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Unfolding the Turbulent Century: A Reconstruction of China's Economic Development, 1840-1912

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Abstract

This paper reconstructs China's economic development between 1840 and 1912 with an estimation of Gross Domestic Product (GDP). It provides for the first time a time series of GDP (per capita) for the late Qing Dynasty (1644-1911), based on sectoral output and value added, in current as well as in constant prices. The present estimation of per capita GDP in the late Qing period comes out higher than previous estimations, but it still suggests low average levels of Chinese living standards. The economy during the late Qing Empire was characterised by a large and growing agricultural sector and displayed only minor structural changes. Only in the beginning of the twentieth century did the economy start to show signs of growth.

Key words: China; GDP; 19th century; living standards

JEL classification codes: E01 N15 O11

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I Introduction

This paper reconstructs total economy movements and changes in living standards in China during the late Qing Empire (1644-1911), i.e. between 1840 and 1912, and produces for the first time an estimate of annual Gross Domestic Product (per capita). The period is a crucial part of what has been coined by Brandt, Ma and Rawski as the "Turbulent Century", the hundred years between 1840 and 1939 (Brandt et al., 2014, p. 80). The turbulence refers in particular to the combination of wars, reforms, and natural disasters that the country faced from the 1840s when a new social and economic order began to emerge. From the late nineteenth century onwards, China became more involved in international trade, began to open up its economy, and started to import new technology from the rest of the world (Maddison, 2007). The historical literature on China commonly describes this era as a break point in the country's long-run economic development.

Recent studies on China's modern economic performance have emphasised that developments in the late Qing period had a long-lasting impact on the national economy. China's post-1949 state-led industrial development can be traced to the early stage of industrialisation in the late nineteenth century (Wu, 2011). The country's present trade performance can also be connected to its experience in the nineteenth century, and thus not only to the 1978 reforms (Keller, Li, and Shiue, 2012). Indeed, Brandt et al. (2014, p. 47) have wondered why potentially favourable changes in social and economic conditions did not produce immediate improvements in the economy during the late Qing period, but only came more than half a century later – with an evident "delay of growth".

Although there are many detailed chronicles of the state of local economies, the picture of the total economy of China in the late Qing period remains rather elusive, which makes a reconstruction of GDP useful. Estimations of real wages have been used as a measure for the standard of living, but these are mainly representative for the city population. Knowing that China had an economy with a large rural population and a large primary sector, GDP per capita seems to be a measure with a more extensive coverage than just wages. New data together with information from recent historical studies of economic activities in the Qing period will be used to facilitate a new reconstruction of GDP. As in all historical GDP estimations the present paper will necessarily involve simplification and approximation, but we see it as an important step forward in the study of the Chinese economy in the Qing period.

The structure of the paper is as follows: section 2 will present a short overview of the literature on China's long-run economic development and the late Qing period in particular; in section 3 we introduce our estimation procedures and the underlying assumptions; in section 4 the new historical reconstruction of GDP will be compared with the results of earlier studies; section 5 provides a new interpretation of the economic stagnation in the late Qing period; section 6 summarises the main findings. The appendix includes references to all the data that have been used and a detailed exposition of all the steps that were taken in the estimation procedure. [2]

II China's growth in the literature

[2] More details can be found in Ma, de Jong, and Chu (2014), Appendix B.

Until recently, the generally-held opinion in the literature is that the pre-1945 Chinese economy experienced hardly any substantial improvements in income. Accordingly, the discussion around the late Qing period has often ended with the conclusion that the Chinese economy was trapped in long-term low income equilibrium. Recent studies have tried to challenge this traditional picture, mainly by looking from twentieth-century perspectives, but the jury is still out. Rawski (1989), for example, concluded that China experienced a substantial increase in per capita production during the interwar period. This would imply a lower level of per capita production in Qing China before WWI and we can therefore ask whether the positive trend in the interwar period can be traced back to the Qing period. Maddison's estimation assumes that sectoral growth of industries and services in 1913-30 can be traced back to the period 1890-1913; his estimation of per capita GDP still supports the familiar view of economic stagnation. Development patterns may have been more complex. WANG (2005) studied the economic dynamics of China through the growth of industries and foreign trade only, and derived a U-shape path of the economy in the late Qing period.

Table 1 summarises previous Chinese GDP estimates of the nineteenth and the early twentieth century. Most of these figures are benchmark estimates for specific years or short periods. Moreover, these GDP estimates are difficult to reconcile with each other because the monetary units are not always expressed in the same currency: some are based on local currencies, while others use internationally-comparable monetary units. It is therefore difficult to get a good idea of the changes in living standards in nineteenth-century China. For the period that we want to investigate, Maddison's work produces five estimates and the most recent study by Xu et al. (2015) contains three estimates. Accordingly, we can only generate a very rough picture of economic development in the late Qing period.

[Place Table 1 here]

Recent studies suggest that the Great Divergence between the Asian and the advanced Western economies had already taken root many decades or even centuries before 1800. For China, the late nineteenth century was a transitional period in between the relatively peaceful early nineteenth century and the fast industrialisation of the 1920s and 1930s. Our new data make it possible to compare Chinese living standards with those of western and other Asian countries. The paper tries to find out whether the Great Divergence continued and even deepened in the final part of the Qing Empire or whether China was able to catch-up with the fast growing economies in Europe and Asia.

III A new estimation of historical GDP

This section presents our estimation of Chinese GDP (per capita) for the period 1840-1912. We will first briefly introduce the method and the general estimation procedure, and then discuss underlying assumptions and data sources. In general, it will apply the same methods and procedures as have been recently used in historical GDP reconstructions for other countries, in particular the large Asian economies of the nineteenth century, such as Japan (Bassino, Broadberry, Fukao, Gupta, and Takashima, 2015, Broadberry, Fukao, and Zammit, 2015), Indonesia (van der Eng, 1992), and India (Broadberry, Custodis, and Gupta, 2015, Broadberry and Gupta, 2010). Similar methods have also been applied for other periods of pre-modern China, such as the reconstruction of pre-1840 Chinese GDP by Broadberry, Guan, and Li (2014), the estimation of 1914/18 Chinese NDP by Ma (2008), and Rawski's estimation of the average growth rate of the Chinese economy from the 1910s to the 1930s (Rawski, 1989).

The present reconstruction of the historical national accounts in late Qing China is based on a consistent estimation of sectoral output and value added. Data quality and availability has always been a central concern in historical GDP reconstructions of the early modern period or for non-market economies. For this we need to apply theoretical insights, proxy indicators and assumptions that have been used in other historical studies. Even for widely-used GDP estimations of advanced western economies, estimation procedures have necessarily involved simplification and approximation, not only for the early modern periods but also for the nineteenth and twentieth centuries. Consequently, for the sectors for which we have only limited data sources we have used methods that are comparable or even similar to those that have been used for England before 1700 (Broadberry, Campbell, Klein, Overton, and van Leeuwen, 2012) and Holland before 1800 (van Zanden and van Leeuwen, 2012). Our sectoral approach is set up as an open and transparent system that allows for the inclusion of improvements whenever new data become available.

We included all economic activities and classified them into the three major sectors of the economy: agriculture, industry, and services. For each sector, we focused on important products or on the major part of production, to guarantee representativeness. For the industrial and services sector we were able to make use of four benchmark estimations of 1840, 1880s, 1920, and 1933, which represent total output in both sectors. The annual movements in between the benchmark years were estimated by us. For agriculture we relied entirely on our own new annual estimations, (see Appendix Table 1). Adding up the three major sectors gives annual nominal levels of GDP. To adjust for price fluctuations in our estimation, we constructed new price indexes for both sectoral and total GDP, corresponding to the framework we have used to estimate current-price GDP. To better position China's pre-modern economy internationally, we also calculated a new benchmark GDP (per capita) for 1912 based on purchasing power parities (PPP).

Agricultural production

A precise estimation of the agricultural sector is essential to understand the size of the pre-industrial economy of China. As a typical agrarian economy, the country concentrated on crop production, such as grains and textile fibres, rather than livestock products (Maddison, 2007, p. 32). The reconstruction of this sector covers major agricultural outputs that were central to agricultural production in late nineteenth-century China, such as food and cash crops, in particular rice, wheat, raw cotton, raw silk, and tea. Other agricultural outputs coming from forestry, livestock farming, and fisheries were assumed to move in proportion with crop production. Textile products and tea do not merely represent cash crops but may also reveal the possible impact of a larger exposure of China to international trade after the mid-nineteenth century and the effect of the early industrialisation which started in cotton and silk manufacturing. The export share of raw cotton, silk products and tea combined was more than 50 per cent of the total export value in late nineteenth-century China (YAN, 1955). For most of the food and cash crops that were included, historical records on output and price were used to calculate gross output value (GOV). For example, to estimate total output of raw cotton we combined domestic consumption and net export, and calculated GOV by multiplying the average export and import price with the estimated volume of total output. Net output value was derived through input/output (i/o) ratios, which we took from previous studies on pre-modern agriculture. To adjust for price movements a general price index for the agricultural sector was constructed, consisting of price series for rice, wheat, raw cotton, raw silk, and tea.

The estimation of the volume of food crops deserves a more detailed treatment, since it was most relevant to living standards in China (Perkins, 1969, p. 396). Land input and land productivity are the major factors affecting food production in our farm accounting model (see also Allen, 2009 for a similar estimation of agricultural productivity in England and China before 1820). Studies on China's agricultural history have provided us with ample information on arable land and crops yields, originally based on official taxation records and local archives on crop production. Our new estimation makes use of these studies but provides new extensions to estimate historical agricultural output.

The first survey of arable land was organised by the People's Republic of China and recorded a level of 1.6 billion mou in 1950. For the period 1850-1911, existing estimates range from 1.2 to 2.0 billion mou (see Ma, de Jong, and Chu, 2014, Table 4).[3] The most recent estimation for the late Qing period gives a level of 1.4 billion mou (SHI, 2015). Using two levels based on benchmark estimates for respectively 1840 and 1914, our estimation of arable land varies around an average of 1.2 billion mou (SHI, 1989, ZHANG, 1991). Although a sudden increase of cultivated land for crops in the central territory of the Qing Empire is not very likely, our estimation does take into account the 1860s immigration wave from middle China into Manchuria, which probably resulted in a slight increase of arable land in the late Qing period as suggested by WU (1985, p.198).

The next step is to calculate total land productivity as the weighted average of unit yields of the different food crops. The weights are determined by the specific use of arable land for various crops per year. Since some crops were harvested twice a year, we also took account of multiple cropping. We assumed constant shares of land inputs for the eight food crops that we included in our estimation and a fixed multiple cropping ratio of 1.32.[4] Unit yields for each food crop were constructed for the period 1840-1912 according to the yield levels of the 1930s and an index reflecting annual harvest fluctuations over the period 1840-1940. Thus, our estimation of land productivity combines unit yields with constant weights, which reflects mainly exogenous shocks to unit yields. Besides exogenous factors such as weather conditions and social and political circumstances, technological progress could in principle have a major influence on both land use and unit yields. According to the literature, however, levels of agricultural technology in late nineteenth-century China did not experience significant changes and did not generate any improvements in agricultural productivity comparable to the agricultural revolution between 1620 and 1820 as described by Bozhong Li

[3] 1 mou = 666.5 square metres= 0.1647 acres.

[4] Multiple cropping ratio = Sown area in one year / Total cultivated area, from Maddison (2007), p. 114, Table A.10. Here we rely on two estimates mentioned in the literature, 1.24 and 1.4 (WU, 1985, p. 180, Maddison, 2007, p. 36, respectively). We applied the average level of 1.32 for all food crops and for the country as a whole.

(Allen, 2009). Therefore, in our estimation the real change of food crop output is driven only by land input and exogenous fluctuations in unit yields.

The assumption of technological stagnation in the late Qing period in our estimation of output is based on the widely-held opinion that pre-modern China's agriculture was essentially static (Allen, 2009, pp. 529-30). The *Cambridge History of China* mentions that "...... the technology and organisation of Chinese agriculture differed little in 1911 from what it had been in 1870 (Even into the 1930s it remained largely unchanged)" (Chapter 1, p. 2). A study on pre-modern China's agricultural technology concludes that the improvements in the late Qing period were happening under traditional technology; new technical breakthroughs were mainly put into use after 1900 (GUO and CAO, 1989). Technological stagnation was also visible in the tendency among farmers to insist on traditional methods (ZHANG, 1957, p. 578). Although nineteenth-century agricultural activities diversified through the adoption of new food crops like maize and sweet potatoes, the spread of the newly imported food alternatives was relatively modest in the last part of the nineteenth century (WU, 1985). We therefore believe that in the late Qing period the rise in output from new food crops had only limited impact on total food crop output, which mainly consisted of widely-cultivated products like rice and wheat.

The new indicator that we use to estimate unit yields in Qing China is the so-called harvest ratio. It is a score on the quality of summer or autumn harvests recorded in the semi-annual official reports from provinces to the central government. In these reports a bumper harvest is set at 100 per cent and a normal harvest at around 75. We interpret the score as a proxy for general agricultural productivity in a specific harvest year relative to an ideal situation, which allows for a consistent long-term comparison of agricultural production.[5] The *Cambridge History of China* has used the harvest ratio to show that there was a downward trend of agricultural production in the course of the nineteenth century (Chapter 1, pp. 6-7). Similar downward trends in provincial levels have also been found in other studies (ZHANG, 1957, pp. 755-70, ZHAO et al., 1995). This primary harvest record contains direct information on year-to-year circumstances that is extremely valuable in revealing annual changes in agricultural output.

We have used the national average harvest ratio calculated by ZHANG (1996, pp. 415-9). This study links the time series of the average harvest ratio with the long-term historical climate change in China for the period 1730-1978. It suggests that there was an essential impact of weather circumstances on agricultural activities and harvests in pre-modern China. From this series, we first constructed an annual harvest index for the late Qing period with the average of the 1930s set at 100. We then calculated unit yields for each food crop that is included in our estimation for the period 1840-1915. For example, the unit yield of rice is supposed to move along the autumn harvest ratio series, and that of wheat followed the summer harvest ratio series. With this procedure we try to capture the aggregate change in

[5] A careful reinterpretation might lead to the question of whether the reported harvest data actually reflects subjective observations on agricultural production which could be affected by the reporters' limited memory of previous harvest conditions. As a test we assumed two alternative possibilities of recollection and checked how much the reported trends will be affected by these alternatives. The first assumption is that the reporter can only remember the maximum level of harvests in the previous 10 years (or 20 years). The new trends are very similar to the original one. The second assumption is that the reporter can only remember the average level of harvests in the previous 10 years (or 20 years). The new trends show a slightly more downward slope than the one of the reported trend in the early nineteenth century. After the 1870s, the new trends are similar to the original one however.

unit yields and circumvent the problem of representativeness that may emerge when estimations are based on one specific region only.

The result of our estimation is a general decline in unit yields and land productivity in the late Qing period, which confirms the findings of early studies (YAN, 1955, p. 949, WU, 1985, p. 197, ZHAO et al., 1995, SHI and MA, 2010). More specifically, our result shows a continuous decline of land productivity through the 1850s-60s and sharp drops around 1874 and 1898, which probably reflects not only negative climate changes but also other adverse exogenous shocks, such as the Taiping Rebellion and the first Sino-Japanese war. Only after 1900 do we find an annual growth of agricultural production of 1.2 per cent, which is roughly in line with Rawski's estimation of 1.4-1.7 per cent for the period from the 1910s to the 1930s. The relatively fast improvement in China's agricultural sector as indicated by Rawski may have had its roots in the last decade of the Qing Empire. Our new estimation of land productivity based on the harvest ratio contributes to the on-going debate on the level of agricultural productivity in the Qing period. The present estimation of land productivity gives an average of 126 kg per mou for the period 1840-1915. This falls within the range of 120 and 150 kg per mou that was reported in previous studies (Perkins, 1969, WU, 1985, GUO, 1994, 1995). If we extend our calculation to the year 1920 the total level of gross agricultural output in China reaches 142.8 billion kg, which is very close to XU and WU's earlier estimation of 141.7 billion kg (XU and WU, 2003).

Industrial production

There are only a few official sources available for a direct quantitative reconstruction of the industrial sector of the late Qing period, in particular for the period before the 1860s. Previous studies on pre-modern China's traditional industries and early industrialisation allow us to obtain a general picture of the secondary sector in the late Qing period. The *Cambridge History of China* points at an "undoubted disruption" of the domestic cotton industry in the late Qing period due to increased openness to international trade (p. 26). In contrast to the collapse of the cotton industry, there is also mention of the expansion in the production of silk goods and tea in response to export demand. But many other domestic industries were probably not affected by nineteenth-century globalisation. We assume these industries to have grown in line with population development, such as rice milling in food-processing and traditional handicrafts like the production of bamboo tools.

For the industrial production of the period 1890-1913 Maddison applied the same rates of industrial growth as were found for the period 1913-33 (Maddison, 2007, p.155). Ma calculated sectoral value added for the period 1914-18 by projecting backward 1931-36 sectoral levels of value added on the basis of Rawski (1989)'s estimation of sectoral growth rates (Ma, 2008, p. 367, Table 3). The present study improves on these estimations by providing a new time series of industrial production for the period 1840-1920. Levels of gross output value are derived through a backward projection of the time series from the level of industrial output in the benchmark estimation of 1920 in XU and WU (2003). To obtain value added, the i/o ratios of handicraft industries in Ou's 1933 estimation are used for the period 1840-1920 (Ou, 1947). Finally the current price series was deflated by a new general price index for the industrial sector, based on price indexes of raw cotton, raw silk, coal, and the estimated agricultural price index above.

The estimation of industrial growth comprises manufacturing, mining, and construction. Figures on manufacturing come from three industries: cotton goods, silk goods, and food-processing. We have used coal production as a proxy for mining. According to previous estimations, manufacturing and mining in the late Qing period together accounted for more than 80 per cent of total valued added in industrial production. Textiles and food processing took up more than 50 per cent of manufacturing output. Other industries in manufacturing and mining were assumed to grow in line with the four proxy industries or with population. The construction sector in our estimation is assumed to grow in line with population. By combining the movements of the four proxy industries and population growth, we can derive the general growth pattern of the industrial sector in the late Qing period.

China's industrialisation started in the late nineteenth century. Artisans' workshop and other traditional production coexisted with newly-established mechanised factories with machinery or new energy inputs. Chang (1962) tried to measure the size of mechanised industrial production in his 1880s GDP estimation and concluded that the share of new production was still negligible in the 1880s. XU and WU (2003) also distinguished between the traditional and the new sector in their estimate for 1920. Using these two estimations as benchmarks, Appendix Table 2 gives the calculation procedure of mechanised factory output for the period between the 1880s and the 1920s. After subtracting the estimated GOV of mechanised production from the estimated GOV of the entire industrial sector, we obtained the GOV of traditional production.

For the estimation of new mechanised industrial production we have used a growth accounting model under the assumption that in the late Qing period the growth of labour productivity of the new industrial sector was dominated by capital deepening. For simplicity we assumed the change of technological efficiency (TFP growth) to be zero. This does not mean that we assumed zero technological progress in our estimation; however, we assumed that new technology was operated in the form of (imported) capital goods. After the 1860s China's economy experienced a rapid increase in imports of capital goods and energy inputs, such as machinery, coal, and iron. And after the 1870s there was a fast increase in the construction of infrastructure and utilities, such as the railway and the telegraph. Using different TFP growth rates other than zero, however, does not significantly alter our estimations of the mechanised industrial sector (Appendix Table 2.b).

Applying a zero TFP growth rate and an estimated average capital income share of 47.8 per cent in our growth accounting model we find a rapid and steady expansion of new mechanised production in the early stage of China's industrialisation. For the period 1885-1920 the GOV of mechanised production increased annually at 8.7 per cent. We can compare our preferred combination of the capital income share and TFP growth with data of other Asian countries in the same period. For instance, the capital income share in Meiji Japan was around 47 per cent and with the given growth rates of GDP and labour, the resulting TFP growth in 1891-1920 was 1.08 per cent per annum (Broadberry, Fukao, and Zammit, 2015). To reach a similar rate of TFP growth in Qing China, the corresponding capital income share in the mechanised industrial sector would need to exceed the level of 60 per cent in the period 1885-1920, which indeed would tend to overestimate the capital income share in Qing China. In the final decade of the Qing Empire, annual growth of mechanised industry production had already reached 9 per cent. Previous estimations resulted in annual growth rates of 10-12.6 per cent for the period 1912-25 (Chang, 1969, Kubo, 2005). We can thus conclude that the start of mechanised industrial production in early twentieth century China can still be traced back to the late Qing period.

Fast growth of mechanised production did not lead to immediate reinforcement of other parts of the industrial sector. Although the share of mechanised production in total industry increased from 6.1 per cent in the 1880s to 21.5 per cent in 1920, traditional production was still dominant in the late nineteenth century (Chang, 1962, XU and WU, 2003). Our estimation shows that traditional industrial production in Qing China decreased through the entire late nineteenth century, which is consistent with the historiography of pre-modern China's handicrafts (PENG, 1957). Only after 1900 did total industrial production start to expand, accompanied by an improving performance of traditional industry (See Appendix Figure 1.6). Rawski (1989) concludes in his study on China's pre-1945 growth that the mutual reinforcement of traditional and new economic sectors contributed to economic growth between the 1910s and the 1930s. Again our estimation reveals that this mutual reinforcement within the industrial sector can be traced back to around 1900.

The service sector

The reconstruction of the service sector includes four sub-sectors: public administration, finance and housing, commercial activities, and other professional services. We have used public spending as the central indicator for public administration, and brought in a new data source to estimate the current value of public spending in the late Qing period. The calculations that were made are based on data published by SHI (2009). This study has data from the Qing archives containing records of revenues, expenditures and inventories of the Silver Treasury.[6] We combined the spending recorded by the Silver Treasury with its relative share in total public spending. SHI argues that the share was 13 per cent before 1894 and around 15 per cent after that year, which is much lower than the share of 30 per cent in the early Qing period (Shi, 2009, p. 102). This may signal a declining influence of the central Qing state on political affairs. For missing data in the period 1840-1912, we referred to previous estimations for public spending of the Qing Empire in SHI and XU (2008). Total public spending in the late Qing period (so including provincial spending) was rather low. The per capita level was 0.27 taels on average, and the average share in GDP was only 1.7 per cent. In 1933 the per capita level had increased to 1.1 taels, a mere 2.7 per cent of GDP.

For other sub-sectors within services there is only limited primary information and we therefore had to rely on the assumptions and benchmark estimations of previous studies. We assumed that commercial activities, e.g. commerce, transportation, and communication, developed in line with agricultural and industrial production. For the late Qing period, the commercial ratio was set at 12 per cent for agricultural products and 60 per cent for industrial products, according to previous estimations such as XU and WU (2003), Broadberry et al. (2014), and Xu et al. (2015).[7] These new estimations of the agricultural and industrial sector enable us to derive levels of value added in commercial activities. For the sub-sectors of

[6] The main archives used in this book are the Yellow Registers ("*Huangce 黄册*"), specifically the registers for aggregate revenues and expenditures ("*Dajin Ce 大进册*" and "*Dachu Ce 大出册*").
[7] The estimation of the commercial ratio of the late Qing period includes two steps: the difference between the producer price and the market price, and the share of marketed product in total output. Details can be found in Xu et al. (2015).

finance, housing, and other professional services we assumed a development that was in line with population growth. The years in between the four benchmark levels of 1840, the 1880s, 1920, and 1933 were thus filled by population growth in log-linear trends (details of the four benchmark estimations are presented in Appendix Table 1). To deflate the new levels of value added in current prices we constructed a general price index for the service sector on the basis of the new agricultural and industrial price indexes, and a price index of gold.

Real GDP and GDP per capita

Adding the three sectors together we are able to derive an annual series of nominal and real GDP (per capita) for the late Qing period. Our GDP deflator is an aggregation of the price indexes of the three sectors that we mentioned before. To calculate real GDP per capita we have used Maddison's population data. Population growth derived from this data series is consistent with other studies on pre-modern China.

To facilitate an international comparison of living standards, our work also includes an independent and new benchmark estimate of GDP (per capita) for 1912 expressed in current purchasing power parities (See Appendix Table 3). Here follows a short explanation of the procedure. The PPP convertor between China (for the year 1912) and the US (for the year 1909) was calculated indirectly from a PPP between China (1912) and the UK (1907). For the agricultural sector three products were included: rice, wheat, and maize. Price data for these products allowed us to calculate market price ratios between China and the UK. The estimated agricultural PPP between China and the UK is 9.10 yuan/£, which is actually quite close to the market exchange rate in 1912, i.e. 9.99 yuan/£. For the industrial sector a manufacturing PPP was used from Ma, De Jong, and Xu (2016). This comparison covers more than 30 manufactured products resulting in a China/UK PPP of 6.61 yuan/£. We assumed that the service PPP equals the average of the agricultural and industrial PPP. The PPP for the whole economy is 8.09 yuan/£. Combining this estimate with the US/UK PPP estimate from Woltjer (2013) of 6.1 $/£, we can now indirectly calculate a new PPP between China and the US of 1.33 yuan/$ (8.09/6.1=1.33). Applying the new China/US PPP to our GDP (per capita) estimate of China for 1912, we obtain a level of 545 dollars, which is slightly lower than Maddison's 1913 estimate of 552 GK dollars. Using this new level a backward projection can be made of Chinese GDP (per capita) both in local currency (in current and constant prices) and in international dollars for the period 1840-1912 in prices of ca. 1910.

IV Plausibility of the new results

The present reconstruction of historical GDP of the late Qing period has resulted in new estimations for both levels and trends of living standards. Appendix Table 4 presents the details. The level of GDP per capita in current prices is 14.6 taels for 1840 and 34.5 taels for 1912. The level in international dollars is 550 for 1840 and 545 for 1912. Taking an average across the entire late Qing period, we arrive at a level of 575 int. dollars and of 36.42 taels in 1912 prices. The real growth of GDP per capita is on average 0.02 per cent annually for the period 1840-1912, with a peak in the 1880s. Real GDP per capita increased annually at 0.29 per cent before the peak and decreased annually at 0.43 per cent after the peak. The economy of late Qing China consisted mainly of agricultural activities, accounting for at least 60 per cent of the total economy.

Figure 1 compares our results with other estimations for the late Qing period and shows that the present estimates of GDP per capita are generally higher.[8] The only exception is Maddison's estimate for 1850, which suggests a higher level of living standards in the early Qing period before the Taiping Rebellion. Our estimates are actually very close to the most recent estimation in Xu et al. (2015). One reason for the higher estimates of per capita GDP is that the population figures that we use are slightly lower than those used by Xu et al. (2015). We can also compare our 1912 benchmark estimate of GDP per capita with other estimates for the 1910s. It is possible to combine the new 1930s China/US PPP in Fukao, Ma, and Yuan (2007) with 1914/18 GDP per capita in 1930 prices estimated by Ma (2008). The resulting level of GDP per capita for 1914/18 is 552 int. dollars, which is in fact very close to our 1912 estimate of 545 int. dollars independently derived from our new China/US PPP for the 1910s.

[Place Figure 1 here]

To test the reliability of the new estimates of per capita GDP, two cross checks were made. One concerns food crop output which formed the most important part of the family budget in late Qing China. According to our estimation, the potential daily energy consumption from food crops could reach a level of 2,600 kcal for the late Qing period, with a range between 2,377 and 2,791 kcal, taking account of an energy loss of ca. 20 per cent.[9] This level is higher than the overall minimum energy requirement of 1,680 kcal/day estimated by the FAO (2008). However, the daily energy intake recommended by the FAO is around 3,100 kcal for males aged 20-25 years, with a mean body weight of 68 kg and a moderately active lifestyle. For the female population under similar conditions, the recommended daily energy intake is around 2,410 kcal (FAO, 2001). Therefore, the production of food staples in late Qing China could barely support a healthy and well-nourished population, if this were the major energy source of food supply. From this we can conclude that a large portion of the Chinese population was on a subsistence level during the late Qing period.

Secondly, we can compare our results with alternative measures of living standards, such as average consumption budgets and wages. Here we refer to the average household budget in the Qing Dynasty as an indicator for consumption. The estimated per capita consumption in a five-person family in the late Qing Empire is 12.7 taels in the relatively wealthy Jiang-Zhe

[8] Our GDP estimates are also higher in terms of silver taels and in current prices. Table 1 shows three other estimates of per capita GDP in current prices and in taels. Our 1840 estimate of 14.60 taels is about 50 per cent higher than LIU's estimate of 10.8 taels (LIU, 2009, p. 153). Chang (1962) arrived at a level of 7.4 taels for the 1880s, whereas our estimation is 11.78 taels. The lower figure of Chang results mainly from his low estimate of the area under cultivation. Another recent GDP per capita estimate for 1840 is 12.95 taels in Broadberry et al. (2014), which is 11-12 per cent lower than our estimate of 14.60 taels for the same year. The difference stems mainly from the applied assumptions of the input/output ratio for grain crops. They assume a ratio of 18 per cent, which in our view is abnormally high (Broadberry et al., 2014, p. 38). We base our calculation on a ratio of about 10 per cent, which is more in line with existing studies. If we use their input/output ratio of 18 instead of 10 per cent, the new 1840 estimate would decrease to 13.56 taels. This difference in the assumed i/o ratio explains half of the difference between our estimate and that of Broadberry et al.

[9] Increasing the energy loss to 40 per cent will lead to an estimated average of potential daily energy consumption of 1,950 kcal. According to Buck's survey data, the range of daily energy consumption in the 1930s was 1,823-4,434 kcal (Buck, 1930, 1937).

region (63.31 taels divided by 5).[10] Our estimation of per capita GDP from the output side is generally higher than this estimated consumption level, except for the 1850s and for particular years in the 1870s-1880s when major disasters happened. As recorded previously, the annual salary of a farm labourer in 1888 was 13 taels in the Shandong province (ZHANG, 1957, P. 692). Our estimated per capita GDP of 1888 is 12.78 taels, which is close to this annual salary. As a proxy for a daily wage, we calculated GDP per capita/day and derived an average of 0.042 taels in current prices. This derived average daily wage is close to the baseline wage for the early Qing period calculated by Allen et al. (2011, Figure 1, p. 16). Again, this signals low living standards in Qing China during the turbulent late nineteenth century.

These new estimations result in a different growth path of the economy compared with Maddison's data for the late Qing period (see Figure 1). Maddison's estimation of per capita real GDP considers the Taiping Rebellion (1851-64) as an important breakpoint in long-term Chinese economic development. The estimation is based on several data points and presumably indicates a stagnation of living standards for the entire Qing period with a sharp decline in 1850-70 that reflects the adverse impact of the Taiping Rebellion. Our estimation provides a time series with more fluctuations: a period of relative stability in the 1840s-50s, a first round of increasing levels in the 1860s-80s, a decrease from the 1880s, and a second phase of rising levels around 1900. Table 2 shows annual growth rates of per capita GDP for these four periods respectively, which in general confirms the stagnation of living standards for the late Qing period.

Surprisingly, we find in the new data no decline in GDP per capita during the Taiping Rebellion, which deserves an explanation. According to our estimation, the Qing economy lost 6 per cent in real terms. But in the same period the total loss of population was more than 8 per cent, which by simple arithmetic leads to an increase in per capita real GDP of around 2.5 per cent. Thus, the huge decline in population explains the seemingly unusual increase in per capita GDP before 1870. In contrast, the decrease in GDP per capita in the 1880s-90s was driven by an increasing population and a rather constant level of total GDP. Only in the 1870s and 1900s did the growth of the total economy surpass population increases, leading to a sustained growth in the economy. Figure 2 presents the population trends in our estimation and compares total GDP with per capita GDP. It is tempting to suggest that Malthusian forces were still responsible for the stagnation of living standards in late Qing China. Cha (2014) also emphasises the role of population growth in nineteenth-century China by stating that the pressure on economic development "comes from nowhere but population growth"; He estimated a generally downward trend of living standards for the Qing period. According to Figure 2, the sudden liberation from the Malthusian trap in the 1860s-70s did not endure; the population recovery in the 1880s-90s led to an immediate decline of per capita GDP.

[Place Figure 2 here]

According to our GDP reconstruction, the most serious economic decline of the late Qing period happened in the 1850s-60s, when both the economy and society were threatened by

[10] FANG (1996) estimated an average consumption basket in the Qing Dynasty for a farmer family with five members living in the Jiang-Zhe region. It covers food, clothing, rent, and fuel. He concluded that in the early Qing Empire the level of annual household consumption was 32.6 taels and in the late Qing Empire 58.31 taels. Following ZHANG (2005), we have added per capita educational expenses to this estimation at an amount of 1 tael per person or 5 taels per family.

wars and natural disasters, such as the Taiping Rebellion in the south (1851-64) and the Nien Rebellion in the north (1852-68). We also find that in these two decades significant setbacks were actually happening in the industrial- and service sectors, more than in the agricultural sector (see Appendix Figure 1. 5.). A recovery in the 1870s-80s shows a total increase of real GDP by 6 per cent. At the beginning of the 1890s the Qing economy had recovered and returned back to its level of before the Taiping Rebellion. One could ascribe the better performance in the 1870s-80s to the politically-inspired "self-strengthening" movement (1860-94) which intended to incorporate new technologies from more advanced western economies. However, this is doubtful since economic growth as we have seen was to slow down again in the 1880s-90s. The growth path of real GDP in our estimation fits well into the general situation of the late Qing Empire that we know from the historiography.[11] Very different from Maddison's interpretation, our work views the late nineteenth century generally as a period of recovery in the long-term economic development of pre-modern China, which to some extent supports the idea of a "resilience" of the economy in the face of the adverse economic and social conditions of the turbulent century as described in Brandt et al. (2014).

The decline of the total economy in the 1895-99 period deserves special attention. This decrease can be attributed to the first Sino-Japanese war (1894-95), to the bad climatic conditions in the 1890s, and perhaps also to worsening trade conditions. Since the 1860s domestic cotton cloth production in Qing China had been negatively affected by large imports; the downward trend became significant in particular in the 1890s (XU and WU, 2003). Similarly, the export of tea reached a peak in the 1880s and started to decline thereafter. We also find a decline in the export of silk goods in the 1890s. The sudden drop in exports may have led to a decline in domestic production. After being involved in globalisation for over half a century, the Qing economy had become more and more vulnerable to shocks from international markets, in particular in the industrial and the service sectors.

Earlier in this section we compared the levels of GDP/capita with other measures of living standards. We can do the same again with the trends and compare them with trends in wages. Although wages declined sharply in the 1850s, Allen, Bassino, Ma, Moll-Murata, and van Zanden (2011) find that real wages in Beijing (north China) had risen back to their former level of the early Qing period by around 1870 and continued to increase until 1900. Demographic indicators in Baten, Ma, Morgan, and Wang (2010) reveal a decline in living standards in South China from 1850 and a recovery from 1900. In contrast with these trends of partial indicators for specific regions in China, ours is a national aggregate and accordingly the economic fluctuations that we find are relatively mild.

In the previous section we have linked agricultural and industrial production of the 1900s with corresponding developments in the interwar period; we can do this also for total GDP per capita. Ma (2008) derived an increase in real NDP per capita by 0.53 per cent per annum for the period from the 1910s to the 1930s. We find almost the same growth rate for the final years of the Qing Empire, with an estimated annual per capita real GDP growth of 0.51 per cent for the 1900s.

[11] However, our work fails to capture some historical events, such as the four-year drought in north China from 1876 to 1879.

Finally, we can put the economic performance of the late Qing period in an international perspective. Table 2 compares annual growth rates of real GDP per capita in Qing China with both advanced western and newly-industrialising Asian economies. The comparison shows clearly the divergence of growth paths between Qing China and Western Europe since the mid-nineteenth century. From the second half of the nineteenth century, Asian economies such as Japan and Indonesia had entered a fast-growth trajectory and were able to catch up with western economies. But Qing China showed no growth acceleration; in the late Qing period annual growth of the economy was much lower than that in contemporary Asian countries. The growth of the Qing economy was still comparable with that of India in 1860-80; however, in the 1900s per capita real GDP of Qing China increased by 5.1 per cent in contrast with a growth of 15.6 per cent in India. We can also make international comparisons at sectoral levels. In the period 1850-74, land productivity of food crops in Qing China declined annually by 0.42 per cent, while in pre-Meiji Japan land productivity increased annually by 0.27 per cent. Qing China's industrial sector started to grow at an annual rate of 2.3 per cent in the 1900s, whereas the corresponding growth rate was 3.3 per cent in India and 4 per cent in Meiji Japan. These data suggest that Qing China was losing out on other Asian countries already in its early stage of industrialisation.

[Place Table 2 here]

V Economic stagnation in the late Qing Empire

The present estimation of per capita GDP confirms that the economy of the late Qing Empire was stagnant at a low level of living standards. This work was not aimed at finding the mechanisms behind the stagnation of the Qing economy and the Great Divergence with the more advanced Western economies. We mainly intended to provide a new quantitative interpretation of the commonly-accepted stagnation of the Chinese economy.

Qing China in the late nineteenth century was an agrarian economy. Figure 3 shows that around two thirds of total GDP (in current prices) was produced in the agricultural sector. The agricultural share in constant prices even reached 70 per cent in the late Qing period. One might suspect that the agricultural share may have been overestimated in our calculations. We have to admit that it is difficult to estimate precisely the agricultural share in a pre-modern economy that was characterised by high agro-industrial or agro-service activities. In our estimation we have placed tea and raw silk in the category of agricultural products, but they can also been seen as processed products, and thus manufactured goods. But reclassifying the two products into the secondary sector will not reduce the agricultural share substantially. Other estimations for Qing China also arrived at agricultural shares above 60 and even 70 per cent (LIU, 2009, GUAN and LI, 2010). And in 1933, the share of agriculture still took up more than 60 per cent of the total economy (Liu and Yeh, 1965). Compared to other Asian economies, the agricultural sector in Qing China was not exceptionally large; the agricultural share was 67.5 per cent in 1881 India, 47.9 per cent in 1880 Indonesia, and around 60 per cent in pre-Meiji Japan (Van Der Eng, 1992, Broadberry, Custodis, and Gupta, 2015, Bassino et al., 2015).

[Place Figure 3 here]

Economic performance in pre-modern China thus largely depended on the growth dynamics of the agricultural sector (Rawski, 1989). The stagnation of the Qing economy in the late nineteenth century can therefore mainly be attributed to difficulties in agricultural development (See Appendix Figure 1.5). Our results reveal a broad stagnation of land productivity and accordingly no significant improvements in agricultural output. Figure 4 illustrates that the estimated land productivity was roughly similar to the development of the population/land ratio, which directly indicates a stagnation of per capita agricultural output for the late Qing period. Note that we estimated land productivity for food crops independently without referring to population and land data. One potential reason behind the poor performance of the agricultural sector may have been that the traditional labour-intensive agricultural production methods were hardly able to sustain a certain level of land productivity after facing huge losses of labour caused by wars and natural disasters in the late nineteenth century. Our findings support the traditional view on economic performance in pre-modern China: population expansion produced high agricultural productivity but a low per capita income, as stated in Wong's study on economic change in late imperial China between 1500 and 1900 (Wong, 1997).

[Place Figure 4 here]

Figure 3 gives an indication of the frozen economic structure in late Qing China. Regardless of all the efforts toward industrialisation, the economy was even showing a growing agricultural sector. If we take Qing China's urbanisation level as a proxy for non-agricultural production, new data seem to support our finding of structural stagnation; a recent study concludes that the urbanisation ratio remained at 7 per cent for the period 1850-95 and increased to 13 per cent in 1918 (Xu, van Leeuwen, and van Zanden, 2015). There are only minor shifts between the three sectors. With both the output value and the share of the industrial sector declining, we even find a mild de-industrialisation in the 1860s-90s, which generally confirms Williamson's (2008) finding on pre-modern China. Even though this was the period of China's early industrialisation with the so-called self-strengthening movement (1860-94), the momentum of newly founded industries was overshadowed by the large sector of traditional production in agriculture and handicrafts.

As discussed in the previous section, agricultural output in late Qing China could barely support the population, which means that there was no room for any savings for reinvestment in the agricultural sector and capital formation in other sectors. In the context of labour-intensive agriculture, efforts to decrease the land/labour ratio are a rational way to increase land productivity. But the relatively low agricultural productivity in the late Qing period implied that there was hardly any potential release of labour to other sectors. In some cases agricultural output may even have fallen below the subsistence level. Economic resources in this specific agrarian economy with a large population and with relatively limited access to international markets were still flowing into agricultural activities. In such an economy it may take a long time to move towards an economic structure favouring industrial production and modern economic growth (Broadberry and Gupta, 2006).

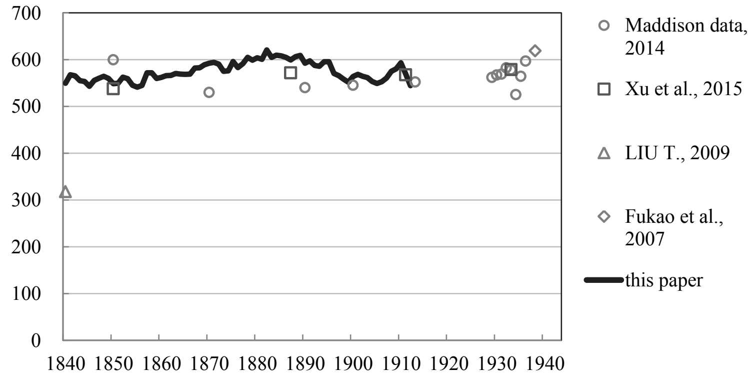
VI Conclusions

Although recent studies have provided new interpretations of the economic performance of late Qing China, the question of whether the economy of the "Turbulent Century" was actually stagnant still seemed open to debate. Our new estimation provides a picture from the output side of the economy and presents for the first time annual data to uncover economic trends and fluctuations. In this paper we have constructed a time series of historical GDP (per capita) in both nominal and real terms for the period 1840-1912.

Several new contributions distinguish the present reconstruction from previous estimations. Our estimation focuses on agricultural production and applies the harvest ratio to indicate the change of land productivity. We study the development of the industrial sector in the context of the early industrialisation of pre-modern China by isolating the fast-growing new mechanised industries from the declining traditional production. For services we included new data on public expenditure. We solved the problem of inconsistency in previous estimations by providing a current PPP estimation in 1912 and time series GDP estimation in international dollars.

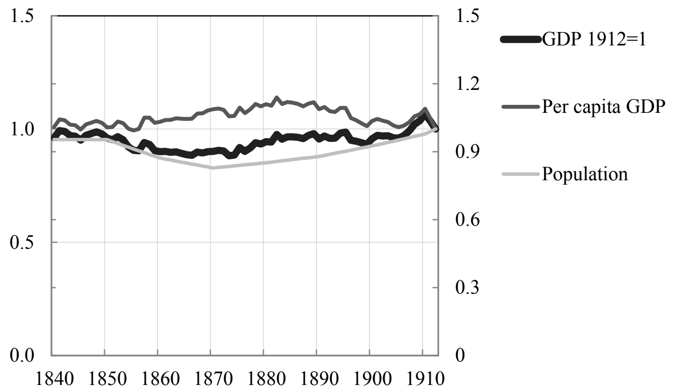
Our work gives an estimation of per capita GDP in the late Qing period that is higher than in most other studies, but still indicates a low level of average living standards. We conclude that the economy was characterised by a large and growing agricultural sector with no significant structural changes. For most of the late Qing period, economic growth was restrained; only in the beginning of the twentieth century did the economy start to show signs of growth. However, even this positive economic performance seems to be insignificant in the context of fast industrialisation among neighbouring Asian countries. A closer investigation into the regional and sectoral characteristics of the economy in the late Qing period may explain the missed opportunity to catch up, the impact of globalisation, and the widening divergence with the West.

Figure 1 Estimations of per capita GDP in China, 1840-1940, in 1990 international dollars



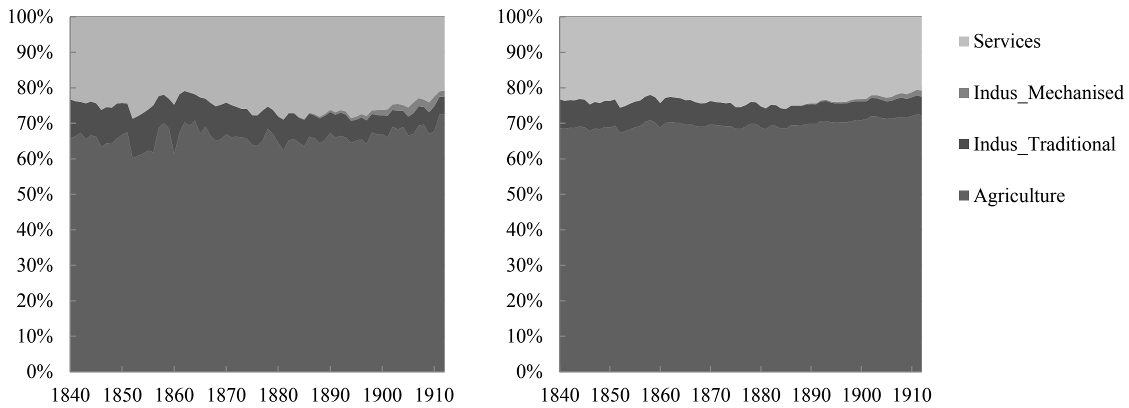
Sources: See the text, collected by the authors.

Figure 2 The new estimation of Chinese GDP and GDP per capita, 1840-1912, in constant prices, 1912=1



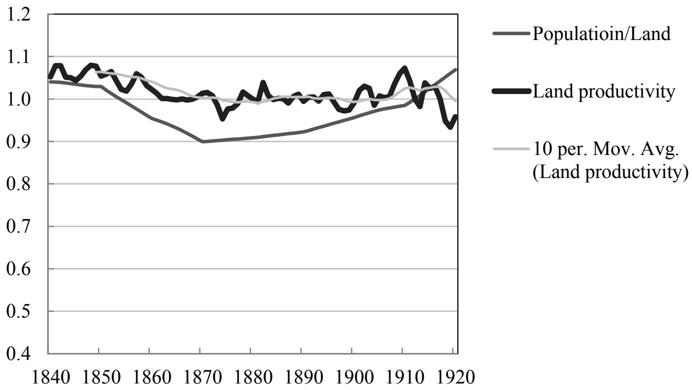
Sources: See the text, estimated by the authors.

Figure 3 Chinese GDP by sector, 1840-1912, in current prices and prices of 1912



Sources: See the text, estimated by the authors.

Figure 4 Land productivity for food crops and the population/land ratio, 1840-1920, 1912=1



Sources: See the text, estimated by the authors.

Table 1 Historical GDP per capita estimates for China, 1800-1936

Period	1800-1920							1930s				
	1800	1840	1840	1880s	1850-1913	1850-1911	1914/18	1933	1933	1933	1931-6	1934-6
	LIU, 1987	LIU, 2009	Broadberry et al., 2014	Chang, 1962	Maddison data, 2014	Xu et al., 2015	Ma, 2008[a]	Ou, 1947	Liu and Yeh, 1965	Maddison data, 2014	Ma, 2008[a]	Fukao et al., 2007
Benchmarks	6.7	10.8	12.95[c]	7.44[b]			52.4	46	59.8		57.4	60.5
Local Currency	1700 tael	Tael, current prices	Tael, current prices	Tael, current prices			1930s yuan	Yuan, current prices	Yuan, current prices		1930s Yuan	1930s Yuan
Benchmarks or Averages		318	594		566	559				579		619
Internationally -comparable Currency		1990 int. dollars [d]	1990 int. dollars		1990 GK dollars	1990 int. dollars				1990 GK dollars		1990 int. dollars

Source: See references, collected by the authors. The new Maddison data is from Bolt and van Zanden (2014).

[a] Here, the value represents net domestic product (NDP).

[b] Our estimate is 12.57 taels for the 1880s. The lower figure of Chang results mainly from his lower estimate of cultivated land area.

[c] Our estimate is 13.65 taels for the 1840s.

[d] The monetary unit "international dollars" is comparable with the "GK dollars" used by Maddison.

Table 2 Annual growth of real GDP per capita for various countries and regions, 1840-1910 (%)

a. Economic growth in some regions, 1840-1910 (%)

	12 W. Europe	W. Offshoots	30 W. Europe	7 E. Europe	L. America	16 E. Asia	Qing China	Qing China (total GDP)	Qing China (population)
1840-1860	1.35	1.47	1.05	0.46			0.11	-0.33	-0.44
1860-1880	0.88	1.68					0.36	0.24	-0.13
1880-1900	1.54	1.90	1.51	1.38	1.32	0.44	-0.34	0.07	0.42
1900-1910	1.02	1.88	1.27	1.32	2.34	0.69	0.51	1.07	0.58

b. Economic growth in some countries, 1840-1910 (%)

	Italy	Holland/ Netherlands	England /GB	India	Indonesia (Java before 1880)	Japan	Qing China	Qing China (total GDP)	Qing China (population)
1840-1860	-0.24	0.17	0.70		-0.28	0.41	0.11	-0.33	-0.44
1860-1880	0.45	1.06	1.01	0.31	0.99	1.31	0.36	0.24	-0.13
1880-1900	0.74	0.82	1.32	0.40	0.63	1.68	-0.34	0.07	0.42
1900-1910	1.67	1.06	0.24	1.56	1.06	1.16	0.51	1.07	0.58

Source: See references, calculated by the authors. Per capita GDP for other countries and regions is from Bolt and van Zanden (2014).

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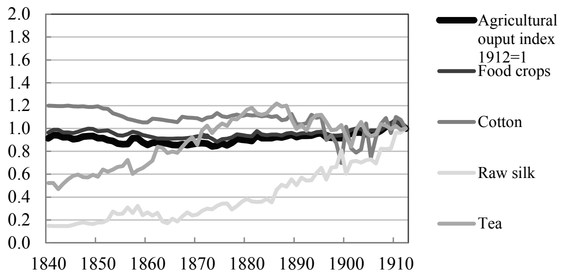
Appendix

Figure 1 Sectoral GDP of China, 1840-1920

1.1



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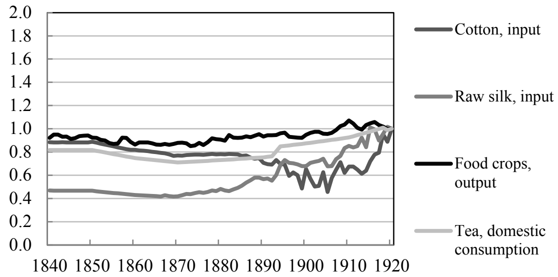

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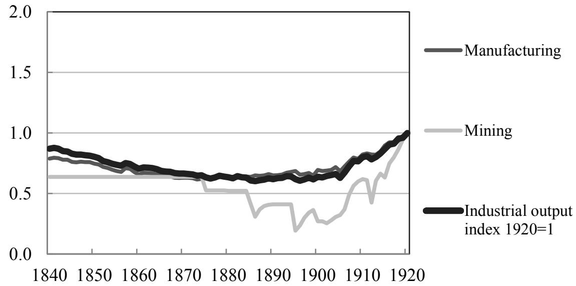

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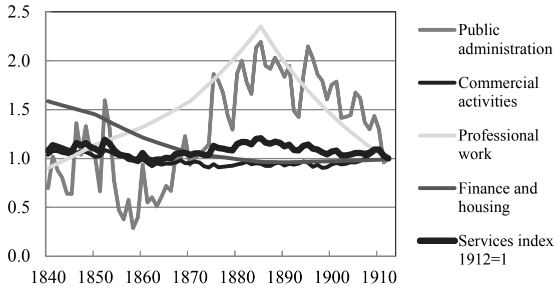
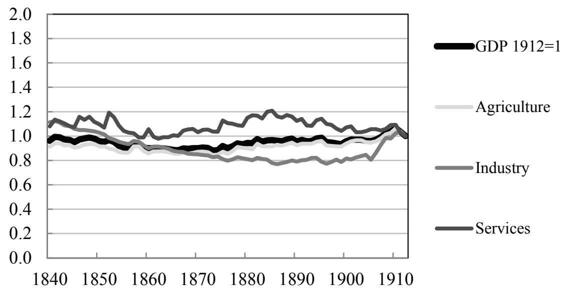
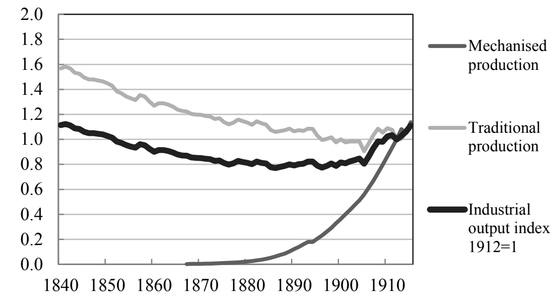


Continued Figure 1

1.5



1.6



Sources: See the text, estimated by the authors.

Table 1 General overview of estimation procedures in the present paper

		Direct estimation		Indirect approach		Aggregates	
a. Agriculture		Volume	Prices	Volume	Prices		Agriculture
Staple crops	Food crops: Rice, wheat, etc. [a].	Cultivated acreage, land productivity (see the main text)	Rice and wheat prices				
Other crops	Cash crops: Raw cotton, raw silk, tea	Domestic consumption, net exports [b]	Domestic prices, export and import prices				
	Other [c]:			% of GOV of food and cash crops (fixed)			
Other agricultural production	Forestry, livestock farming, fishery			% of GOV of food crops (fixed)			
Total: agriculture		GOV		% of GOV		Add up direct and indirect estimation	GOV
				Input/output ratio: 10% (fixed)		VA is 90% of GOV	VA
		Sectoral output values per item: weights	Sectoral price levels per item: unit prices			Agricultural price index	Annual real VA

		Direct estimation		Indirect approach		Aggregates	
b. Industry		Volume	Prices	Volume	Prices		Industry
Manufacturing	Textiles [d]:						
	Cotton [e] and silk goods			Inputs [f]: raw cotton, raw silk			
				Domestic output (estimated above), net exports	Export and import prices of raw cotton and raw silk		
				Based on the 1920 benchmark estimation of GOV of cotton and silk goods			
	Food processing:						
	Oil, liquor, flour, tobacco, etc.			Inputs:			
				Agricultural output	General price level of agriculture		
				Based on the 1920 benchmark estimation of GV of food processing			
	Other manufactured goods [g]:			Log-linear interpolation between three benchmark per capita estimates: 1840, 1885, 1920	Prices assumed to be equal to the general price movements in manufacturing		
Total: Manufacturing				Add up indirect estimation of GOV		GOV	
				Input/output ratio: 60% (fixed)		VA	

Continued Table 1.b. Industry

				Sectoral output values per item: weights	Sectoral price movements per item	Manufacturing price index; Annual real VA	
Mining	Coal	Output volume	Domestic prices, export and import prices	Input/output ratio: 67%-50%			
	Other:			% in VA of mining (fixed)			
Construction				Log-linear interpolation between three VA (per capita) benchmark estimates: 1840, 1885, 1920	Prices assumed to be equal to the general price movements in manufacturing		
Total: Industry				Input/output ratios: Manufacturing :60%; Mining: 67%-50%		Add up direct and indirect estimation of VA	VA
				Sectoral output value per item: weights	Sectoral price movements per item	Industrial price index	Annual real VA

c. Services		Direct estimation		Indirect approach		Aggregates	
		Volume	Prices	Volume	Prices		Services
Public administration	Public spending	Archival records			Estimated with the general price level of agriculture and industry, and the price of gold		
Commercial activities				% of VA of agriculture and industry (fixed) [h]	Estimated with the general price level of agriculture and industry		
Professional work				Log-linear interpolation between three VA (per capita) benchmark estimates: 1840, 1885, 1920	See 'Public administration'		
Finance and housing				See "professional work"	Estimated with the price movement of gold		
Total				VA		Add up indirect estimation of VA	VA
				Sectoral VA per item: weights	Sectoral price movements per item	Service price index	Annual real VA

d. GDP	direct estimation		Indirect approach		Aggregate	
	Volume	Prices	Volume	Prices		GDP and GDP per capita
Agriculture	Estimated real growth	Estimated sectoral price				
Industry			Estimated real growth	Estimated sectoral prices		
Services			Estimated real growth	Estimated sectoral prices		
Total						Nominal GDP
			Weighted prices series based on the price series of the three major sectors		GDP deflator	Real GDP
	Population					GDP per capita

e. Four benchmark estimations [i]

	1840, current prices			1880s, current prices				1920, 1930s prices, Chinese Yuan				1933, current prices		
	Value	Per capita	Share	Value	Per capita	Share	I/O ratio	Value	Per capita	Share	I/O ratio	Value	Per capita	Share
	Billion Tls.	Tls.	%	Billion Tls.	Tls.	%		Billion Yuan	Yuan	%		Billion Yuan	Yuan	%
GDP	4.485	10.886	100.00	2.777	7.438	100.00	0.10					28.86	57.72	100.00
Agriculture	2.734		60.96	1.672		60.22		9.445				18.76		65.00
Industry	0.565		12.60	0.204		7.33						3.36		11.64
Manufacturing	0.409		9.12	0.126		4.53		1.206		100		2.68		9.29
Cotton goods				0.073		2.61	0.63	0.192			0.85			
Silk goods				0.019		0.67	0.51	0.037			0.72			
Food processing				0.015		0.54		0.439						
Tea				0.007		0.26	0.92	0.014			0.92			
Other				0.020	0.053			0.538	1.139					
Mining	0.058		1.29	0.048		1.72		0.291				0.21		0.73
Coal				0.013		0.47		0.107						
Construction	0.098	0.238	2.19	0.030	0.080	1.08						0.47	0.94	1.63
Services	1.186		26.44	0.901		32.45						6.74		23.35
Commercial activities	0.659		14.69	0.257		9.26						4.34		15.04
Finance and housing	0.317	0.769	7.07	0.239	0.639	8.59						1.24	2.48	4.30
Other professional services	0.115	0.279	2.56	0.241	0.646	8.69						0.34	0.68	1.18
Government	0.095		2.12	0.164		5.90						0.82		2.84

Notes:

[a] Here includes rice, wheat, millet, kaoliang, barley, maize, and sweet potatoes.

[b] Here, net exports include raw cotton, cotton yarn, and cotton cloth.

[c] According to previous estimations, here includes oil seeds, soy beans, fruit and vegetable.

[d] Textile products are important in estimating industrial output. For England's industrial output before 1700, wool and woolen cloth was one of the representative products. For the period 1700-1870, the cotton industry was the leading sector in the industrial sector of Great Britain. Cotton cloth was always an important industrial product in eighteenth- and nineteenth-century India.

[e] For manufacturing, we use input value to infer gross output value. For instance, for the period 1840-1920 we use the annual volume and price index of raw cotton as the proxies of the volume and price index of cotton goods and thus the growth index of cotton industry in current prices, setting 1920 as the base year. Then, the GOV of the cotton goods in 1920 estimated by XU and WU (2003) can be used for backward projection. After deducting a 60 per cent of input value, we obtain a time series of value added for the cotton industry for 1840-1920.

[f] This input-based approach has been used e.g. to estimate pre-1700 textile output in England and also the industrial output in the Republic of China in the 1930s.

[g] According to the 1920 benchmark estimation, here includes leather, timber products, chemicals, paper and publishing industry, etc.

[h] The ratios are from the benchmark estimations for 1840 and the 1880s. Such short-cut assumptions are often used to estimating the service sector, such as commerce and transport in England before 1700 and trade in Indonesia in the nineteenth century. Housing and domestic services are often assumed to grow in line with population.

[i] The 1840 benchmark estimation for GDP is from LIU (2009). The 1880 benchmark estimation for GDP is from Chang (1962). The 1920 benchmark estimation for agriculture and industry is from XU and WU (2003). The 1933 benchmark estimation for GDP is from Liu and Yeh (1965).

Table 2 Estimation of new mechanised production in the industrial sector in China, 1885-1920

a. Estimation procedure

	Benchmark estimations, GOV, current prices	capital, Estimated	labour, Estimated	price index for industrial goods	GOV, current prices	GOV, constant prices	Aver. real Growth per annum (every five years)
	Mill. Tls.	1000CNY		1913=100	Mill. Tls.	1913prices	(%)
1885	26	2964	90140	77.7	26.09	33.58	
1890		7855	182343	102.1	78.91	77.29	18.14
1895		14741	280274	92	120.23	130.69	11.08
1900		34900	382981	112.2	260.52	232.19	12.18
1905		65076	492068	122.3	435.90	356.42	8.95
1910		129102	607029	105.6	582.59	551.70	9.13
1915		201318	684524	101.8	739.38	726.31	5.65
1920	864	257929	413040	137.6	864.06	627.95	-2.87

Notes: Capital income share, estimated =0.4777.
Using the growth accounting model: $g_{Y,1885,1920} - g_L = \alpha(g_K - g_L) + g_{TFP}, g_{TFP} = 0$.
Robust check for this assumption, TFP growth=0, is in Table 2.b.
Industrial price index: LIU, F. and WANG, Y., 1997, p. 203-206.
Capital and labour estimations: XU and WU, 2003. See details in Ma, de Jong, and Chu (2014), Appendix B.
Labour for the period 1912-20: from Lieu, 1927, p. 91.
Two benchmark estimations are from Chang (1962) and XU and WU (2003).

b. Robustness tests on TFP growth and capital income shares

	capital income shares	TFP growth, per annum	Growth of mechanised production, GOV, per annum, 1900-10
	%	%	%
this paper	47.77	0.00	9.04
Robust check	0	-3.94	9.01
	10	-3.13	9.01
	20	-2.31	9.02
	30	-1.48	9.03
	40	-0.65	9.03
	45	-0.23	9.04
	50	0.19	9.04
	55	0.61	9.04
	60	1.03	9.05
	65	1.46	9.05
	70	1.89	9.06
	80	2.75	9.06
	90	3.62	9.07
	100	4.49	9.08

Notes: Using the growth accounting model: $g_{Y,1885,1920} - g_L = \alpha(g_K - g_L) + g_{TFP}$.
Robust check for the relationship between TFP growth and assumed capital income shares:
$g_{TFP} = (g_{Y,1885,1920} - g_L) - \alpha(g_K - g_L)$.

Table 3 A benchmark GDP estimation of China for 1912

a. A China/US PPP for ca. 1910 (Chinese Yuan/ $)

	Chinese Yuan Prices/Ton [a]	UK £ Prices/Ton [b]	PPP Yuan per £	Chinese weights [c]	British weights [d]
Agriculture			**9.10**[e]		
Rice	101.85	10.10	10.08	0.89	0
Wheat	71.40	8.14	8.77	0.10	0.80
Maize	46.49	6.88	6.76	0.01	0.20
Agriculture			9.10	0.79	0.118
Industry			6.61 [f]	0.02	0.441
Service			7.85 [g]	0.19	0.441
The economy as a whole:					
	China/UK PPP		**8.09**		
	China/US PPP		**1.33**[h]		

Sources: Constructed by the authors.

[a] The Chinese prices for wheat and maize are the wholesale prices in Tianjing in 1913, from the statistical material recollected by KONG and PENG (1988). The Chinese price for rice is the market price in Yangzi Delta in 1912, from Wang (1992), Table 1.1.

[b] The UK prices are from Jacks, O'Rourke, and Williamson (2011).

[c] The Chinese weights within the agricultural sector are calculated by a combination of market prices in 1912-1913 and output quantities in 1915. The output data is from the Chinese census of 1915. The Chinese weights of the whole economy in 1912 are from the estimation in this paper.

[d] The UK weights within the agricultural sector are assumed to be opposite of the Chinese weights in general. We also assume that in 1912 the UK output of rice was negligible. The UK weights of the whole economy are from Feinstein (1976), which are actually employment shares of the three sectors.

[e] Fisher PPP is calculated here.

[f] The industry PPP for 1912 is assumed to equal the manufacturing PPP from Ma, de Jong, and Xu (2015).

[g] The service PPP for 1912 is assumed to be the average of the agriculture and manufacturing PPP.

[h] Using US/UK PPP ($/£), 6.1, from Woltjer (2013), we calculate China/US PPP from China/UK PPP, 8.09/6.1=1.33.

b. A benchmark estimate of GDP per capita for China and the US in 1912 in 1990 international dollars

China	
GDP per capita (Yuan) [a]	51.75
US	
GDP per capita ($)	359.6
Exchange rates in 1912	
exchange rate (Yuan per $)	2.06
PPP (Yuan per $) [b]	**1.33**
Comparative China/UKGDP per capita (%)	
At the exchange rate	0.068
At PPP	0.109
GDP in 1990 international dollars	
US [c]	5017
China	**545**
Maddison's estimation for 1913	**552**

Sources: Constructed by the authors.

[a] The per capita GDP in Chinese Yuan is calculated from the level in taels. In 1912, officially 1 tael=1.5 Chinese Yuan. 34.5 taels×1.5 Chinese Yuan/tael=51.75 Chinese Yuan.

[b] PPP is from Table 3.a in this Appendix.

[c] The estimate of per capita GDP for 1909 US is from Maddison's estimation.

Table 4 Nominal and real GDP per capita in China, 1840-1912, in tael. Real GDP/cap in prices of 1912.

	Per capita GDP	**Value added per capita**			**GDP deflator**	**Per capita GDP**	**Per capita GDP**
		Agricultural sector	Industrial sector	Service sector			
	current prices	current prices	current prices	current prices	1912=1	1912prices	int. Dollars
1840	14.60	9.74	1.60	3.27	0.42	34.82	549.72
1841	15.85	10.49	1.57	3.78	0.44	35.95	567.70
1842	15.68	10.40	1.34	3.93	0.44	35.82	565.60
1843	13.40	8.79	1.36	3.25	0.38	35.16	555.20
1844	13.89	9.23	1.31	3.35	0.40	35.07	553.66
1845	13.18	8.68	1.24	3.27	0.38	34.42	543.41
1846	11.91	7.55	1.24	3.12	0.34	35.20	555.76
1847	12.15	7.83	1.24	3.09	0.34	35.49	560.34
1848	12.44	8.02	1.26	3.17	0.35	35.75	564.44
1849	13.39	8.85	1.32	3.23	0.38	35.46	559.84
1850	14.14	9.41	1.26	3.47	0.41	34.75	548.74
1851	13.20	8.76	1.04	3.40	0.38	34.82	549.71
1852	9.24	5.55	1.03	2.66	0.26	35.63	562.56
1853	9.28	5.64	1.04	2.60	0.26	35.42	559.26
1854	9.22	5.67	1.06	2.49	0.27	34.55	545.49
1855	9.63	6.03	1.11	2.48	0.28	34.29	541.46
1856	10.25	6.51	1.40	2.35	0.30	34.52	545.12
1857	16.30	11.23	1.46	3.61	0.45	36.22	571.88

1858	17.09	11.89	1.34	3.85	0.47	36.24	572.20
1859	14.71	9.99	1.21	3.50	0.41	35.45	559.80
1860	11.56	7.36	1.68	2.52	0.32	35.62	562.39
1861	18.54	12.72	2.08	3.74	0.52	35.86	566.17
1862	25.34	17.93	2.23	5.18	0.71	35.89	566.64
1863	24.31	16.88	2.25	5.18	0.67	36.15	570.79
1864	25.09	17.45	1.81	5.83	0.70	36.07	569.45
1865	18.87	12.74	1.95	4.18	0.52	36.03	568.82
1866	20.28	13.74	1.56	4.98	0.56	36.06	569.39
1867	16.14	10.68	1.49	3.97	0.44	36.87	582.17
1868	14.26	9.20	1.38	3.68	0.39	36.90	582.69
1869	14.81	9.74	1.44	3.62	0.40	37.33	589.37
1870	15.58	10.39	1.39	3.81	0.42	37.54	592.69
1871	14.38	9.45	1.29	3.64	0.38	37.64	594.24
1872	13.60	8.90	1.13	3.56	0.36	37.42	590.86
1873	12.54	8.20	0.99	3.35	0.34	36.43	575.22
1874	11.83	7.77	1.00	3.05	0.32	36.48	576.05
1875	11.53	7.35	0.96	3.22	0.31	37.75	596.10
1876	11.65	7.45	1.01	3.19	0.32	36.94	583.28
1877	12.93	8.49	1.12	3.32	0.34	37.48	591.76
1878	15.67	10.63	0.97	4.06	0.41	38.31	604.88
1879	13.05	8.68	0.89	3.47	0.34	37.94	599.03
1880	11.47	7.38	0.86	3.23	0.30	38.27	604.25
1881	10.50	6.60	0.94	2.97	0.28	38.07	601.02
1882	12.44	8.13	0.97	3.34	0.32	39.32	620.84
1883	13.03	8.55	0.96	3.52	0.34	38.33	605.16

1884	12.54	8.06	0.90	3.58	0.32	38.62	609.86
1885	12.00	7.64	0.92	3.43	0.31	38.53	608.30
1886	13.77	9.13	0.93	3.71	0.36	38.33	605.18
1887	13.65	8.98	0.92	3.75	0.36	37.96	599.41
1888	12.78	8.25	0.96	3.56	0.33	38.40	606.25
1889	13.57	8.89	1.00	3.67	0.35	38.57	609.06
1890	14.43	9.66	0.94	3.82	0.38	37.53	592.55
1891	13.35	8.83	0.95	3.58	0.35	37.84	597.52
1892	13.86	9.26	1.01	3.60	0.37	37.23	587.91
1893	14.24	9.43	1.05	3.76	0.38	37.11	585.89
1894	14.70	9.47	1.03	4.20	0.39	37.73	595.72
1895	15.35	10.01	1.04	4.30	0.41	37.73	595.71
1896	15.88	10.47	1.14	4.28	0.44	36.15	570.82
1897	15.95	10.33	1.28	4.35	0.44	35.84	565.93
1898	19.90	13.39	1.23	5.28	0.56	35.38	558.67
1899	18.34	12.30	1.25	4.80	0.52	34.96	551.94
1900	18.27	12.24	1.23	4.80	0.51	35.73	564.09
1901	17.94	11.98	1.44	4.52	0.50	36.03	568.95
1902	22.92	15.83	1.45	5.64	0.64	35.76	564.56
1903	22.58	15.55	1.63	5.39	0.63	35.58	561.85
1904	22.35	15.24	1.36	5.74	0.64	35.06	553.52
1905	18.72	12.56	1.47	4.69	0.54	34.79	549.39
1906	19.99	13.61	1.83	4.54	0.57	35.02	552.91
1907	24.72	17.22	1.92	5.59	0.70	35.54	561.08
1908	25.97	18.03	1.83	6.11	0.71	36.42	575.12
1909	23.10	15.66	2.07	5.37	0.63	36.77	580.55

1910	26.73	18.53	2.68	5.52	0.71	37.58	593.41
1911	37.06	26.67	2.43	7.96	1.03	36.10	569.95
1912	34.50	24.95	2.35	7.21	1.00	34.50	544.78
Aver.	16.14	10.81	1.34	3.99	0.44	36.42	575.01
Max	37.06	26.67	2.68	7.96	1.03	39.32	620.84
Min	9.22	5.55	0.86	2.35	0.26	34.29	541.46

Sources: See the text, estimated by the authors.