Living Standards in China between 1840 and 1912: a new estimation of Gross Domestic Product per capita

Ye Ma and Tianshu Chu

Groningen Growth and Development Centre
University of Groningen

Version 31 July 2013

Prepared for the European Historical Economics Society Conference 6-7 September 2013, LSE London

Please do not quote without permission of the authors

Abstract

This paper investigates China’s economic development between 1840 and 1912. We study living standards and the general economic trends in the late Qing dynasty by reassessing the reliability of existing estimations of per capita GDP and introducing a new estimation. Existing studies on China’s historical GDP in the 19th century leave several puzzles; more cross checks are needed to improve on these estimations. Our own estimation provides for the first time a continuous time series based on the previous estimations supplemented with new data. We see this as a starting point for future research on 19th century developments in the Chinese levels of economic welfare and performance.

JEL classification codes: E23 E30 N15 N9

1 We are grateful to Harry Wu, Jan Luiten van Zanden and Bas van Leeuwen for giving us valuable advice and information on useful data sources. In preparing this first draft, we have received valuable advice from many colleagues, including Pinghan Liang, Dayong Zhang, and participants in the May 2011 seminars at RIEM, Southwestern University of Finance and Economics, Chengdu, China and participants of the Asian Historical Economics Conference at the Hitotsubashi University, Tokyo, 13-15 September 2012. All errors are the responsibility of the authors.

2 Ye Ma, University of Groningen, y.ma.4@student.rug.nl; Tianshu Chu, Southwestern University of Finance and Economics, chutianshu@ymail.com.
1. Introduction

In this paper we present a new estimation of historical GDP and GDP per capita for the Chinese economy in the late 19th and early 20th century, i.e. the late Qing Empire (1840-1912). During this period, the so-called “years of trouble”, China faced a combination of wars, natural disasters, and economic reforms. Many see this era as a break point in China’s long-run economic development. On the one hand, it can be seen as a period of economic distress, which stands in contrast with a relatively prosperous 18th century. On the other hand, it can also be viewed as a period in which the new social and economic conditions began to replace the old ones (Brandt et al., 2012, p.27). China’s economy lost its position as the world’s largest economy, became involved in international trade, started to open its domestic market, and imported new technology from the rest of the world (Maddison, 2007).

Recent studies of China’s development in the late 19th century support the long-lasting influence of it on China’s modern economy. Harry Wu concludes that China’s post-1949 state-led industrialization can be traced back by a path of development that began in the late 19th century (Harry Wu, 2011). Keller et al. also attribute China’s present trade performance to its experience in the 19th century, rather than exclusively to the 1978 reforms (Keller et al., 2012). Brandt et al. relate the resilience of the Chinese modern economy to its performance in the 19th century, and argue that even in the mid-19th century, the economy was so resilient that “it had the inbuilt capacity not only to withstand certain shocks but also to restore stability in the wake of potentially destabilizing disasters” (Brandt et al., 2012, p.49). Although recent studies have found some implicit linkages between the economy of the 19th century and the present one, more evidence is still needed to firmly prove them. To understand China’s modern economy and its specificities, we have to look at its economic history in the late 19th century.

Understanding China’s economic history has broader implications. As the world’s largest economy in the past and the second largest one today, China’s economy always had the power to affect the rest of the world, but it also has been influenced by global developments. To obtain a complete understanding of world economic development, China’s economic situation in the late 19th century is therefore an important topic. However, our knowledge about 19th century China is still rather limited. We need more solid information on annual movements in national income, otherwise long-run economic analysis is impossible. Moreover, previous GDP estimations show contradictory outcomes, which prevent us from getting a good understanding of the whole economy. This paper intends to address the main puzzles around the historical GDP estimates for the late 19th century. For this purpose, we provide a new estimation and construct a consistent time series of GDP. The reconstruction will involve simplification and approximation, but we see it as one step out of many in the study of the 19th century Chinese economy.
The structure of the paper is as follows: in section 2, we summarize several important studies on historical GDP estimations for the late 19th century and introduce the three main puzzles that still remain; section 3 gives our own GDP estimation; section 4 tries to explain and solve the three puzzles with these new GDP estimates. Appendix A provides background information about the history of China. Appendix B explains the derivation of our new estimation in greater detail.

2. Two groups of studies and three puzzles

In this section, we will summarize the results of existing studies on Chinese GDP in the late 19th and early 20th century. We will classify all recent studies into two groups. Based on this classification, we will show that at least three puzzles need to be solved. Finally, we will explain that a new estimation is necessary for a better understanding of China’s economy in the 19th century.

2.1 Two groups of studies

The literature on China’s historical GDP provides us with some benchmarks of income levels for specific years and three sets of time-series estimates of per capita GDP during the period 1000-1933. Table 1 covers all the recent historical GDP estimates.

[Table 1]

We will mention here the three most important studies. Firstly, Maddison’s estimations generate a long-run historical GDP dataset and provide a general trend of Chinese economic development. For our period 1840-1912 there are 5 level estimates. These are based on a composition of previous estimations, especially the GDP estimates for 1933, from Paosan Ou (1947) and Ta-chung Liu and Kung-chia Yeh (Liu and Yeh, 1965). In Table 1, we have listed most of the benchmark studies that Maddison employed in his estimation.

The next estimation is from Chung-li Chang (1962), which is often cited and can be seen as the first GDP estimation for the 19th century. The study concludes that per capita GDP in the 1880s was about 7.4 taels (in current prices), or 113 Geary-Khamis (GK) dollars in 1990 prices. The estimation is based on sector information, retrieved from historical documents and related studies. For instance, the author uses the

---

3 Names of authors working in North America and Europe and publishing in English are presented in Western style (e.g. Debin Ma). Names of Chinese authors based in Asia and writing primarily in Asian languages appear in the East Asian fashion, with the surname first and capitalized for clarity (e.g. WU Chengming). The purpose of the classification is to distinguish between English and Chinese texts, so that the reader knows where we rely on translations.

4 Maddison used 1990 GK dollars in his estimation. We apply a similar monetary unit for the purpose of comparisons. From now on, we will express this term “US dollars in 1990 prices” as “1990 USD” for short or “dollars” without specific indication.
amount of cultivated land, the proportion of land area used for different food crops, and their yields per unit area to estimate agricultural output.  

The third estimation has been made recently by GUAN Hanhui and David Daokui Li (GUAN and D. Li, 2010). Their average GDP estimate is about 230 dollars during the long period 1402-1626, and is the result of very detailed archival work. This study draws also attention to an earlier period of the Ming Empire. Moreover, it is the first to provide a time series of per capita GDP estimates for more than 200 years. We repeat that time series estimates for China’s historical GDP before 1933 are rare.

Maddison’s estimation depends mainly on secondary sources. Maddison combined growth rates for the pre-1933 period with an existing 1933 income level to project levels of GDP backward into the 19th century. He produced total economy estimates only. The two other estimates are derived using a sector-based value-added approach. These calculations follow the three-sector classification as we know it from modern national accounting: agriculture, industries, and services. GDP estimates are obtained by adding up the output of all sectors. In contrast, Maddison’s procedure derives GDP per capita estimates first. Next, total GDP is derived by multiplying GDP per capita levels with the population size. To be sure both the macro and the sector approaches are mutually connected; e.g. assumptions in the macro approach are based on some of the estimates in the sector studies.

2.2 Three puzzles

Table 2 compares the results of the two approaches for the 19th century. They show great discrepancies which need clarification.

[Table 2]

The first puzzle is how to explain the great difference between the levels that come out of the macro approach and those that are the result of the sector approach. As shown in Table 2, the average per capita GDP level in Maddison’s estimation is around 550 dollars, whereas in the sector studies it is less than 200 dollars. A recent benchmark estimate by LIU Ti for 1840 gives a per capita GDP level of 318 dollars, which is still much lower than Maddison’s (LIU Ti, 2009; see our Table 1, column 5). The big difference in the outcomes of the two groups of studies keeps us from getting a good grasp of the general living standards in the 19th and early 20th century. Even for the well-documented year 1933, different studies come up with different results. This implies that although we use the year 1933 as the benchmark, it is still difficult to generate a plausible time-series estimate for the 19th century with backward-projections.

The second puzzle concerns the long-term trends in the various GDP estimates. If we

---

5 The definition of food crops is related to the principal food components in the Chinese diet (see Appendix B).
link the different sector studies in chronological order, they show a substantial economic decline. During the period 1840-1920, per capita GDP decreased roughly by 40 percent in total. In contrast, Maddison’s estimation shows hardly any change in levels in the same period. There is no easy answer to the question which of the two groups of studies is closer to reality: was the economy stagnant at a per capita GDP of almost 600 dollars from the 1840s, or did the economy decrease from a level of 300 dollars in the 1840s to 150 dollars in the 1920s?

The third puzzle is whether the absolute levels of the GDP estimates in the sector studies represent a sustainable situation. On average they are roughly one third of Maddison’s estimates. To be specific, a reasonable GDP estimate should satisfy the requirement that with such a level the economy was able to produce at least subsistence levels for the majority of the population. If the estimates in sector studies do not pass this test, major improvements will be necessary.

2.3 The Great Divergence and the extension of the puzzles

Solving these discrepancies in China’s historical GDP will also help to understand the long-run comparative development of the Western and Asian economies. In this section, we will shortly touch upon the discussion of the great divergence between Europe and China. The big issues around the great divergence can be seen as an extension of the puzzles mentioned above.

Maddison’s long-run estimations reveal that China’s per capita GDP was higher than that of Europe from the 10th to the early 15th century. After that the Chinese economy went into a long period of stagnation, while in the meantime the European economy began to take off, setting the stage for the so-called great divergence between Europe and Asia. In Maddison’s research, the timing dates back to roughly the 16th century. More differently, Pomeranz (2000) believes that the timing of the great divergence is much later, starting in the 19th century.

However, as shown in the three puzzles, the sector studies illustrate a potentially different picture of the long-run economic development in pre-modern China. First, per capita GDP in the 16th century was around 250 dollars, which is less than a half of Maddison’s estimate (GUAN and D. Li, 2010). If the lower estimate were true, it implies that at the supposed start of the great divergence, the difference between European and Chinese per capita GDP levels was already very large. It would push back the dating of the great divergence to a period already before the 16th century. This can be seen as the extension of the first puzzle.

Second, if we would accept the declining trends that the sector studies produce for the 19th century, then the supposed economic decline in this period also contributed to the increasing discrepancy between the West and China. Thus, it supports the idea that the timing of the rapid divergence should be pushed further into the late 19th century.
Moreover, around the 16th century there might have been a moderate economic revival, which is different from the stagnation suggested by Maddison’s outcomes. Recent estimations from LIU Ti (2009) and GUAN and D. Li (2010) support this idea. It may indicate that the difference in absolute levels of welfare between Europe and China had been reduced at the supposed start of the great divergence. We see this point as the extension of the second puzzle.

The discrepancies in the present literature justify a reassessment of the Chinese economy in the second half of the Qing Empire (1840-1912). As was shown in Table 1, there are actually very few direct GDP estimates for this period, let alone time-series estimates.

### 2.4 A brief overview of the “Turbulent Century”

The 19th century is the so-called “Turbulent Century” in China’s historiography and it refers especially to the period after 1840. Table 3 compares different sources of social turbulence between the early and late Qing Empire (1640-1840 and 1840-1912, respectively). We find that the general social circumstances worsened significantly after 1840.

During the second half of the Qing Empire, there were many wars and natural disasters, like floods and famines. Around 100 million people lost their lives during this period because of these disasters. The most serious population loss probably occurred in the 1850s, mainly caused by the Taiping Rebellion from 1851 to 1864. A large part of the wealthy southern area of Qing China had been devastated and approximately 20-30 million people died of the war and the famines and plagues that went with it. At the same time, the Nien Rebellion (1851-1868) burst out in northern China followed by a massive flood of the Yellow River in 1851. The large decrease in silver reserves of the central government indicates that the Qing state had lost a large part of its control power (see Table 3, line C). Its capacity to support extra-expenditures, such as excess military spending and relief funds, had been weakened considerably.

In the meantime, however, there were also political and economic reforms, which may have improved people’s standards of living. From the 1860s, forced by a deterioration of tax income, the Qing state officially permitted the settlement of Han Chinese in Manchuria (Maddison, 2007, p.36). In this period the cultivated area of China actually increased. After the First and the Second Opium war (1839-1842 and1856-1860), the country was forced to open several new ports to western trade and

---

6 The place in northeastern China was always seen as the original place for the royal blood of the Qing Empire and was a restricted place for common Han Chinese.
residence. Another result of the exposure to international trade was that structure of agricultural production began to change. There was export of cotton, soy beans, ore, and timber.\(^7\) There was some industrialization and Qing China was trying to catch up with the more advanced European economies. There are indications that the economy recovered gradually under the so-called Tongzhi restoration during 1861-1875. However, in the historical records we find no direct proof for a significant economic improvement in the late 19\(^{th}\) century. Brandt et al. speak of a paradox (2012). They observe economic reforms in this period, which should have benefited the economy; however, significant economic growth actually took place only after the 1978 reforms. They call this the “delay of growth”.

3. A new estimation of historical GDP

In this section we will present our new GDP estimation. First, we will present estimations of value added in the three major sectors of the economy respectively. Details are given in Appendix B. Second, we will make cross checks per sector to see whether our new estimation is acceptable. In the third place we will evaluate the economic development in late Qing China based on our sector estimates.

3.1 The agricultural sector

Our estimation tries to cover China’s output of the major agricultural products during 1840-1912. As a typical agrarian economy, the country concentrated on crop production, such as grains and textile fibers, rather than livestock products (Maddison, 2007, p.32). In order to facilitate taxation, there are lots of official documents and records on crops. For these reasons, we focus on the estimation of crop production. We distinguish between two categories and two types of crops. The two categories concern so-called food and non-food crops. The most important food crop is rice; cotton is an example of non-food agricultural production. The type of crop discerns between the degrees of intensity of land-use. Food crops are mainly land-intensive; while, e.g. soy beans are not. Because we use different methods to calculate the value of crop production in different categories and types, an introduction to these crops and their categories is given in Appendix B, Table B.1. In total, we have four groups of agricultural products and activities including cattle farming.\(^8\) By adding up the four items, we obtain total value added in the agricultural sector.

\(^7\) For non-food crops, we mean the rest crops, other than principal food, like oil seeds, vegetables, and flowers. Here, we realize that soy beans can also be consumed as food, but we classify it as a non-food crop. There are two reasons: first, in general Chinese do not consume soy beans as their principal food, compared with rice and wheat; second, we follow the previous studies, where it has been calculated as a non-food crop, for instance, XU and WU (2005, p.1098).

\(^8\) There are other ways of classification. The group of food crops in our classification is very similar to the category “cereals” in Maddison's research (Maddison, 2007, p. 118). Perkins' estimation uses “Grain Output” which includes the cereal group, potatoes, and other tubers (Perkins, 1969, p. 16-17). In Table B.1 we follow the same procedure and summarize the food crops also as “grains”.
Here we will focus mainly on food crop production because it is the most relevant to people’s living standards in China (Perkins, 1969, p.396). The estimation of crop production is usually constrained by the unreliability of the information on cultivated area, yields, and imports of new food crops (maize, Irish and sweet potatoes), especially for the 19th century (Perkins, 1969). In our calculation we will deal with these issues accordingly.

3.1.1 An estimate of cultivated land

The most important question is how much of the cultivated area was used for crop production in the late 19th century. The range of estimations in the existing literature is quite wide, from 0.8 billion to 2 billion mou, as is shown in Table 4. We believe that the most plausible level is around 1.2 billion mou. From the first land survey organized by the People’s Republic of China we know that the total land area for cultivation was around 1.6 billion mou in the 1950s. Another reliable survey which was organized by the Republic of China shows that the level was around 1.4 billion mou in the 1930s. During the 1910s the level was around 1.2 billion mou (Perkins and Israel, 1975). See Appendix B, Figure B.1.

Based on the general level, we constructed a time series of cultivated land. Figure B.1 shows our new final estimate of cultivated land during 1840-1915. In our calculation, we rely on three data sources: two benchmark estimates from recent historical studies and one time series of cultivated land data from historical records. The two estimates are: 1.15 billion mou for 1840; 1.26 billion mou for 1914 (SHI Zhihong, 1989; ZHANG Youyi, 1991). Both studies made amendments on the official records from Qing China and the Republic of China respectively. To build a time series, we also need reliable trends to link the two data points.

As is shown in the datasets compiled by YAN Zhongping, there was no increase in the cultivated area in the main territory of the Qing Empire, except Manchuria, Xinjiang, and Tibet (YAN Zhongping or Yen Chung-ping, 1955). Taking into account the immigration into Manchuria from the middle part of China after the 1860s, we expect a mild increase in the total cultivated area. WU Hui provides a time series of the cultivated area from 1840-1915 in the form of five-year averages, which pays special attention to Manchuria (See WU Hui, 1985, p.198, although no detailed information about the data source are mentioned in this book). The general level of this time series is higher than the two level estimates mentioned before, which we think are more reliable. Therefore we use this third data source to provide estimations for the trend only, and link it to the two data points for 1840 and 1912. We explain the method and the calculation procedure in Appendix B.
Another issue here is the intensity of land-use during one year, e.g. in case of multiple cropping. To estimate the actual land input involved in food crop production, we need to find out how many times seeds were sown in one year, to calculate the multiple cropping ratio. The ratio is neglected in many studies, but we add it to our estimation. The best solution is to find the ratio for each food crop for each region. Here we rely on two levels mentioned in the literature, 1.24 and 1.4 respectively (WU Hui, 1985, p.180, Maddison, 2007, p.36). We take the average of 1.32. This is an average for all food crops and for the country as a whole.

3.1.2 Yields

Now we turn to the estimation of yields per unit area of food crops. Official records about yields per unit area began in the 1930s. For the earlier period there is information in regional documents, but they are too scattered to facilitate a good estimation for the whole country. We have two major data sources: the first one is a study that covers a period from the 1700s to the 1930s by LIU Ruizhong (1987); the second one is the official agricultural survey for the 1930s, which is extensively discussed by YAN Zhongping (1955). Appendix table B.5, columns 1 and 2, gives the ranges of the yields for different crops during the 1700s through the 1930s.

Most studies assume that for the different crops the average yield in the 1930s is a plausible estimate for the yield in the late 19th century. Before directly applying the estimates to our calculation, we need to justify this by comparing the underlying circumstances between the two periods, i.e. the late half of the 19th century and the 1930s. Both periods were characterized by poor harvests because of the negative effects of wars and natural disasters. If we set the result of a big harvest year at 100 percent and a normal harvest at 75, than the level of output per unit area was 50-60 during the 1840-1894 period, around 50 during 1894-1920, and 64 during 1927-1937 (LIU Yanwei, 2001, p.25, LIU Kexiang, 2001, p.103). Although a complete comparison should include details such as rainfall and temperature, we think that the impact of social disorder was much more significant. According to the above comparison, we roughly conclude that the yields between the two periods were similar; we believe it is reasonable to apply the yields of the 1930s to estimate the yields for the late 19th century.

We assume that the yields were constant over time. The underlying assumption is that agricultural technology in the late 19th century was fixed. There might have been some technological advances in the agricultural sector. But, considering the negative social and natural conditions displayed in Table 3, we think it is still safe to make the assumption of zero technical progress. Thus, the only potential improvement on this estimation is the inclusion of the changing weather conditions.

---

9 Multiple cropping ratio = Sown area in one year / Total cultivated area, from Maddison (2007, p.114, Table A.10).
10 In the late 19th century, there were lots of rebellions and international wars. In the 1930s, there were many civil wars among different regional military forces.
Probably the single most important contribution in agricultural production in the Qing Empire is the introduction of new food crops. To fight the problem of famine, the Qing governors encouraged the cultivation of sweet potatoes and maize. We make specific adjustments to allow for these two new products (see details in Appendix B).

3.1.3 Cross checks

Now we can calculate the annual output of food crops and levels per capita during 1840-1912. On average, the per capita food output was 318 kilograms per year, the range being between 293 and 339 kilograms. Figure 1 displays the annual trend. We calculated the upper and lower limits by using the maximum and minimum values of cultivated area and yields (see the data in Appendix Figure B.1 and Table B.5). Our results show that on average, the upper limit was 429 kilograms, while the lower was 191 kilograms. Figure 1 shows an upward trend until 1870, after which a decline set in. For the period 1840-1912 as a whole food output hardly changed. Presumably the economy gradually recovered from the First and Second Opium wars (1851-1864) and then began to decline even before the Sino-Japanese war (1894-1895).

[Figure 1]

Is this new estimation plausible? We make three cross checks of our estimation of food crop production. First, we will test the estimated yields using related studies. In our estimation, the annual output per unit area was 105.2 kilograms in the late Qing Empire (total output divided by the cultivated area). In previous studies, we find 128 kilograms in the Ming Empire and 183.5 kilograms in the Qing Empire (GUAN and D. Li, 2010, p.6, LIU Ruizhong, 1987, p.109). In general, the per capita output in the second half of the Qing Empire was around 120-150 kilograms (Perkins, 1969; WU Hui, 1985, GUO Songyi, 1994, 1995). Seen from these studies, our figure might underestimate the total level of output, even considering the upper limit in our estimation, which is around 120 kilograms.

Second, we test whether the estimated output level is consistent with the results of other related studies. As mentioned above, the average per capita output of food crops in our estimation was 318 kilograms during 1840-1912. Deducting 40 percent of the total output for seeds, feed grains, reserves, and alcohol production, the monthly per capita production was 16 kilograms. Compared with previous studies, we suppose that our estimation is consistent. In Perkins (1969, p.398), the general annual level in the Qing Empire was around 250-375 kilograms. In WU Hui (1985, p.192), the monthly per capita output in 1833 was 16.2 kilograms. Actually, the estimated output per capita per year during the Qing Empire decreased from 576 kilograms in 1753 to 314

---

11 Commonly it is a composition of rice, wheat, and beans in southern China, a composition of wheat and beans in the northern area. Historians estimate the national level of composite yields using the ratios of cultivated land in the two parts of China as weights respectively.
kilograms in 1812. In the middle of the Qing Empire, the level was even lower than that in the 3rd century (WU Hui, 1985, p.191). From this viewpoint, our estimation confirms the opinion that over the long haul, Qing China’s agricultural production in per capita levels was much lower than in previous empires.

The last point that we want to raise is whether the low food production in the late 19th century could cover the minimum daily energy intake that is necessary to survive. After all, grains, sweet potatoes, and maize were the main energy sources in China. Here, we assume that the per capita output equals the per capita consumption. LIU Ruizhong believes that the minimum food consumption per capita in the 18th century was 290 kilograms (1987, p.107). Our estimation is higher than this subsistence level.

We calculated the available daily energy consumption per capita through the annual food production in the period 1840-1912.12 We find that if the energy loss was 20 percent of the total daily intake, the average daily energy consumption was 2393 kcal, the range being between 2203 and 2548 kcal. In fact, this is rather close to the situation in modern China, with 2970 kcal in 2005-2007.13 Even if we assume that the energy loss was 40 percent, the average daily energy consumption was 1795 kcal, which is still close to the minimum requirement of 1800 kcal, according to the FAO. There are two other studies that give energy estimations. From Buck’s survey data (Buck, 1937, p.73), the general range of the daily energy consumption in the 1930s was 1823-4434 kcal, which supports our estimation. In Chung-li Chang (1962, p.293), the estimated daily energy consumption was about 1800 kcal in the 1880s, which is much lower than our estimation but still proves that the general living standard in the 1880s was sustainable.

To sum up, based on the cross check of production capacity, our estimation is lower than the level provided by previous studies. But based on the cross check of average energy consumption levels, there might be the possibility of overestimation. In general, our estimation passes two cross checks. We conclude that our estimation of food crop production in the late 19th century is plausible and confirms sustainability.

For the remaining three categories within agricultural activities mentioned in Table B.1, we estimate the unknown value through a known figure by applying a fixed ratio or proportion between the two, based on the literature (see details in Appendix B). Finally, average value added in the agricultural sector during the period 1840-1912 was estimated at 11.85taelsper head of population, with a range of 6.35-27.54taels; its average proportion in total GDP was 75.3 percent. Overall, the average growth rate was 1.4 percent. We find a decrease of about 0.9 percent annually before the 1880s. This was followed by an increase of 4.2 percent per year, mainly because of rising price levels. Low levels of value added were found in the 1850s and the 1880s.

12 For different food crops, the energy data is from Nutrient Data Laboratory, http://www.nal.usda.gov/
3.2 The industrial sector

There are relatively few data sources for the collection of quantitative information for every industry. The existing literature, however, allows us to obtain a rough sketch of this sector. But we focus on a perspective that is different from other related studies.

In our estimation, we direct our attention to the early development of modern industrial production. We believe that one of the major economic contributions in the late Qing Empire is the start of industrialization and the so-called self-reinforcing movement between 1860 and 1895. This movement was characterized by the spread of foreign technology and the start of state-owned factories in the iron, coal, textile, and transportation equipment industries. Later, the development broadened through the spread of privately-owned factories. Some of the former state-owned factories were taken over by private owners. After 1894, the coexistence of modern factories and traditional handcraft workshops was common in many industries. We believe that the new situation of technology transfer from outside is an important aspect of China’s early industrialization, which deserves special attention. Therefore, our estimation tries to grasp not only the development of the proto industry, but also the early phase of industrialization.

Nevertheless, the traditional production was still dominant. In the 1920s, the modernized sectors can be estimated at 20 percent of total industrial production (XU and WU, 2005, p.1051). In our definition, a modern factory in China in the late 19th century was characterized by new production technologies supported by European machinery. In contrast, handcraft workshops kept the traditional way of production (see for the same classification in Liu and Yeh, 1965). In practice, it can be difficult to make a distinction between the two. Large and advanced workshops may have been just one step away from modern factory production; on the other hand in factories without a well-trained labor force, “new” production with novel technology may exist only in name.

Our estimation goes in two steps: first, for benchmark years we make a distinction between value added of the imported new technology and the traditional workshops; second, we estimate a time series of output for both sectors. We find that the proportion of factory production in total industrial production increased from 5.4 percent in 1885 to 21.5 percent in 1920 (see Appendix B, Table B.8 for details). It may indicate a very fast increase in factory production in the early phase of industrialization.

3.2.1 Factory production

In this section, we construct a time series of the value produced by the modern factory
system. We start by making two benchmark estimates, for 1885 and 1920 respectively. These benchmarks are derived by adding up all the major industries, as shown in Table B.8, column 1. We follow a procedure that was used by Debin Ma (2008, p. 367, Table 3) who estimated value added for the period 1914-1918 in the secondary and tertiary sector. Debin Ma projected the 1931-1936 industrial sectors’ GDP levels backward to the period 1914-1918, using a growth rate estimated by Rawski (1989). In the present case, we treat the year 1920 as the benchmark and back-project levels of value added to 1885, using an average annual growth rate.

To estimate the annual growth rates during the period 1885-1920 we introduce a method based on growth accounting (see details in Appendix B). In our Cobb-Douglas production function we assume that the growth of the technology residual was close to zero at that time, because technology was directly bought from the western world and took the form of capital accumulation. Measuring growth means in this case that time series of capital and labor input have to be estimated.

We combine two data sources to construct time series of capital input for factory production. Table B.9, line 1, lists four estimates of capital input for 1885, 1894, 1913, and 1920, from XU and WU (2005, p. 378-450 and p. 1040-1054). For the years, 1894, 1913, and 1920, they provide the capital estimation for different kinds of factory production in the industrial and the service sector. For the 1880s, the estimated capital level is 29.64 million Chinese Yuan, which includes manufacturing industries, mining and production of basic metals using machinery, transportation, and communication (XU and WU, 2005, p. 379)\(^{14}\). Based on their description of industrial development in the 1880s, it is impossible for us to accurately separate transportation and communication from the industrial sector. Thus, in our estimation the capital input means the capital used in the industrial sector, transportation, and communication. As was shown in Table B.8 and Table B.9, we put the two sub-sectors in the service sector, transportation and communication, into the industrial sector. Our consideration is the main output in the transportation and communication sector at the beginning of industrialization should be the construction of infrastructures, such as railways.

Here, we give some clues on how to estimate capital input. In XU and WU (2005), they calculated the value of fixed capital on the basis of quantity indicators, such as the number of spindles in textile mills, and tonnage of ships, etc. For missing capital data for industries, they use initial capital or net assets as proxies; for some industries railway mileage or installed power-generating capacity as an approximation. They also distinguish factory production from traditional workshops. To fill in all the missing data points for other years, we use annual initial capital during the period 1872-1912 as the annual increments (YAN Zhongping, 1955, p. 93-95). We implicitly assume that the depreciation rate of capital is zero. After the procedure, we get a rather smooth line of capital input during 1885-1920 (see Figure 2.4). The figure

\(^{14}\)Here, the monetary unit is the Chinese Yuan in the 1930s.
shows that the rise in capital outlays accelerated after 1900.

With the estimated capital and labor inputs and the general price level for industrial products, we calculate growth rates of factory production in the late 19th century (see details in Appendix B). After repeating the back-projection procedure, we obtain levels. We find that the per capita output in factory production increased from 0.07 taels in 1885 to 1.84 taels in 1920. The average growth rate calculated from the two benchmarks is 9.5 percent; our time series generates a growth rate of 10.9 percent, which is reassuringly close.

Although during the period the average growth rate of factory production was around 10-11 percent annually, this did not affect the total growth rate of GDP significantly, because the initial proportion to GDP was even less than 3 percent. As mentioned above, agricultural production took up a major part of the whole economy but had an annual growth rate lower than 1 percent. The momentum of early industrialization in late Qing China was overshadowed by slow growth in the agricultural sector.

We can do some cross checks. First, we test the consistency of our estimation. As an upper limit, we quote Liu and Yeh’s estimation for 1933, which is another study that makes a distinction between the added value produced by the modern and by the traditional sector. Since we do not employ their estimation into our estimation for the benchmarks, we can safely use it as a cross check. Their study concludes that the proportion of the value resulting from new production was 5.4 percent of GDP in 1933. In our estimation, the proportion was less than 3 percent in the period 1840-1912. For the per capita level, their average estimate is 2.16 taels, which is the net value of new production; our average is 0.88 taels, which is the total value of new production. Our estimation for the 19th century is much lower than theirs for the 1930s. To conclude, there is no overestimation problem in our results.

We can also check the reliability of the growth rates that we found. We use four figures (Figure 2.1-2.3) to show that after the 1860s the economy experienced a quick increase in the imports of fundamental inputs for industrialization, such as machinery, coal, and iron. The average growth rates were 10.2 percent for machinery imports between 1887 and 1916, 6.2 percent for coal imports in the period 1885-1920, and 4.7 percent for the iron, steel and tin imports in the same period. These rates may well support the increase in output that we found. We also find that imports accelerated after 1900, similar to the capital inputs.

[Figure 2]

3.2.2 Cross checks for the whole proto industrial sector

For the traditional production during 1840-1920, we make an approximation that is shown in Table B.10. The question is whether we can rely on the general trend given
by the three existing benchmark estimates, which together implicitly indicate that handcraft production decreased first, but then increased to an even higher level. This may be a plausible development. The imports of new technology probably had a negative effect on the traditional production first, but later on beneficial effects from knowledge spillovers may have come in. But it is still difficult to support or falsify the trend because of lack of data; more data research will be necessary. We conclude that on average the net value in the proto industrial sector during the period 1840-1912 was 1.45 taels per capita; the range was 0.52-2.75 taels; its average proportion in GDP was 9.4 percent; the average growth rate was 0.4 percent.

We use the estimation for 1914-1918 from Debin Ma (2008, p.367, Table 3) as a cross check. In his calculation, the per capita net domestic production of the industrial sector for 1914-1918 was 2.79 taels on average and its proportion in GDP was around 8 percent. On the basis of our own calculations for this period, we arrive at a level of 3.08 taels for the period 1914-1918 and an estimated proportion in GDP in 1912 being already higher than 8 percent. According to this, we might overestimate net value added. A possible reason for this is that we applied the net value added proportion to the whole sector. The estimate needs further improvements (see Appendix B, 2.3 for details).

3.3 The service sector

We include three sub-sectors in our estimation for the service sector: public administration, finance, and commercial activities. We will concentrate here on public administration, because we employ a new data source that distinguishes our estimation for services from previous studies. For the two other subsectors, we refer to Appendix B for details.

3.3.1 Public administration

For public administration, we focus on government expenditure and estimate its value added combining central government expenditure and the proportional share of it in total governmental expenditure.

The new dataset that we use in this section is compiled from a historical document called Huyouinkuhuangce (SHI Zhihong, 2009). As part of the governmental routine, the Qing state recorded in this document the annual central government income and expenditure, and also the treasury reserves. The expenditure records mainly include military spending, official’s salaries, relief funds, administration costs, and royal funds. According to Figure B.4, the central expenditure for most years during the late Qing Empire was lower than 12 million taels, which was the regular level during the early Qing Empire. In contrast, government expenditure in postwar periods was either extremely high, such as the years after the Sino-Japanese War, or extremely low, such
as the years after the Taiping Rebellion.

Second, we assume that the proportion of central government expenditure in the total was 13 percent before 1894 and 15 percent after 1894, decreasing from a level of 30 percent in the early Qing Empire (based on SHI Zhihong, 2009, p.102). This may indicate the declining control power of the central government. To put this into a historical perspective: according to the official data from the China Statistical Yearbook\textsuperscript{15}, the proportion was around 50 percent between 1978 and 1980, and was about 25 percent in the recent decade.

In our estimation, we find that total government expenditure was around 104.3 million taels; the per capita level was rather low, only 0.27 taels on average; the proportion in GDP being around 1.7 percent. Using two previous studies as a cross check, total expenditure amounted to 95 million taels in 1840 and 164 million taels in the 1880s (Chung-li Chang, 1962, LIU Ti, 2009). However, in our estimation the 1840 figure is 79.3 million taels and the average level for the 1880s is 107.2 million taels. So, we might underestimate the value. The possible reasons are twofold: first, the original records covered a major part of central expenditure, but not all; second, we might underestimate the proportion of the central expenditure to total government expenditure. Also here further improvements are necessary.

We find that in the late 19\textsuperscript{th} century, the Qing state was in great trouble to maintain its normal operations. As shown in Figure 5, the proportion of public income and expenditure to GDP decreased significantly in the second half of the Qing Dynasty. For most years in this period, the expenditure was higher than the income. In others years, the Qing state barely sustained the balance. It means that public savings decreased continuously and possibly failed to recover until the end of the empire. Figure 6 compares the situations in UK and in Qing China. In the late 19\textsuperscript{th} century, the public income/ GDP ratio in UK was around 8 percent, while it was even less than 2 percent. Figure 7 roughly demonstrates the changes in the ratio starting from the 18\textsuperscript{th} century. Compared to modern China, Qing China indeed lacks the capacity to influence the economy.

One could easily ascribe these difficulties to the wars after 1840. However, we believe that the crisis actually started in the early Qing Empire before the international wars. The decrease of the public income/GDP ratio and the public expenditure/GDP ratio can be traced back to the late 18\textsuperscript{th} and early 19\textsuperscript{th} century (see Figure 5). Moreover, the tension between the central and local controllers was likely to intensify. In most years of the Qing Empire, the central government collected 25 to 33 percent of the total government revenue to support its regular expenditure and it held high reserves before 1800 (SHI Zhihong, 2009). By tracing the annual reserves in the state treasury, we can see that the state lost control. E.g. to put down the White Lotus Rebellion (1796-1805), the Qing state exhausted nearly 70 percent of the treasury reserves, which decreased

\textsuperscript{15}http://www.stats.gov.cn/tjsj/hdsj/2011/indexeh.htm
from 70 million taels in 1795 to 20 million taels in 1798. During the entire late Qing Empire, the reserves remained around 10-20 million taels and never got back to a level of 35 million taels which was the regular level of reserves in the early Qing Empire. The proportion of central revenue in the total declined from 22 percent before 1850 to 14.7 percent in 1903 (SHI Zhihong, 2009, p.43, p.63).

3.3.2 Cross checks for the whole service sector

By adding up the three subsectors, we obtain total value added in the service sector for the period 1840-1912: on average it was 2.35 taels per head; the range was 1.76-3.68 taels; its proportion in GDP was around 15.3 percent; the average growth rate was about 1 percent.

Also here we use previous studies as cross checks. The per capita value in this sector was 2.9 taels in 1840 (LIU Ti, 2009), 2.3 taels in the 1880s (Chung-li Chang, 1962), and 7.3 taels in 1914-1918 (Debin Ma, 2008). According to our estimation, the 1840 estimate is 2.2 taels, and the average level for the 1880s is 1.9 taels. The maximum level in our estimation is only half of the level in the estimate from Debin Ma (2008). We probably underestimate the value; because of data limitations, we could not include the value added created by professional groups like doctors and teachers.

3.4 GDP per capita in taels of silver

In our calculation, the estimate for total GDP is 6.38 billion taels for 1840 and 12.61 billion taels for 1912. Accordingly, the per capita GDP estimate is 14.91 taels for 1840 and 34.31 taels for 1912 (see Figure 3). The average during the period 1840-1912 was 15.65 taels of silver, and the range was 9.83-34.71 taels. The growth rate of nominal per capita GDP was around 1.1 percent.

The Chinese economy in the late 19th century consisted mainly of agricultural and service activities. The proportion of the two sectors in GDP was rather stable. It varied between 80 and 95 percent. In general, the proto industrial sector took about 10 percent of GDP. In the 1880s, the proportion was only 5 percent. But, this low level is also caused by our use of the benchmark estimate from Chung-li Chang (1962). In Maddison’s estimation for 1890, the percentage shares for the three sectors agriculture, industry, and services were 68.5, 15.3, and 16.2 respectively (Maddison, 2007, p.60). The percentage shares in our 1890 estimation are: 78.2, 6.3, and 15.5. These discrepancies show that there is room for more refinements in the calculation.
To estimate real GDP, we have to construct a time series of general price levels for the period 1840-1912. We define a consumption basket represented by gold and rice, their weights being 25 percent and 75 percent respectively (according to LIU Ti, 2009, p.151). Using the domestic price series of gold and rice, we obtain an annual general price level. We find that on average, real per capita GDP (in prices of 1840) was 15.85 taels, with a range between 14.00-17.63 taels. From Figure 3 we can see that there was hardly any changeover the whole period and in total a long-term decrease of 0.09 percent. However, in specific sub periods the economy fluctuated considerably. In the 1870s, we see a turning point. Before the year 1876, the economy grew at an average annual rate of 0.43 percent. However, in specific sub periods the economy fluctuated considerably.

LIU Ti calculated a per capita level of GDP in 1840 of 10.8 taels (LIU Ti, 2009, p.153). Our level estimate is 50 percent higher. Did we overestimate the historical GDP level in the present reconstruction? To evaluate the plausibility of our new estimation, we provide two more cross checks.

First, the minimum requirement for a plausible GDP estimate is that people at least can survive at the estimated levels of per capita GDP. We have shown that in the late Qing Empire food production could support the daily energy requirement of the Chinese. Let’s check this by looking at the average household budget. FANG Xing (1996) estimated the consumption basket for a farmer family with five members living in the Jiang-Zhe province. It covers food, cloths, rent, and fuel. He concludes that in the early Qing Empire the annual household consumption was 32.6 taels and in the late Qing Empire 58.31 taels. According to ZHANG Yan (2005), we need to add per capita education expenses to this estimation of 1 tael. Thus, the estimated per capita consumption in the late Qing Empire is 12.7 taels. In our estimation, the per capita GDP from the production side is higher than the average consumption level. It means that the aggregate output level was able to sustain an above-minimum living standard for the population in the late 19th century.

Second, we think that a plausible GDP series should also match at least some of the major historical events that impacted on the economy. Some of the fluctuations in our time series fit well with major historical events. As mentioned before, the 19th century is labeled in Chinese historiography as the “years of troubles” or the “turbulent century”. In particular in the second half of the century China experienced a complicated situation of wars and political and economic reforms. From this viewpoint, our estimation is probably more reliable than Maddison’s GDP estimates.

To mention a few, three major wars: the first Opium War (1839-1842), the Taiping Rebellion (1851-1864), and the first Sino-Japanese War (1894-1895); two major reforms: the Tongzhi restoration (1861-1875), the so-called self-strengthening movement (1860-1894).
for specific years which altogether show a very stable economy. In contrast, our time series of real GDP per capita captures at least two major events: the Taiping Rebellion (1851-1864) and the Tongzhi restoration of 1861-1875 (see the shaded areas in Figure 3). Our estimation also illustrates that during the so-called self-strengthening movement (1860-1894), even with the opening up of the domestic market and the substantial influx of technology, the economy declined steadily after the 1870s. It was only until 1900 that it stopped to decrease. Here, our estimation provides the quantitative substantiation for the “economic difficulty” in the late 19th century.

The fluctuation of real per capita GDP during the years of the Taiping Rebellion is visible in particular in the period 1851-1864. In total, per capita GDP in 1840 prices decreased by 4.4 percent, i.e. annually 0.3 percent on average. This mild decline was mainly caused by the increase of the general price level. Annually, nominal per capita GDP increased by 3.8 percent. Agricultural and service sector output per capita increased by 4 and 1.7 percent, respectively, but industrial production declined by 3 percent. At the same time, the general price level increased by 4.1 percent annually. According to our assumptions regarding the consumption basket, the increase of rice prices is the main force behind the decrease. During this period, the price of rice increased by 82 percent in total, i.e. annually 4.4 percent on average.

During the years of the Tongzhi restoration1864-1875, we find an increase of per capita GDP. In total, per capita GDP in 1840 prices increased by 16 percent, i.e. about 1 percent annually. The increase of real GDP was the result of a large decrease of the general price level. In total, nominal per capita GDP declined by 36 percent, while the general price level declined by 45 percent; the price of rice decreased by 48 percent.

4. Summary and answers to the three puzzles

Let’s summarize the contributions of our new estimation. We have employed new methods and data sources, but derived our new estimation also from earlier studies on historical GDP. As we have mentioned, one of the aims of our estimation was to construct a time series of GDP by improving and linking existing studies. For the agricultural sector, we have provided a new time series of cultivated area and added a multiple cropping ratio to our calculation; for the industrial sector, we focused on the value added of factory production and applied a new method to estimate its growth rates with the help of a Cobb-Douglas production function; for the service sector, we have used a new data source to estimate government expenditure. Moreover, we have constructed a time series of historical GDP for 73 years to look at trends in China’s long-term development.

The main problem in the estimation of historical GDP is that the degree of autarky in pre-modern China was probably high. The issue is in fact similar to the neglect of non-market work in calculating GDP nowadays. For a low-commercialized economy,
a market-value-based GDP calculation may therefore generate imprecise results, especially if households use their backyard for home production. Later improvements and more cross checks for upper limits will be necessary.

Now we will come back to the issues that we put forward in the first part of the paper. We will start with the third puzzle and then work back to the second and the first one (see Table 2, column 5). The third puzzle concerned the low GDP estimates in the sector studies. We conclude that these estimates produce in general sustainable levels of income, which is above subsistence. Our estimation is not only sustainable, but also consistent with most of the sector studies, especially food production. Although sector studies still might underestimate the actual GDP, they follow the same procedure and use similar data sources as we have obtained to make our GDP estimates. The existing sector studies and also our estimation satisfy the minimum requirement for a plausible GDP estimate, i.e. the lower limit. Without having a proper upper limit, it remains difficult to decide whether there is underestimation in the sector studies or overestimation in Maddison’s figures.

For the second puzzle, concerning the issue whether the economy was stable or declining during the late Qing Empire, we agree with Maddison’s outcome that there was no economic growth or decline over the whole period, if we apply the same approach of value conversion. However, for sub periods we find wide fluctuations (see Figure 4). Maddison’s estimations do not take into account the possibility of break points and structural changes. Our estimation shows more detailed changes in the trend. Surprisingly, our estimation indicates that before economic decline set in—that actually contributed to the “Great Divergence”—China’s economy managed to grow for around 30 years from 1840 to 1870.

The first puzzle concerned the large discrepancy of GDP estimates between the macro- and sector studies. Before any comparison between Maddison’s estimation and ours will be made, we first need to convert GDP in silver to 1990 USD. Tentatively, we use three different ways of value conversion and present the three results in Figure 4. There are three points to be noticed here. First, we convert our GDP estimates to 1990 USD, not to 1990 Geary-Khamis (GK) dollars used in Maddison’s estimation. Since one GK dollar equals one 1990 USD, we can refer to the 1990 GK dollar directly in the paper, but we maintain the term “1990 USD” to avoid confusion. Second, limited by data availability our estimated Chinese/US Fisher PPP convertor is a bilateral measure, in contrast to the multilateral GK convertor. Third, also limited by data availability the product basket that we chose to calculate the Fisher index is extremely basic, including only wheat and gold. In this section, we repeat the procedures provided by Fukao et al. (2007), which compares the three approaches of value conversion in detail. Appendix B, section 4, gives our simplified version.

[Figure 4]
The first approach makes use of the official or market exchange rates (MER) between China and the United States. Although it is easy to perform, the estimated series reflects not only the domestic economy, but also the benchmark country’s economic situation. For example, the big drop (1860-1865) of the MER-adjusted GDP per capita in Figure 4 can be attributed mainly to the sharp decrease in U.S. price levels in the same period, even though the market exchange rates were stable. In this value conversion, the average GDP per capita was 251 dollars.

The second approach is the so-called current PPP conversion. Using the Fisher index, we obtain estimates for China by starting from the U.S. level of GDP in 1990 USD. By repeating the procedure for every year, we can get a series of current PPP-adjusted GDP levels per capita. The average is 243 dollars. For the period 1840-1870, however, there are only three estimates of U.S. GDP per capita in 1990 prices. Accordingly, we have only three estimates of Chinese GDP per capita. This makes it difficult to analyze trends before 1870. And, especially for the period 1860-1865, we do not know whether the wars affected the economy significantly. We calculated the Fisher index based on our assumption of a simple two-goods economy. In order to cover the whole period 1840-1912, we choose to use the price data of wheat and gold, and not export and import data which started from the 1860s. If we obtain price data for more commodities we could improve on the existing estimation.

Following the third approach, which is also a PPP-based adjustment, we try to repeat Maddison’s value conversion. In general, we take the year 1933 as the benchmark year and derive the GDP estimates for every year from the benchmark year via the Fisher index. We get a GDP per capita series that is back-projected from the 1933-level. The average is 551 dollars, which represents the highest level of our three approaches. Maddison followed the same approach of value conversion with back-projection, and his levels resulted in an average of about 554 dollars. In general, our GDP estimation supports Maddison’s results when using his approach of value conversion.

Maybe the gap between the two kinds of GDP estimation- macro and sector studies—will become smaller if a more realistic commodity basket can be applied. After all, the two share almost the same underlying sources. Our estimation is mainly based on the commonly-used sources and Maddison’s approach of value conversion, through which we derive similar results compared to Maddison’s estimation. With regard to the first puzzle we conclude that the large discrepancy that we have seen in Table 2 stems from an underestimation bias caused by value conversion with the market exchange rate. Applying a more sophisticated approach of value conversion will probably reduce this discrepancy.
Table 1. Per capita GDP estimates from existing studies, Qing China, 1000-1933 and our new estimation, 1840-1912

<table>
<thead>
<tr>
<th>Estimation for</th>
<th>Macro Studies</th>
<th>Sector Studies</th>
<th>Our new estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1402-1626</td>
<td>1800</td>
<td>1640-1840</td>
<td>1840</td>
</tr>
<tr>
<td>Averages</td>
<td>557.0</td>
<td>230.0</td>
<td>351.5</td>
</tr>
<tr>
<td>Per capita GDP (1990U SD)</td>
<td>Benchmarks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>450.0</td>
<td>318.0</td>
<td>112.5</td>
<td>103.1</td>
</tr>
<tr>
<td>Averages</td>
<td>4.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taels</td>
<td>Benchmarks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.8</td>
<td>10.8</td>
<td>7.4</td>
<td></td>
</tr>
<tr>
<td>(1700 prices)</td>
<td>(1600 prices)</td>
<td>(1840 prices)</td>
<td>(1880 prices)</td>
</tr>
</tbody>
</table>

Source: See references, collected by the authors.
Most of the studies give results in units of silver or 1930 Chinese Yuan. We adjusted these estimates according to the official exchange rates or the gold/silver ratios between China and the U.S., and the historical U.S. CPI.
The 1933 exchange rate is based on Perkins, 1975: 1 Chinese Yuan= 0.26 dollars; in the 1930s, 1 Tael= 1.5 Chinese Yuan.
Table 2. A comparison of per capita GDP estimates in two groups of studies and the “three puzzles”

<table>
<thead>
<tr>
<th>Puzzles</th>
<th>Two groups of studies</th>
<th>Our estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Macro Studies</td>
<td>Sector Studies</td>
</tr>
<tr>
<td></td>
<td>1800-1933</td>
<td>1840-1920</td>
</tr>
<tr>
<td>1. Average per capita GDP (1990 USD)</td>
<td>558</td>
<td>554</td>
</tr>
<tr>
<td></td>
<td>(Current-PPP) 242.5</td>
<td>(Backward-projected) 550.9</td>
</tr>
<tr>
<td>2. Total change per period</td>
<td>-3.6%</td>
<td>-8%</td>
</tr>
<tr>
<td></td>
<td>(Current-PPP) -32%</td>
<td>(Backward-projected) -6%</td>
</tr>
<tr>
<td>3. Sustainable</td>
<td>Yes</td>
<td>?</td>
</tr>
</tbody>
</table>

Source: Collected and calculated by the authors.
Table 3. Social disorder in Qing China, 1840-1912

<table>
<thead>
<tr>
<th></th>
<th>1640-1840 (Early Qing Empire)</th>
<th>1840-1912 (Late Qing Empire)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Wars</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number</td>
<td>60</td>
<td>54</td>
</tr>
<tr>
<td>Per year</td>
<td>0.3</td>
<td>0.75</td>
</tr>
<tr>
<td><strong>B. Natural disasters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number</td>
<td>2646</td>
<td>2698</td>
</tr>
<tr>
<td>Per year</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td><strong>C. Reserves in the state treasury</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average level (in millions Taels)</td>
<td>30</td>
<td>10</td>
</tr>
</tbody>
</table>

Source: Collected by the authors.

Table 4. Estimates of cultivated land in existing studies of Qing China, 1840-1912, in billions Mou

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average level</td>
<td>0.81</td>
<td>1.27</td>
<td>1.40</td>
<td></td>
<td>1.11</td>
<td>1.20</td>
<td>2.10</td>
<td></td>
</tr>
<tr>
<td>Specific years</td>
<td>1.15</td>
<td>1.26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Collected by the authors. 1 square kilometer = 1500 mou
Figure 1. Estimated per capita food crop output in kilograms, Qing China, 1840-1915

Sources: See the text, estimated by the authors.
Figure 2. Imports of industrial inputs in Qing China, 1860-1920

2.1. Machinery imports, 1887-1916, in million Yuan

2.2. Coal imports, 1867-1920, in million Tael

2.3. Iron, steel, and tin imports, 1867-1920, in 1000 Tael

2.4. Capital inputs in factory production, 1885-1920, in billion Yuan

Source: Collected and constructed by the authors. Figure 4.1 is from CHEN Zhen et al. (1957), p. 818. Figure 4.2, 4.3 are from Hsiao Lianglin (1974), p. 42 and p. 49. Figure 4.4 is constructed from XU and WU (2005), p. 379 and p. 1046 and YAN Zhongping (1955), p. 94. “Yuan” means Chinese Yuan in the 1930s.
Figure 3. Our new estimation of per capita GDP in Qing China, 1840-1912, in Taels

Sources: See the text, estimated by the authors.
Figure 4. Estimates of per capita GDP and the three approaches of value conversion, Qing China, 1840-1933, in 1990USD

Source: See the text, estimated by the authors.
Figure 5. Public finance in Qing China, 1700-1912, in percentage of total GDP

Source: Collected and calculated by the authors. The nominal GDP before 1840 is from Broadberry, Guan and Li (2012), Figure 3. The data on public income and expenditure is from SHI Zhihong (2009).
Figure 6. Public finance in the UK and Qing China, public income/GDP ratio, 1840-1912, in %

Source: Collected and calculated by the authors.
Figure 7. Public finance in China, public income/GDP ratio, 1700-2011, in %

Source: Collected and calculated by the authors. The nominal GDP before 1840 is from Broadberry, Guan and Li (2012), Figure 3. The data on public income and expenditure is from SHI Zhihong (2009). The data after 1978 is from the China Statistical Yearbook (2012).
Appendix A Background information about the history of China

Table A.1. Empires in Chinese history

<table>
<thead>
<tr>
<th>Empires</th>
<th>Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Han Empire</td>
<td>206BC-220AD</td>
</tr>
<tr>
<td>Tang Empire</td>
<td>618- 907</td>
</tr>
<tr>
<td>Song Empire</td>
<td>960- 1279</td>
</tr>
<tr>
<td>Yuan Empire (Mongol)</td>
<td>1271- 1368</td>
</tr>
<tr>
<td>Ming Empire</td>
<td>1368- 1644</td>
</tr>
<tr>
<td>Qing Empire (Manchu)</td>
<td>1644– 1912</td>
</tr>
<tr>
<td><strong>The late Qing Empire</strong></td>
<td><strong>1840- 1912</strong></td>
</tr>
<tr>
<td>Republic China</td>
<td>1912- 1949</td>
</tr>
</tbody>
</table>

Source: Cambridge history of China

Table A.2. Major historical events during the Qing Empire, 1800-1920

<table>
<thead>
<tr>
<th>Wars</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>The White Lotus Rebellion</td>
<td>1796-1805</td>
</tr>
<tr>
<td>The first Opium War</td>
<td>1839-1842</td>
</tr>
<tr>
<td>The second Opium War</td>
<td>1856-1860</td>
</tr>
<tr>
<td>The Taiping Rebellion</td>
<td>1851-1864</td>
</tr>
<tr>
<td>The Nien Rebellion</td>
<td>1852-1868</td>
</tr>
<tr>
<td>The first Sino-Japanese War</td>
<td>1894-1895</td>
</tr>
<tr>
<td>Political or economic reforms</td>
<td></td>
</tr>
<tr>
<td>The Tongzhi restoration</td>
<td>1861-1875</td>
</tr>
<tr>
<td>The self-strengthening movement</td>
<td>1860-1894</td>
</tr>
<tr>
<td>The reform 1901</td>
<td>1901-1906</td>
</tr>
</tbody>
</table>

Source: Cambridge history of China

Table A.3. Units of measurement in the paper

<table>
<thead>
<tr>
<th>Area</th>
<th>1 square kilometer= 1500 mou</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>1 jin = 500 grams</td>
</tr>
<tr>
<td>Exchange rates</td>
<td>1 Chinese Yuan= 0.26 US dollars, in 1933</td>
</tr>
<tr>
<td></td>
<td>1 tael = 1.5 Chinese Yuan in the 1930s</td>
</tr>
<tr>
<td></td>
<td>1 Qing tael = 37.3 grams of silver.</td>
</tr>
</tbody>
</table>

Appendix B A new estimation of historical GDP, 1840-1912

This appendix introduces our GDP estimation. Parts 1-3 cover the three major sectors of GDP, respectively; part 4 is on value conversion.

1. The agricultural sector

We list the major agricultural products and activities in Table B.1. In the following four sections, we will explain the methods of calculation for the four categories respectively.

Table B.1. Four groups of agricultural products and activities

<table>
<thead>
<tr>
<th>Groups</th>
<th>Main products and activities</th>
</tr>
</thead>
</table>
| 1. Food crops that were land-intensive (Grains)\(^{17}\) | Rice  
Wheat  
Millet  
Kaoliang  
Barley  
Maize  
Sweet potatoes  
Other food crops |
| 2. Non-food but land-intensive crops (Economic crops) | Soybeans  
Cotton lint  
Mulberry and silkworm (raw silk)  
Oilseeds  
Peanuts  
Astragalus root  
Opium poppy |
| 3. Non-food crops that were not land-intensive (Economic crops) | Tea  
Fruit and vegetable  
Flower |
| 4. Others | Cattle farming, fishery, and forestry |

Source: Chung-li Chang (1962); LIU Ruizhong (1987); XU and WU (2005).

\(^{17}\)See also footnotes 5 and 7.
1.1 Food crops

For food crops, our calculation is from the production side, which is summarized by equation (1.1):

\[ Y_t = \sum_i A_i K_i \]  

(1.1)

where \( Y \) is the gross value of food crop production measured in silver; \( A \) is the yield per unit of the \( i \)th food crop in silver; \( K \) is the input of cultivated area for the \( i \)th food crop (the crop area in a period); \( t \) is the year index. In total, we have eight food crops. With the input/output ratio, we can then derive value-added in the food crop production. We will first introduce how to find \( K \), then \( A \), and finally the input/output ratio.

1.1.1 How to find \( K \)

We apply the following equation to estimate and construct a time series of \( K \).

\[ K_i = \text{the cultivated area} \times \text{the proportion of the } i \text{th food crop} \times \text{the multiple cropping ratio} \]  

(1.2)

We will introduce the three parts in the equation step by step.

1.1.1.1 The cultivated land

Having two point estimates and a trend estimate for the period in between, we propose a method of “calibrating” the trend with a simple example. For simplicity, the example contains only two unknown data points, not the 71 data points which are calculated in the paper.

First, we have a time series, from year 1 to year 4, with a known growth rate. We cannot apply it directly, since its average level is higher than what we believe reasonable. We show the time series in Table B.2, column 1. Second, for the new time series we only know the levels for year 1 and 4, denoted by \( E_1 \) and \( E_4 \) in column 4. To fill in the two missing data points, \( X_2 \) and \( X_3 \), we “copy” the trend of the old time series to the new one by assuming the same rates of annual changes between the two, as shown in column 3. To make the assumption simple, we actually assume that for the two time series, their second-order differences are the same. Then, we will give the details of the “copying” method in Table B.3.

By reversing the calculation in Table B.2, we have Table B.3. Column 1 is directly from column 3 in Table B.2. In the last column of Table B.3, we reinterpret column 4 in Table B.2, and present the relationship among different time points using the above assumption. To calculate \( X_1 \) and \( X_2 \), the only unknown is \( v_2 \), which can be derived from the relationship between \( E_1 \) and \( E_4 \). Following the same procedure for more years, we obtain the estimated time series of cultivated area in Figure B.1. We also provide the
maximum and minimum levels among the existing literature.

Table B.2. A simple example on how to construct a new time series

<table>
<thead>
<tr>
<th>Year</th>
<th>The existing time series</th>
<th>The new time series</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Y1</td>
<td>E1</td>
</tr>
<tr>
<td>2</td>
<td>Y2 = Y2/Y1</td>
<td>X2</td>
</tr>
<tr>
<td>3</td>
<td>Y3 = V3</td>
<td>X3</td>
</tr>
<tr>
<td>4</td>
<td>Y4 = V4</td>
<td>E4</td>
</tr>
</tbody>
</table>

Source: Collected by the authors.

Table B.3. The procedure for constructing a new time series

<table>
<thead>
<tr>
<th>Year</th>
<th>Rates of annual changes</th>
<th>Annual changes</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>E1</td>
</tr>
<tr>
<td>2</td>
<td>v2</td>
<td>X2 = v2* E1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>V3 = V3/V2 = W3</td>
<td>X3 = v3* X2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>= (v2* W3)*v2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>= (v2)^2* E1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>V4</td>
<td>E4 = v4* X3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>= (v2* W3)*W4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>= (v2)^3* E1</td>
<td></td>
</tr>
</tbody>
</table>

Figure B.1. Estimations of the cultivated land, 1840-1915, in Mou

Source: Calculated by the authors.
1.1.1.2 The proportion of food crop cultivation

Not all the cultivated area contributed to food production; some non-food crops were also land intensive, such as soy beans. In our calculation, we believe that the proper proportion of the food crop cultivation in the late Qing Empire was around 85%. By surveying the existing literature, we find that the figure decreased in the course of time. GUAN and D. Li use 92.35% as the plausible level for the Ming Empire (GUAN and D. Li, 2010, p.7). Several studies use 90% for the early Qing Empire (GUO Songyi, 1994, XU and WU, 2005, LIU Ti, 2009). WU Hui suggests that the proportion for the late Qing Empire should be below 85% (WU Hui, 1985, p.199). So, in Table B.1 the eight food crops should take up around 85% of the cultivated area in total. Based on this knowledge, we adjust the proportions of the eight different food crops.

1.1.1.3 The proportions of different food crops

The two steps of our adjustments are documented in Table B.4. First, we take averages of the three data sources from the 18th century to the 1930s, and apply these averages to the period 1840-1912 (See Table B.4, column 3). Liu and Yeh also use the similar averages in their estimation for 1933 (Liu and Yeh, 1965). For instance, the proportion of rice cultivation was 29.7% in the 18th century, 29.3% in the 1910s, and 28.3% in the 1930s. We apply their average, 29%, to our calculation. Here, we assume that the proportions did not change over time. In other words, we implicitly assume a fixed technology in the use the cultivated land during the period 1840-1912.

| Table B.4. The proportions of food crops used in previous studies and our adjustments, in % |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| LIU Ruizhong,   | Perkins,        | Buck,           | Our adjustments |
| 1987            | 1969            | 1930, 1937      |                 |
| 1700-1800       | 1914-1918       | the 1920s-1930s | 1840-1912       |
| Rice            | 29.7            | 29.3            | 28.3            | 29.1            | 29.1 |
| Wheat           | 18.9            | 24.5            | 16.3            | 20              | 20   |
| Millet          | 11.34           | 4.2             | 9.4             | 8.3             | 8.3  |
| Kaoliang        | 11.7            | 9.9             | 4.7             | 8.8             | 8.8  |
| Barley          | 9               | 8.5             | 4.4             | 7.3             | 7.3  |
| Maize           | 3.6             | 5.58            | 3.7             | 4.3             | 8.5  |
| Sweet potatoes  | 1.8             | 1.8             | 2.4             | 2               | 2    |
| Other food crops| 3.96            | 11.5            | 3.7             | 6.4             | 6.4  |
| **In total**    | **90**          | **95**          | **72.9**        | **86.6**        | **90** |

Source: Collected by the authors.

The second step is to make adjustments of two crops, sweet potatoes and maize. According to WU Hui, the proportion of sweet potatoes was below 2% before the 1930s
To avoid arbitrariness, we keep the ratio, 2%. As for maize, we use the data collected by YAN Zhongping (1955), estimated at 6% in the 1850s and 11% in the 1900s (YAN Zhongping, 1955, p.359). We use their average, 8.5%, in our calculation. See the final version of the proportions in Table B.3, column 4.

1.1.1.4 The multiple cropping ratio

We apply 1.32 to our estimation (see the text section 3.1.1). Now we have the amount of land input. Accordingly, we need to know the value of output per unit in order to compute the gross value.

1.1.2 How to find \( A \)

\( A \) is the yield per unit measured in silver. For the \( i \)th food crop, we estimate \( A \) by equation (1.3).

\[
A_i = \text{yield} \times \text{price}_i
\]

We will introduce the two parts in the above equation separately.

1.1.2.1 The yields per unit area

There are two steps in our calculation. First, for every food crop we take the average between the maximum and the minimum among the previous estimations (Table B.5, column 4). These averages are very much similar to those from the official records in the 1930s (Table B.5, column 3). So, we suppose that it is safe to use these averages as the yield estimates for the period 1840-1912. The second step is the inclusion of maize and sweet potatoes. For the two, we directly cite the estimations from WU Hui’s estimation (WU Hui, 1985; See Table B.5, column 5).

<table>
<thead>
<tr>
<th>Table B.5. The yields per unit for different food crops and our adjustments, in Jin per mou</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The yield estimates in the existing literature</strong></td>
</tr>
<tr>
<td><strong>The 1700s-1930s</strong></td>
</tr>
<tr>
<td>Rice</td>
</tr>
<tr>
<td>Wheat</td>
</tr>
<tr>
<td>Millet</td>
</tr>
<tr>
<td>Kaoliang</td>
</tr>
<tr>
<td>Barley</td>
</tr>
<tr>
<td>Maize</td>
</tr>
<tr>
<td>Sweet potatoes</td>
</tr>
<tr>
<td>Other food crops</td>
</tr>
</tbody>
</table>

Sources:
For rice, the minimum is from the estimation for the 1910s (Perkins, 1969); the maximum is from the estimation for the 1880s (Chung-li Chang, 1962).

For wheat, the minimum is from the estimation for the 1920s-1930s (LIU Kexiang, 2001); the maximum is from the estimation for the Qing China before 1840 (LIU Ti, 2009).

For millet, the minimum is from the estimation for the 1930s (Perkins, 1969); the maximum is from the estimation for the 1880s (Chung-li Chang, 1962).

For kaoliang, the minimum is from the estimation for the 1930s (Buck, 1930, 1937); the maximum is from the estimation for the 18th century (LIU Ruizhong, 1987).

For barley, the minimum is from the estimation for the 1930s (Buck, 1930, 1937); the maximum is from the estimation for the 18th century (LIU Ruizhong, 1987).

The official data recorded by Republic China is from YAN Zhongping (1955).

For maize and sweet potatoes, the estimation is from WU Hui (1985).

For other food crops, the estimation is from LIU Ruizhong (1987).

1.1.2.2 Prices

Two steps were involved to find price information. We started with the time series of rice prices. We use the price in Yangzi delta to represent the country level, since it forms an average of the rice price in six different regions and it is comparable to the country-level price from PENG Xinwei (1957) (see Figure B.2.1 and Figure B.2.2). Second, through the price ratios between rice and other food crops (PENG Xinwei, 1957, LIU Ti, 2009), we get the price series for other food crops. For example, we have three ratios from previous studies: for rice, 1 shi = 150 jin; for wheat, 1 shi = 142 jin; for the same amount of money, 1 shi of wheat = 0.8 shi of rice. Then, we get the price ratio between wheat and rice, 0.845. Here, we assume that the price ratio between rice and wheat is constant over time. Figure B.2.3 approximately justifies our assumption.

---

18 The yield estimates in LIU Ruizhong (1987), are based on Liu and Yeh (1965).
19 Jin is a Chinese weight unit, 1 jin = 500 grams. Shi refers to an ancient Chinese volume unit for measuring grains.
Sources: Price data for Yangzi Delta are from Wang, 1992, Table 1.1. Price data for other provinces are from “Grain Price Table Between 1821 and 1912” and the Qing-era Grain Price Database.

Figure B.2.2 Rice prices, 1840-1915, in Taels per one hundred jin

![Rice prices, 1840-1915](image)

Sources: as shown in the figure.

Figure B.2.3 Rice and wheat prices, Shandong Province, 1840-1911, in Taels per one hundred shi

![Rice and wheat prices](image)

Sources: Price data are from “Grain Price Table Between 1821 and 1912”.

---

20 We are grateful to Bas van Leeuwen (Utrecht University) for kindly providing these price data.

21 [http://140.109.152.38/](http://140.109.152.38/)
1.1.3 How to find the input/output ratio

To derive value-added in food production, we need an input/output ratio. Table B.6 contains several estimates used by previous studies. We apply the ratio used by LIU Ti (2009): 0.096.

Table B.6. The input/output ratios used in previous studies

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>The 1930s</td>
<td>0.14</td>
<td>0.1</td>
<td>0.1</td>
<td>0.096</td>
<td>0.1857</td>
</tr>
<tr>
<td>The 1920s-1930s</td>
<td>1700-1800</td>
<td>1600-1840</td>
<td>1402-1626</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Collected by the authors.

1.2 Non-food but land-intensive crops

The rest of the cultivated area was left for non-food crop production. As classified in Table B.1, this was still land-intensive. In general our method goes like this: first, we find the most important crops and estimate their value; second, we estimate the proportion of those crops to the total value in this group. With the two steps, we can then derive the total value of production.

Among the crops mentioned in Table B.1, we choose three crops to simplify our calculation, cotton, soy beans, and raw silk. They were the main export goods of the Qing Empire in the late 19th century. For instance, the export proportion of soy beans increased from 0.1% in the 1870s to 1.2% in the 1890s, then to around 15% in 1910s (YAN Zhongping, 1955, p. 76, XU and WU, 2005, p. 84 and 1004). By studying the three products, we can cover a major part of the crop production in this group. The price and output data for the three products can be found in YAN Zhongping (1955) and XU and WU (2005). We interpolate the missing data points.

Previous studies give us clues about how to find the proportion of the three main products to the value in this category of food crops. It was 49.6% in the 1910s (XU and WU, 2005, p.1098) and 44.8% in the 1930s (Perkins, 1975, p.385). The proportion of cotton and raw silk was over 30% in the early Qing Empire (LIU Ti, 2009, p.147). We apply the average between the 1910s and the1930s, 47.2%, in our calculation.

1.3 The remaining non-food crops

The rest of the non-food crop production was not land-intensive. Applying the same method as in the section above, we first choose tea as the most important product. Even though its export proportion decreased since the 1870s, tea was still the most important export good of Qing China (XU and WU, 2005), with a proportion of around 50% in the 1880s (YAN Zhongping, 1955, p.76). The price and output (exports and domestic sales) data can be found in XU and WU (2005). We interpolate the missing data points.
Then, the value of the remaining non-food crop production can be estimated by equation (1.4)

\[ r = 10.09\% \times (\text{food crops} + \text{non-food but land-intensive crops} + \text{tea}) \] (1.4)

In previous sections, we have obtained the value of food crops, non-food but land-intensive crops, and tea. The proportion, 10.09%, is from the estimation for the 1930s (Paosan Ou, 1947, XU and WU, 2005, p.1099).

### 1.4 Other agricultural production

Finally, we add other agricultural activities into the previous estimation, such as cattle farming, fishery, and forestry. Based on Table B.7, we believe that they accounted for about 11% of agricultural value added in the late Qing Empire.

<table>
<thead>
<tr>
<th>Source</th>
<th>1402-1626</th>
<th>1700-1800</th>
<th>1640-1840</th>
<th>1910s</th>
<th>1930s</th>
</tr>
</thead>
<tbody>
<tr>
<td>GUAN and D. Li, 2010</td>
<td>8-10%</td>
<td>12%</td>
<td>10%</td>
<td>11%</td>
<td>18.13%</td>
</tr>
<tr>
<td>LIU Ruizhong, 1987</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LIU Ti, 2009</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perkins, 1969</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paosan Ou, 1947</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Source:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>See the references, collected by the authors.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In our estimation, value added in the agricultural sector was 4.34 billion taels of silver in 1840; 11.72 billion taels of silver in 1912.

### 2. The proto industrial sector

The first step in our estimation is to separate factory production from handcraft workshops. We do this for three benchmark years, 1840, 1885, and 1920, see Table B.8 and B.10. The output levels are respectively: 2254 million taels in 1840 (LIU Ti, 2009); 485 million taels in 1885 (Chung-li Chang, 1962); and 4029 million taels in 1920 (XU and WU, 2005).

In fact we only need to “split” the estimate for 1885 (Chung-li Chang, 1962). First, XU and WU (2005) already provide the value for the two forms of production in 1920. Second, there is no need to split the estimate for 1840 as we assume that all industrial production was traditional by nature; foreign technology was only imported after the 1860s. Chung-li Chang (1962) does not distinguish between the two forms of production in his estimation for the 1880s.

Our separation for the 1885 estimate is based on the descriptive documents in XU and WU (2005). After some adjustments, we obtain a new benchmark estimate for factory production: 26.1 million taels in 1885.
Table B.8. The two forms of production in 1885 and 1920: factory and handcraft workshop

A. Total value of the industrial production in 1885, in million Taels

<table>
<thead>
<tr>
<th></th>
<th>Factory</th>
<th>Handcraft workshop</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacturing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Textile</td>
<td>21.78</td>
<td>209.83</td>
<td>231.61</td>
</tr>
<tr>
<td>Other</td>
<td>0.00</td>
<td>92.25</td>
<td>92.25</td>
</tr>
<tr>
<td><strong>Mining and manufacture of basic metals</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>1.00</td>
<td>12.00</td>
<td>13.00</td>
</tr>
<tr>
<td>Gold</td>
<td>0.40</td>
<td>2.60</td>
<td>3.00</td>
</tr>
<tr>
<td>Pigiron</td>
<td>0.04</td>
<td>3.60</td>
<td>3.64</td>
</tr>
<tr>
<td>Steel</td>
<td>0.11</td>
<td>0.00</td>
<td>0.11</td>
</tr>
<tr>
<td>Other</td>
<td>0.00</td>
<td>108.20</td>
<td>108.20</td>
</tr>
<tr>
<td>Transportation</td>
<td>2.00</td>
<td>30.00</td>
<td>32.00</td>
</tr>
<tr>
<td>Communication</td>
<td>0.77</td>
<td>0.00</td>
<td>0.77</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>26.10</td>
<td>458.48</td>
<td>484.57</td>
</tr>
<tr>
<td><strong>Proportion</strong></td>
<td>5.39%</td>
<td>94.61%</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

B. Total value of the industrial production in 1920, in million Taels

<table>
<thead>
<tr>
<th></th>
<th>Factory</th>
<th>Handcraft workshop</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacturing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mining and manufacture of basic metals</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>70.44</td>
<td>123.23</td>
<td>193.67</td>
</tr>
<tr>
<td>Transportation</td>
<td>189.18</td>
<td>199.51</td>
<td>388.69</td>
</tr>
<tr>
<td>Communication</td>
<td>15.86</td>
<td>1.70</td>
<td>17.56</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>864.06</td>
<td>3164.82</td>
<td>4028.88</td>
</tr>
<tr>
<td><strong>Proportion</strong></td>
<td>21.45%</td>
<td>78.55%</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

Source: Part A is mainly from Chung-li Chang (1962). Since it does not directly provide the value of the two forms of production, we make the separation here and list the value of the new production according to XU and WU (2005). Part B is from XU and WU (2005), p.1051.
Itael of silver=1.5 Chinese Yuan, in the 1930s.
We put the two sub-sectors in the service sector, transportation and communication, into the industrial sector. Our consideration is presented in the text section 3.2.1.

2.1 The total value of factory production during the period 1885-1920

Our estimation of the growth rates applies growth accounting techniques, but limited to one sector. We make the following assumptions. Equation (1.5) is the assumed production function with the property of constant returns to scale,

\[ Value_t = P_t \times Y_t = P_t \times AK_t^\alpha L_t^{1-\alpha} \]  (1.5)

where Value is the total value of the factory output; P is the general industrial price level; Y is the factory output level; K is the fixed capital input; L is the labor input in the factory production. Also, the parameters, \( \alpha \) and A, are assumed to be constant for the period concerned.

We describe the data used in this section as follows. The dataset of the annual industrial price levels during 1885-1920, i.e. \{P\}, \( \forall t = 1885, \ldots, 1920 \), is from WANG Yuru (2005), p.471, Table.6. We have four data points of capital input and three data points of labor input as listed in Table B.9. To deal with missing data, we first assume that the depreciation rate of capital is zero. Then, we use the initial capital inputs of the new factories established annually as the increments (YAN Zhongping, 1955, p.94). By connecting the four points in Table.B.9, line 1, we get a rather smooth line of capital inputs during 1885-19120 (see Figure 2.4). To obtain annual labor input, we assume that the proportion of factory labor to the total population moved steadily over time. Then, we construct the time series of capital and labor inputs during 1885-1920, i.e. \{K_t, L_t\}, \( \forall t = 1885, \ldots, 1920 \).

Table B.9. Capital and labor input in factory production, 1885-1920

<table>
<thead>
<tr>
<th>Year</th>
<th>1885</th>
<th>1894</th>
<th>1913</th>
<th>1920</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital input (in millions Yuan)</td>
<td>29.64</td>
<td>121.55</td>
<td>1786.73</td>
<td>2579.29</td>
</tr>
<tr>
<td>Labor input</td>
<td>90140</td>
<td>693890</td>
<td>413040</td>
<td></td>
</tr>
<tr>
<td>Proportion to the population</td>
<td>0.02%</td>
<td>0.16%</td>
<td>0.09%</td>
<td></td>
</tr>
</tbody>
</table>

Source: Capital data are from XU and WU (2005), p.379 and p.1046. Labor data for 1885 are from XU and WU (2005), p.379; for the period 1912-1920, data are from Lieu (1927), p.91. Population data are from Maddison (2007).

Now, we turn to the unknown parameters in equation (1.5), \( \alpha \) and A. Because A is a constant in our assumptions, it disappears from the growth rates according to equation...
(1.5). We try to find the proper $\alpha$ for the period concerned, given the information from the two point estimates in Table B.8. Rearranging equation (1.5) with the year 1920 as the base year, we have equation (1.6).

$$\ln \frac{\text{Value}_{1885}}{\text{Value}_{1920}} = \ln \frac{P_{1885}}{P_{1920}} + \alpha \ln \frac{K_{1885}}{K_{1920}} + (1 - \alpha) \ln \frac{L_{1885}}{L_{1920}}$$

(1.6)

Using the data from Table B.8, column 1 and Table B.9, column 1 and 4, we derive the parameter $\alpha$ by equation (1.6).

$$\alpha = 0.48$$

We obtain equation (1.7) by putting the parameter $\alpha$ into equation (1.6). Then, we calculate the annual growth rates during 1885-1920, denoted by $g$.

$$g_t = \ln \frac{\text{Value}_t}{\text{Value}_{1920}} = \ln \frac{P_t}{P_{1920}} + 0.48 \ln \frac{K_t}{K_{1920}} + (1 - 0.48) \ln \frac{L_t}{L_{1920}}$$

(1.7)

, where $\{P_t, K_t, L_t\}, \forall t = 1885, \ldots, 1920$

By equation (1.7), we construct the time series of the total value of the factory production during the period 1885-1920, i.e. $\{\text{Value}_t\}, \forall t = 1885, \ldots, 1920$. Figure B.3 shows our results.

Figure B.3. Total value of factory production, 1885-1920, in million Taels

Source: Constructed by the authors.
2.2 The total value of handcraft production during the period 1840-1920

Starting from the three benchmark estimates in Table B.10, line 2, we assume that the per capita value in traditional workshops moved steadily during 1840-1920. With the estimated traditional output per capita and population data, we then derive the time series of the total value of the traditional production during the period concerned.

Table B.10. Total value of the traditional production, 1840-1920

<table>
<thead>
<tr>
<th>Total value (in million Taels)</th>
<th>LIU Ti, 2009</th>
<th>Chung-li Chang, 1962</th>
<th>XU and WU, 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>1840</td>
<td>2250</td>
<td>458.48</td>
<td>3164.82</td>
</tr>
<tr>
<td>1885</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1920</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Per capita levels (in Tael)

<table>
<thead>
<tr>
<th>Per capita levels (in Tael)</th>
<th>LIU Ti, 2009</th>
<th>Chung-li Chang, 1962</th>
<th>XU and WU, 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>1840</td>
<td>5.46</td>
<td>1.23</td>
<td>6.71</td>
</tr>
<tr>
<td>1885</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1920</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Collected by the authors. The data on population is from Maddison (2007).

2.3 The proportion of net value

Paosan Ou shows that in 1933 the net value proportion for mining and metal manufacture was around 50%; for textile manufacture 29%-30%; and for ceramics manufacturing 60% (1947). In general, we apply a ratio of 40% for the industry to calculate value added. Later improvements are necessary because the choice of the ratio here is rather arbitrary, we have to admit.

In our estimation, the value added in the proto industrial sector was 0.9 billion taels of silver in 1840; and 1.2 billion taels of silver in 1912.

3. The service sector

3.1 Public administration

First of all, we need to deal with the missing data problem. For the missing data during 1821-1850, we impute the average expenditure under the Emperor Daoguang (1821-1850), which was 11 million taels.

In our estimation, the value of public administration was 79 million taels of silver in 1840 and 175 million taels of silver in 1912.

---

22LIU Ti (2009) gives the net value directly, i.e. 900 million taels. We use the net value ratio, 40%, to obtain the total value.
3.2 Finance

Including real estate and renting, we calculate the value of the early financial sector based on the three benchmark estimates in Table B.11. For simplicity, we assume that the per capita value in the financial sector moved steadily during 1840-1933. With the population data, we derive a time series of the net value.

In our estimation, the value added in the early financial sector was 0.32 billion taels of silver in 1840 and 0.52 billion taels of silver in 1912.

![Figure B.4. The central government expenditure, 1840-1912, in million Taels](image)

Table B.11. The net value in the financial sector, 1840-1933

<table>
<thead>
<tr>
<th>Year</th>
<th>LIU Ti, 2009</th>
<th>Chung-li Chang, 1962</th>
<th>Liu and Yeh, 1965</th>
</tr>
</thead>
<tbody>
<tr>
<td>1840</td>
<td>320</td>
<td>238.6</td>
<td>826.7</td>
</tr>
<tr>
<td>1885</td>
<td>0.78</td>
<td>0.64</td>
<td>1.65</td>
</tr>
</tbody>
</table>


3.3 Commercial activities

For commercial activities, we calculate the value created by wholesale and retail trade. We use a ratio to derive the value. In Chung-li Chang’s estimation, the commercial/non-commercial ratio was 0.086 in the 1880s (Chung-li Chang, 1962); in Maddison’s
estimation, it was 0.097 in 1890 (Maddison, 2007, p.254); Paosan Ou’s estimation was 0.107 in 1933 (Paosan Ou, 1947, p.12); the estimate of Liu and Yeh was 0.104 in 1933 (Liu and Yeh, 1965, p.66). Based on their estimates, we suppose that the ratio was around 0.09 during 1840-1912. In our estimation, the value in the commercial sector was 0.5 billion taels of silver in 1840 and 0.89 billion taels of silver in 1912.

Adding up the three sub-sectors, we get the value added levels in the service sector: 0.9 billion taels of silver in 1840 and 1.6 billion taels of silver in 1912.

4. Calculating per capita GDP in 1990 USD: three approaches

In order to make an international comparison, we convert the Chinese GDP into 1990 USD. We present three value conversions.

4.1 Market exchange rates (MER)

The first approach follows equation (1.8) to estimate GDP per capita in 1990 US prices in the year $t$.

$$p_t^{CN} q_t^{CN} \times e_t \times \frac{p_{1990}^{US}}{p_t^{US}}$$

(1.8)

where $p$ is the domestic price level; $q$ is the corresponding real output; $e$ is the market exchange rate between the US and Qing China. Our estimation gives the nominal Chinese GDP per capita in silver, $p_t^{CN} q_t^{CN}$. First, we estimate the market exchange rate, $e$, through the silver/dollar ratio. Second, we use the general U.S. price levels, or the GDP deflators to translate the value in year $t$ to 1990 prices.

The approach is accurate if the law of one price holds, $e_t \times \frac{p_{1990}^{US}}{p_t^{US}} = 1$. However, it usually does not hold, since it fails to consider the price level of non-tradable goods. The conversion based on market exchange rates tends to underestimate the level of real GDP per capita for lower income countries (Balassa and Samuelson, 1964).

4.2 Current PPP converters

The GDP per capita in 1990 US prices in year $t$ can be calculated in the second way as:

$$p_{1990}^{US} q_t^{CN} = \left(\frac{p_t^{CN} q_t^{CN}}{p_t^{US} q_t^{US}}\right) \times \left(\frac{p_{1990}^{US} q_t^{US}}{p_{1990}^{US} q_t^{US}}\right) \approx \frac{q_t^{CN}}{q_t^{US}} \times \left(p_{1990}^{US} q_t^{US}\right)$$

(1.9)

where CN is short for China; $p_{1990}^{US}$ is the 1990 US price; $t=1840-1912$. Now, $p_t^{CN} q_t^{CN}$ is the nominal Chinese GDP measured in dollars in year $t$, derived from our GDP estimates and the market exchange rates. $p_t^{US} q_t^{US}$ is the current U.S. GDP in year

---


\( r^{25} \cdot p_{1990}^{US} q_{1990}^{US} \) is Maddison’s U.S. GDP estimate in 1990 prices in year \( t \). In general, we try to estimate the ratio of real GDP between the two countries in every year, \( \frac{q_t^{CN}}{q_t^{US}} \). Thus, we need to first find the current PPP converter in year \( t \),

\[
\frac{p_t^{CN}}{p_t^{US}}
\]

, which is also the Fisher average. Here, we assume that the commodity basket has only two goods, wheat and gold.\(^{26}\) For simplicity, we assume that the weights for China were 75% and 25%, respectively and for the U.S. 25% and 75%, respectively. In 1935, the weight for agriculture in GDP is 62.5% for China, 11.7% for the U.S. (See Yuan, Fukao, and Wu, 2008, p.327, Table 1). So, our assumption seems justified. We also assume that these weights were constant over time.

Following the standard procedure we calculate the Fisher index, which means the Chinese general price level relative to that of the U.S. in year \( t \). The estimated Fisher indexes for 1933 from previous studies are listed in Table B.12. Compared with other results, the index derived from our assumptions of the two-goods economy is obviously higher than others (0.75). Next we obtain the current-PPP adjusted GDP per capita in Figure 4. Since it is possible that we overestimate the relative price level between the U.S. and Qing China, current-PPP adjusted GDP would be underestimated. The average annual Fisher indexes for the period 1840-1912 is 1.01, which indicates that the general price levels for the assumed consumption basket are similar in the two countries (See Table B.12, column 4). This explains why our current-PPP adjusted GDP estimates are quite similar to the MER-adjusted GDP estimates (See Figure 4).

<table>
<thead>
<tr>
<th>Type</th>
<th>Expenditure- side PPP</th>
<th>Production- side PPP</th>
<th>“Proxy-GDP” PPP</th>
</tr>
</thead>
<tbody>
<tr>
<td>The index</td>
<td>0.32</td>
<td>0.64</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.01 (on average)</td>
</tr>
</tbody>
</table>

Source: Collected by the authors.


\(^{26}\)Sources: The prices of wheat and gold for China are from PENG Xinwei, 1957, Chapter 8. The prices of wheat for the U.S. are wholesale prices, from James E. Boyle, Chicago Wheat Prices for Eighty- one Years, p.69-71. The prices of gold for the U.S. are from Lawrence H. Officer, "The Price of Gold, 1257-2009," MeasuringWorth, 2010. URL: http://www.measuringworth.com/gold/
We also tried to use different consumption weights of rice, e.g. 50%, to make a cross check. Because of our assumption of the two-goods symmetric economy, the final results of GDP estimation remain unchanged.

4.3 Backward projection from Maddison’s 1933 estimate

Figure B.5. A cross check of GDP per capita in 1990USD for Qing China, 1840-1912

Source: Calculated by the authors. We change the consumption weight of rice from 75% to 50%, and then to 25%.

Thirdly, the GDP per capita value in 1990 US prices in year $t$ can be calculated as:

$$p_{1990}^{US}q_t^{CN} = \left(\frac{p_t^{CN}q_t^{CN}}{p_{1933}^{CN}q_{1933}^{CN}}\right) \times (p_{1900}^{US}q_{1933}^{CN}) \approx \left(\frac{q_t^{CN}}{q_{1933}^{CN}}\right) \times \left(p_{1990}^{US}q_{1933}^{CN}\right)$$

where CN is short for China; $p_{1990}^{US}$ is the 1990 US price; $t=1840-1912$. Here, $p_t^{CN}q_t^{CN}$ denotes current Chinese GDP in year $t$ measured in taels of silver, derived from our estimation. $p_{1933}^{CN}q_{1933}^{CN}$ is the nominal Chinese GDP estimate in 1933, which is 39.83 taels. $p_{1900}^{US}q_{1933}^{CN}$ is Maddison’s Chinese GDP estimate for 1933, which equals to 578.61 dollars. Similarly, we try to estimate the ratio of real Chinese GDP between

---

27 For the 1933 estimate in taels, we use the estimate from Liu and Yeh (1965).

28 The 1933 estimate in 1990 USD is from the Maddison website: http://www.ggdc.net/maddison/oriindex.htm.
any year $t$ and 1933, $\frac{q^C_t}{q^C_{1933}}$. Thus, we need to first find the PPP converter in year $t$,

$$\frac{p^C_t}{p^C_{1933}},$$

which is also the Fisher average. We repeat the similar assumptions as mentioned above. The commodity basket has only two goods, wheat and gold. The consumption weights are constant over time, and are 75% and 25%, respectively. Following the standard procedure we calculate the Fisher index, which means the general price level in year $t$ relative to the 1933 price level. Then we obtain the backward-projected GDP per capita in Figure 4.

We also tried to use different consumption weights of rice to perform a cross check. We changed the weight of rice from 75% to 50% and then to 25%. The resulting GDP levels in 1990USD are shown in Figure B.5. Because the weight of rice decreases, the estimated GDP deflators or the Fisher averages cannot fully compensate for the fluctuation of nominal GDP which is caused by the rice price. Therefore, the smaller the weight of rice becomes, the more the resulting real GDP series in 1990USD would be similar to the nominal GDP series, like in the period 1860-1870. The average GDP per capita decreases from 551 dollars to 515 dollars, and further to 484 dollars.
References


Brandt, L., Ma, D. & Rawski, T.G. 2012, From divergence to convergence: re-evaluating the history behind China’s economic boom, Economic History Working Papers 41660, London School of Economics and Political Science, Department of Economic History.


Buck, J.L. 1937, Land Utilization in China: a study of 16,786 farms in 168 localities, and 38,256 farm families in twenty-two provinces in China, 1929-1933, Oxford University Press [etc.], Oxford [etc.].


FANG, X. 1996, "QingdaJiangnanNongmingdeXiaofei [Study on the Farmers’ consumption in the Qing Dynasty in southern China]", Zhongguojingjiishiyanjiu, , no. 3, pp. 91-98.


Institute of Economics, Chinese Academy of Social Science 2009, Grain Price Table Between 1821 and 1912, Guangxi Normal University Press, Guangxi.


LIANG, F. 1980, ZhongguoLidaiHukoTiandiTianfuTongji (Dynastic Data of China's Households, Cultivated Land and Land Taxation), Shanghai People's Press, Shanghai.

Lieu, D.K. 1927, China's industries and finance, Chinese Government Bureau of Economic Information, Beking, Shanghai.


LIU, R. 1987, "Shibashijzhongguorenjunguominshourugujijiqiyuyingguo de bijiao [Study on national income in 18th century China]", Zhongguojingjishiyianjiu, , no. 3, pp. 105-120.


Ou, P. 1947, China's National Income, 1933, Institute of Social Sciences Academia Sinica Monograph Serie, Shanghai.

PENG, X. 1958, Zhongguohuoibishi [History of Money in China], Shanghai People's Press, Shanghai.


SHI, Z. 2009, QingdaHubuYinkuShouzhi he KucunTongji [Statistical materials on the government income and expenditure, and reserves in the state treasury in the Qing Empire], 1st edn, People's Press, Fujian.


WU, H. 1985, Zhongguolidailiangshimuchanliangyanjiu [Study on agricultural production in Chinese history], Beijing nongyechubanshe, Beijing.


ZHOU, R. 2001, "Qingdaiqianqiqengdimianji de zonghekaodha he chongxingusuan [Study on the estimation of cultivated land in the Qing Dynasty]", Jianghanluntan, no. 9, pp. 57-61.