The Qing State's Influence on Early Manufacturing of the 1910s: New Measurements at the Provincial Level

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Abstract

This article provides new measurements for the Qing state investment in new technology and scientific knowledge at provincial levels from the late nineteenth and early twentieth centuries, including the Self-strengthening Movement of 1861-95. We use an Exploratory Factor Analysis to separate the Qing state investment into two dimensions, military-related and infrastructure-related. The new measurements indicate a shift in the Qing state investment after the First Sino-Japanese War of 1894-95 from military-related to infrastructure-related programmes and present the first attempt to quantitatively illustrate provincial variations in the late-Qing reforms of the 1860s-1910s. Based on the new measurements, we then examine the relationship between the Qing state investment and the provincial differences in the 1910s private manufacturing. A regression analysis concludes that on average both of the two dimensions of the Qing state investment have a negative impact on provincial manufacturing output. Though the military-related state investment may have a positive influence on the heavy industry and a negative effect on the light industry. The Qing state investment in general failed to promote the expansion of modern factory production. Thus, the developmental role of the Qing state in China's early industrialisation is very limited.

Keywords: Industrialisation; State investment; Pre-war China

JEL classification: N15, N65, O14, O47, P21

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1 Introduction

China experienced drastic social changes and fierce political conflicts in the second half of the nineteenth century and the early twentieth century, including the collapse of the Qing Empire in 1911. Known as an early phase of industrialisation, the economy of pre-war China gradually recovered from decades of social disorder and reached a "golden decade" of industrialisation in the period 1927–37. It is believed that the Qing state's Self-Strengthening Movement (1861–95) is the beginning of the history of China's industrialisation and modernisation. Not only was the Qing state an influential force in political and institutional reforms, but it also tried to directly intervene in the economy through various programmes aiming at adopting Western technology and reinforcing military strength. The programmes of self-strengthening ranged from state-owned factories and mines, training in Western scientific knowledge, to new infrastructural outlays such as railways and telegraph.

Researchers have paid attention to the long-term development of China's industries and particularly the early industrialisation of the late nineteenth century under the regime of the Qing Empire. Accordingly these studies have discussed the connection between economic development and the role of the Qing state (Wang, 2000; Xu and Wu, 2003; Wu, 2011; Wong, 2014; Brandt, Ma and Rawski, 2016). Most of these studies conclude that the role of the Qing state and the state investment in the Self-Strengthening Movement had a limited or negative effect on industrial development; however, these conclusions are based on limited empirical evidence. Moreover, only a few studies try to examine the size and scope of the Qing state's investment in industrialisation before evaluating the role of the state, and these studies provide estimations for the public expenditure at the national level on the programmes of self-strengthening for the period 1860s–1890s (Deng, 1998; Fan, 2003). Although in general the research on the Qing state seems to emphasise the negative impact, the role of a state in the process of industrialisation can be positive. For instance, at the beginning of industrialisation, state initiative and financial support can be crucial for large and high-risk investment in innovations (Wu, 2011). This study will therefore re-evaluate the Qing state's role in pre-war China's industrialisation and carry out an econometric analysis according to a new measurement of the Qing state's investment in self-strengthening programmes at the provincial level.

State intervention is an important factor behind the development of China's industrialisation. For pre-war China in the first half of the twentieth century, government intervention continued as an important part of the economy after the end of the Qing regime. Nowadays, the pace of modern China's industrial growth has been deeply directed by various industry-promoting policies and public investments. This study on the Qing state investment will bring a historical perspective to understanding China's long-term economic development and its current economic trajectory, thereby contributing to the broader global history of industrialisation and future research to compare different paths of industrialisation between Asian countries.

The first part of this study is to review Qing state investment in various programmes and to derive new measures for the state's investment at the provincial level. Based on available historical records, we grouped various self-strengthening programmes into four major categories, including military production and state-owned factories, training in Western technology, railways, and telegraph, and calculated seven indicators for the Qing state investment in each of the 22 provinces during the Self-Strengthening Movement of the 1860s–1890s. Similarly, we continued to quantify the Qing state's investment in provinces until the end of the Qing regime, i.e. the 1860s–1910s. We use the seven indicators as proxies for the public capital accumulated during the Self-Strengthening Movement and during the

late Qing period respectively to capture changes across time. We then use an Exploratory Factor Analysis to extract the information common to the seven indicators of the Qing state's investment for all sample provinces. The result of the factor analysis shows that among categories of the Qing state's investment two dimensions common for all sample provinces can be distinguished: military-related and infrastructure-related state investment. Since it is not possible to add up the indicators of different types of investment, factor scores estimated for the two dimensions of state investment are taken as the new measures for accumulated public capital. Accordingly, this study gives a quantitative description of Qing state investment. The new measures draw attention to the variations of the Qing state's investment at the provincial level.

The second part is to examine the relationship between the Qing state's investment and China's early manufacturing. With the new measurements for Qing state investment, an econometric analysis is applied in this study. We look at manufacturing industries in 22 provinces for the years 1912 and 1916 and check the relation with Qing state investment before the end of the Qing regime in 1911. According to estimation results, the 1910s manufacturing industries were negatively affected by the military-related state investment. Somewhat unexpectedly, the Qing state investment in infrastructure – mainly railways – also had a negative effect on private manufacturing. In contrast to previous studies, we find a positive influence of Qing state investment only on the heavy industry. The new measures and the econometric analysis reveal more complex relationships between the Qing state's investment and China's early industrialisation.

The rest of this article is broken down into the following sections. Section 2 introduces the historical background and the related literature on the Qing state's Self-Strengthening Movement and its relationship with China's industrialisation and economic growth. Section 3 discusses the factor analysis and the new measures for Qing state investment. Section 4 examines the relationship between the Qing state's investment and pre-war China's industrial development. Section 5 discusses the conclusions.

2 Literature and historical background

2.1 The Self-Strengthening Movement of 1861–95

This section introduces the Qing state's Self-Strengthening Movement and related discussions in historical studies. From the 1860s, a number of programmes were formulated in pursuit of importing, promoting and adopting Western technology, principally to reinforce military strength, which had become the major concern of the Qing state after the Opium Wars. Based on a number of historical studies regarding the movement's developments, Table 1 lists major categories of these self-strengthening programmes related to industrialisation and gives a few examples of well-known programmes (Chen, 1986; Xia, 1992; Xu and Wu, 2003). These new technological imports consisted of both goods and machinery as well as their associated knowledge production. The Qing state was at this time the most important investor in adopting new machinery-related technology. For instance, it was the founder of the largest iron and steel factory in Qing China before its privatisation in 1906.

Table 1 The Qing state-invested programmes during the Self-Strengthening Movement

Programmes	Examples
Military production	
Arsenals and shipyards	The Kiangnan Arsenal, The Foochow Navy Yard
Other state-owned factories	
Textiles, coal and metal mining, metal refining	The Hanyang Iron and Steel Factory, The Kaiping Mines
Western-style education	
Military training schools	The Foochow school
Foreign-language schools	The Peking Tung-wen Kuan
Educational missions to other nations	
Infrastructure and services	
Telegraph, railways	
Inland river shipping	e.g. China Merchants' Steam Navigation Company
City water supply, electricity supply	

Notes: Grouped by the author. Many programmes of self-strengthening continued to operate after the First Sino-Japanese War of 1894–95. More details are provided in Appendix 1.

Most of these programmes – which involved the establishment of arsenals, shipyards and mines, as well as schools to interpret and translate Western scientific knowledge – were operated at the provincial level. The movement was initiated by certain high court officials and a number of leading provincial officials, who had witnessed the power of Western military technology during the rebellions of the mid-nineteenth century and had thus realised the need of the country to prepare for external interventions and confrontations. These programmes nevertheless required approval by the throne. They were financed by public funds, mainly through the likin tax (a domestic commercial tax) and customs income, and sometimes directly supported through local military funds. Although a number of archival sources indicate that many Qing officials harboured doubt regarding Western technology and the attitude of the Qing throne was seemingly ambiguous, this study generally considers the public investment in self-strengthening programmes as state investment no matter the location and the promotor.

Table 1 groups the Qing state-invested programmes into several major categories: military production, other state-owned factories especially in heavy industry, Western-style education, and infrastructure. However, among these categories the primary task of the self-strengthening programme was military development. More than half of the related investment went directly into munition-making and shipbuilding (Deng, 1998). Among other communication and transportation technologies, the Qing state's interest in telegraphy was primarily for military use, and the construction of telegraph lines from 1879 was instigated much earlier than the railways.

Programmes in different categories were also interconnected. For example, military munitions production required intensive coal and metal mining, metal refining, and the new transport system. As part of the new Western-style education, training schools along with arsenals, shipyards and telegraph offices taught Western scientific methods, including theoretical navigation and telegraphy technology. Similarly, foreign-language schools not only provided the translators needed in Sino-Western diplomacy but also translated Western mathematics and sciences into Chinese. The Qing state also tried to increase the state financial strength although the priority was given to reinforcing its military strength. The Qing state invested in the textile industry in HUB province not only for the profit but also with the hope to use the profit to expand military expenditure.

Most historical studies are in agreement that the Self-Strengthening Movement ended at the Qing Empire's defeat in the Sino-Japanese War of 1894–95, which signified the failure of the Qing state's effort to strengthen its military power (e.g. Xia, 1992; Fan, 2003). In an earlier survey, Huang and Jiang (1980) pointed out that whether the Qing state abandoned the self-strengthening programmes after 1895 was still under debate. Chen (1986) noted that the Qing state's inability to maintain the investment required for self-strengthening programmes after the First Sino-Japanese War weakened its potential for industrialisation. Nevertheless, the Self-Strengthening Movement is considered as a key component in China's history of industrialisation and modernisation, and the movement both promoted and provided access to Western technology and sciences and thereby revealed a changing attitude toward the West. Importantly, it was the self-strengthening programmes that introduced new technology to some of the remote inland regions in Qing China, such as the first iron and steel factory founded in Guizhou province by local officials in 1892. Before the 1890s nearly all the telegraph lines in northwest China were constructed through public expenditure; in this period private lines were only set up in the highly-commercialised area along the south coast.

The fundamental questions around the Qing state's investment are "whether they [the programmes] could continue to grow and whether they could, by the stimulus of their success, lead to changes in their institutional and economic environment" (Kuo and Liu, 1978, p. 519). This study tries to answer the questions. Section 2.1 surveys the discussions on the Self-Strengthening Movement itself; and Section 2.2 summarises the literature on its relationship with early industrialisation. Appendix 1 includes more information on late Qing reforms.

Prior to evaluating the influence of Qing state investment, it is important to address the size and scope of the Self-Strengthening Movement and the late Qing reforms, including, for example, the amount of public expenditure on adopting Western technology. A few estimations give the amount at the national level. According to Chen (1995) and Deng (1998), it only accounted for about 6 per cent of public expenditure in contrast to the similar type of public expenditure in Meiji Japan of 15 per cent. Zhou (2000) and Fan (2003) gave an even lower estimation of 2.4–2.9 per cent for Qing China. The transmission of Western knowledge started in a few provinces but was not confined to these provinces. The previous estimation at the national level does not show regional variation; thus, new measurement at the provincial level is necessary to show the coverage and distribution of these programmes within Qing China.

There are several weaknesses in current studies around the Self-Strengthening Movement and in measuring public capital in history. First, limited data availability makes it not feasible to estimate the total public expenditure. At this moment, the historical records are available mainly for military production especially for some well-known and large programmes such as the Kiangnan Arsenal and the Foochow Navy Yard. Moreover, based on Fan (2003), only the Qing state expenditure before 1895/6 on military factories and related training institutes can be traced to the provincial level. Second, it is difficult to assess the investment in the programmes of self-strengthening after 1895. Current estimations focus on the period before 1895 since most studies presume that the Qing state's Self-Strengthening Movement ceased after 1895. Third, it is difficult to separate one category of state investment from others since most programmes of self-strengthening were interconnected, particularly those involved with military construction. To evaluate the role of public capital, the analysis needs to consider the influence of different types of state investment. These weaknesses motivate the use of factor analysis in this study to provide a new measurement.

2.2 Qing state investment and China's early industrialisation

After providing a brief introduction of Qing state investment in the 1860s–1910s, this section reviews the literature on the influence of Qing state investment on pre-war China's industrialisation. The big push hypothesis on industrialisation motivates the theoretical analysis in this section, as discussed in previous studies (e.g. de Haan, 2005; Jaworski, 2017). The big push hypothesis helps to understand and rethink the influence of Qing state

investment in new technology, which was often embodied in fixed capital. In general, when private incentives are not sufficient, direct state intervention may also lead to industrialisation. The state's investment in certain regions may therefore explain regional differences in industrial performance.

A high fixed cost or uncertainty about future profits may prevent private industries from investing in new technology. Public investment in general purpose technology may lower the risk and facilitate industrialisation. In order to reinforce military power, the Qing state initially focused on modern military equipment and shipbuilding in the period 1860–95, which in the late nineteenth century were often related to machinery, metallurgy, new energy, and a new production organisation of modern factories. For the whole country, state-owned military factories established between 1860 and 1895 might not be the first production units using new technology from the West. For example, there were already private oil-crushing workshops using machines in the early 1840s in the lower Yangzi delta. However, for most provinces, these military factories were not only the initial samples of new technology application but were also state-approved, which may signal a positive attitude towards the use of Western technology from the upper class of the bureaucratic system and which may have subsequently encouraged private investment in provinces. The fast increase in the net import of coal and machinery since the 1890s indicates a process of capital deepening in China's pre-war industrialisation. The level of capital stock associated with modern industrial technology was of primary concern at the beginning of China's industrialisation. Thus, Qing state investment in new technology may have facilitated the general expansion of modern industrial production.

We then consider specific channels through which potential spillovers from the Qing state investment could flow to regional private industries. First, after the end of the Qing Empire, part of the state-owned capital stock went to private sectors. Our sample contains 66 military factories established in the period concerned, among which 16 were still in production and owned by the state in the early 1910s, 14 were sold out to private owners, and 23 had stopped operation before 1910. After the closing of some factories, machines were moved to other state-owned factories or directly sold out to private owners. Some may question the limited influence of a few new military-related factories on pushing the economy towards industrialisation considering the large agrarian economy in pre-war Chinese. This study tries to connect Qing state investment, which concentrated in some regions, with the performance of regional industrial sectors rather than the overall economic performance. In this channel of spillover, public capital accumulated early in the late Qing period may be transformed later into private capital and the new technology embodied in public capital may benefit local private industries. Second, the spillover from the human capital accumulated through Qing state investment may be socially beneficial, although it remains difficult to measure the benefit at provinces. The Qing state's investment in new educational institutions may change the formation of human capital, but also the investment in military and infrastructure construction. Although not the main purpose, Qing state-invested factories commonly provided training programmes on the application of new technology and courses on modern scientific knowledge. This is particularly important for the traditional education of pre-war China, which may have had difficulties in adopting new industrial technology and accepting the scientific knowledge behind the new technology. State investment and intervention gave the initial and possibly the only access to new technology for local residents and industries in some regions before the extension of treaty ports into inland China. We may want to check for gains in local industries from the Qing state investment; however, to be noted, the gains, if there are any, from big push policies may fail to translate into economic growth in private sectors under certain circumstances, as discussed in previous research (e.g. Jaworski, 2017). For instance, if there is the mismatch between military and civilian uses of the capital stock accumulated previously, then the Qing state's investment in reinforcing the national defence may have failed to create the push to industrialisation.

We try to link the investigation into Qing state investment with the literature on the role of public capital in economic growth. Here, public capital is often defined as public non-military spending on capital, such as the government expenditure on infrastructure construction. It is natural to think of the importance of infrastructure in economic growth since it is used in nearly every economic sector, such as railways and telecommunications. The Qing state was particularly interested in constructing the telegraph system during the period 1860–96, and then turned to the railways after 1896.

However, we may not simply expect a positive influence of the Qing state's infrastructure investment. The actual relationship between public capital in infrastructure and economic growth is complicated in a modern economy. As mentioned in Romp (2007), infrastructure cannot generate sustained economic growth by itself. To what extent public capital contributes to productivity increase varies among industries, according to the level of dependence on infrastructure input in the production process. For instance, food processing and textiles are more sensitive to transportation costs and then to the expansion of railways. The effect also depends on specific social and economic conditions. Local market conditions and political institutions may influence the operation of public assets. Historians have already pointed out the problem of inefficiency in maintaining and operating public assets under the intervention of the Qing state, which may discourage the private use of newly constructed infrastructure (e.g. Wang, 2000; Xu and Wu, 2003). One characteristic of modern infrastructure is the interconnection of infrastructure services and correspondently the economy of scale (Azariadis and Stachurski, 2005). The gain from investing in one portion of the infrastructure network will be restricted by the level of the completeness of the system. The coverage ratio of new transportation and telecommunication systems in Qing China was still at a very low level compared with the level of the 1930s. Therefore, new infrastructure may not sufficiently support industrial activities, especially for manufacturing. Even if the country benefits from new infrastructure, not all regions are equally benefited; constructing new railways may lead to resource reallocation. With the rise of new industrial centres, the industrial production in other regions may shrink and relocate.

We also summarise briefly the previous discussions about the Qing state's role in early industrialisation and modernisation, particularly with regards to the Self-Strengthening Movement of the 1860s–90s. The review of the related literature goes back to the 1980s when researchers began to interrogate the positive side of the Qing state's efforts towards industrialisation, and when some historians suggested studying the Self-Strengthening Movement from an economic perspective (Huang and Jiang, 1980; Chen, 1986). The consensus reached after decades of discussion is that the Qing state initiated the industrialisation of China, no matter what was the intention behind (Chen, 1995; Jiang, 1997). In the late nineteenth century, Qing state investment dominated the modern industrial sector in some early industrialised cities, including Tianjin, Wuhan and even Shanghai (Jiang, 1993). Among Tianjin's modern factories, there were around 10 thousand workers hired by state-owned factories, while there were approximately 1,500 in private factories.

As for the relationship between Qing state investment and industrial growth, the conclusions in the literature remain ambiguous. Some studies focus on the positive influence. Xia (1992) stated that the Qing state's investment in military modernisation indirectly contributed to the civilian side e.g. through education and then the process of industrialisation. Yu (2008) and Zhou (1996) emphasised the initial introduction of Western technology and machinery production to Qing state investment and concluded that the experience and knowledge accumulated during the state investment period later benefited the private sector.

The Qing state's investment largely changed the pace and direction of China's urbanisation through the development of the industrial sector (Song, 1995; Tu, 1996). Moreover, Lu (2002) pointed out that the Self-Strengthening Movement reinforced the formation of new industrial centres in Qing China. Liang (2015) recently explained regional differences in industrial establishments in the period 1842–1916 through the expansion of railways. Although not

explicitly mentioned, Liang (2015) gave the empirical evidence of a positive relationship between the regional industrial performance and infrastructure construction initiated and financed by the Qing state. Other studies point out that the influence of Qing state investment should be limited since the financial capacity of the Qing state may not have sufficiently supported all the investment programmes in military modernisation and in related heavy industries at the same time (Chen, 1986; Chen, 1995).

Others argue that the negative influence outweighs the positive. The Qing state may have tried to perform its developmental role in industrialisation, which perhaps generated a temporary boost to industrial growth; however, this may ultimately have failed to create sustained economic growth in the long run. In short, this line of argument portrays the capacity of the Qing state as limited in instigating sufficient developmental changes, and even posits the Qing state as an obstacle to industrial growth. In Xu and Wu's (2003) work on the history of China's early capitalism, they concluded that these state-initialised enterprises suffered management inefficiency, such as corruption, nepotism and appropriation, and most were finally bankrupted or privatised because of Qing state intervention. Based on cases at the industrial level, they concluded that Qing state investment failed to construct a modern industrial sector before the end of the Qing Empire. Rawski (1989) similarly contends that in the long run the influence of state-owned enterprises in promoting industrial growth was very limited; until 1932, among large industrial enterprises, only a small fraction was state-owned. A very recent survey study reviewing the history of China's industrialisation claims that most of the Qing state's investment in new technology generated no spillovers into private production (Brandt, Ma and Rawski, 2016). As for the reason behind this, some argue that the Qing state was unable to provide the necessary institutional support for industrialisation because the political institutions in an otherwise traditional agrarian country were a major obstacle to implanting industry-favoured economic institutions (Wu, 1999; Wang, 2000). The financial capacity of the Qing state may have limited the choice and implementation of polices to help support industrial development, which could be a fundemantal factor behind the decline of the Qing economy in the nineteenth century as well as its inability to industrialise (Vries, 2015). Others consider governmental intervention as the main obstacle to economic efficiency and argue that it slows down potential industrial growth in the long run (Wu, 2011; Brandt, Ma and Rawski, 2016). Deng (1998) argued that the industrial policy targeted at military modernisation and related heavy industries is one of the main reasons behind the failure of the Qing state to promote industrialisation. Based on a theoretical model, Dai and Bie (2010) concluded that Qing state investment indeed intended to bring in new technology from the West; however, it ultimately hindered the expansion of Western technology when the priority of state-owned enterprises was diverted to maintain monopolistic profits.

Researchers are thus still uncertain about the relationship between Qing state investment and industrial growth, although it is generally accepted that the Self-Strengthening Movement of the 1860s–90s initiated by the Qing state opened up the process of China's industrialisation. It is therefore not reasonable to ignore the influence of Qing state investment when looking at China's early industrialisation before WWII. At this moment, most conclusions in the existing literature are derived through case studies rather than a quantitative and systematic analysis that tries to directly examine the correlation between Qing state investment and industrial performance. The econometric method is still rarely used in studying China's early industrialisation before the 1930s, with the exception of Liang (2015).

For the first time, this study tries to evaluate the Qing state's contribution to industrialisation, specifically whether the Qing state's investment in industrialisation related programmes that accumulated until the 1910s contributed to the regional differences in industrial performance of the period 1912–16. As shown in the next section, it is still very difficult to form a causal relationship, but we still find through the econometric analysis a significant correlation between Qing state investment and regional industrial outcomes. The quantitative assessment differs from previous analysis in two aspects. In contrast to studies that focus on industrial

growth across time, this work draws attention to regional differences in industrial outcomes. This study also tries to associate the Qing state's investment in less-developed provinces with its industrial outcomes by focusing beyond large-scale investment programmes in wealthy provinces, such as the Jiangnan Arsenal in Shanghai, Jiangsu province. Thus, this study intends to provide a more balanced and comprehensive assessment of Qing state investment at the provincial level within China.

3 New measurements for the Qing state investment and factor analysis results

This section quantifies the Qing state's direct investment in programmes related to new industrialised production and organisations at the provincial level for two periods, 1860–96 and 1860–1910, respectively. The new measures better capture the Qing state investment in new technology and scientific knowledge. With the new measures, this study tries to evaluate the Qing state's effort to reinforce the national defence and to increase the national wealth in the last decades of the Qing Empire. Particularly, the new measures focus on provincial differences, rather than estimating the total investment for the country. Providing measures for the two periods intends to reveal the variations before and after 1896.

3.1 Data collection

The data collection in this study started from grouping various state-invested programmes in several major categories: new education and training, military production, state-owned factories, telegraph and railways. Because of data availability, the Qing state's investment in services is not included, such as those for transportation services e.g. China Merchants' Steam Navigation Company and utilities such as the electricity supply. Investment in small-scale mining that relied on traditional technology is also not included in the data. The data collection instead focuses on Qing state investment in manufacturing and infrastructure construction which may have promoted the adoption of Western technology and new styles of education

The data collection pays attention to the investment programmes financed through the Qing state's public expenditure. Regular operation in state-owned enterprises was often subsidised by the Qing state. Including the initial capital, the capital stock in state-owned enterprises was formed primarily through the Qing state's investment, which can be used to represent the influence of the state in industries. During the Self-Strengthening Movement, the Qing state noticed the importance of some heavy industries, such as iron and steel, in constructing new military power. We then put the Qing state's investment in heavy industries that were connected with military construction into the category of military production. The Qing state also invested in other private industries but provided only part of the initial capital. Different from state-owned enterprises, the capital stock in state-sponsored enterprises was partly formed through the Qing state's investment. Two forms of management structure were applied to state-sponsored enterprises: official and merchant joint management, and merchant management under official supervision. Because of the complexity of management structure, the Qing state's direct influence on capital formation in state-sponsored enterprises is unclear. Therefore, this study separates state-sponsored enterprises from the above categories of public investment but uses the Qing state investment in private industries as a control variable in the regression analysis in Section 4.

For some large-scale self-strengthening programmes, information on the Qing state's public expenditure is available in historical archives and related secondary sources. Studies on the Qing state's public finances have tried to estimate the total expenditure on new military factories, new educational institutions, and infrastructure construction during the Self-Strengthening Movement (Deng, 1998; Fan, 2003). The categories of state investment in military, educational and infrastructure programmes are interconnected and estimating one category of investment from the public expenditure side can be misleading. The first railways

approved by the Qing state were part of the construction of a state-owned iron and steel factory. Concerning new education, a better estimation should also consider the training in new technology organised by military factories, railways and telegraph offices for their staff members. Historical records on the establishment of state-owned enterprises contain the information of initial capital and sometimes annual subsidies from the Qing state. However, the records do not denote whether the investment went into capital formation, the training in new technology or regular maintenance. The value of machinery and buildings is a reasonable indicator for capital stock in military factories and manufacturing industries; however, it is not suitable for estimating the investment in new educational institutions. Comparable and systematic indications for the public capital accumulated during the late Qing period are still not available because of the complexity of the historical records and also the data availability.

A new dataset was constructed to reveal the distribution of the Qing state's self-strengthening programmes in provinces. The number of new establishments during the reform period is currently the best indicator for provincial variations. We first collected a list of the state-owned military-related factories established in the period 1860–96 and then extended the list up to ca. 1910. The first list shows the military investment regarding the Self-Strengthening Movement until the First Sino-Japanese War of 1894–95 and the latter includes (almost) all the relevant military investment before the end of the Qing Empire. We collected information on both large and small factories from both primary and secondary sources, and then calculated the number of establishments in a given province within Qing China. Similarly, we referred to historical maps of China's early transportation and communication to obtain the numbers of train stations and telegraph offices constructed in a given province for the period 1860–96 and the period 1860-1910 respectively. We also calculated how many prefectures in one province can be connected by railways or telegraph lines. Besides new educational institutions established directly by the Qing state, we added in the training schools organised by military factories, train stations and telegraph offices. The number of new educational institutions established after 1896 was obtained from the first educational census of the Republic of China and matched with the new establishments before 1896. Appendix 1 gives more information on the dataset, including the calculation procedure, primary and secondary data sources (See Table A 3 and Table A 4 in the Appendix.). Considering provincial attributes such as the size of population and territory, we changed the indicators in absolute value to relative terms. The measures in relative terms will be applied to the quantitative analysis later in Section 3.2.

The new military industry of the late Qing period is the central target of the Self-Strengthening Movement. We calculated the accumulated operation years of all state-owned military-related factories in a province as another indicator for the intensity of the influence of state investment in provinces. Presumably, the influence may accumulate across time. We also calculated the average operational years of a military-related factory in one province. Utilising recent historical studies on the Self-Strengthening Movement, we obtained the information on how a new state-owned factory was established, such as when the Qing state approved the new investment and when the factory started its production (See Table A 4 in the Appendix.). The final year of operation for a state-owned factory is not always very clear, especially for some small-scale factories. Referring to historical archives (ZGSXH, 1961), we tried to check whether it was in operation in 1896 and in 1910. For small factories, the final years they were mentioned in the historical records we managed to refer to are treated as the final year of operation. Because of the complexity of historical records and data availability, it is still not feasible to calculate the years of operation for new educational institutions and new infrastructure. This study used the number of establishments and years of operation as proxies for the public capital stock accumulated through Qing state investment. These new indicators may underestimate provincial differences in public capital stock, while previous studies may overestimate the differences by focusing on large military-related factories concentrated in a few provinces.

Appendix 1, Table A 5, shows the dataset we constructed on Qing state investment during the late Qing period in both absolute and relative terms, covering 22 provinces and two periods, 1860–95 and 1860–1910. Take Jiangsu province (JS) in the lower Yangzi delta as an example. There were five military-related factories until 1896 and seven until 1910, 0.47 and 0.66 per square kilometres respectively. The accumulated operational years of military-related factories in JS increased from 80 to 146 and the average years of operation were 16 until 1896 and 21 until 1910. The number of new educational institutions increased from 12 to 24, 0.39 to 0.74 per thousand people. The number of telegraph offices increased from 10 to 24, from 0.91 to 2.18 per prefecture within JS. In 1896, telegraph connections had already covered 70 per cent of the prefectures. In contrast, there were still no railways constructed in JS until 1896. Table A 5 shows clearly that the development of railways in the late Qing period was far behind other categories of state investment. Until 1895/6 at the national level, only six prefectures had railway connections, while 122 prefectures had telegraph connections. Although it is generally believed that the Self-Strengthening Movement failed and was terminated in around 1895 following military failure in the First Snino-Japanese War, the new dataset constructed shows that the Qing state continued to invest in related self-strengthening programmes in the post-1896 period. Most military-related factories established before 1896 continued in operation after the war with Japan and the total number increased by 16. The total number of prefectures that had railway connections increased to 64 in 1907. The total number of new educational institutions increased from 51 in 1896 to 203 in 1909.

The new dataset shows a provincial distribution of Qing state-invested programmes in the late Qing reforms. Until 1910, the Qing state constructed 13 military-related factories in HUB province, eight in ZHL province, seven in JS province, and five in FJ province together accounted for half of the military-related factories established in the late Qing period. Previous historical studies have noted that Qing state investment in the Self-Strengthening Movement was fundamentally regional-based since the major initiators of the late Qing reforms were mainly local officials. The new dataset indicates that Qing state investment was not restricted to a few provinces. Different from regionally based military investment, telegraph construction was more equally distributed among provinces. Until 1896 all 22 provinces were involved in certain categories of investment programmes in the late Qing reforms. This study provides a more comprehensive picture of the Qing state's direct investment in new technology and scientific knowledge. In particular, it reveals that different categories of state investment may have different influences on industrial growth.

3.2 Factor analysis

The data analysis in this study is based on seven indicators for the Qing state's investment in military construction, education and infrastructure (Table 5. b). Without a standardised measurement for historical capital stock, the multidimensionality of the indicators prevents us from obtaining a complete overview of Qing state investment. Additionally, we cannot compare two categories of state investment using indicators on different scales. For instance, the new indicators cannot reveal whether the Qing state invested more in new educational institutions than telegraph construction. Following the method used in Jong-A-Pin (2009), this study uses a factor analysis to solve the scaling problem and to reduce the dimensions of state investment. The factor analysis also helps to identify underlying factors behind various categories of state-invested programmes and to reveal provincial differences through these factors. The study tries to derive a set of new measures suitable for comparative and regression analysis and to evaluate the Qing state's investment at provincial levels.

In this study, the factor analysis assumes that the indicators for the categories of Qing state investment are "generated" from a set of unobserved common factors. The method will extract the information common to all indicators and also retain a certain level of variance contained in different indicators. Table 2 is the correlation matrix calculated from the seven indicators in relative terms, from which we derived common factors through a factor analysis. Previewing the results: two common factors can be distinguished from the set of seven

indicators for Qing state investment in provinces: (1) the military-related dimension and (2) the infrastructure-related dimension. We then estimated the values of the factors of the two dimensions, i.e. factor scores. This study uses the factor scores as new measures for Qing state investment at provincial levels. The new measures are used in empirical analysis in Section 4 to assess the impact of Qing state investment on industrial production.

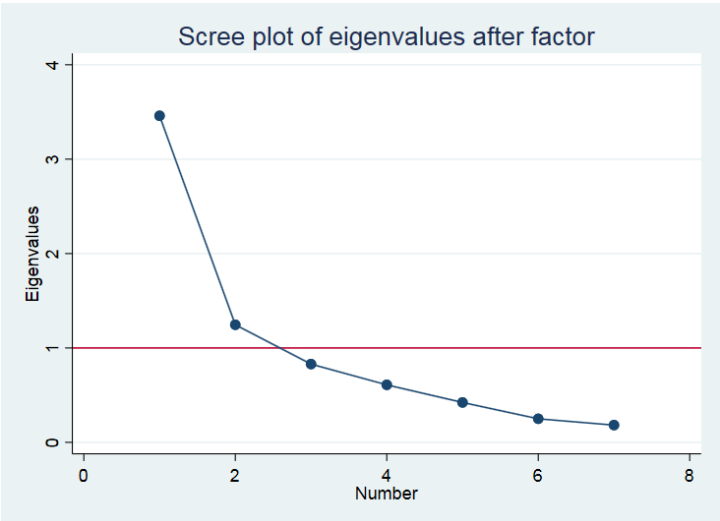
Table 1 Correlation matrix of the indicators for the Qing state's investment

	EduNrpopu	*Telepref*	*Telestapref*	*Railpref*	*Railprovcap*	*MilitNrkm*	*Militlife*
EduNrpopu	1						
Telepref	0.44	1					
Telestapref	0.48	0.73	1				
Railpref	0.56	0.46	0.57	1			
Railprovcap	0.41	0.41	0.53	0.80	1		
MilitNrkm	0.20	0.55	0.46	0.15	0.14	1	
Militlife	0.18	0.29	0.25	0.13	0.13	0.24	1

Notes: The table shows correlation coefficients. "*EduNrpopu*" is an indicator for state investment in education. "*Telepref*" and "*Telestapref*" are indicators for telegraph construction. "*Railpref*" and "*Railprovcap*" are indicators for railways. "*MilitNrkm*" and "*Militlife*" are indicators for military construction. Appendix 1 gives more information on the indicators for the Qing state's investment.

To decide how many factors should be exacted, we used several statistical tests. Firstly, we considered Catell's scree test and used the elbow criterion and the Kaiser criterion. In Figure 1, the elbow is between the second and third factor and only the first two factors have an eigenvalue greater than one. The first two factors explain a relatively large part of the variance contained in the seven indicators (67 per cent). Thus, a two factor model is appropriate. Secondly, we conducted a Likelihood Ratio test, which rejected the null hypothesis that the two factor model was equivalent to a saturated model. Thirdly, a two factor model gave the lowest value of the Akaike's information criterion and the Schwarz criterion.

Figure 1 Catell's scree test



Notes: Constructed by the author. The figure is a scree plot with eigenvalues on the vertical axis and the number of factors on the horizontal axis.

Based on the correlation matrix in Table 2, we conducted a factor analysis with two common factors. Since the financial capacity of the Qing state restricted the level of total investment and affected all possible categories of state investment, we assume different factors to be correlated with each other. We then used promax rotations that allow for correlated factors, other than commonly used orthogonal rotations. The resulted correlation coefficient between the two factors is 0.36, significant at the 5 per cent level. Although moderately correlated, the two underlying factors reflect two different dimensions of state investment during the late Qing reforms.

The resulted factor loadings are shown in Table 3. Without any previous assumptions, the factor analysis generated two dimensions of the Qing state's investment. The first factor has high loadings for indicators measuring the Qing state investment in railways. Thus, the factor is labelled as "infrastructure-related state investment". Accordingly, the second factor is labelled as "military-related state investment", in contrast to the first factor related to civilian-use public infrastructure. Military-related state investment can be separated from civilian-use public investment. Table 3 also shows that for most indicators the value of unique variance is below 30 per cent. Thus, a large part of variations in the seven indicators can be attributed to the two dimensions of state investment. We estimated the factor scores for the two dimensions of the Qing state investment through Bartlett scoring conditional on all seven indicators. The factor scores are considered in this study as new measures for the Qing state's investment in the late Qing period. To be noted, the factor scores for the two dimensions are both rescaled to have mean two, which avoids any negative factor scores. Appendix 2 shows the factor scores for provinces and for two periods, 1860–96 and 1860–1910 (See Table A 7 in the Appendix).

Table 2 Rotated factor loading matrix and unique variance

Indicators	Infrastructure-related	Military-related	Unique variance
Railpref	0.9455	-0.0457	0.1371
Railprovcap	0.903	-0.0671	0.2265
EduNrpopu	0.6415	0.1589	0.4851
MilitNrkm	-0.1883	0.8913	0.2988
Telepref	0.2896	0.717	0.2428
Militlife	-0.1407	0.6293	0.6521
Telestapref	0.4811	0.5573	0.2523

Notes: Constructed by the author. Factor loadings are estimated using the principal-component factor method. The method of rotation is promax. The factor loadings larger than 0.3 (in absolute terms) are marked in grey. For variable information, see notes in Table 2.

There are limitations in the new measures of the Qing state investment, which are estimated mainly through the numbers of the Qing state-invested programmes at the provincial level. Comparison based on the new measures may underestimate the differences between provinces. The operation and management of the state-invested programmes may be more efficient in some provinces. Similarly, the new measures do not consider the capital requirements different between categories of the state investment. To capture more variations, we calculated the years of operation but only for military-related programmes. Even with the possibility of underestimation, the quantitative analysis in this section reveals considerable variations between provinces. In particular, the new measurements are estimated through a statistical method that allows for future updates on new data and new historical findings

3.3 Measuring state investment in the late Qing period: a new description

This study provides a new description of the late Qing reforms through the two dimensions estimated through the factor analysis. Firstly, we can interpret the Qing state's "attitudes" towards different categories of investment programmes through the factor loadings and the

new measures. This two factor model implies that constructing new educational institutions was not given a priority in the late Qing reforms. The factor loading for the indicator for new educational institutions is lower than that of the indicators for railways. Table 4 shows to what extent an indicator for a category of state investment is related to the two dimensions of state investment, respectively. The investment in education is more related to infrastructure construction than military construction. There were special training schools for railways and telegraph, although many educational institutions established before 1896 served the need for military training and production. After the First Sino-Japanese War, many military training schools were forced to shut down. As one category of infrastructure construction, telegraph construction is more associated with military investment, while the railways are only moderately correlated with military investment.

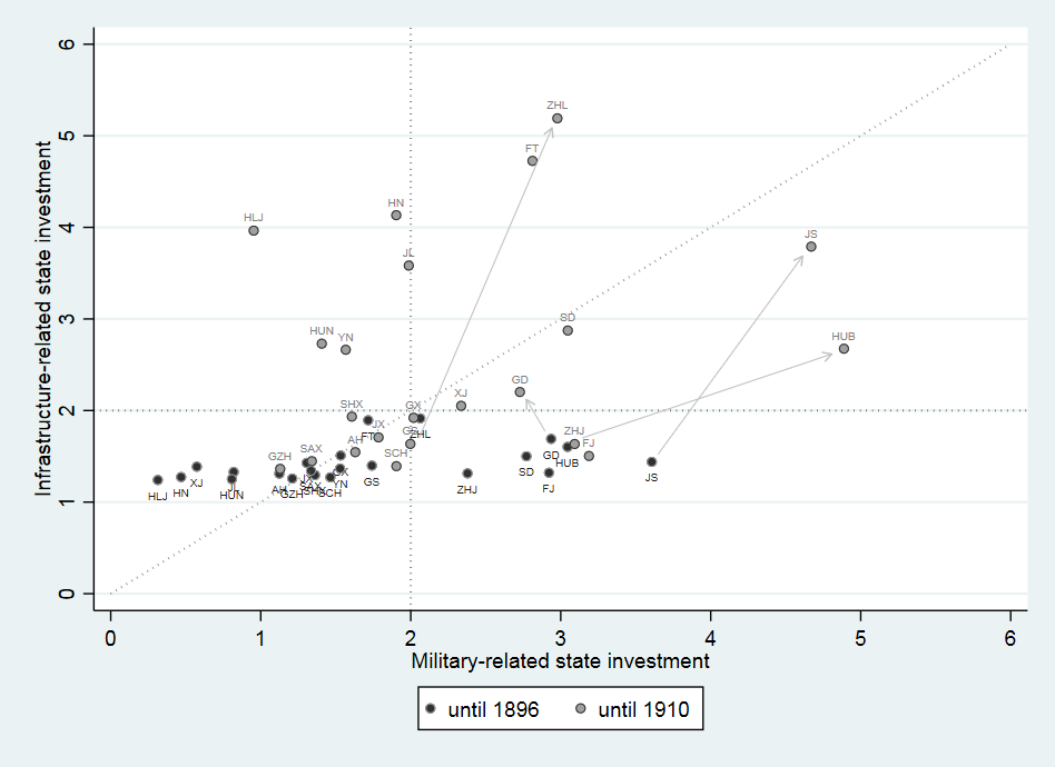
Table 3 Correlations between indicators and the two dimensions of the Qing state investment derived from the factor analysis

Indicators	Infrastructure-related	Military-related
EduNrpopu	0.7024	0.4049
Telepref	0.5645	0.828
Telestapref	0.6948	0.7418
Railpref	0.928	0.3168
Railprovcap	0.8773	0.2792
MilitNrkm	0.1536	0.8191
Militlife	0.1006	0.5753

Notes: Constructed by the author. The correlation matrix is obtained from factor score predictions. The correlation larger than 0.5 is marked in grey. For variable information, see notes in Table 2.

Figure 2 shows the provincial distributions of the Qing state investment from the military-related and infrastructure-related dimensions. For each one of the 22 provinces in Qing China, Figure 2 gives the factor score of military-related state investment on the horizontal axis and the factor score of infrastructure-related state investment on the vertical axis. The two factor scores together position a province in the figure. The figure also illustrates the change of provincial variations between the two periods, 1860–96 and 1860–1910. The factor score estimated in this study is not a measure for the absolute value of public investment accumulated in a certain period, but to capture differences between provinces as a relative term. For the pre-1896 period, the military-related dimension explains a majority of provincial variations in state investment. The Qing state investment in military construction concentrated in a few provinces left other provinces far behind: as shown in Figure 2, those positioned right to the average line have a high level of military-related investment. Meanwhile, the Qing state did not give enough attention to infrastructure construction in this period. The factor scores for the infrastructure-related dimension are all below the average line and show no significant differences relative to the military-related dimension. For most provinces, the Qing state's investment before 1896 had a strong bias towards military construction.

Figure 2 Comparison of factor scores between provinces and two periods, 1860–96 and 1860–1910



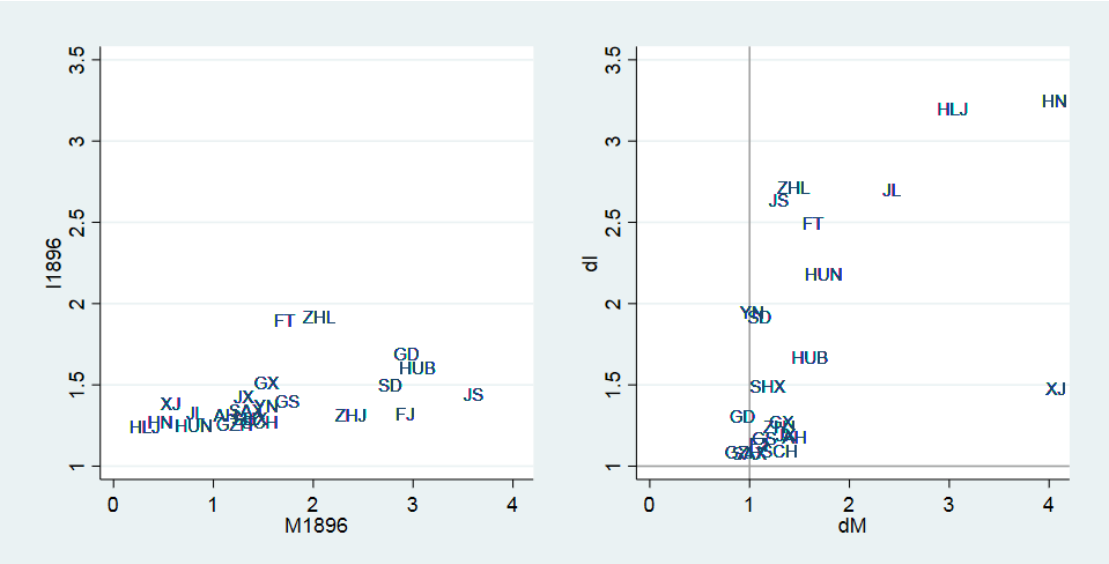
Notes: Constructed by the author from the factor scores listed in Appendix 2. The black circle denotes factor scores for the period 1860–96. The grey circle denotes factor scores for the period 1860–1910. The arrow marks the differences in factor scores between 1896 and 1910. A 45-degree line is included in the figure for reference. The short forms of province names are marked in the figure. Appendix 4 lists full province names. The factor scores for the two dimensions are both rescaled to have mean two, marked in the figure as dotted lines.

We then look at the Qing state's investment in the entire late Qing reforms. Figure 2 shows that provincial variations in both of the two dimensions of state investment for the period 1860–1910 are more significant than for the pre-1896 period. The 45-degree line in the figure divides provinces into two groups and addresses whether the Qing state invested more in military-related programmes. The upper half has a higher level of state investment in infrastructure than in military construction. Most of these provinces are located in North China, such as ZHL province including the national capital city Peking, Manchuria in the northeast (including FT, JL and HLJ provinces), and HN province along the Yellow River. Conversely, the lower half has a higher level of investment in military construction, such as JS province in the lower Yangtze delta and HUB province in central China. The Qing state's investment of the period 1860–1910 as a whole did not show a clear tendency towards either of the two dimensions, different from the pre-1896 period.

Qing state investment in most provinces was expanded for the period 1896–1910 for both two dimensions. The average factor scores for the period 1860–1910 are higher than the period 1860–96. For most provinces, the factor scores for the two dimensions increase in the post-1896 the period. The arrows in Figure 2 mark the changes across time. According to the figure, the increase in state investment in ZHL and JS is biased towards infrastructure construction, while the bias in HUB is towards military construction. GD (South China) is exceptional in that military-related state investment declined in the post-1896 period in contrast to an increase in infrastructure-related investment. We then calculated the changes in

the factor scores between the period 1860–95 and 1860–1910 and denoted the changes as new measures for Qing state investment in the post-1896 period. Figure 3 compares the two dimensions of Qing state investment in the pre-1896 period with the post-1896 period.

Figure 3 Factor scores for the Qing state investment and changes in provinces, the pre-1896 and post-1896 periods



Notes: Constructed by the author. The left graph shows the factor scores for the Qing state investment in the period 1860–96, *M1896* and *I1896*. The right one shows the changes in the Qing state investment in the period 1896–1910 measured by the changes in factor scores, *dM (M1910/ M1896)* and *dI (I1910/ I1896)*.

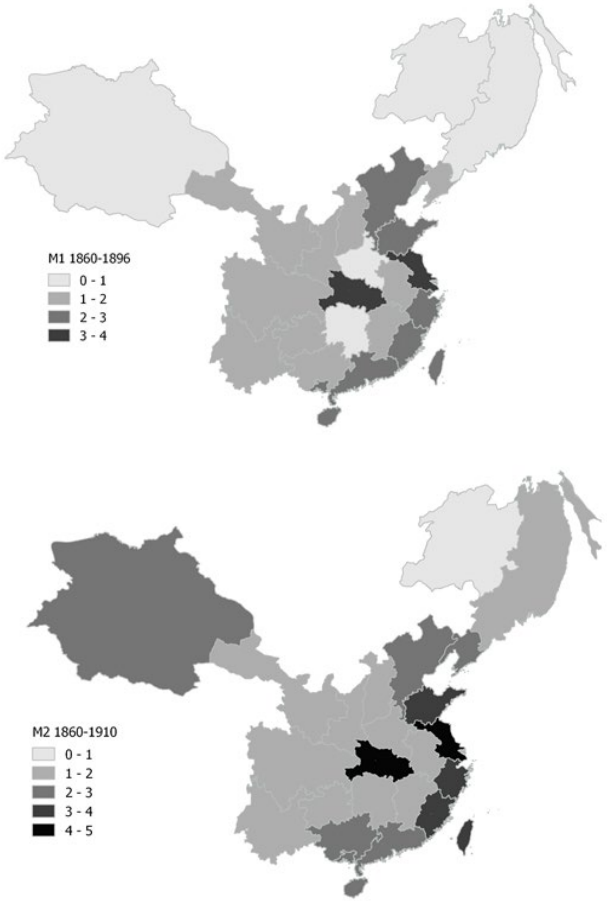
Historical studies on the late Qing reforms often focus on the Self-Strengthening Movement of the 1860s–1890s and tend to neglect the connections between the post-1896 reforms and the pre-1896 reforms. The new dataset and the factor analysis in this study indicate that Qing state investment in new technology and scientific knowledge continued throughout the entire late Qing period, but shifted significantly in the post-1896 period. Whereas in the pre-1896 period Qing state investment focused on military-related construction, post-1896 state investment largely shifted toward infrastructure-related construction. Figure 3 confirms the shift in Qing state investment after the First Sino-Japanese War of 1894–95.

The quantitative method used in this study allows us to compare the two dimensions of the Qing state investment at the provincial level and track the changes in provinces across time. Figure 4 illustrates the resulted provincial distribution of factor scores for the two dimensions and the two periods. In the four maps in Figure 4, provinces are grouped according to the same numerical categories and distinguished by grey scales. For the pre-1896 period, provincial variations in the military-related state investment are demonstrated clearly in the map. In contrast, according to the numerical categories in Figure 4, no significant provincial differences can be found for the infrastructure-related state investment. Although with provincial variations, most provinces had been involved in Qing state-invested programmes during the Self-Strengthening Movement as illustrated in the figure. For the entire period until the end of the Qing regime, i.e. 1860–1910, Figure 4 demonstrates different provincial patterns between the two dimensions of Qing state investment during the late Qing reforms. Provinces along the south coast and XJ province along the northwest border had a higher level of military-related state investment relative to most inland provinces. The exception is HUB as a centre of inland waterways along the Yangzi River. This provincial pattern had by

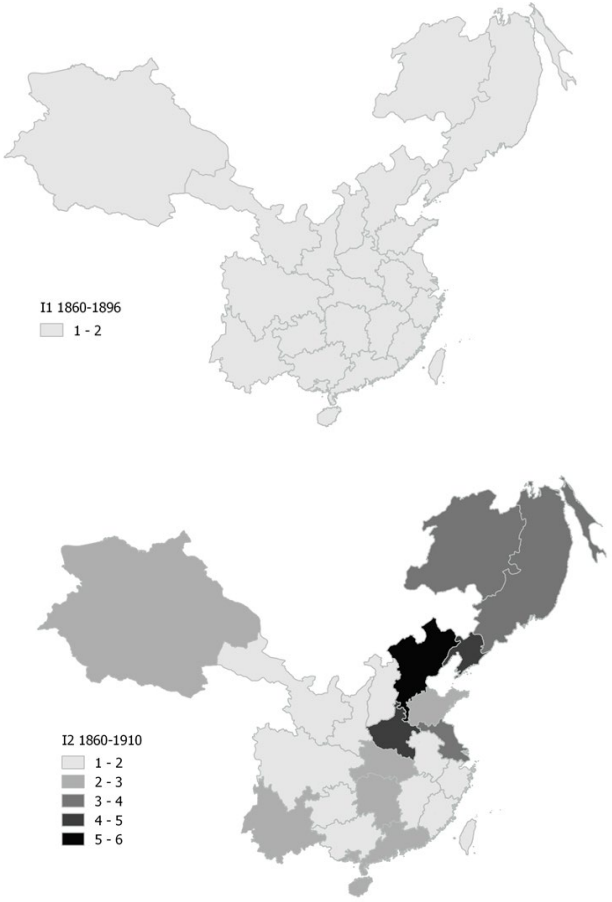
large formed before 1896 and was thereafter reinforced. The infrastructure-related state investment, in particular railway construction, mostly concentrated in the north such as in ZHL with the national capital, while south and southeast China might benefit more from waterways along the Yangzi River and the south and southeast coast. In contrast, this provincial pattern in the infrastructure-related state investment formed during the post-1896 period.

Figure 4 Regional differences in the Qing state investment, two dimensions and two periods, 1860–96 (period 1) and 1860–1910 (period 2)

a. Military-related state investment (*M*)



b. Infrastructure-related state investment (*I*)



Notes: Constructed by the author from the factor scores listed in Appendix 2. For the same dimension of investment in a column, the categories are distinguished by the same grey scales. The map is based on the Qing territory of 1820 but only shows the provinces the sample covers. The map data is from China Historical GIS data V4 (Harvard Yenching Institute and Fudan Center for Historical Geography, 2007).

The leading provinces in the late Qing reforms are positioned on the top right of Figure 2 with the factor scores above the averages for both of the two dimensions. Table 5 lists the top and bottom five provinces for each of the two dimensions of Qing state investment. The leading provinces for the two dimensions are different: ZHL and FT for the infrastructure-related investment, JS and HUB for the military-related investment (see also Figure 4). The rankings reflect that the provinces in the top group of one dimension do not always end up in the top of the other dimension. The provinces in the bottom groups of the two dimensions have more overlaps than in the top group. This reinforces the assumption underlying the factor analysis that the common factors of state investment are moderately correlated with each other. Of note, in the rankings for the infrastructure-related investment, HLJ and HN provinces move from the bottom group of the pre-1896 period to the top group of the post-1896 period. GZH and SCH provinces had a very low level of infrastructure-related state investment, probably because the two provinces located in southwest China have complex geographical and adverse weather conditions that would likely have restricted construction work during the late Qing period. HLJ province, part of Manchuria, can be seen as another case with a top level of state investment in infrastructure but a bottom level of the military-related state investment during the late Qing reforms.

Table 4 Rankings of the top and bottom five provinces for the two dimensions of the Qing state investment, 1860–96 and 1860–1910

	1860–1896	1860–1910	1860–1896	1860–1910
Ranking	Infrastructure-related	Infrastructure-related	Military-related	Military-related
1	**ZHL**	**ZHL**	**JS**	**HUB**
2	**FT**	**FT**	**HUB**	**JS**
3	GD	HN	GD	**FJ**
4	HUB	HLJ	**FJ**	ZHJ
5	GX	JS	**SD**	**SD**
22	HLJ	**GZH**	**HLJ**	**HLJ**
21	HUN	**SCH**	HN	GZH
20	**GZH**	SAX	XJ	SAX
19	**SCH**	FJ	**HUN**	**HUN**
18	HN	AH	JL	YN

Notes: Constructed by the author. The upper panel shows the top five provinces. The lower panel shows the bottom five provinces. Appendix 4 lists province names and the short forms.

4 The Qing state's influence on early manufacturing in the 1910s

4.1 Model specification

This section looks into the question: whether the Qing state investment in new technology and new methods of production in the late Qing period contributed to regional differences in industrial performance in 1912/16. The factor scores estimated in the previous section quantify the Qing state's investment in provinces and make it possible to study directly the relationship between Qing state investment and China's early industrialisation before WWII. The quantitative analysis in this study is based on cross-section panel-data regressions on industrial performance, adding Qing state investment as explanatory variables. This study follows the method used in the research on public capital and economic growth. The stock of public capital, *G*, is taken into consideration as parts of a production function. According to the literature review in de Haan (2005) and Romp (2007), the function form can be written as follows:

$$Q_i = A_i(G)F(K_i, L_i, G),$$

where Q is the real output of industry i, A is the technology term, K is the fixed capital stock of private industries, L is the employment level. The growth effect of public capital may depend on the specific characteristics of an industry. De Haan (2005) pointed out that in the above model public capital would affect private production in two ways: as a production input or through technology efficiency. As mentioned previously in Section 2, in the related literature public capital is often defined as infrastructure, such as railways. Besides the expansion of railways and telegraph lines, a large part of Qing state investment in new technology is related to military modernisation. Military fixed capital cannot be treated as a third input factor in private industries; therefore, military-related Qing state investment may take effect through technology efficiency. However, estimating a Cobb-Douglas production function in a log form does not distinguish the two ways of modelling public capital.

Correspondingly, the baseline model specification in this study is:

$$Y_{ir}^{1912} = \alpha + G_r{}'\beta + X_{ir}^{1912}{}'\gamma + X_r^{1912}{}'\delta + Z_r{}'\lambda + \upsilon_i + \varepsilon_{ir},$$

where Y_{ir}^{1912} is the gross output value (*GOV*) for industry i in province r in 1912 and υ_i refers to an industry fixed effect. Other indicators for industrial performance will be tested later using the same model specification. The data on *GOV* is from the Agricultural and Industrial Statistical Yearbook (for short, the Yearbook of 1912, 1916) published by the Agriculture and Industry Department, Republic of China. The Yearbook also contains the data on employment and the number of industrial establishments. The data structure combines both a provincial and an industrial dimension, including 22 provinces in Qing China and 31 manufacturing industries for two years, 1912 and 1916. The manufacturing industries covered by the Yearbook range from food processing and textiles, to the heavy industry such as chemicals and metal products. Machine manufacturing and shipbuilding were rare in China during the early 1910s and are thus not included in the sample. The industrial establishments include both factories employing more than seven workers and small-scale handicraft workshops often operated by families. Traditional production still dominated China's industrial sector in the early 1910s. The average share of handicraft workshops across all provinces in manufacturing industries in 1912/16 was above 95 per cent according to the Yearbook.

This study looks at the industrial production in the early 1910s; however, we cannot directly use the new measures for the Qing state's investment for the period 1860–1910, i.e. *M1910* and *I1910*. As discussed in Section 3, the direction of the Qing state investment shifted from military production to infrastructure construction in around 1896. The regression analysis also considers the shift by dividing the entire period of late Qing reforms since 1860 into two periods, 1860–96 and 1896–1910, i.e. the pre-1896 and the post-1896 periods. The new measures for the post-1896 period are denoted as follows: *dM* for the increase in military-related investment and *dI* for the increase in infrastructure-related investment.

$$M1910 = M1896 * (M1910/M1896) = M1896 * dM, where\ dM = M1910/M1896.$$

$$I1910 = I1896 * (I1910/I1896) = I1896 * dI, where\ dI = I1910/I1896.$$

As in the above equations, this study represents the Qing state's investment in new technology in the late Qing period using four variables: *M1896* for the military-related investment in the pre-1896 period, *I1896* for the infrastructure-related investment in the pre-1896 period, *dM*, and *dI* for the changes in the post-1896 period.

Provincial industrial performance may react differently to the four variables of state investment. Another feature of the Qing state investment is the interconnection between military-related and infrastructure-related investment, especially for the pre-1896 period. The vector G_r contains the above four variables of the Qing state investment in province r and also two interaction terms, *M1896*I1896* and *dM*dI*. After taking the natural logarithm, the parameter vector β gives the elasticity of the Qing state's investment on industrial output,

which may depend on the level of military or infrastructure investment in the same province. According to the literature review in Section 2, the sign and the significant level of β are ambiguous.

The vector X_{ir}^{1912} contains the basic explanatory variables in a log-term production function, including the employment in an industry in 1912 (*EMP*). Since the data on the fixed capital of private manufacturing of 1912 is not available, the regression uses the total number of factories and handicraft workshops (*NrFH*) as a proxy for capital input. The regression uses another two variables to control the fixed capital stock of an industry in a province. The share of handicraft workshops of industry *i* in province *r* (*NrHshare*) measures the concentration level of handicraft workshops of an industry. With the same number of industrial establishments, a higher share of handicraft workshops may indicate a lower stock of fixed capital. The share of factories in the total number of industrial establishments in a province (*NrF_FHprov*) indicates the development of new and large-scale factory production. A higher level of new factory production in a province may lead to a generally higher stock of fixed capital for all industries in this province.

The vector X_r^{1912} contains provincial variables of 1912, which may influence the general industrial performance in province *r*, such as education, population density and natural resources. For instance, public expenditure on agriculture and industry arranged by the Republic of China may also affect provincial industrial output. For education, the number of primary and middle schools in a province in 1912 is used as a proxy. We have included in the factor analysis the number of new Western-style educational institutions financed by the Qing state. These Qing-period educational institutions are considered to be equivalent to higher education. Some early educational institutions established before 1896 were transformed into universities and technical schools according to the 1902 regulation on higher education. For natural resources, the regression considers cultivated acreage and coal output in a province. The total coal output for one province in this regression includes the output from its neighbouring provinces. For geographical features, the regression distinguishes the provinces along the west border from others. The Qing state investment might be the primary source of new technology for these provinces far from the coast or far from the major rivers suitable for inland transportation.

The vector Z_r is designed for the robustness of the influence of the Qing state investment. It contains provincial variables that may also serve to bring in new technology and may promote the process of industrialisation in provinces. The number of treaty ports opened in a province before 1910 (*NrTrPort1910*) indicates the level of openness to trade in a province and represents the possibility of getting access to new technology. The regression also includes the number of private enterprises using machinery before 1912, including those funded through foreign direct investment (*NrMFDI1911*) and by domestic investment (*NrMpriv1909*). Many of these enterprises were concentrated in the coastal region or along the Yangzi River, providing services for transportation companies such as packaging, machine fixing and maintaining. Without Qing state investment, a manufacturing industry in these provinces that had experienced an early expansion of machinery production before 1910 may have a better chance of development later in the early 1910s. Appendix 3 presents in detail all the variables used in the regression analysis and the descriptive statistics of these variables.

The similar model specification is used to test if Qing state investment influenced the growth in provincial industries between 1912 and 1916. Here, "*d*" denotes the changes in explanatory variables across time:

$$dY_{ir} = \alpha + G_r{}'\beta + \theta Y_{ir}^{1912} + dX_{ir}{}'\gamma + dX_r{}'\delta + Z_r{}'\lambda + \upsilon_i + \varepsilon_{ir},$$

where dY_{ir} is a dummy variable that equals to one when the gross output value of industry *i* in province *r* in 1916 was higher than in 1912.

Figure 5 describes the relationship between industrial performance in 1912 and Qing state investment at provincial levels. Differences in manufacturing labour productivity across provinces are apparent in the figure. However, the relationships with the four variables representing Qing state investment seems unclear. Section 4.2 discusses the regression results and our evaluation of the Qing state investment.

Before we turn to regression results, problems of endogeneity need to be discussed. In general, this regression analysis cannot fully identify the causality between Qing state investment in provinces and provincial variations in industrial development, but the focus of this study is to establish quantitatively whether a correlation exists, which would in turn be helpful for future research. We consider several possibilities for endogeneity. The first concern is the provincial variation in industries of the 1910s might have already formed before the Qing state began to invest in new technology in the 1860s, although the regression analysis does not directly control pre-1860 regional industrial situations. Quantitative indications and standard measurements for all provinces are lacking for a comprehensive analysis of China's historical industrial development at the provincial level. We have made a systematic comparison of industrial performance over most provinces in the late Qing period based on the first industrial yearbook published in the early 1910s. Rather than the Yangzi delta and Guangzhou province in the south, this comparison refers to Manchuria, north and central China as the leading industrial regions of the 1910s.

This finding may suggest a shift in the regional distribution of industrial production across time. Relative to traditional proto-industries, new industries, such as those dealing in certain chemicals, did not widely exist before opening to international markets but increasingly affected domestic industrial production during the late Qing period. We believe that a new manufacturing sector developed during the late Qing reforms and especially grew rapidly in the period 1905–16 according to the records on industrial establishments (Zhang, 1988). Although we cannot measure provincial variations in industries before the Self-Strengthening Movement in this study, the regression analysis considers related economic endowments that were not often changed with industrial development, such as geographical and agricultural conditions.

Secondly, Qing state investment might tend to flow into those provinces that favoured new technology and new factory production from the West. We may assume that those provinces already had better economic performance or a better chance to develop local industries. Thus, the regression analysis considers coal output (*Tcoalprov*), population density (*popuden*) and cultivated land (*CA1910*) to represent economic endowments in a province. We may also assume that openness to international trade changed local attitudes towards the West and also the growth of local industries; therefore, the regression analysis considers the influence of treaty ports (*NrTrPort1910*). Bringing in machinery-based production may gradually affect local attitudes on new technology. The advantage of machinery in production had been noticed early by the proponents of the Self-Strengthening Movement. The regression analysis also considers other channels through which the new technology from the West could affect locals and local industries: early private investment and FDI in machinery-based production (*NrMpriv1909, NrMFDI1911*).

The state-invested programmes during the late Qing reforms were not randomly distributed, as demonstrated in Figure 4. The attitude of local governments towards the West may largely determine the level of local involvement, as the Self-Strengthening Movement was from the outset promoted by several major local governors. Although as a potential instrumental variable measuring local governments' attitude towards the West is not feasible in this study, we believe that the new measures for the two dimensions of the Qing state's investment estimated in this study already reveal a clear intention behind the state investment. Comparing with industrial performance in provinces, we cannot make a simple conclusion on the correlation between Qing state investment and industrial production.

4.2 Regression results

We firstly look at the average marginal effects of Qing state investment on manufacturing industries at the provincial level. Table 6 shows the estimation results from the baseline regression with the set of contrail variables in Section 4.1. The estimated marginal effects in column 1 are from the regression, including the four variables representing Qing state investment but with no interaction terms (*M1896, I1896, dM, dI*). The results in column 2 are from the same regression but including the interaction terms, *M1896*I1896* and *dM*dI*. Columns 3 and 4 repeat the same estimation as in columns 1 and 2 using the data sample of 1916. Columns 5 and 6 report the results from the logit regression on the change in industrial output between 1912 and 1916. The tests for model specification are listed at the low part of the table. The joint effect of the four variables of the Qing state's investment in the log-linear regression is significant as denoted in the table for the two samples. The two interaction terms are also significant at least for the 1912 sample. Thus, we keep both of the two interaction terms in the following regressions. These tests show that including Qing state investment in the regression analysis helps to explain the performance of the manufacturing industry in 1912, even considering a set of control variables.

Table 1 Baseline estimation results: average marginal effects (AME) of the Qing state investment

	(1)	(2)	(3)	(4)	(5)	(6)
	Baseline	Baseline	Baseline	Baseline	logit	logit
	no cross terms	cross terms	no cross terms	cross terms	no cross terms	cross terms
SAMPLES	1912	1912	1916	1916		
VARIABLES	*GOV*	*GOV*	*GOV*	*GOV*	*Prob(GOV1916/GOV1912>1)*	*Prob(GOV1916/GOV1912>1)*
dM	-0.0486	0.221	0.370	0.768	-0.025	0.012
	(0.287)	(0.331)	(0.435)	(0.620)	(0.045)	(0.010)
dI	-0.581	-1.439***	-1.862***	-2.118***	-0.071	-0.013
	(0.495)	(0.469)	(0.616)	(0.693)	(0.048)	(0.011)
M1896	-0.907**	-0.910**	-1.316***	-1.565***	-0.041	-0.015
	(0.360)	(0.354)	(0.383)	(0.478)	(0.078)	(0.013)
I1896	-1.817	-1.465	1.595	2.320	0.026	0.062
	(2.032)	(1.537)	(1.138)	(1.464)	(0.187)	(0.054)
Observations	570	570	575	575	651	651
Number of industries	31	31	31	31	31	31
Industry FE	YES	YES	YES	YES	YES	YES
Likelihood-ratio test (P-value)	0.0000***[a]	0.0000***[b]	0.0252**[a]	0.4390[b]	0.0163**[a]	0.0249**[b]
adj R^2	0.745	0.755	0.701	0.701	0.350	0.360

Notes: The baseline estimation takes the form of log-linear function and uses the fixed-effects regression model. The logit estimation uses the fixed-effects logistic regression model. The four variables, *M1896, I1896, dM, dI,* represent the two dimensions of the Qing state investment for the pre-1896 and post-1896 periods.
Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.
Likelihood-ratio tests: [a] a test comparing the regression (1) with the model without the four key variables for the Qing state investment; [b] a test for the significance of the interaction terms, *dM*dI* and *M1896*I1896*, by comparing the regression (2) with (1), regression (4) with (3), and regression (6) with (5).

For both the 1912 and 1916 sample, the Qing state investment are significantly related to manufacturing GOV through two variables in the regression: the pre-1896 military-related investment (*M1896*) and the post-1896 infrastructure-related investment (*dI*). Both of the two dimensions of the Qing state's investment – military-related or infrastructure-related – may have a negative impact on the manufacturing industry, holding the other control variables constant. The investment periods for the two dimensions are also crucial for the influence. The estimation results indicate the influence of the pre-1896 military-related investment persisted at least until the early 1910s, controlling the post-1896 state investment. On average, a manufacturing industry may have a lower gross output value in 1912/16 if it was located in a province with a higher level of military-related state investment before 1896 or a higher level of infrastructure-related investment after 1896. One per cent of differences in the new measures for the Qing state investment between provinces will lead to 0.9–1.4 per cent of differences in provincial industrial output. The crowding-out effect of public investment on private manufacturing seems to be limited in the 1912 sample but higher in the 1916 sample. As for the changes in manufacturing GOV between 1912 and 1916, Qing state investment may fail to affect the possibility of growth in manufacturing.

The new technology adopted initially by the Qing state in military production during the Self-Strengthening Movement might benefit the private sector. However, the regression on private manufacturing GOV derives a significantly negative effect of the pre-1896 military-related investment. As for the pre-1896 infrastructure-related investment, the regression cannot identify a significant effect. Together, the Self-Strengthening Movement of the 1860s–90s, which primarily targeted military modernisation, constitutes a historical case against the big push hypothesis on early industrialisation. This regression analysis continues to check the Qing state's investment in military-related production after 1896. At an average level, the follow-up investment may not significantly affect local industries in the 1910s.

We try to interpret the marginal effect of the Qing state investment on manufacturing output via the following output elasticity equation, holding private capital and employment constant. The output elasticity of public capital contains two parts: the effects of public capital through the technology term and as another factor input. Although the regression estimation of a log-term production function cannot separate the two parts on the right-hand side of the elasticity equation, the equation still helps to understand the effect of military-related state investment.

$$\frac{\partial \mathrm{Q}}{\partial \mathrm{G}}\frac{G}{Q_i} = \frac{\partial A_i(G)}{\partial G}\frac{G}{A_i(G)} + \frac{\partial F_i(K_i, L_i, G\,)}{\partial G}\frac{G}{F_i(K_i, L_i, G\,)},$$

where *i* denotes industry *i*. We assume that military-related state investment during the late Qing reforms can only affect private production through the technology term in a production function; the public capital accumulated cannot be used directly as capital input in private production. Thus, the output elasticity of military-related state investment on private production equals to the elasticity on the technology term, holding capital and labour input constant.

$$\frac{\partial \mathrm{Q}}{\partial \mathrm{G_M}}\frac{G_M}{Q_i} = \frac{\partial A_i(G_M)}{\partial G_M}\frac{G_M}{A_i(G_M)},$$

where *i* denotes industry *i* and *M* denotes military-related state investment. If there is no spillover from the Qing state's military-related investment or the new technology introduced by the Qing state through military modernisation was not incorporated into private manufacturing, the regression will derive a non-positive estimate for the output elasticity. The estimation results from the baseline model show a negative relationship: the pre-1896 military-related investment in the Self-Strengthening Movement may be related to a lower level of technology efficiency in the private manufacturing industry.

We then explain the negative effect of military-related investment on technology efficiency and private manufacturing production. The regressions on the number of industrial

establishments (*NrFH*, *NrH_FH*, *NrH*) show that pre-1896 military-related state investment may have a significant effect however result in a higher number of handicraft workshops or a higher share of handicrafts in manufacturing industry (see Table 7, column 3, 4, 8 and 9). By assuming a lower level of technology efficiency in traditional small-scale handicrafts, the shift toward handicrafts production will lead to a lower level of the average technology adopted in the manufacturing industry. This finding also supports the argument that the diffusion of new technology from military production to civilian manufacturing was inefficient during the late Qing reforms. The mismatch of technology preference between military and civilian use could be a reason behind the negative correlation, as noted in Jaworski (2017). During the Self-Strengthening Movement, the priority of the Qing state's investment was military modernisation and related heavy industries. However, China's early manufacturing consisted of labour-intensive and light industries in the 1910s. An attempt of the Qing state to reinforce its monopolistic status in new technology and factory production could also be an important reason, as pointed by Dai and Bie (2010). As for the spillover from the human capital invested by the Qing state before 1896, its influence in the 1910s can be very limited. The adoption of new technology requires a certain level of "social capability", for example, that creates widespread acceptance of the new technology and the new organisation of production (Abramovitz, 1986). It may have taken some considerable time for new Western-style education established before 1896 to affect social conditions and then to increase technology efficiency in manufacturing.

We then look at the post-1896 infrastructure-related state investment in the regression analysis. To be noted, the Qing state had already invested in telegraph construction in 1879, and the new telegraph system had covered a large part of Qing China until 1896, which constituted a large part of the pre-1896 infrastructure-related state investment. The telegraph system may improve market integration; however, the estimation results show that the influence of early-invested infrastructure on manufacturing seemed to be insignificant in the 1910s. Thus, a positive effect may exist for a certain period but not persist until the 1910s. For the period after 1896, public infrastructure, especially railways, became the target of the Qing state investment in new technology. Table 6, however, presents a significant and negative correlation between the post-1896 infrastructure-related state investment and private manufacturing production

Similarly, we try to understand the marginal effect of the Qing state investment in infrastructure-related construction through the output elasticity of public capital as follows:

$$\frac{\partial \mathrm{Q}}{\partial \mathrm{G}}\frac{G}{Q_i} = \frac{\partial A_i(G_I)}{\partial G_I}\frac{G_I}{A_i(G_I)} + \frac{\partial F_i(K_i, L_i, G_I)}{\partial G_I}\frac{G_I}{F_i(K_i, L_i, G_I)},$$

where *i* denotes industry *i* and *I* denotes infrastructure-related state investment. We assume that the Qing state's infrastructure-related capital can affect private production through the technology term and as another factor input at the same time. We also assume that the technology term of the above elasticity equation should be non-negative; thus, a higher level of infrastructure capital will be associated with a higher level of technology efficiency in local industries, especially for the late Qing reforms. Training schools for the workers in railway stations and telegraph offices were part of the new educational institutions established by the Qing state, different from colleges and language schools. By investing in local infrastructure, the Qing state may directly help to improve human capital in provinces.

Taking infrastructure capital as an input, the relationship between public infrastructure and private production is not straight-forward in empirical works. Thus, the sign for the second term on the right-hand side of the elasticity equation is under debate. We may expect a positive effect of railways on industrial growth through diminishing transportation costs and increasing market integration (Atack, Haines and Margo, 2008). The effect can be insignificant because China's railway system in the early 1910s was far from completed and still not a substitute for traditional transportation methods. Azariadis and Stachurski (2005)

concluded that the industry-level estimates for the output elasticity of infrastructure capital could range from negative to positive across various model specifications and samples of modern economies. Therefore, the negative effect of the post-1896 infrastructure-related state investment indicates that the loss in private manufacturing from the newly constructed infrastructure after 1896 exceeds the gain through increasing technology efficiency. As discussed previously, the influence of Qing state investment directly on technology efficiency can be very limited in the late Qing period because, for instance, the channel through increasing human capital may take quite some time to reveal a significant and positive effect. However, according to Section 3, new educational institutions may not have been the first target of the late Qing reforms.

We then explain the negative effect of the post-1896 infrastructure-related state investment on private manufacturing in the 1910s. New infrastructure constructed, mostly railways after 1896, raised the level of market integration in Qing China. Industrial activities may cluster in these regions along the railways and leave other regions less developed. Then, at the national level, the overall effect could be either positive or negative. Some manufacturing industries may benefit more from the new infrastructure, but the overall effect in a province may still be negative. Meanwhile, the extent of openness was enlarged with more treaty ports and the permission for FDI after 1896. These largely changed domestic market conditions and may make the exports of primary goods and raw materials more profitable than producing industrial goods (Williamson, 2008). The expansion of the domestic railway system may reinforce the process of structural change toward primary goods production, such as in agriculture and mining, and lead to an overall decline in industrial activities in all provinces and possibly an increase in commercial services in regions with lower transportation costs.

Regressions on the number of industrial establishments in Table 7 presents an insignificant marginal effect of the post-1896 infrastructure investment for the 1912 sample but a negative effect for the 1916 sample. In the same regressions, Qing state investment in infrastructure before 1896 may have a strong and negative effect on the number of industrial establishments for the 1912 sample but a positive effect for the 1916 sample. The results on the total number of factories and handicraft workshops (*NrFH, NrH*) are unstable; this may also imply that the influence of the railways constructed in the late Qing period had time lags. The regression also shows that a higher level of infrastructure-related state investment after 1896 may be unable to affect and even decrease the share of traditional handicrafts in the manufacturing industry (*NrH_FH*). In the 1910s, traditional small-scale workshops were still the main force of industrial production in pre-war China. Different from Liang's (2015) work on railways, which pointed out a strong promoting effect on new factory establishments in the period 1840s–1910s, the regression analysis in this study intends to look at the structure of the early manufacturing industry and handicrafts workshops in pre-war China. In addition, this study uses a set of new measures for public infrastructure in Qing China.

In this study, we evaluate the influence of Qing state investment on private manufacturing concerning not only gross output value (*GOV*). As mentioned above, Table 7 shows the estimation results of the baseline regression on other indicators for industrial performance: employment (*EMP*), the total number of factories and handicraft workshops (*NrFH*) and the share of handicrafts in manufacturing industry (*NrH_FH*). Other than the regression on *GOV*, the signs of the estimated effects in Table 7 vary between the 1912 and 1916 sample and the results are more significant for the 1916 sample, which makes the interpretation difficult. As mentioned previously, the estimation results indicate that handicraft workshops as traditional industrial production tended to react to Qing state investment first, rather than the new factory production. Therefore, we can conclude that the overall influence of Qing state investment in promoting modern factory production is insignificant and even negative.

Table 2 Estimation results of other indicators for industrial performance: average marginal effects (AME) of the Qing state investment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SAMPLES	1912	1912	1912	1912	1912	1916	1916	1916	1916	1916
VARIABLES	*GOV*	*NrFH*	*NrH*	*NrH_FH*	*EMP*	*GOV*	*NrFH*	*NrH*	*NrH_FH*	*EMP*
dM	0.221	0.248	0.402	0.043	0.318	0.768	3.043***	3.272***	-0.048	4.943***
	(0.331)	(0.455)	(0.439)	(0.042)	(0.510)	(0.620)	(0.582)	(0.565)	(0.058)	(0.599)
dI	-1.439***	0.677	0.637	0.012	0.322	-2.118***	-2.595***	-2.701***	0.083	-5.221***
	(0.469)	(0.563)	(0.578)	(0.100)	(0.602)	(0.693)	(0.753)	(0.746)	(0.080)	(0.854)
M1896	-0.910**	0.986**	1.083**	0.082	0.857*	-1.565***	-0.919*	-0.812	0.082*	-1.694***
	(0.354)	(0.437)	(0.439)	(0.080)	(0.487)	(0.478)	(0.531)	(0.524)	(0.044)	(0.601)
I1896	-1.465	-6.464***	-6.827***	-0.156	-6.309***	2.320	4.327**	4.318***	-0.252	7.906***
	(1.537)	(1.426)	(1.434)	(0.173)	(1.541)	(1.464)	(1.669)	(1.633)	(0.168)	(1.845)
Observations	570	577	570	570	577	575	583	575	575	583
Industry FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
adj R^2	0.755	0.408	0.416	0.0531	0.401	0.701	0.439	0.453	0.0723	0.446
Number of industries	31	31	31	31	31	31	31	31	31	31

Notes: The used model specification is the same as column 2, Table 6.
Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

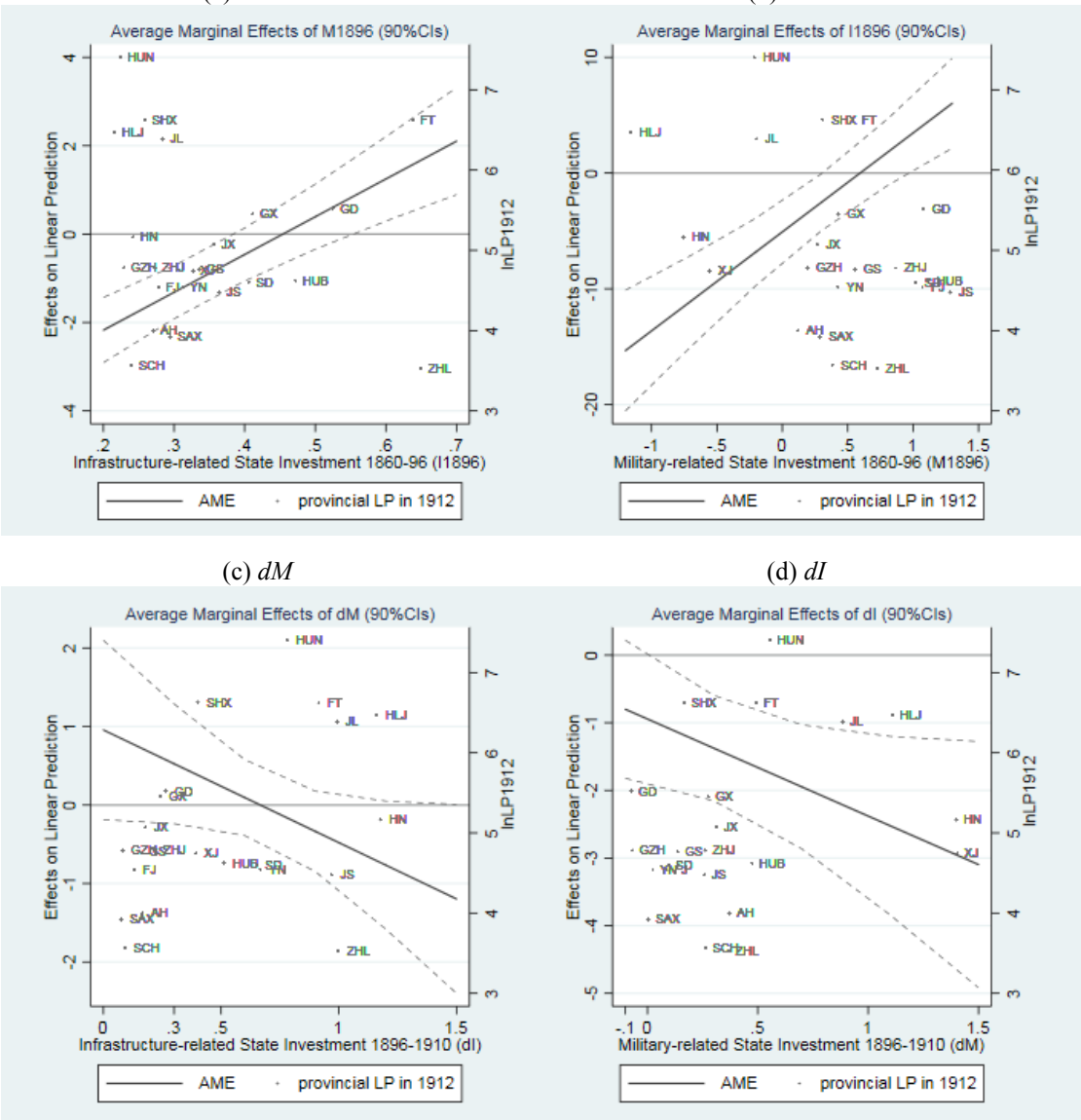
The model specification considers the interaction terms between military-related and infrastructure-related state investment for the pre-1896 and post-1896 periods, *M1896*I1896* and *dM*dI*, respectively. The coefficient of the interaction term *M1896*I1896* is significant and positive, while the coefficient of the interaction term *dM*dI* is however insignificant in the regression analysis. At least during the Self-Strengthening Movement, different categories of Qing state-invested programmes can be interconnected, and the two dimensions of Qing state investment reinforced each other. The marginal effect of the military-related state investment may increase with the level of infrastructure-related investment, vice versa.

Figure 5 demonstrates the interconnection between the two dimensions of the Qing state's investment. The marginal effect of the military-related investment can be positive for the provinces with a higher level of infrastructure-related investment (see Figure 5 (a)). However, the figure shows that most provinces had a very low level of infrastructure-related investment in the pre-1896 period, and thus a negative marginal effect of the military-related investment. Similarly, in the pre-1896 period, the marginal effect of infrastructure-related investment can be positive only for the provinces with a higher level of military-related investment, although most provinces had a moderate level of military-related investment before 1896 (see Figure 5 (b)). In the post-1896 period, the marginal effect of infrastructure-related investment can be negative regardless of the level of military-related investment (see Figure 5 (d)).

As discussed previously, in general the Qing state's investment may have a negative influence on private manufacturing of the 1910s. According to Figure 6, Qing state investment during the Self-Strengthening Movement may have a positive influence in some provinces, for instance, the military-related investment in north China, i.e. ZHL and FT, and the infrastructure-related investment in the coastal region and the lower Yangzi delta, such as FJ, GD and JS. The late Qing reforms of 1860–1910 seemed to have a strong negative influence on three provinces, HN along the Yellow River, HLJ and JL as part of Manchuria. The figure shows provincial variations in the estimated marginal effects of the Qing state investment and helps to examine the effects in a specific province.

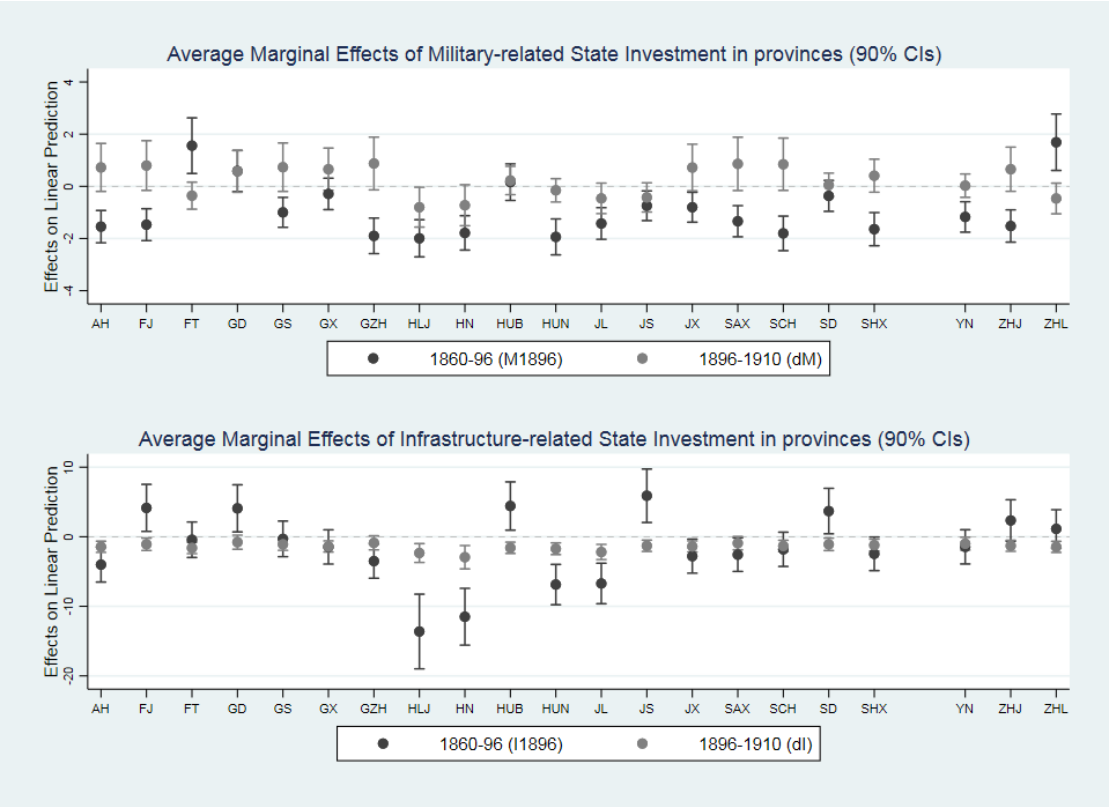
Figure 1 Average marginal effects (AME) of the Qing state investment, the pre-1896 and post-1896 periods

(a) *M1896* (b) *I1896*



Notes: Constructed by the author. The used model specification is from column 2, Table 0.6. "*LP*" denotes the average gross labour productivity in manufacturing in a province. The four variables for the Qing state investment are on the horizontal axis taking log forms. The dots in the figure indicate from the right vertical axis the relationship between manufacturing labour productivity in 1912 and the four variables representing the Qing state investment at provincial levels.

Figure 2 Provincial variations: average marginal effects of the two dimensions of the Qing state investment, the pre-1896 and post-1896 periods



Notes: Constructed by the author. The used model specification is from column 2, Table 0.6. The estimates for Xinjiang (XJ) province are missing because of the limited sample size in XJ.

4.3 Robustness check

We divided the full sample into two parts – heavy and light industry – to check whether the problem of mismatch in assessing Qing state investment disappears by looking at the sample of heavy industry. The heavy industry in this study contains manufactured products like metal, glass, chemical and paper. Table 8 examines the robustness of the previous estimation results in sub-samples of specific industries. The Chow tests indicate that the effects of Qing state investment differ between light and heavy industries. We find a significant and positive effect of the post-1896 military-related state investment only on heavy industry, while the effect of the pre-1896 military-related investment may still be negative on both heavy and light industries. Furthermore, the Qing state's infrastructure-related investment seemed to have no significant effects on the light industry of the 1910s. Figure 7 compares the marginal effects of the military-related state investment after 1896 conditional on the infrastructure-related investment, which confirms the differences in the effects between the light and heavy industries. The figure shows that the Qing state's military-related investment after 1896 may benefit the heavy industry in those provinces with limited modern transportation access in the 1910s.

The influences of the Qing state's investment during the late Qing reforms may also vary with manufacturing industries. Table 9 presents the estimation results for the sub-samples of specific manufacturing industries. The focus is on two categories of light industry and another two categories of heavy industry. For the metal and glass industries, the Qing state's military-related investment may have a positive influence on private production, although the effect may not be significant for the chemical industry. In contrast, ror the leading industries of pre-war China, i.e. textiles and food processing, the military-related investment may have a negative influence for both the pre-1896 and post-1896 periods. The Qing state's infrastructure-related investment may have a negative effect on the heavy industry but may not affect the light industry significantly. Thus, the Qing state's continued investment in military-related construction after 1896 may have promoted the development of the heavy industry; however, in general the sub-sample regressions support the results from the previous regressions with the full sample.

The average marginal effect of the Qing state investment may be biased towards those provinces with a higher level of state investment. Table 10 examines the robustness of the previous estimation results in sub-samples that exclude specific provinces. Five provinces as listed in Table 5 are considered to be excluded from the full sample: FT, ZHL, JS, GD and HUB. Especially, the sub-sample regressions show that the post-1896 military-related investment may have a positive influence in most provinces when excluding one province with a higher level of state investment. This finding implies that a moderate level of military-related state investment may help local industrial development in pre-war China. In general, excluding these provinces from the regression analysis does not significantly change the estimation results.

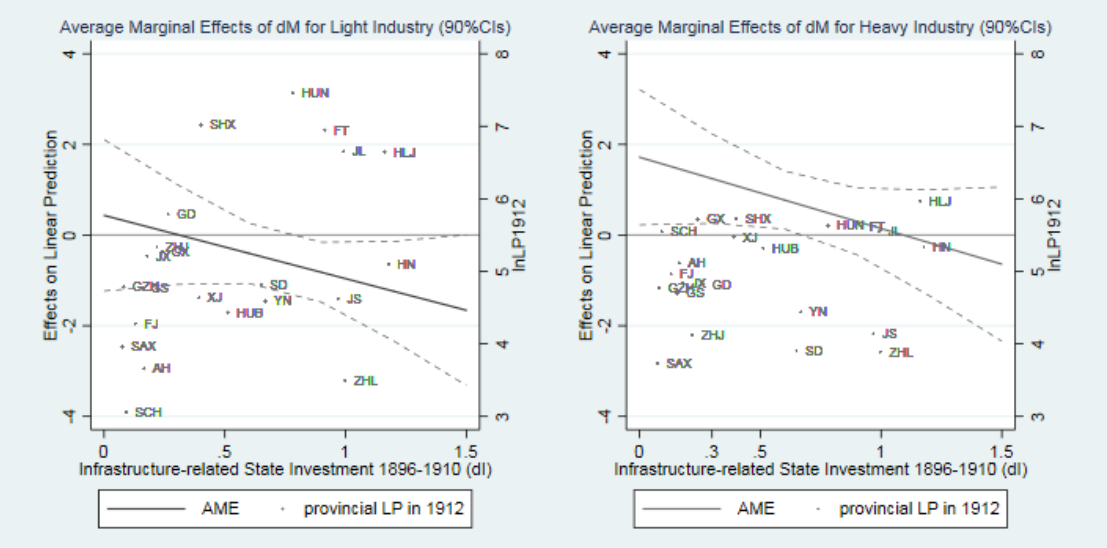
Table 3 Estimation results: average marginal effects (AME) of the Qing state investment, the heavy and light industry

	(1)	(2)	(3)	(4)	(5)	(6)
SAMPLES	Full sample	Light industry	Heavy industry	Full sample	Light industry	Heavy industry
	1912	1912	1912	1916	1916	1916
VARIABLES	*GOV*	*GOV*	*GOV*	*GOV*	*GOV*	*GOV*
dM	0.221	-0.297	0.934**	0.768	0.338	1.674*
	(0.331)	(0.456)	(0.438)	(0.620)	(0.853)	(0.909)
dI	-1.439***	-0.983	-1.606**	-2.118***	-1.301	-3.285***
	(0.469)	(0.668)	(0.674)	(0.693)	(0.921)	(1.008)
M1896	-0.910**	-1.030**	-0.459	-1.565***	-1.499**	-1.826***
	(0.354)	(0.480)	(0.503)	(0.478)	(0.637)	(0.692)
I1896	-1.465	-1.919	-1.492	2.320	1.931	3.412
	(1.537)	(2.052)	(2.147)	(1.464)	(2.001)	(2.123)
Observations	570	304	266	575	304	271
Industry FE	YES	YES	YES	YES	YES	YES
adj R^2	0.755	0.784	0.728	0.701	0.739	0.672
Likelihood-ratio tests (P-value)	0.0000***	0.0064***	0.0013***	0.4390	0.0193**	0.0978*
Chow tests (P-value)	0.0314**			0.0117**		
Number of industries	31	16	15	31	16	15

Notes: The used model specification is the same as column 2, Table 6. The four variables, *M1896, I1896, dM, dI*, represent the two dimensions of the Qing state investment for the pre-1896 and post-1896 periods.
Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.
Likelihood-ratio tests are for the significance of the interaction terms, *dM*dI* and *M1896*I1896*.
The likelihood-ratio Chow test is for the hypothesis that the coefficients of the model do not differ between the light and heavy industry.

Figure 3 Average marginal effects (AME) of the post-1896 military-related investment, the light and heavy industry

(a) The light industry (b) The heavy industry



Notes: Constructed by the author. The used model specification is from column 2 and 3, Table 8, respectively. "*LP*" denotes the average gross labour productivity in the heavy and light industry in a province. The variable on the horizontal axis also takes a log form. The dots in the figure indicate from the right vertical axis the relationship between manufacturing labour productivity in 1912 and the post-1896 military-related state investment at the provincial level.

Table 4 Estimation results: average marginal effects (AME) of the Qing state investment, samples of specific industries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SAMPLES	Food processing	Textiles	Chemicals	Metal and glass	Food processing	Textiles	Chemicals	Metal and glass
	1912	1912	1912	1912	1916	1916	1916	1916
VARIABLES	*GOV*	*GOV*	*GOV*	*GOV*	*GOV*	*GOV*	*GOV*	*GOV*
dM	-1.127	-1.170*	0.758	1.286**	-0.524	1.120	1.176	3.152**
	(0.741)	(0.671)	(0.626)	(0.611)	(1.369)	(1.469)	(1.239)	(1.533)
dI	0.037	-1.382	-1.930*	-0.919	-1.678	-1.610	-2.269*	-5.230***
	(1.353)	(1.079)	(1.029)	(0.722)	(1.640)	(1.401)	(1.325)	(1.794)
M1896	-0.975	-2.440***	-0.778	0.305	-2.439**	-1.545	-1.457	-2.473**
	(0.943)	(0.733)	(0.771)	(0.675)	(1.022)	(1.012)	(0.879)	(1.220)
l1896	-2.024	-1.553	-0.669	-2.378	5.153	0.755	2.347	5.716
	(4.401)	(3.236)	(2.994)	(3.436)	(3.290)	(3.303)	(2.831)	(3.580)
Observations	126	116	169	77	125	116	172	78
Industry FE	YES	YES	YES	YES	YES	YES	YES	YES
adj R^2	0.693	0.849	0.697	0.781	0.663	0.795	0.687	0.635
Number of industries	6	6	10	4	6	6	10	4

Notes: The used model specification is the same as column 2, Table 6.
Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

Table 5 Estimation results when specific provinces are excluded from the full sample

	(1)	(2)	(3)	(4)	(5)	(6)
SAMPLES	1912/6	1912/6	1912/6	1912/6	1912/6	1912/6
Excluding provinces	FT	ZHL	JS	GD	HUB	Five provinces
VARIABLES	*GOV*	*GOV*	*GOV*	*GOV*	*GOV*	*GOV*
dM	0.448**	0.451**	0.244	0.458*	1.031**	-0.153
	(0.223)	(0.227)	(0.410)	(0.271)	(0.414)	(0.623)
dI	-1.071***	-1.189***	-0.989***	-0.917***	-0.900***	-1.644***
	(0.258)	(0.288)	(0.262)	(0.290)	(0.248)	(0.352)
M1896	-1.249***	-0.856***	-0.823*	-0.719***	-0.184	-1.937***
	(0.330)	(0.238)	(0.432)	(0.243)	(0.344)	(0.564)
l1896	0.362	-1.283*	-0.766	-0.671	-1.272*	-0.458
	(0.740)	(0.673)	(0.646)	(0.631)	(0.708)	(1.399)
Observations	1,095	1,145	1,145	1,145	1,145	859
Industry FE	YES	YES	YES	YES	YES	YES
adj R^2	0.725	0.718	0.718	0.718	0.718	0.725
Number of industries	31	31	31	31	31	31

Notes: The used model specification is the same as column 2, Table 6. The full sample pools both the 1912 and 1916 sample. The five provinces are Fengtian (FT), Jiangsu (JS), Zhili (ZHL), Guangdong (GD) and Hubei (HUB).
Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

5 Conclusion

This study reviews the Qing state's investment in new Western technology and new methods of production during the Self-Strengthening Movement of 1861–95 and the late Qing reforms until the end of the Qing Empire, i.e. 1860–1910. We used an Exploratory Factor Analysis to distinguish major dimensions of Qing state investment and accordingly constructed new measures for Qing state investment through two dimensions: military-related investment, such as in arsenals and shipyards, and infrastructure-related investment, such as in railways and telegraphy. Although providing training and education in Western technology and scientific knowledge was part of the self-strengthening programmes before 1896, it was not incorporated in the mainstream educational system until the end of the Qing regime. Therefore, in the factor analysis new educational institutions do not stand out as a primary dimension of Qing state investment.

The new measures make it possible to compare Qing state investment between the pre-1896 and post-1896 periods. Although the Qing state continued to invest in military production after the First Sino-Japanese War, the priority of the state investment seemed to be given to railway construction. Rather than an overall measurement of the Qing state investment, the new measures focus on provincial variations. In the pre-1896 period, a few leading provinces that were heavily involved in military construction can be distinguished from the rest. Although in general the post-1896 state investment focused on infrastructure, the directions of state investment in provinces diverged significantly during the late Qing reforms.

This study tries to connect the state investment under the Qing regime with the manufacturing industry of the 1910s through regression analysis using the new measures. Both of the two dimensions of the Qing state investment are significantly correlated with the gross output value of private manufacturing in the 1910s. The estimation results differ between categories of manufacturing industries and between the two periods. The pre-1896 military-related state investment may have a negative influence while the post-1896 military-related investment may have a positive influence on the heavy industry and in some provinces. The infrastructure, especially railways constructed after 1895, may have a negative influence on the heavy industry but an insignificant effect on the light industry. The evaluation of Qing state investment also considers other indicators for pre-war China's manufacturing such as the number of factories and handicraft workshops and the share of handicrafts. The Qing state-invested military factories and infrastructure during the late Qing reforms and new technology embodied in the state investment may fail to generate more private investment in large-scale machinery-based factories relative to a large number of traditional handicraft workshops. The regression analysis shows that after considering international trade and early FDI, the influence of Qing state investment remained statistically significant. Although it is still difficult to make a conclusion on causality, this study finds a strong correlation between the Qing state investment and pre-war China's industrialisation.

Appendix 1

This Appendix demonstrates how the data are collected from historical records and how the indicators used in the factor analysis are calculated. To understand the Qing state investment in the period 1860–1910, a series of state-invested programmes are considered and grouped into several major categories: new education and training, military production, state-owned factories, telegraph and railways. The data collection and processing aims at providing a provincial distribution of state investment and revealing the changes between the two periods, 1860–96 and 1860–1910.

1.1 New education and training

The Qing state investment in new education in the two periods 1860–96 and 1860–1910 is measured by the number of new Western-style educational institutions approved and financed by the Qing state's public spending. The new Western-style education in the late nineteenth century China referred to new technology and scientific knowledge. Table A 1 lists types of the new educational institutions covered in data collection. Educational missions to other countries were also part of the Qing state investment in new knowledge. However, most of the students were from GD province, and it is difficult to identify the potential effect of the educational missions at provincial levels.

Data collection for the pre-1896 period focuses on language schools, training schools and early modern colleges. Not only providing the training in foreign languages for diplomatic staff, but the Qing state's language schools were also state-approved translation institutions. The training schools often along with military factories, railway stations and telegraph offices taught practical subjects on mechanical skills, navigation and telegraph. A few traditional schools tried to incorporate new subjects such as mathematics and economics into the traditional curriculums. Newly established Western-style colleges in the late Qing period turned to a completely new curriculum for modern scientific knowledge. Some new educational institutions were later transformed into early modern universities and colleges in the post-1896 period. The 1907 educational reform affected the number of higher educational institutions in a province; the data collection for the post-1896 period considers this change and only refers to universities and technical schools. In the late Qing period, primary and middle schools with Western-style teaching were still rare.

We construct a list of these new educational institutions as in Table A 1 and collect the information on the locations and the years of establishments through various historical records (see Table A 4). The new educational institutions in the late Qing period also includes military training schools, according to Fan (2003)'s dataset. Because of data availability, the data collection does not consider the size of an educational institution because for many small educational institutions records on student numbers are missing. We then calculate the number of new educational institutions in one province established in the two periods 1860–96 and 1860–1910 (*EduNr*). Considering provincial population, we calculate the number of new educational institutions per thousand people that may indicate the attainability of new knowledge in a province (*EduNrpopu*). The formulas are listed in Table A 3.

1.2 Military production and related state-owned factories

Military modernisation was the central target in the Qing state's Self-Strengthening Movement. Table A 2 lists three types of new establishments related to the Qing state's intention of constructing the new military force: military arsenals and shipbuilding dockyards, state-owned factories financially related to military production, the production of heavy industry and mining. The new establishments were represented by the application of new Western technology and particularly the adoption of machinery-based production. The regular operation of these establishments heavily relied on the Qing state's financial support.

We construct a list of these military-related establishments as listed in Table A 2 and collect the information on the locations, the initial and final years of operation from both primary and

secondary sources (see Table A 4). The data also considers small-scale military factories, according to Fan's (2003) dataset. Particularly, the contribution of the historical data collection in this study is to add in the information on the final operation years of military-related establishments.

We calculate the number of new military-related establishments in a province and the number of accumulated operation years over military-related establishments in a province for the two periods 1860–96 and 1860–1910 (*MilitNr, MilitNryear*). Considering provincial territory, we calculate the number of military-related establishments per ten thousand square kilometres that may indicate the attainability of new technology in a province (*MilitNrkm*). We also calculate the average years of operation over the number of military-related establishments in one province that may indicate the efficiency of the operation and management in a province (*Militlife*). The formulas are listed in Table A 3.

1.3 Telegraph and railways

Data collection on the Qing state investment in public infrastructure pays attention to telegraph and railways in the late Qing reforms. The construction of telegraph connections initialised early in the 1870s. Railways were the main theme of the social and political reforms in Qing China particularly after 1896. In the 1910s, most railway lines were state-owned and a large part of telegraph lines was managed by the state. The data collection does not include the Qing state investment in inland-river shipping services i.e. China Merchants' Steam Navigation Company since the potential provincial effect is difficult to identify. More importantly, we intend to look at infrastructure construction that can bring in new technology and contribute to public capital stock. The Qing state also invested in city water supply and electricity supply but only in a few cities such as in Shanghai and Guangzhou. We do not consider public utilities in this period also because the capital stock may be formed through the Qing state investment.

For telegraph, we calculate the number of prefectures in a province that had telegraph lines passed by and the number of telegraph offices in a province for the two periods 1860–96 and 1860–1910 (*TeleprefNr, TelestaNr*). Considering the number of prefectures in a province, we then calculate the share of prefectures connected by telegraph lines in a province and the average number of telegraph offices in a province (*Telepref, Telestapref*). For railways, similarly, we calculate the number of prefectures in a province that had railway lines passed by and the number of prefectures that had direct railway connections to the provincial capital city (*RailprefNr, RailtocapNr*). Considering also the total number of prefectures in a province, we then calculate the relative terms of the two indicators for railways in a province (*Railpref, Railprovcap*). The information on telegraph and railways is from historical maps as listed in Table A 4.

Table A 5 lists all the new indicators for the major categories of the Qing state investment in both absolute and relative terms for the two periods. Table A 6 gives the summary statistics of the new indicators.

Table A 1 Educational institutions

Types	Explanations	Examples
Language schools	Also official translation institutions	The Peking Tung-wen Kuan
Training schools	Many were built up with military arsenals, shipbuilding dockyards and infrastructure construction. The new training subjects include mechanical skills, navigation and telegraphy.	The modern military academy in Tianjin (North China); The Foochow school in FJ province (Southeast China)
Colleges established before 1896	Some were later transformed or incorporated into provincial universities and technical schools after the 1907 educational reform. Their new curriculums focus on modern scientific knowledge.	The Ziqiang College (Ziqiang Xuetang) in HUB province (Central China); The Zhongxi College (Zhongxi Xuetang) in ZHL province (North China)
Some traditional schools (Shuyuan)	Those incorporated Western-style teaching and new subjects such as mathematics and economics in the late Qing period	The Lianghu Shuyuan in HUB province (Central China) which opened new subjects in 1891
Provincial universities and technical schools after 1896	Most were newly established or transformed from traditional schools in 1907–9.	The Jingshi College (Jingshi Da Xuetang) in Peking (North China)

Notes: Constructed by the author.

Table A 2 Military production and related state-owned factories

Types	Explanations	Examples
Military arsenals and shipbuilding dockyards		The Jiangnan Arsenals in Shanghai, the Fuzhou Navy Yard in FJ province (Southeast China)
State-owned factories financially related to military expenditure	The investment in these factories was mainly from military funds. One objective of investing in these factories is to support military production in a province financially.	The Lanzhou woollen factory in GS province (Northwest China), the Hubei Textile Company in HUB province (Central China)
Heavy industry and mining	These factories of heavy industry and mining fields provided raw materials for military production.	The Hanyang iron and steel factory in HUB province (Central China), Ironworks in GZH province (Southwest China), the Kaiping Mines in ZHL province (North China)

Notes: Constructed by the author.

Table A 3 New indicators for the Qing state investment and calculation procedures

Variable names	Explanations and calculation procedures
a. Absolute terms	
EduNr	Nr of educational institutions in a province
MilitNr	Nr of military-related establishments in a province
MilitNryear	Nr of operation years over all military-related establishments in a province $MilitNryear_k = \sum_i (operation\ years\ until\ year\ t)_{ik}$, *t= 1896, 1910*, for military-related establishment *i* in province *k*.
TeleprefNr	Nr of prefectures in a province that have telegraph lines passed by
TelestaNr	Nr of telegraph offices in a province
RailprefNr	Nr of prefectures in a province that have railway lines passed by
RailtocapNr	Nr of prefectures that have direct railway connections to a provincial capital
b. Relative terms considering provincial population and territory size	
EduNrpopu	EduNr/ provincial population, per thousand people
MilitNrkm	MilitNr/ the territory size of a province, per ten thousand square kilometres
Militlife	Aver. operation years of a military-related establishment in a province. MilitNryear/ MilitNr
Telepref	Share of prefectures in a province that has telegraph lines passed by TeleprefNr/ Nr of prefectures in a province
Telestapref	Aver. Nr of telegraph offices TelestaNr / Nr of prefectures in a province
Railpref	Share of prefectures in a province that has railway lines passed by RailprefNr / Nr of prefectures in a province
Railprovcap	Share of prefectures that have direct railway connections to a provincial capital RailtocapNr / Nr of prefectures in a province

Notes: Constructed by the author.

Table A 4 Data sources for the Qing state-invested programmes

Types	Primary sources	Secondary sources
Education	The first educational yearbook of 1932, 1934; ZGSXH, 1961; Chen, 1981; Shu, 1985; Gao 1992.	Fan, 2003.
Military production and related state-owned factories	Chen and Yao, 1957; Chen, Yao and Feng, 1958; Chen, 1961; ZGSXH, 1961; Sun and Wang, 1962; Yan, 1989.	Zhang, 1984; Zhang, 1988; Deng, 1998; Zhou, 2000; Fan, 2003.
Railways	ZGSXH, 1961; China postal album, 1907.	Jin and Xu, 2000.
Telegraph	Li, 1896; China postal album, 1907.	
Demographical and geographical information		Cao, 2001; Hou, 2001

Notes: Constructed by the author.

Table A 5 New indicators for the Qing state investment at provincial levels for the periods until 1896 and until 1910: absolute and relative terms

a. Absolute terms	*MilitNr*		*MilitNryear*		*EduNr*		*TeleprefNr*		*TelestaNr*		*RailprefNr*		*RailtocapNr*	
Provinces	1895	1910	1895	1910	1894	1909	1896	1907	1896	1907	1894	1907	1894	1907
HLJ	0	0	0	0	0	1	0	4	0	4	0	6	0	3
JL	1	1	15	20	2	6	0	6	0	4	0	5	0	1
FT	2	2	15	30	3	9	3	5	7	26	1	6	0	3
ZHL	6	8	103	143	10	40	8	15	7	37	4	12	0	7
SD	3	4	42	64	7	13	9	10	12	21	0	4	0	2
HN	0	1	0	14	0	7	1	11	1	13	0	8	0	5
SHX	2	3	5	23	0	7	7	7	3	6	0	2	0	1
SAX	1	1	4	4	0	3	5	5	2	2	0	0	0	0
GS	3	3	27	27	0	4	8	10	6	7	0	0	0	0
XJ	2	3	14	15	1	3	0	11	0	16	0	0	0	0
SCH	1	1	19	34	0	10	8	11	6	12	0	0	0	0
HUB	9	13	39	115	6	14	7	11	7	25	1	3	0	1
HUN	1	3	5	17	0	10	2	6	2	11	0	4	0	3
JX	0	2	0	12	0	7	7	7	4	6	0	1	0	0
AH	1	1	4	4	0	7	3	5	4	11	0	0	0	0
JS	5	7	80	146	12	24	8	11	10	24	0	6	0	3
ZHJ	3	3	23	23	0	7	6	9	7	15	0	0	0	0
FJ	5	5	71	91	4	7	6	6	6	13	0	0	0	0
GD	2	2	31	61	6	14	13	11	26	24	0	2	0	1
GX	0	0	0	0	0	3	8	9	10	23	0	1	0	0
YN	1	1	11	11	0	3	9	11	9	19	0	4	0	3
GZH	2	2	10	10	0	4	4	3	2	3	0	0	0	0
Total	50	66	518	864	51	203	122	184	131	322	6	64	0	33

b. Relative terms	*MilitNrkm*		*Militlife*		*EduNrpopu*		*Telepref*		*Telestapref*		*Railpref*		*Railprovcap*	
Provinces	1895	1910	1895	1910	1894	1909	1896	1907	1896	1907	1894	1907	1894	1907
HLJ	0.00	0.00	0.00	0.00	0.00	0.62	0.00	0.50	0.00	0.50	0.00	0.75	0.00	0.25
JL	0.04	0.04	15.00	20.00	0.55	1.12	0.00	0.75	0.00	0.50	0.00	0.63	0.00	0.13
FT	0.08	0.08	7.50	15.00	0.47	0.87	0.38	0.63	0.88	3.25	0.13	0.75	0.00	0.38
ZHL	0.19	0.25	17.17	17.88	0.29	1.08	0.44	0.83	0.39	2.06	0.22	0.67	0.00	0.88
SD	0.20	0.26	14.00	16.00	0.17	0.30	0.69	0.77	0.92	1.62	0.00	0.31	0.00	0.25
HN	0.00	0.06	0.00	14.00	0.00	0.23	0.07	0.79	0.07	0.93	0.00	0.57	0.00	0.63
SHX	0.12	0.19	2.50	7.67	0.00	0.60	0.35	0.35	0.15	0.30	0.00	0.10	0.00	0.13
SAX	0.05	0.05	4.00	4.00	0.00	0.32	0.42	0.42	0.17	0.17	0.00	0.00	0.00	0.00
GS	0.04	0.04	9.00	9.00	0.00	0.57	0.53	0.67	0.40	0.47	0.00	0.00	0.00	0.00
XJ	0.01	0.02	7.00	5.00	0.58	1.40	0.00	0.73	0.00	1.07	0.00	0.00	0.00	0.00
SCH	0.02	0.02	19.00	34.00	0.00	0.22	0.31	0.42	0.23	0.46	0.00	0.00	0.00	0.00
HUB	0.49	0.71	4.33	8.85	0.29	0.64	0.64	1.00	0.64	2.27	0.09	0.27	0.00	0.13
HUN	0.05	0.14	5.00	5.67	0.00	0.38	0.12	0.35	0.12	0.65	0.00	0.24	0.00	0.38
JX	0.00	0.12	0.00	6.00	0.00	0.47	0.50	0.50	0.29	0.43	0.00	0.07	0.00	0.00
AH	0.07	0.07	4.00	4.00	0.00	0.28	0.23	0.38	0.31	0.85	0.00	0.00	0.00	0.00
JS	0.47	0.66	16.00	20.86	0.39	0.74	0.73	1.00	0.91	2.18	0.00	0.55	0.00	0.38
ZHJ	0.30	0.30	7.67	7.67	0.00	0.38	0.50	0.75	0.58	1.25	0.00	0.00	0.00	0.00
FJ	0.41	0.41	14.20	18.20	0.27	0.45	0.55	0.55	0.55	1.18	0.00	0.00	0.00	0.00
GD	0.09	0.09	15.50	30.50	0.22	0.48	0.76	0.65	1.53	1.41	0.00	0.12	0.00	0.13

GX	0.00	0.00	0.00	0.00	0.00	0.21	0.53	0.60	0.67	1.53	0.00	0.07	0.00	0.00
YN	0.03	0.03	11.00	11.00	0.00	0.22	0.41	0.50	0.41	0.86	0.00	0.18	0.00	0.38
GZH	0.11	0.11	5.00	5.00	0.00	0.33	0.25	0.19	0.13	0.19	0.00	0.00	0.00	0.00
Aver.	0.13	0.17	8.08	11.83	0.15	0.54	0.38	0.61	0.42	1.10	0.02	0.24	0.00	0.18

Notes: "1894/5/6" denotes the period 1860–96; "1907/09/10" denotes the period 1860–1910. Indicators in the lower panel are used in the factor analysis in Section 3.

Table A 6 Summary statistics for all the indicators for the Qing state investment

	VARIABLES	N	mean	s.d.	min	max
1	*EduNr*	44	5.773	7.386	0	40
2	*EduNrpopu*	44	0.344	0.334	0	1.404
3	*TeleprefNr*	44	6.955	3.563	0	15
4	*TelestaNr*	44	10.30	8.786	0	37
5	*Telepref*	44	0.494	0.250	0	1
6	*Telestapref*	44	0.760	0.706	0	3.250
7	*RailprefNr*	44	1.591	2.705	0	12
8	*RailtocapNr*	44	0.750	1.542	0	7
9	*Railpref*	44	0.130	0.227	0	0.750
10	*Railprovcap*	44	0.091	0.189	0	0.875
11	*MilitNr*	44	2.636	2.660	0	13
12	*MilitNryear*	44	0.729	0.846	0	2.943
13	*MilitNrkm*	44	0.146	0.178	0	0.714
14	*Militlife*	44	0.234	0.177	0	0.680

Notes: Constructed by the author.

Appendix 2

Table A 7 Factor scores estimated for the two dimensions of the Qing state investment and the changes between the two periods, 1860–95 and 1860–1910

Periods	1860–1896		1860–1910		1896–1910	
Provinces	*M1896*	*I1896*	*M1910*	*I1910*	*dM*	*dI*
ZHL	2.06	1.91	2.98	5.19	1.44	2.71
FT	1.72	1.89	2.81	4.73	1.64	2.50
JL	0.82	1.33	1.99	3.58	2.42	2.70
HLJ	0.31	1.24	0.95	3.96	3.04	3.19
SD	2.77	1.50	3.05	2.87	1.10	1.91
HN	0.47	1.27	1.90	4.13	4.06	3.25
SHX	1.36	1.29	1.61	1.93	1.18	1.49
JS	3.61	1.44	4.67	3.79	1.29	2.63
AH	1.12	1.31	1.63	1.55	1.45	1.18
JX	1.31	1.43	1.79	1.71	1.37	1.19
FJ	2.92	1.32	3.19	1.50	1.09	1.14
ZHJ	2.38	1.31	3.09	1.63	1.30	1.24
HUB	3.05	1.60	4.89	2.67	1.61	1.67
HUN	0.81	1.25	1.41	2.73	1.74	2.18
SAX	1.34	1.34	1.34	1.45	1.00	1.08
GS	1.74	1.40	2.00	1.64	1.15	1.17
XJ	0.57	1.39	2.34	2.05	4.07	1.48
SCH	1.46	1.27	1.90	1.39	1.30	1.10
GD	2.94	1.69	2.73	2.20	0.93	1.30
GX	1.53	1.51	2.02	1.92	1.32	1.27
YN	1.53	1.37	1.57	2.66	1.02	1.95
GZH	1.21	1.26	1.13	1.36	0.93	1.08
Aver.	1.68	1.42	2.32	2.58	1.66	1.79
s.d.	0.87	0.19	0.99	1.11	0.88	0.70

Notes: Constructed by the author according to the factor analysis in Section 3. *dM: M1910/ M1896; dI: I1910/ I1896.*

Appendix 3

Table A 8 Summary of all variables used in the regression analysis

Variables	Explanation	(1)	(2)	(3)	(4)	(5)
		N	mean	sd	min	max
indus	*i*, subindustries in manufacturing, *i*= 1–31					
prov	*r*, provinces, r=1–22					
GOV	Gross output value, million Yuan, ir	682	5.983	85.60	0	2040.00
EMP	Employment at the end of the year, million, ir	682	0.016	0.099	0	1.882
NrFH	The total number (*Nr*) of industrial establishments, including factories and small-scale handicraft workshops, *ir* [a]	682	2275	11193	0	213567
NrF_FH	Share of factories, *ir*	682	0.039	0.138	0	1
probGOV	Dummy=1 if *GOV1916/GOV1912*>1, *ir*	682	0.601	0.490	0	1
NrHshare	Share of handicraft workshops for industry *i* in province *r*, *ir*	570	0.037	0.077	0	0.763
NrF_Fhprov	Share of factories in a province	22	0.038	0.050	0.002	0.162
NrSchtthpopu	Nr primary and middle schools per 10,000 people, *r*	22	2.056	1.259	0.286	5.469
Tcoalprov	Total coal output in a province and its surrounding provinces, Ton, *r*	22	12.520	9.587	0.355	32.893
pubexpen	Public expenditure on agriculture and industries in a province, million *Yuan*, *r*	22	0.368	0.644	0.001	2.842
popuden	Population density of a province, Per square kilometre, *r*	22	101	77	1	306
DwBorder	Dummy=1 if a province is along the west border, *r*	22	0.227	0.419	0	1
CA1910	Cultivated acreage in a province in 1910, million Shi Mou, *r*	22	59	34	12	127
NrTrPort1910	Nr Treaty Ports opened in a province before 1910, *r*	22	3.409	3.042	0	11
NrMFDI1911	Nr Private firms using machines established through FDI in a province before 1911, *r*	22	1.818	4.502	0	21
NrMpriv1909	Nr Private firms using machines established through domestic investment in a province before 1909, *r*	22	1.682	6.654	0	32
heavy	Dummy=1 for the heavy industry, including metal products, glass, chemicals, and paper	682	0.484	0.500	0	1
grpNrFQstate10	Dummies for the Qing state investment in private industries before 1910, *ir*	682	0.742	0.559	0	2
M1896	Factor score for military-related state investment before 1896, *r*	22	1.683	0.894	0.314	3.607
I1896	Factor score for infrastructure-related state investment before 1896, *r*	22	1.424	0.189	1.241	1.915
M1910	Factor score for military-related state investment before 1910, *r*	22	2.317	1.010	0.953	4.888
I1910	Factor score for infrastructure-related state investment before 1910, *r*	22	2.576	1.140	1.363	5.191
dM	The change in the factor score for military-related state investment between 1896 and 1910, *r*	22	1.657	0.899	0.929	4.071

dI	The change in the factor score for infrastructure-related state investment between 1896 and 1910, *r*	22	1.792	0.714	1.078	3.245

Notes: "*ir*" is short for industry *i* in province *r*. "*r*" is short for province *r*. The sample includes two years, 1912 amd 1916. [a] Here, a factory is defined as a working place hiring more than seven workers.

Table A 9 Data sources of all variables used in the regression analysis

Variables	Calculation procedures and equations	Data sources
GOV	See Table A2.1.	The 1912/6 Agricultural and Industrial Statistical Yearbook published in 1914 and 1919 (for short, the Yearbook)
EMP	See Table A2.1.	The 1912/6 Yearbook
NrFH	See Table A2.1.	The 1912/6 Yearbook
NrF_FH	Nr factories for industry *i* in province *r* / Nr factories and handicraft workshops for industry *i* in province *r*	The 1912/6 Yearbook
probGOV	Dummy=1 if *GOV1916/GOV1912*>1	
NrHshare	Nr handicraft workshops for industry *i* in province *r*/ Nr factories and handicraft workshops in province *r*	The 1912/6 Yearbook
NrF_FHprov	Nr factories in province *r*/ Nr factories and handicraft workshops in province *r*	The 1912/6 Yearbook
NrSchtthpopu	Nr primary and middle schools in province *r*/ population of province *r*	Shu, 1985; Fan, 2003; Cao, 2001; Hou, 2001
Tcoalprov	See Table A2.1.	The 1912/6 Yearbook
pubexpen	See Table A2.1.	The 1912/6 Yearbook
popuden	Population of province *r*/ the land area of province *r*	Cao, 2001; Hou, 2001
DwBorder	Dummy=1 if a province is along the west border	According to the 1820 map of Qing China (CHGIS V4)
CA1910	See Table A2.1.	Perkins, 1969
NrTrPort1910	See Table A2.1.	Yan, 1989
NrMFDI1911	See Table A2.1.	Chen and Yao, 1957; Chen, Yao and Feng, 1958; Chen, 1961
NrMpriv1909	See Table A2.1.	Chen and Yao, 1957; Chen, Yao and Feng, 1958; Chen, 1961
heavy	See Table A2.1.	
grpNrFQstate10	Dummy=2 if there is a state-owned or initiated factory in industry *i* in province *r*; =1 if there is a state-owned or initiated factory in province *r*.	Chen, Yao and Feng, 1958; Chen, 1961; Zhang, 1988
M1896	Estimated in Section 3	Estimated by the author. See Appendix 2.
I1896	Estimated in Section 3	Estimated by the author. See Appendix 2.
M1910	Estimated in Section 3	Estimated by the author. See Appendix 2.
I1910	Estimated in Section 3	Estimated by the author. See Appendix 2.
dM	*M1910/ M1896*	Calculated by the author. See Appendix 2.
dI	*I1910/ I1896*	Calculated by the author. See Appendix 2.

Notes: "*ir*" is short for industry *i* in province *r*. "*r*" is short for province *r*.

Appendix 4

Table A 10 Provinces in Qing China

Provinces	Macroregions	Short forms
Zhili	North China	ZHL
Fengtian	Manchuria	FT
Jilin	Manchuria	JL
Heilongjiang	Manchuria	HLJ
Shandong	North China	SD
Henan	North China	HN
Shanxi	Northwest China	SHX
Jiangsu	Lower Yangzi	JS
Anhui	Lower Yangzi	AH
Jiangxi	Middle Yangzi	JX
Fujian	Southeast Coast	FJ
Zhejiang	Lower Yangzi	ZHJ
Hubei	Middle Yangzi	HUB
Hunan	Middle Yangzi	HUN
Shaanxi	Northwest China	SAX
Gansu	Northwest China	GS
Xinjiang	West China	XJ
Sichuan	Upper Yangzi	SCH
Guangdong	Lingnan Coast	GD
Guangxi	Lingnan Coast	GX
Yunnan	Yungui	YN
Guizhou	Yungui	GZH

Notes: The macroregions are generally based on G.William Skinner's classification (Skinner, Henderson and Berman, 2013).

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