increased the likelihood of provincial capitals being connected to the telegraph network. In column (6), removing provincial capitals reduced the regression coefficient, though it remained statistically significant. Overall, the results in Table 4 demonstrate that the baseline findings are not driven by specific sub-samples, and that the impact of telegraph access on the growth of industrial enterprises during the early industrialization period was robust.

Table 4: Test of Subsamples

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Removal of the financial sector	Commercial enterprises	Government-supervised commercial enterprises	Before 1927	Exclusion of Jiangsu Province	Exclusion of provincial capitals
Telegraph	0.059***	0.053***	0.012**	0.051***	0.060***	0.042**
	(0.018)	(0.017)	(0.006)	(0.018)	(0.020)	(0.016)
Control fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Baseline control	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.392	0.381	0.134	0.495	0.386	0.309
N	15879	15879	15879	13509	15008	14338

Note: Control of fixed effects includes all fixed effects in Table 1. The same applies below.

4.2.2 Competition test and other robustness tests

Despite extensive controls in the baseline regression, omitted variable bias may still be a significant concern in this paper. Previous research has shown that both the modern military industry (Bo et al., 2023) and the spread of Christianity (Bai and Kung, 2014) had a profound impact on modern economic development. In particular, military-industrial sites may be correlated with telegraph locations. To account for this, we controlled for the influence of the military industry and missionaries in columns (1) and (2) of Table 5. Compared to column (6) of Table 1, the estimated coefficient shows a slight decrease but remains statistically significant at the 1% level. This suggests that controlling for these two competing factors does not alter our baseline conclusion. Additionally, columns (3), (4), and (5) further account for regional commercial culture, climate suitability (heat appropriateness), and population density in 1880. While the statistical significance of the results decreases, they remain significant at the 5% level.

Table 5: Competitive Test and Additional Controls

Variable	(1)	(2)	(3)	(4)	(5)
Telegraph	0.047***	0.047***	0.044**	0.044**	0.038**
	(0.018)	(0.018)	(0.018)	(0.017)	(0.016)
Military industry	0.167***	0.166***	0.131***	0.131***	0.111***
	(0.061)	(0.061)	(0.050)	(0.050)	(0.036)
Missionaries		-0.014	-0.003	-0.003	0.014
		(0.016)	(0.015)	(0.015)	(0.015)
Commercial culture			Yes	Yes	Yes
Heat appropriateness				Yes	Yes
Population density					Yes
Control all fixed effect	Yes	Yes	Yes	Yes	Yes
Baseline control	Yes	Yes	Yes	Yes	Yes
R^2	0.403	0.403	0.417	0.416	0.441
N	15879	15879	15879	15879	15879

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4.3 Event Study Method

In this paper, we adopt the event study method to validate the DID identification assumption and observe telegraphy's dynamic effect on the entry of enterprises. This identification hypothesis requires a similar pattern in the entry of industrial enterprises between the treatment group and control group prior to a locality's access to telegraph. Specifically, we adopt the following event study model:

$$firm_{ct}=\sum_{k\geq -5,k\neq -1}^{15}\beta_k Telegraph_{ct}^{k}+Controls\times Time_t+\gamma_c+\omega_t+\delta_{pt}+\varepsilon_{ct} \quad (4)$$

In equation (4), the control variables and fixed effects are specified in the same way as in equation (1). However, the core explanatory variable $Telegraph_{ct}^{k}$ in equation (4) is a dummy variable that determines whether a series of prefectures were connected to the telegraph network during different periods. Specifically, it is a dummy variable representing five years before and 15 years after the access to the wired telegraph. Therefore, the difference in the number of industrial enterprises between prefectures with and without telegraph access in year k is measured by a series of estimated coefficients $\beta_k(k\in[-5,15], k\neq -1)$ of $Telegraph_{ct}^{k}$. When $k<0$, the estimated value of coefficient β_k is not significant and shows no significant temporal trend, indicating that there is no systematic difference between the treatment group and the control group before the telegraph access. Thus, the DID identification assumption is valid.

Figure 1 presents the result from the event study method. The horizontal axis represents the year of telegraph access, with the year when a prefecture was connected to the telegraph designated as 0. Negative values refer to the period before telegraph access, and positive values refer to the period after telegraph access. The vertical axis denotes the regression coefficient, and the vertical dotted line represents the 95% confidence interval. In line with the specifications in the existing research literature, we set the -1 period as the reference group in the event study method. As can be seen from the chart, the regression coefficient for the entry of enterprises is approximately 0 and not significant. This implies that the entry of industrial enterprises was mainly driven by access to the wired telegraph rather than being due to systematic differences in the social and economic conditions among various prefectures. At the same time, the absence of a prior trend also indicates that our DID specification complies with the parallel trend hypothesis. As reported in Table 2, the positive baseline result of the telegraph's impact on the growth of industrial enterprises is a causal effect.

The results presented in Figure 1 also show that telegraph access will have a significantly positive impact on the entry of industrial enterprises only after the fourth year. The wired telegraph was a major revolution in traditional means of information transmission in China. It took businesses and individuals some time to understand, accept, and utilize this technology. Various restrictions on the commercial use of the telegraph greatly hampered its effectiveness. As time passed, telegraphy started to have a growing influence on the entry of enterprises, indicating that access to the telegraph led to the agglomeration of modern industrial enterprises.

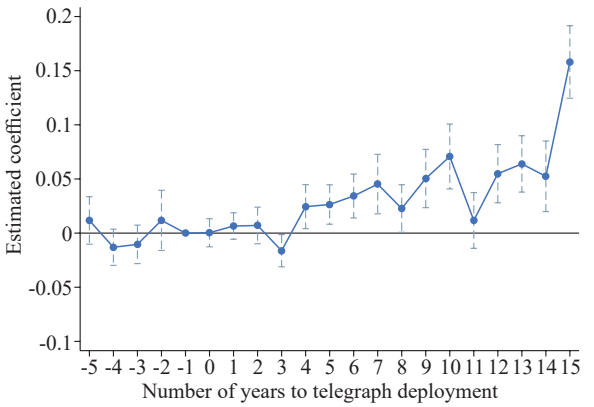

Figure 1: Dynamic Effect of Telegraph Access on the entry of Enterprises

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The latest theoretical research on DID indicates that a treatment event with a staggered deployment could cause a bias in the estimated results of the classical DID. For instance, Goodman - Bacon (2021) holds that, within the context of a valid "parallel trend" assumption, the TWFE - DID (two-way fixed effects - difference-in-differences) estimation may still encounter the problem of "inappropriate control", where the early treatment group is wrongly regarded as the control group for the late treatment group. Based on various approaches, theoretical economists have developed a "heterogeneous - robust" estimator to address the potential deviation of TWFE - DID. However, there are still disputes about which estimator is the best. In this paper, we employed the method of Callaway and Sant'Anna (2021) for a robustness test and specified the sample period for the event study as the entire sample interval. By computing the average treatment effect for specific group-period and aggregating the group and period dimensions, the estimator prevents the treatment group from being misidentified as the control group, thereby reducing the estimation bias.

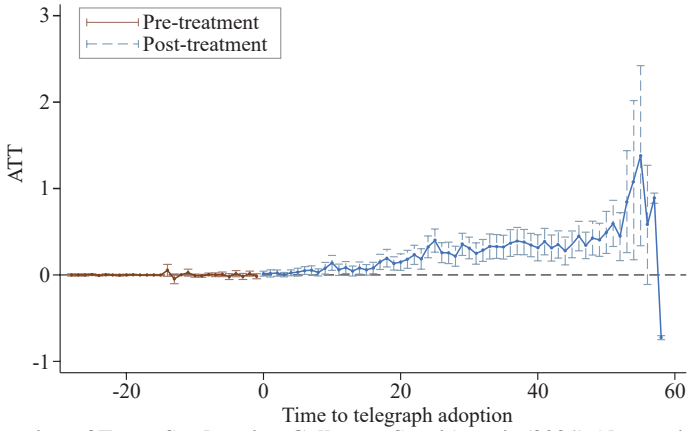

Figure 2: Illustration of Event Study using Callaway-Sant'Anna's (2021) Alternative Estimator

Figure 2 shows the dynamic effects estimated using the method from Callaway and Sant'Anna (2021), which align closely with the results from the classic DID approach shown in Figure 1. The estimated coefficients are insignificant prior to treatment and do not exhibit any significant temporal trends. In the first four years following telegraph connection, there was no statistically significant growth effect on enterprise entry. However, in the years that followed, the growth effect increased and became statistically significant, indicating that our baseline estimation is unlikely to suffer from serious bias due to "inappropriate control" issues. Over time, the treatment effect displayed a clear upward trend, suggesting that the event study results reflect a long-term effect rather than being constrained to a specific time period.

5. Mechanism Analysis

As shown in the above analysis, the connection of various localities in China to the wired telegraph network in the late 1870s affected the location choices of industrial enterprises and had a long-term impact. Prefectures that gained early access to the wired telegraph network were more likely to develop industrial clusters during the subsequent 60 years of economic development. Although the research literature has thoroughly discussed the economic development effects of contemporary communication technologies such as ICT, 3G, or AI, there has been a lack of research on early communication technologies (Ploeckl, 2023), and the growth mechanisms by which these technologies influenced early-stage industrialization have been unclear. In this section, we used three mechanisms, including market

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integration, human capital accumulation, and the development of auxiliary commercial organizations, to expand this area of research.

5.1 Information Transmission and Market Integration

The telegraph fundamentally transformed long-distance communication. As the government's monopoly on information transmission was dismantled, business information has flown more swiftly and cost-effectively, fostering market integration (Gao and Lei, 2021; Hao et al., 2022; Ploeckl, 2023). The accelerated development of a unified market contributed to price stability for key raw materials essential for early industrial growth and enabled businesses to respond more quickly to commodity price fluctuations.

In this paper, we assessed the level of market integration in the lens of food price volatility, drawing on data from Wang Yejian's *Database of Grain Prices in the Qing Dynasty*. This dataset provides monthly maximum and minimum prices for various grain crops across prefectures. Due to data limitations, our analysis focuses solely on premium rice prices in nine provinces throughout China[5]. Following Gao and Lei's (2021) methodology, we examine the market integration effect of telegraph expansion by analyzing the changes in the annual average maximum price.

We further explored whether market integration could facilitate the entry of industrial enterprises. Specifically, we defined the market integration variable "*Integration*" as the square variance between the average price of each prefecture and the average price within the province. In column (1) of Table 6, market integration is incorporated into the regression, with only the fixed effect being controlled. The regression results show that telegraph access had a more significantly positive effect on the entry of industrial enterprises in prefectures with better market integration. Column (2) further includes the baseline control, and the regression results remain consistent.

Table 6: Telegraph Connection and Market Integration

Variable	(1)	(2)
	firms	firms
Integration	0.064***	0.032***
	(0.019)	(0.008)
Prefecture FEs	Yes	Yes
Year FEs	Yes	Yes
Provincial FEs-year	Yes	Yes
Baseline control	No	Yes
N	3047	3047
R^2	0.348	0.468

5.2 Commercial Organizations and Banking Sector Development

Telegraph technology facilitated collective collaboration by reducing the costs of information exchange. In this section, we examined two types of auxiliary commercial organizations that affected enterprise entry: trade chambers and the modern banking sector. Trade chambers were established in response to foreign economic incursions into modern China, with the goal to "protect commerce and open up business information". The first trade chamber, the "Shanghai Commercial Conference Office", was founded in 1902. Over the next decade, the office developed 293 trade chambers across 159 cities,

[5] Including Jiangsu Province, Fujian Province, Yunnan Province, Guangdong Province, Anhui Province, Guangxi Zhuang Autonomous Region, Guizhou Province, Hubei Province, Hunan Province, etc.

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accommodating more than 80,000 tradenames and creating a three-tier management system of general trade chambers, chapters, and branches[6]. Telegraphy facilitated communication between these levels of organizations and their members, fostering a competitive market environment. We gathered information about the establishment of local trade chambers from the first five agricultural and commercial statistical forms compiled by the Ministry of Agriculture and Commerce. Column (1) of Table 7 shows that telegraph access significantly increased the number of trade chambers. In column (2), we introduced the number of trade chambers into the baseline cross-sectional instrumental variable regression. The treatment effect of telegraph access decreased to 0.920, with diminished significance, suggesting that trade chambers partially explain the impact of telegraph access on the growth of enterprise entry.

As discussed in our research background, telegraph access also significantly influenced the business transactions and organizational structures of the banking sector. It reduced information asymmetry across regions and mitigated the principal-agent problem in internal bank management, leading to an expansion of banks and their subsidiaries (Lin et al., 2021). We obtained data on banks and their subsidiaries from the *National Yearbook of Banks*, compiled by the Economic Research Office of the General Administrative Division of the Bank of China in 1934. This yearbook contains detailed information about the establishment of subsidiaries, branches, local offices, remittance departments, and other affiliated institutions. Column (3) of Table 7 indicates that wired telegraph access increased the number of bank subsidiaries, though the effect was weakly significant. In column (4), we narrowed the scope to focus on head offices of banks and their subsidiaries and branches, given that these institutions offered more comprehensive services and were more likely to be distributed across broader geographic areas, necessitating telegraph use. The regression results show an increase in the significance of telegraph's effect on the growth of bank subsidiaries. Column (5) includes the number of banks in the baseline cross-sectional instrumental variable regression, reducing the treatment effect of telegraph access to 0.924. This suggests that the number of banks may partially explain the relationship between telegraph access and growth of enterprise entry. Finally, when both the number of trade chambers and the number of banks were included in column (6), the treatment effect of telegraph access decreased to 0.648 and became insignificant. Overall, the regression results in Table 7 suggest that telegraph access contributed to modern China's early industrialization as it helped increase the number of trade chambers and foster the development of financial markets.

Table 7: Telegraph Access and Development of Commercial Organizations and Financial Systems

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Number of trade chambers	firms	Number of banks	Number of banks 1	firms	firms
Telegraph	1.061***	0.920*	0.994*	0.663**	0.924**	0.648
	(0.407)	(0.480)	(0.528)	(0.329)	(0.422)	(0.440)
Number of trade chambers		0.405***				0.256**
		(0.126)				(0.108)
Number of banks					0.428***	0.433***
					(0.086)	(0.084)
Provincial FEs	Yes	Yes	Yes	Yes	Yes	Yes
Baseline control	Yes	Yes	Yes	Yes	Yes	Yes
N	241	241	241	241	241	241

Notes: Numbers in parenthesis are standard errors clustered at the provincial level; ***, ** and * represent significance at the 1%, 5% and 10% levels. All regressions are instrumental variable estimations. The same applies below.

[6] Compiled by the authors based on the *First Agricultural and Commercial Statistical Statement in 1912*.

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5.3 Human Capital Accumulation and Knowledge Spillover

Human capital accumulation and technology spillover are key drivers of early-stage economic development. In modern China, telegraphy was introduced on the premise of ensuring sovereignty over telegraphy. Efforts were made to cultivate independent telegraphy professionals through translating electrical engineering books and establishing telegraph schools. Many graduates from these academies later made significant contributions to education in China.

Using the *Years of Birth and Death of Scientists and Technologists in Modern China*, we compiled a list of scientists and technologists of various disciplines born after 1840, categorized at the prefectural level. These individuals played pivotal roles in modern China's industrialization. For example, Hu Xiyuan created China's first lightbulb and established the first lightbulb factory in the country. Feng Ru, China's first aircraft designer, maker, and aviator, made significant contributions to the early development of the aircraft industry. As shown in column (1) of Table 8, access to wired telegraph services increased the number of specialized scientific talent in a locality by 61.5%. In column (2), we introduced both telegraph access and the number of engineers into the regression analysis, revealing a significantly positive correlation between the number of engineers and the number of enterprises. Compared to column (4) of Table 2, the estimated coefficient of telegraph access decreased from 1.350 to 1.104, suggesting that the presence of specialized scientific talent partially explains the effect of telegraph access on enterprise entry.

Subsequently, we studied whether access to the telegraph affected the supply of education related to the cultivation of professional scientific talent. In order to develop human resources for telegraph operations, the self-strengtheners set up six telegraph academies upon the inception of telegraph development. Some students were sent overseas for further studies, and supported China's development of communications industry after their return[7]. To some extent, the establishment of telegraph academies expedited educational modernization in China. The introduction and translation of telegraph-related books, as well as the exchange of information, facilitated the spread of Western technologies to China.

In this paper, we merged two data sources to quantify the impact of various educational resources on the cultivation of specialized scientific talent and the growth of modern industrial enterprises. First, we analyzed the supply of university education, using the list of universities from the *First China Education Yearbook* (1934). The regression results in column (3) show that prefectures with early access to wired telegraph had a significantly higher supply of university education. Next, we examined the availability of specialized technicians through industrial schools[8], based on the *List of Nationwide Industrial Schools* (1916). The regression results in column (4) indicate that regions with telegraph access were more likely to establish additional industrial schools. Finally, column (5) explores the sources of specialized scientific talent. The results suggest that universities were the primary institutions for fostering specialized scientific talent, whereas the effect of industrial schools was insignificant. This finding aligns with the distinct objectives of each educational system: while industrial schools focused on developing skilled workers, the proficiency of operational skills was not a key factor in the development of scientific talent.

In column (6), we incorporated scientific talent and the two types of educational supply into the regression of growth in the entry of industrial enterprises on wired telegraph access. Compared with column (4) of Table 2, the estimated coefficient of wired telegraph access decreased and became insignificant, the impact of industrial schools was very limited and insignificant, and the impact of the

[7] A British naval officer surnamed Shore, also recorded: "A few of the most promising students in the telegraph school will receive advanced education in electrical engineering. They will be sent to renowned telegraph schools and institutions in Britain to complete their studies. These students will be educated in the installation and maintenance of telegraph lines and can eventually become telegraph engineers" (Chinese Historical Society, 2000).

[8] Industrial schools are similar to today's vocational schools, and can be divided into Class A industrial schools and Class B industrial schools. The former corresponds to secondary education, and the latter corresponds to primary education.

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number of scientific talent and universities was positive and significant. Overall, the regression results in Table 8 suggest that telegraph access could promote the accumulation of human capital, which is a vital source of long-term economic growth, by increasing the reserve of scientific talent and the supply of college education.

Table 8: Telegraph Access and Human Capital Accumulation

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Number of scientific talent	Firms	Number of colleges	Number of industrial schools	Number of scientific talent	Firms
Telegraph	0.615**	1.104**	0.455*	0.729**		0.768
	(0.270)	(0.511)	(0.246)	(0.320)		(0.546)
Number of scientific talent		0.399**				0.270*
		(0.176)				(0.141)
Number of colleges					0.228***	0.588***
					(0.086)	(0.187)
Number of industrial schools					0.097	0.203
					(0.066)	(0.127)
Provincial FEs	Yes	Yes	Yes	Yes	Yes	Yes
Baseline control	Yes	Yes	Yes	Yes	Yes	Yes
N	241	241	241	241	241	241

6. Concluding Remarks and Further Discussions

The direction and impact of technological revolutions are becoming increasingly abrupt, unpredictable, selective, and difficult to control. While the first technological revolution precipitated the Great Divergence between China and the West, the telegraph revolution reduced the costs associated with the flow of knowledge and information, triggering the Great Convergence among some developing countries. This paper explores a specific historical context to identify the sources of growth in China's industrial economy. Despite the limitations of available data and literature, we view this economic growth trend as a transient and relatively weak convergence for China. Given that the development and deployment of telegraph technology were exogenous to China's early economic development, we investigate how reductions in communication costs due to the communications technology revolution influenced the influx of industrial enterprises in modern China.

Using long-panel data from 1858 to 1937 and employing a difference-in-differences (DID) identification strategy, we found that the adoption of wired telegraph had a positive and lasting impact on the entry of industrial enterprises in a locality. Compared to prefectures without telegraph access, those with telegraph access experienced a 5.7% increase in the number of newly established enterprises.

Our baseline result can be explained by three mechanisms: market integration, accumulation of human resources, and the development of auxiliary commercial organizations. Although we focus on grain market integration due to data limitations, similar effects are likely significant in other factor and commodity markets, capital markets, and international trade. The human capital accumulation mechanism aligns with Balawin's assertion that lower communication costs facilitated the transfer of knowledge from developed to developing countries, thereby contributing to the Great Convergence. This also addresses why the Great Convergence has thus far occurred in only a few developing countries: it requires selective technology importation and the nationalization of human capital.

China's economic structure prior to the outbreak of the War of Resistance Against Japanese Aggression (1931-1945) bears resemblance to that of many developing countries today. Therefore,

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research on China's prewar economic growth sources carries relevant implications for policymaking today. Our study suggests that even in an agrarian economy with limited national capabilities and insufficient knowledge of modern science and technology, early-stage industrialization can be achieved by grasping technological sovereignty and talent initiative, and fully leveraging the advantages of information infrastructure in shaping a unified large market.

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