Measuring China's performance in the world economy. A benchmark comparison between the economies of China and the UK in the early twentieth century

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Introduction

The late nineteenth to early twentieth century, known for drastic social and economic changes in China's economic history, has been viewed as a century-long pursuit of modernisation and industrialisation and also as a process of catching up with more advanced economies. Economic historians have been trying to explore the very beginning of modern China's ongoing industrialisation and the 1920s–1930s is commonly believed to be the most important period for China's industrial development before WWII, even though researchers have long been interested in the pre-war development of China's industry from the late nineteenth century (Brandt, Ma and Rawski 2017; Xu and van Leeuwen 2016; Yuan, Fukao and Wu 2010).[1] Pointing to an earlier year (period) in the history of China's pre-war industries, our study contributes to the literature by providing a new benchmark estimation of China's industrial performance for the 1910s. The year 1912 was the first year of the re-

1. Some studies declare that China's post-1949 state-led industrialisation can be traced back along a development path that began in the late nineteenth century (Wu 2011; Wong 2014). Historical studies on China's early industries refer to the influence of the Self-Strengthening Movement of 1861–1895 (for instance, Wu and Xu 2003). It is still difficult to say exactly when China started to industrialise; for some industries, records show new factories established in Shanghai before 1860 (Zhang 1989).

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publican era after the fall of the Qing Empire and, in particular, the first year with industrial data collected systematically and published as official yearbooks. Measuring the level of industrial development in this particular year evaluates the previous efforts toward industrialisation over the late Qing period (1840–1911). It provides a starting point for looking at the subsequent development until the outbreak of the war with Japan in the 1930s.

Measuring China's industrial performance in the 1910s improves our understanding of China's industrial development before WWII. Our new estimation provides a new benchmark to position pre-war China's industrial productivity level relative to contemporaneous economies in both Europe and Asia. Together with the 1930s benchmark estimated previously, this study, for the first time, presents the catch-up process in the industrial sector between China and more developed economies from the 1910s to the 1930s – when the industrial sector expanded rapidly in China.[2] Secondly, extrapolating backwards from the new 1910s benchmark, this study traces the relative development of China's early industries back to the late nineteenth century, with the estimates indicating the process of industrialisation during the years ruled by the Qing Empire.[3]

Specifically, this study compares the level of China's early industrialisation in the 1910s relative to that of the highly developed economy of the UK by estimating manufacturing purchasing power parities (PPPs) and calculating relative levels of manufacturing labour productivity between the two economies. Additionally, we compare the early industrial development between China and Japan, taking UK manufacturing as the reference. Moreover, this study continues by measuring industrial performance in various regions or provinces within China. With more regions and provinces included, the study reveals regional patterns of industrial performance, contributing to the discussion on the leading regions in China's industrialisation before WWII.[4]

2. In the 1910s–1930s, the growth of China's new industrial output exceeded that of Japan, India and Russia, according to Brandt, Ma and Rawski (2017). Yuan, Fukao and Wu (2010) constructed production-side PPPs for manufacturing industries and measured comparative output and labour productivity for three Asian economies of the 1930s, i.e., China, Japan and Korea, setting the US as the reference country. Their estimation for China indicates a level of labour productivity considerably lower than that of other Asian economies in their comparison.

3. To understand industrial development in the late nineteenth century, this study refers to the Ma and de Jong (2019) estimation for the period 1880s–1920s and compares China's industrial performance with that of Japan in the 1890s – the earliest estimates available for the quantitative comparison between China and Japan.

4. The literature on the regional distribution of China's early industries often refers to the total output in a region from the manufacturing sector or from a representative industry. Shanghai and its surrounding area are commonly described as the center for industrial production at a very early stage of China's industrialisation.

Discussions on a new estimation of China's historical GDP, recently published by Broadberry, Guan and Li (2018), have renewed attention to the "great divergence" in per capita incomes between Europe and China and their relative stage of economic development in general (Pomeranz 2000; Broadberry, Guan and Li 2021; Solar 2021). Understanding China's industrialisation and its position in the world economy contributes to "the great divergence" debate by pointing to the connection between industrialisation and economic growth, which has broad implications for future research. As the world's largest economy – at least until the early nineteenth century – and the second-largest today (or even the largest), China's economy has the power to affect the rest of the world and also has long been influenced by global developments.[5] Understanding China's early industrialisation and economic development in general contributes to our understanding of the history of the world economy since industrialisation.

This article proceeds as follows. Section 2 provides general information on the Chinese economy before the 1930s, relative to the UK economy, in terms of output, employment and trade. Section 3 presents a benchmark estimate of labour productivity in manufacturing between China and the UK, applying a so-called industry-of-origin approach using purchasing power parities (PPP) to compare values of production in various industries in both countries. Industrial data and sources are provided in Section 4, in which we introduce the Chinese official yearbook of 1912 in detail. In Section 5, we report the estimated manufacturing PPPs and the comparative levels of China/UK manufacturing labour productivity and then discuss the application and interpretation of the new indicator. Section 6 contains concluding remarks.

The Chinese economy in the early twentieth century

Our comparison between China and the UK is based on the first Chinese industrial census of 1912 and the first UK industrial census of 1907.[6] The UK economy of 1907, the Chinese economy of 1912 and the 1930s represent dif-

5. According to Maddison's estimation, per capita income in China was higher than that of Europe from the tenth to the early fifteenth century and, in terms of total output, China was the world's biggest economy for several centuries before the economic decline of the nineteenth century (Maddison 2007, p. 11). According to World Bank data, China has been the second-largest economy since 2010, measured by GDP in current US dollars. According to GDP data published by the IMF, China became the second-largest economy in around 2000 and the largest in 2014, based on PPP measures.

6. To deal with the mismatch of census years, we will first calculate manufacturing PPPs between 1912 China and 1907 UK and then through extrapolation derive the manufacturing PPPs and comparative labour productivity for the 1910s. See Table 3 for the result.

ferent stages of economic development and industrialisation. Here we look at the economic structure, the structure of manufacturing, and trade patterns of the two economies in the early twentieth century. Appendix 2 gives more data and references discussed in this section.

GDP per capita and economic structure

Around the 1910s, the UK economy left the Chinese economy far behind in levels of per capita GDP, although the two economies were comparable in total GDP levels. Adjusted by market exchange rates, China's GDP per capita level was around 7–10 per cent of the UK level in 1907 and 1911. Using market exchange rates may underestimate the level of per capita GDP for China relative to the UK level because they may not reflect the true domestic purchasing power of the currencies involved. It is more appropriate to use a PPP-based comparison; according to the new PPP estimated by Ma and de Jong (2019), China's GDP per capita level was 13.3 per cent of the UK level in 1911. The ratio is 12.2 per cent for 1907 and 11.7 per cent for 1912 based on the new GDP estimates for China in Ma and de Jong (2019) and Maddison's estimation of UK GDP. The above comparisons indicate roughly similar levels of economic development for China between 1907 and 1912 as a percentage of the UK level, which makes the comparison between 1912 China and 1907 UK feasible.

In both 1912 and 1935, agriculture in China had a share of more than 60 per cent in total GDP. By contrast, over 90 per cent of the UK GDP in 1911 was produced in the industrial and services sectors. The agricultural share in total GDP in China decreased in the period 1907–1935 by around ten percentage points. Nevertheless, the size of China's industrial sector in the total economy was small compared with the UK in 1911. Yuan, Fukao and Wu (2010) also stressed China's relative inferior position in industrialisation in 1935, as indicated by a low share of utilities and transportation in total GDP.

Manufacturing structure

In both 1912 and 1935, China remained in the early stage of industrialisation, compared with UK manufacturing in 1907. Chinese manufacturing in this period concentrated mainly on food processing and textiles; the two manufacturing branches took up around 80 per cent of gross output and absorbed more than 70 per cent of total manufacturing employment. In UK manufacturing, around 50 per cent of gross output and employment was created by mechanical engineering and the production of mineral-based intermediate materials, including chemicals, building materials, metal and machinery. The share of metal and machinery industries in China was 12.6 per cent in 1935.

In the same year it was already 37.9 per cent in Japan, to put it in an Asian perspective (Yuan, Fukao and Wu 2010, Table 2, p. 328).

In 1912, China's food-processing industry produced more than 60 per cent of gross output with around 40 per cent of manufacturing employment; in 1935 the share became even larger. The textile industry created around 10 per cent of gross manufacturing output but being a very labour intensive sector it employed more than 30 per cent of the manufacturing labour force. Textiles expanded further to a level of around 20 per cent of gross manufacturing output in 1935. The manufacturing sector had a relatively high share of chemical products in 1912, mainly because of an extremely high level of oil production (e.g., cottonseed oil); but the share declined significantly in 1935. Despite the intention of the state to promote capital-intensive production, food-processing and textile industries dominated the manufacturing sector during the period 1912–1935.

The above comparisons are based on the gross output value, including both new factories and traditional handicraft workshops which better represent the overall situation of China's industrialisation before WWII. Within the handicraft workshops, food processing became the leading activity.

Looking at the regional level, we find that there were large differences in volumes and productivity of food processing. We grouped Chinese provinces into nine "macroregions", according to Skinner, Henderson and Berman (2013).[7] In the Lower Yangzi region, the output share of food processing was below 40 per cent, and the employment share was below 30 per cent. Northeast and Northwest China seemed to have a higher level of productivity in food processing, with around 60 per cent of output produced by around 30 per cent of employment. The textiles and related clothing products took more than 30 per cent of the manufacturing output and employment in the Lower Yangzi region, similarly to the UK level of 1907.[8] The structural shift toward intermediate goods production, such as chemicals, metal and building materials, indicates the growth potential of China's industrial sector already before WWII, however, with regional differences.

7. Boundaries of macroregions, based on river systems and other geographical conditions, and the boundaries of provinces in early twentieth century China overlap not exactly. For instance, in Skinner, Henderson and Berman (2013) the macroregion "North China" includes the north part of Anhui and Jiangsu province, but we put the two provinces into the region "Lower Yangzi". Therefore, our grouping at the provincial level can only approximately represent the physiographic macroregions in China. Appendix 3 shows the map of "macroregions" discussed in this study.

8. Following the comparison at regional levels of Pomeranz (2000), we compare manufacturing structures between a region in China and the UK in this section (see the appendix, Figure A 2.2). Considering the problem of scale in comparing China as a whole and the UK, in section 5.2 we continue to compare manufacturing productivity between regional China and the UK.

Trade pattern

To show the trade patterns for China and the UK, we regrouped the trade-related industries into three categories, following Yuan, Fukao and Wu (2010, p. 329): "primary goods", "(relatively) simple manufactured goods" and "sophisticated manufactured goods".[9] The shares for the three categories of products indicate stages of industrial development. As a country concentrates more on industrial production, its exports will shift more towards manufactured goods and its imports towards primary goods. With a much higher level of industrialisation, the UK in 1907 exported mainly manufactured goods, such as textiles, metals, and machinery, and imported primary goods, such as food products and raw materials. The UK export share of manufactured goods was 81 per cent in 1907, while the import share of primary goods was 72 per cent. Both in 1912 and 1935, China presented an opposite position relative to the UK. Around 70–80 per cent of Chinese exports were primary goods, while the import share of manufactured goods was around 50–70 per cent. The contrasting structures between the Chinese and the UK trade may also imply different characteristics of production, such as the Chinese specialisation in primary goods production.

Compared with its trade shares in 1912, Chinese exports of primary goods in 1935 decreased by ten percentage points. Until 1935, China had nearly no exports of sophisticated manufactured goods. In the 1910s–1930s, the import of primary goods increased by around 20 percentage points together with an increase in the imports of sophisticated manufactured goods such as machinery products. This change may reveal an expansion of machinery-based production in China and an increase in the domestic output of simple manufactured goods. Compared with the trade shares in 1912, Chinese imports of textiles decreased significantly in 1935, while the imports of other manufactured goods increased, particularly machinery and transportation equipment.

Calculating Purchasing Power Parities

This study follows the standard approach to constructing industry-of-origin PPPs developed by the International Comparison of Output and Productivity Program (ICOP) at the University of Groningen (van Ark and Mad-

9. (1) "primary goods" includes "foodstuffs and live animals" and "raw materials, minerals, fuels"; (2) "(relatively) simple manufactured goods" includes all manufactured goods except "machinery and transport equipment", and (3) "sophisticated manufactured goods" includes "machinery and transport equipment".

dison 1988; van Ark 1993). Recently, the ICOP approach has also been applied to the period before WWII (Fremdling, de Jong and Timmer 2007; de Jong and Woltjer 2011) and also to the period before WWI (Woltjer 2013; Veenstra 2014). These studies not only prove that it is feasible to apply modern techniques for historical periods, but they also stress the advantages of the price-based method over the quantity-based method in productivity comparisons.[10]

This study estimates new manufacturing PPPs for 1912 China with 1907 UK as a reference country, following the methods applied in three studies on estimating PPPs of the 1930s: Fremdling, de Jong and Timmer (2007) gave a Germany/UK comparison for 1935/1936; de Jong and Woltjer (2011) provided a US/UK comparison for 1935; Yuan, Fukao and Wu (2010) presented a China/US comparison also for 1935.[11] Three extensions are made based on the newly estimated manufacturing PPPs. Firstly, we will compare (gross) labour productivities between China and the UK for 1912/1907, by using a single deflation procedure. This implies that we measure and compare the prices of gross manufacturing output. Ideally, we should also adjust for comparative movements in the prices of intermediate inputs, so as to get a double deflated estimate for the value-added of the production process.

A later improvement for this study, therefore, is to use double deflation instead of single deflation, which is considered to be the preferred approach for productivity comparisons, especially for the early twentieth century (Fremdling, de Jong and Timmer 2007; de Jong and Woltjer 2011).[12] The double deflation approach helps to capture differences in the technical input-output coefficients for a given industry between two economies, which might be due to, for example, differences in production methods, the type of materials used, and the imported materials. All these differences are essential to understand the early stage of China's industrialisation in the 1910s. However, both quantity and price information for inputs is not widely available in China's industrial statistics of the early twentieth century, when the newly established government of the Republic of China started to organise the first nationwide census of economic activities. Another future improvement is to adjust for

10. The quantity-based method often uses physical output per worker as a measure of productivity performance, while the price-based method uses output value per worker. The latter guarantees a higher coverage of industries in comparing productivity. Moreover, the representation of matched output for non-matched output is higher for price than for quantity ratios (Fremdling, de Jong and Timmer 2007, p. 359).

11. With the intention to compare price-based productivity levels between the 1910s and the 1930s, this study follows the estimation procedures applied for the 1930s PPPs in estimating the 1910s PPPs to ensure the consistency in methods.

12. In constructing PPPs, single deflation refers to output price data only, while double deflation considers price data for both output and intermediate inputs (See also Fremdling, de Jong and Timmer 2007, pp. 359-360).

differences in hours worked between the two countries instead of only using employment data.[13]

The newly-calculated indicator of comparative labour productivity of the 1910s will be used to show the relative changes between China and the UK in the 1910s–1930s.[14] Secondly, we estimate the level of China's manufacturing productivity in the 1890s relative to the UK level based on the 1910s PPP. Doing so, we can describe the path of China's early industrialisation before WWII and, in particular, compare the process of industrialisation between China and Japan in the 1890s–1930s. Thirdly, we present regional variation in early industrial development within China by calculating the comparative labour productivity between a given region in China and the UK following the same procedure.

We first introduce the procedure to calculate a new manufacturing PPP. Unit values (*uv*) are derived by dividing gross output values (*o*) by quantities (*q*). For each matched product *i*, the unit value ratio between two countries (*UVR*) is calculated as the following equations.

$$uv_i = \frac{o_i}{q_i}$$

$$UVR_i^{\frac{CN}{UR}} = \frac{uv_i^{CN}}{uv_i^{UK}}$$

In this study, the UK is taken as the base country. The product's *UVR* indicates the relative producer price for a matched product in the two countries. *UVRs* of individual products need to be aggregated to derive relative prices for sub-industries, for branches, and the manufacturing sector. We take sub-industry *j* as an example and label the relative price with a superscript *j*. The weights of both the base country (the UK) and the other country (China) can be used in the aggregation, which provide a Laspeyres type PPP (*L*) and a Paasche type PPP (*P*), respectively. The Fisher index (*F*), the geometric average of the Laspeyres and Paasche indices, will be used in the single deflation process. The PPPs for industry *j* are given by the following equations (see Deaton and Heston 2010, p. 6).

13. For state-owned factories in 1912 China, average weekly hours worked were around 55 hours.

14. The comparative labour productivity of the 1930s will be calculated according to the US/UK comparison in de Jong and Woltjer (2011) and the China/US comparison in Yuan, Fukao and Wu (2010).

$$L_j^{\frac{CN}{UK}} = PPP_j^{\frac{CN}{UK}} = \sum_{j=1}^{I} W_{ij}^{UK} UVR_{ij}^{\frac{CN}{UK}}$$

$$P_j^{\frac{CN}{UK}} = PPP_j^{\frac{CN}{UK}} = \sum_{j=1}^{I} W_{ij}^{CN} UVR_{ij}^{\frac{UK}{CN}}$$

$$F_j^{\frac{CN}{UK}} = \sqrt{L_j^{\frac{CN}{UK}} P_j^{\frac{CN}{UK}}}$$

where $i=1,\ldots,I$ denotes the matched products in industry j; for each country $w_{ij} = o_{ij} / o_i$ denotes the output share of the ith product in industry j; and $o_j = \sum_{i=1}^{I} o_{ij}$ denotes the total value of matched output in industry j.

In this study, the aggregation of the *UVRs* are weighted in multiple steps, first according to their output shares in the sub-industry (*Weight III*), then according to the industry's shares in the manufacturing branch (*Weight II*), and finally according to the branch shares in manufacturing as a whole (*Weight I*). Thus, the new manufacturing PPPs are derived using a "pyramid" type of approach, which consists of three steps (Yuan, Fukao and Wu 2010). The first step derives industry-specific PPPs, using Weight III. The second step aggregates these industry-specific PPPs to yield branch level PPPs, using Weight II. The final step aggregates these branch-level PPPs to derive a single PPP for the whole manufacturing sector, using Weight I. For the last step, we use the branch shares directly from the census data. As a result, the aggregated PPP in the final step will reflect the actual share of each branch for which *UVRs* are available and taken as representatives for their branches. The underlying assumption is that for non-matched products and sub-industries the assumed PPPs are the same as the PPPs calculated for the matched part in the second step. Appendix 1 shows the detailed calculation procedure. Future research should consider alternative assumptions dealing with product matching and differences in output structures between two economies to improve the calculation.

Now we can measure the difference in (gross output) labour productivity between China and the UK, as the PPP-adjusted gross output value per worker in China relative to the gross output value per worker in the UK.

$$GO_{LP}^{\frac{CN}{UK}} = \frac{\frac{O^{CN}}{l^{CN}} / F^{\frac{CN}{UK}}}{\frac{O^{UK}}{l^{UK}}}$$

where GO_{LP} denotes the ratio of (gross) labour productivity between the two countries; $o = \sum_{j=1}^{J} o_j$ denotes the gross output values for the manufacturing sector, $j=1,\ldots, J$ denotes the matched branches in the manufacturing sector; l denotes the labour force involved in the matched branches; $F\frac{CN}{UK}$ denotes the manufacturing purchasing power parity estimated above to adjust the manufacturing output values between China and the UK.

Sources and data

This section introduces the data and sources used in constructing PPPs and labour productivities, including data structures, concepts and definitions, industrial classification, coverage, and problems in using the data sources. Three categories of data are used in this study: (1) product and sub-industry data for the calculation of unit values (*UVs*) and unit value ratios (*UVRs*), (2) output value data to arrive at weighted and aggregated PPP estimation for industrial branches and the total manufacturing, and (3) employment data to calculate productivity levels. The dataset is constructed mostly from two official surveys: for the UK we have referred to the *First Census of Production* of 1907 published by the Board of Trade of the UK (1912); for China the *Agricultural and Industrial Statistical Yearbook* of 1912 published by the Agriculture and Industry Department of the Republic of China (1914).[15] The Chinese industrial census will be introduced in more detail since the census has rarely been used in measuring industrial performance.

The industrial census of China of the 1910s

The *Agricultural and Industrial Statistical Yearbook* for the Republic of China of 1912, published in 1914, is the result of the first nationwide survey organised by the government of the new Republic of China. The survey summarises the economic situation in the first year of the republican period of China and after the overthrow of the 270-year-old Qing Dynasty. The yearbook of 1912 is based on local economic reports collected at the end of 1912 and combines three industrial surveys: the survey of the textile industry of 1896, the survey of the silk industry of 1901, and the industrial survey of the period 1907–1908. The yearbook series was published annually until 1921.

The industrial census in the yearbook of 1912 contains information on more than one hundred products and 36 sub-industries in the manufacturing sector and also the information on mining and the financial sector. Informa-

15. The yearbook of 1916 is used to cross check the data of 1912.

tion on manufacturing products was collected from individual plants or industrial units and then organised by sub-industries. The census has data on gross output (quantities and values) for individual products and employment for sub-industries. The national aggregates in the industrial census of 1912 are based on provincial information covering 21 provinces and the capital city (see the map of the 21 provinces in Figure 2). Although it has several drawbacks (see below), the industrial census of 1912 is still a critical archival record for understanding the early industrialisation in pre-war China. It provides not only first-hand information but also a comprehensive understanding of China's manufacturing industry in the 1910s.

Chang (1969) and Xu and Wu (2003) questioned the reliability of the early Chinese industrial censuses of the 1910s. They mentioned that the coverage of regions and provinces ranged between 6 and 26, and the number decreased largely in the end of the 1910s because of domestic social disorder. This decrease in coverage may lead to an underestimation of total industrial output. Nevertheless, even with the coverage problem, the use of the data source is still possible, according to Xu and Wu (2003). There are some shortcomings in this industrial census of 1912, although it covers 21 provinces. Firstly, the census misses information on three northern provinces, Tibet, (Inner) Mongolia and Qinghai, and one south province, Guizhou, which, however, were not significantly industrialised in the 1910s. Secondly, some products are not registered in the census. For instance, the census only contains the numbers of factories and employment for the production of machinery, ships and vehicles, metal, and electricity, but no corresponding information on output values. A recent estimation shows that the census covers around 65 per cent of the manufacturing output in 1912 (Guan 2011). Even if we should find a matched product in the missing sector in both China and the UK, *UVRs* will not primarily affect the estimation of manufacturing PPPs since the output share of the missing sector is relatively small. Thus, the problem of coverage in the census of 1912 will not seriously affect the result of this study.[16] We, therefore, believe that the census of 1912 can be used to calculate the real output and labour productivity. [17]

It is essential to use the same data source for prices, output and employment to guarantee the internal consistency of the PPP and labour productivity calculation. By matching products in the manufacturing sectors in both

16. We have used Xu et al. (2017)'s industry GDP estimation to deal with the coverage problem. Their study estimates the output shares of manufacturing branches from different data sources. The substitution for Weight I does not affect the final results in a significant level, though. The new manufacturing PPP based on a different set of weights is 6.171.

17. The choice of the 1912 yearbook also considers data availability and quality. The 1912 yearbook covers relatively more provinces and more sub-industries and products with the data on both output value and quantity, which is necessary for calculating the new indicator of comparative labour productivity.

China and the UK, we were able to find 30 products and sub-industries and seven manufacturing branches to estimate PPPs between the two economies. We may underestimate actual labour productivity in both China and the UK because unmatched products are mainly from newly established capital-intensive industries with higher productivity. Because of the lower coverage ratio for the UK manufacturing sector in the comparison, the level of underestimation may be more significant for the more developed economy. Thus, we may underestimate the productivity difference between China and the UK in the 1910s.

The Chinese industrial census of 1912 defined a factory as an enterprise that hired at least seven workers, which is similar to the definition in the Japanese *Census of Factories* of 1935.[18] However, output data in the Chinese census cover both factories and family workshops that hired less than seven workers. It is not feasible in this study to separate the output of family workshops from the total output. The UK census excludes "domestic workshops" that hired only family members, although without a clear definition of factory employment. A precise cross-country comparison at industrial levels depends on how the "modern" and "traditional" sectors are defined in the official statistics for each country and how and whether we can separate the two. The comparison based on the two censuses may overestimate the productivity difference in the 1910s between China and the UK, because (1) the traditional component of Chinese manufacturing still dominated in size over the modern sector in the 1910s; (2) the productivity of the traditional sector was on average lower than that of the modern sector.

Official statistics may differ in their definitions and concepts, such as gross output value and employment, which can lead to the bias in the productivity comparison. We do not find notable differences between the Chinese census and the UK census on this matter. For instance, the UK census defines employment as "the average number of persons employed on the last Wednesday in January, April, July and October in the factories, together with the number ordinarily employed in the workshops", while the Chinese census defines employment as "the average number of persons employed in one year". The Chinese census only includes gross output, while the UK census provides data on intermediate inputs and net output as well.

We measure the productivity level of China's manufacturing in 1912 relative to the UK manufacturing in 1907. The census years for the comparison differ by five years. Although the choice of benchmark years is partly deter-

18. The Japanese census of factories of 1935 defines a factory as an enterprise that hired five or more workers and used machine power (Yuan, Fukao and Wu 2010). The definition of a factory in the Chinese census of 1912 was preliminary and temporary. Later, China's first Factory Law, passed in 1929, defined a factory as an enterprise that hired at least 30 workers and also employed machine power (Lieu 1955).

mined by data availability, we need to take account of changes of productivity levels in China's manufacturing and the possible effects of business cycles and differences in capacity utilisation. China's real GDP increased annually at around 2 per cent in the period 1907–1910 but quickly decreased back to the 1907 level in the period 1911–1912 (Ma and de Jong 2019). Factory production experienced a rapid increase driven by inputs of capital and labour and by increasing returns, in particular in this early stage of development. However, the growth of the manufacturing sector, including both factories and handicraft workshops, was very slow in the period 1907–1912. If we assume that the increase of Chinese manufacturing was faster than that of UK manufacturing in the period 1907–1912, we may underestimate the gap between the two economies, and this will result in a lower comparative China/UK labour productivity. For now, we do not adjust for the year difference. By comparing these two census years, we still capture the nature of Chinese industrial development on the eve of the First World War relative to the UK level.

Data matching and coverage

For matching products and industries, this study follows the industrial classification of the UK census of 1907. We regrouped the Chinese manufacturing industries into 11 branches, as listed in Table 1. The Chinese census gives detailed product and industry information on a lower level of aggregation, which makes it easy to fit the Chinese industries into the classification used in the UK census. We moved some seed-crushing industries in the Chinese census (e.g., cottonseed oil) to the branch *Chemicals* and others to the branch *Food, Drink and Tobacco.* Future improvement in the classification will be based on the two-digit industries as defined in the ISIC (*International Standard of Industrial Classification*), especially for comparing with modern industrial production.

Following the standard "industry-of-origin" PPP approach, as explained in the methodology section, we matched similar products between China and the UK and then derived prices per unit of product, or unit values (*UVs*), in the national currency of each country. It will be difficult to match products shared between two countries precisely without having detailed information about their characteristics. The Chinese census of 1912 used in this study lacks detailed explanations of products and industries. Hence, other explanatory records have to be used. We relied on two sources for the Chinese manufacturing industry: (1) *Report on a Survey of China's Industry* (NRC 1937) and (2) *Study Materials of Industrial History in Contemporary China*, vol. 4 (Chen 1961). There is a wealth of information in the UK census at the product level.

TABLE 1 ▪ *Product matches and coverage ratios in comparing manufacturing industries, China/UK, 1912/1907*

			Number of matched products and sub-industries	Coverage ratios			
				In gross output value		In employment	
				China, 1912	UK, 1907	China, 1912	UK , 1907
	Total manufacturing	Short forms	30	0.71	0.39	0.62	0.30
1	Food, drink and tobacco	Food	7	0.78	0.64	0.51	0.49
2	Textiles	Textiles	7	0.92	0.89	0.94	0.86
3	Wearing apparel	Wearing apparel	4	0.40	0.26	0.40	0.21
4	Leather and leather products	Leather	1	0.23	0.06	0.23	0.02
5	Chemicals	Chemicals	8	0.85	0.64	0.79	0.60
6	Stone, clay, and glass products	Building materials	1	0.56	0.07	0.55	0.10
7	Paper and printing	Paper	2	0.07	0.15	0.07	0.08
8	Lumber and wood products	Wood	0				
9	Metal industries	Metal	0				
10	Iron, steel, engineering, and shipbuilding	Iron and engineering	0				
11	Miscellaneous		0				

Sources: Constructed by the authors.

This study finds 30 matches of products and sub-industries and classifies them into seven branches. The sample of products ranges from cotton piece goods to chemical products. Table 1 gives the range of coverage in terms of gross output and employment and shows to what extent the Chinese and the UK economies shared similar manufacturing products. We used the number of matches and the coverage ratios to indicate the range of coverage. The calculated coverage ratios are the share of gross output value or employment for matched products and sub-industries in each country. This study covers 70 per cent of the Chinese manufacturing output and 40 per cent of the UK level; 60 per cent of the Chinese manufacturing employment and 30 per cent of the UK level. The coverage ratios vary significantly among branches. There are three branches for which the coverage ratio is higher than or close to 50 per cent for both countries: (1) food, drink, and tobacco, (2) textiles, and (3) chemicals.

The coverage ratios for the manufacturing sector as a whole are different between China and the UK. The differences in coverage are even more significant in this study, compared with the coverage ratios in other pre-WWII productivity studies (Fremdling, de Jong and Timmer 2007) and also pre-WWI productivity studies (Woltjer 2013; Veenstra 2014), in which the differences are usually below 20 percentage points. However, these are comparisons between developed countries. The coverage ratio between a less developed country and a more developed country can vary significantly due to differences in industrial structure and phases of industrial development. In a China/US manufacturing comparison for the 1930s, 35.7 per cent of Chinese products and 17.2 per cent of US products are covered (Wu 2001). In a China/Japan comparison for 1935, about 72 per cent of Chinese products and 30 per cent of Japanese products are covered (Yuan, Fukao and Wu 2010). In the 1910s, China was still in an early stage of industrialisation, compared with the UK, and was slowly recovering from previous social disorder. The industrial structure in China in the 1910s was still biased towards traditional production compared to the UK. As mentioned before, most of the manufacturing production and employment in China centred on simple manufactured goods.

The differences in coverage between the two economies can also be explained by the availability of information on products, the heterogeneity of product and quality across countries, and differences in quantity specifications (units of measurement). The China/UK comparison provides various examples. In Chinese manufacturing, mats and matting production was an important industry which can also be found in the Chinese export reports, but the UK census of 1907 only gives the production value. The Chinese census records the gross output of gloves made from various textiles, while the UK census only reports gloves made from leather. We excluded these two products or sub-industries from the comparison. Silk production is another case. The Chinese census of 1912 lists nine different types of silk products, while there is only one entry of silk products in the UK census of 1907. Thus, we used the aggregated silk output in China and compared this value with the silk output in the UK. Similar procedures have been used to compare oil, liquor and sugar production between the two countries. For paper and printing, we classified the nine different types of paper listed in the Chinese census into two general types as listed in the UK census: first-class writing paper and paper for printing. For these industries, the average levels of the Chinese products are compared with the UK products, which may underestimate productivity differences between the two countries. Further improvements should consider the quality bias and tests for robustness.

Analysing the new levels of prices, productivity and GDP

New manufacturing PPPs

We calculated the gross output PPPs according to the methodology described above and Appendix Table A 1.2 presents the Laspeyres, Paasche and Fisher PPPs from the binary comparisons between China and the UK for the manufacturing industry as a whole and for all matched branches. The estimated PPP for manufacturing in China relative to the UK is 6.14 *Yuan*/Pound. Compared with the market exchange rate in 1912 (9.99 *Yuan*/Pound), the PPP-adjusted relative producer price level for Chinese manufacturing is 0.62 (See Appendix Table A 1.2). This indicator suggests that the price level of the matched products in China was lower than the level measured by the market exchange rate. The lower producer price for China relative to the UK may indicate that non-tradable goods had a lower price level in China than in the UK in the 1910s, as we know from the standard Balassa-Samuelson effect. Productivity growth in the tradable goods sector will eventually raise the price of non-tradable goods when an economy is more involved in foreign trade (Balassa 1964; Samuelson 1964). Therefore, the manufacturing PPP between China and the UK may also indicate different stages of economic development of the two economies. As discussed in previous sections, the UK economy was undoubtedly more developed, industrialised and involved in international trade than the Chinese economy in the early twentieth century.

A further decomposition of the manufacturing sector offers additional insights into the price structure of these two economies. Firstly, the relative prices (*UVRs*) between China and the UK differ across products and sub-industries. For instance, the *UVRs* for sugar and seed oil are over 20, which are far above the branch average of 8.29 in food processing and 14.34 in Chemicals. In the same branches, the *UVRs* for liquor and soap are both around 6. Secondly, the specific pattern of industrial specialisation for a country is reflected in the relative price structure between the two countries. Chinese manufacturing in 1912 focused on food processing (65 per cent), while UK manufacturing in 1907 was concentrated more on textiles (32 per cent) and engineering (22 per cent). PPPs for food-processing and textiles largely determine the manufacturing PPP in this study. Within these branches, considerable structural differences exist, illustrated by the gap between the Paasche and Laspeyres PPPs for branches, especially for food processing. In China, liquor was an important product in food processing, while in the UK, flour was the important one. In this calculation, the Laspeyres PPPs are smaller than the Paasche PPPs for some manufacturing branches, e.g., the chemical industry, which is mainly caused by high *UVRs* between China and the UK

and high weights for China for some products and industries, such as the oil-crushing industry. [19]

According to our new PPP estimates, the gaps between the PPP-implied price level and the market exchange rate vary across industries and products. The gap is relatively small for food processing, leather and paper, but significant for textiles and chemicals. Manufactured products are generally tradable goods, and by nature, their PPPs should be close to market exchange rates (Prasada Rao and Timmer 2003). Although it is difficult to provide a comprehensive explanation, a comparison between the import and export value of certain manufactured products provides some clues to understanding the gap. Taking the trade of textile products in China as an example, in 1912 the import value was 1.28 times the export value, while the ratio between imports and exports decreased to 0.63 in 1935. Cotton piece-goods and cotton yarn took up 88 per cent of the total import value of textiles, while cotton materials and raw silk took up 14 and 57 per cent of the total export value of textiles respectively. Thus, in 1912 the Chinese economy exchanged intermediate goods in textile production for textile manufactures. As discussed previously, the Chinese economy in the 1910s tended to export primary goods, including intermediate inputs for manufacturing, such as cotton materials and raw silk, and to import manufactured products such as cotton piece-goods. The higher demand for imported goods in China than the foreign demand for China's exports may have driven up the exchange rate of foreign currencies. The method of single deflation used in calculating the manufacturing PPP may also contribute to the difference between PPPs and exchange rates.

Labour productivity

Table 2 presents the results of comparative gross labour productivity between China and the UK for different manufacturing branches using the branch-specific PPPs, and a weighted average for the manufacturing industry as a whole. Labour productivity, measured as gross output per worker in this study, reflects the level of capital deepening and the level of technology efficiency, compared with the base country. In general, labour productivity in the Chinese manufacturing of 1912 was around 9 per cent of the UK level of 1907. For all the matched branches, pre-war China's labour productivity lev-

19. From the consumption side, the Laspeyres price index is often greater than the Paasche price index, especially in measuring price changes over time, due to the substitution effect. The PPPs calculated in this study may imply that substitutions between the Chinese and the UK products are not possible. Considering that most of the matched products are tradable, the Laspeyres-Paasche ratio may be related to product mismatching and quality difference. Also, the PPPs calculated here are from the production side.

els were substantially lower than the UK levels. As mentioned above, the coverage problem in comparing a less developed economy with a more developed one may underestimate the difference in labour productivity since in this comparison the matched industries, which are often low-productivity industries, do not represent the manufacturing sector in the more developed economies. Appendix Table A 1.3 compares the levels of gross labour productivity in matched and unmatched branches for the two economies and indicates that in this study the comparison of the matched branches will not significantly misinterpret the difference between the two economies. After all, both of the two economies were at an early stage of industrialisation from a long-term perspective. Taking the timing into consideration, the comparison is still reasonable.

TABLE 2 ▪ *Comparative labour productivity in manufacturing, China/UK, 1912/1907, 1935*

		Comp. *LP* China, 1912/1907		Comp. *LP* China, ca. 1935
	Samples	**1**	**2**	
		UK, 1907 =1	**UK, 1907 =1**	**UK, 1935 =1**
	Total manufacturing	0.086	0.097	0.157
1	Food	0.061	0.053	0.152
2	Textiles	0.027	0.028	0.115
3	Leather	0.016	0.049	0.126
4	Wearing apparel	0.123	0.153	0.190
5	Chemicals	0.024	0.023	0.263
6	Building materials	0.101	0.073	0.382
7	Paper	0.034	0.061	0.278

Sources: See the text, estimated by the authors. Employment is defined as numbers employed rather than hours worked. Fisher PPPs in Appendix Table A 1.2 are used here. For the comparative China/UK labour productivity in 1935 (comp. *LP*), we combined two estimates, the comp. *LP* US/UK ca. 1935 calculated by de Jong and Woltjer (2011) and the comp. *LP* China/US ca. 1935 calculated by Yuan, Fukao and Wu (2010). Sample 1 covers only the 30 matched products and sub-industries. Sample 2 covers the seven matched manufacturing branches, including all the products both matched and non-matched in each branches.

Next, we evaluate whether the Chinese economy experienced a catch-up phase in manufacturing during the early decades of the twentieth century relative to the UK manufacturing. To answer this question, we constructed comparative labour productivity between China and the UK in 1935, based on de Jong and Woltjer (2011) and Yuan, Fukao and Wu (2010). The former provides a relative labour productivity level between the US and the UK (2.24), while the latter provides a relative level between China and the US concerning new factory production (0.07). We then derived an indirect labour productivity level between China and the UK for 1934-35 (0.1568). Here, the

1935 benchmark estimation represents also an upper limit of comparative labour productivity in the manufacturing sector in 1935. The comparison illustrates catch-up in manufacturing of China relative to the UK in the period between 1912 and 1935. However, the catching-up effect may be limited, taking into account the possible underestimation of the comparative China/UK labour productivity in the 1910s relative to the 1935 level, since the 1912 sample includes both factories and handicraft workshops. The value of traditional manufacturing was above two times of the new factory production in the 1910s and even around three times in the 1930s (Liu and Yeh 1965; Ma and de Jong 2019). For most manufacturing branches listed in the table, China's labour productivity improved considerably in the period concerned, except for in the industry of wearing apparel. The production of wearing apparel was already a leading industry in 1912 China in terms of labour productivity.[20] However, a large part of employment stayed in the food-processing and textile industries. Notably, the catching-up effect in this study is in relative terms, taking labour productivity in UK manufacturing as constant.

The industrial development in the period concerned reveals a narrowing of the gap between China and the early industrialised economies. The improvement was not unique to China, especially compared with the pace of industrialisation in Japan. Table 3 puts the investigation into a big picture, including other industrialised economies in the early twentieth century and looks at pre-war China's industrialisation from an international perspective. Referring to labour productivity levels, the performance of China's early manufacturing was even further below the leading industrialised economy, the US, in the 1910s. The manufacturing industry in the selected Western countries experienced difficulties in growth from the 1910s to the 1930s. In contrast, the surge of industrialisation in Japan and China was significant.

20. The estimated labour productivity of wearing apparel for 1912 China is derived from two kinds of matched products compared with the UK: shoes and hats, taking around 40 per cent of the output of wearing apparel in China and 26 per cent in the UK. The process of clothing manufacturing in traditional China differed from the West (and also the quality); therefore, finding comparable product pairs is not easy. Moreover, the 1912 industrial census does not contain the records on foreign enterprises (Guan 2011). Similarly, the new Republican government may not be able to organize an extensive industrial survey in concessions in its first year. This study may underestimate the actual labour productivity in China's clothing manufacturing since modern tailoring for Western garments introduced to Shanghai in the 1910s–1920s was highly concentrated in the International Concession of Shanghai according to Bergère (1990). Thus, this study may overestimate the labour productivity difference in this sub-industry between China and the UK, if the labour productivity of the unmatched products in China, such as shirts, underwear and suits, is considerably higher than the labour productivity of matched products. Since wearing apparel took relatively a small share in manufacturing in both China and the UK, an overestimation should not significantly change the results in Table 2.

TABLE 3 ▪ *Comparative labour productivity in manufacturing, various countries, ca. 1910, 1935 (UK=100)*

	US	Germany	Sweden	Italy	Japan	China
1907	190.0	106.4			20.8	
1911				58.8		
1912						9.7[a]
1913	212.9	119.0	101.6		24.4	
1935	207.8	102.0	97.0	51.4	38.8	15.7[b]

Sources: Collected by the authors. For other industrialised economies, the estimates of comp. *LPs* are from Broadberry (1997), pp. 53-57.
[a] Here we converted the comp. *LP* 1912CN/1907UK in Table 2 to the comp. *LP* 1912CN/1912UK here using the growth rates of UK's real output and employment in manufacturing between 1907 and 1912 (Broadberry 1997, Table A3.1 (a), p. 43).
[b] From Table 2.

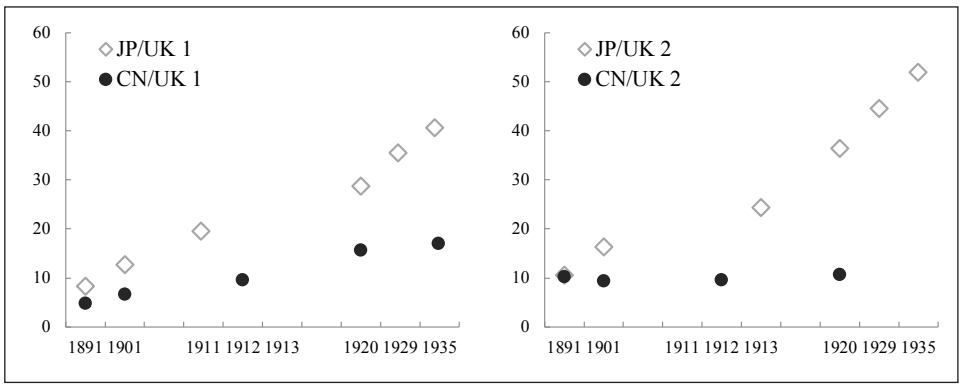
We then estimated the level of comparative China/UK labour productivity for the late nineteenth century, extrapolating from the 1910s benchmark based on real growth rates of manufacturing output per worker for the two economies.[21] Figure 1 presents and compares manufacturing labour productivity in China and Japan, respectively, from the 1890s to the 1930s, both relative to the UK level. The dots in the figure show the increase in comparative China/UK labour productivity in the early stage of industrialisation. According to the previous GDP estimation, two estimations of real growth rates related to China's early manufacturing could be used in the extrapolation. We first applied the real growth of factory production per worker from the 1890s to the 1920s, which gave a higher level of comparative labour productivity in the 1920s. We then used the real growth of manufacturing production per capita, which gave a lower level of comparative labour productivity in the 1920s but a higher level in the 1890s.

This figure shows clearly the divergence in early industrialisation within Asia between China and Japan before the 1930s. For Japan, comparative labour productivity increased from around 10 per cent to more than 40 per cent of the UK level between the 1890s and the 1930s. For China, the increase in comparative labour productivity moved from 5–10 per cent to around 15 per cent. The difference in manufacturing labour productivity between the two economies increased considerably in the early twentieth century and may have already existed in the early 1890s. It is commonly believed that the two economies started the process of industrialisation in the second half of the nine-

21. The choice of the year 1891 is from the estimation of industrial output per worker from previous studies, the earliest available for the comparison between China and Japan.

teenth century. Since then, Japan had embraced industrialisation and shifted quickly towards a more industrialised economy. The catch-up process between Japan and the UK, as illustrated in Figure 1, confirms the success of Japanese industrialisation. In contrast, for the same period, China suffered from natural disasters and wars, including, in particular, the First Sino-Japanese War of 1894-95.[22] Despite various trials and attempts towards industrialisation from both private and public sectors of the economy, including the Self-Strengthening Movement (1861–1895) supported by the Qing state and the constitutional reform (1903–1911), until the 1930s China was by large an

FIGURE 1 ▪ *Comparative labour productivity, Japan/UK, China/UK, the 1890s–1930s (UK=100)Source: DSCD 10 November 1904, p. 967.*



Sources: See the text, constructed by the authors. The comp. *LP* CN/UK for 1891–1920 is calculated based on the 1912 benchmark estimate in Table 3. The comp. *LP* CN/UK for 1935 is also from Table 3. "CN/UK 1" is calculated from real growth rates of China's factory production per worker. "CN/UK 2" is calculated from real growth rates of China's manufacturing production per capita, including both traditional and modern production. The data on China's real growth rates in factory production and manufacturing output are from the GDP estimation in Ma and de Jong (2019). "JP/UK 1" is derived from the 1935 estimate of comp. *LP* in Broadberry, Fukao and Zammit (2015). "JP/UK 2" is derived from the 1913 estimate of comp. *LP* in Broadberry (1997). The real growth rates of output per worker for the UK and Japan are also from Broadberry, Fukao and Zammit (2015). Since the UK and Japan's output both include mining, the figure may overestimate the difference between China and Japan, if the labour productivity in mining was higher than in manufacturing.

22. This study shows the divergence in early industrialisation between China and Japan possibly started in the early 1890s. This finding may inspire a further investigation into the role of the 1894-95 Sino-Japanese War in this divergence process since the 1890s. As argued in Ma (2008), China's defeat in the war and the subsequent Shimonoseki Treaty "set off the first major wave of Chinese industrialisation" (p. 372). The treaty of Shimonoseki "granted foreigners the right to establish factories in the treaty port, lifting the floodgate of foreign direct investment in China and indirectly legitimizing Chinese modern enterprises" (Ma 2008, p. 372). Although the number of factories established per year continued to increase after 1894 (Zhang 1989), the competition from foreign factories might render domestic industrial development into an unfavorable situation which may delay the process of technology adoption and capital deepening afterwards. If the divergence in industrialisation happened before the war, China's defeat might be the result of the delayed industrialisation rather than the cause.

agrarian economy (Ma 2008). Considering the change before the 1910s in comparative manufacturing labour productivity between China and the UK as shown in Figure 1, we may as well conclude from an optimistic viewpoint that economic and social reforms that had been changing economic and political institutions during the late Qing period at least might not widen the gap before the collapse of the Qing Empire.

Following the same procedure, we calculated regional manufacturing PPPs and comparative labour productivity for regions within China relative to the UK. Considering the economic scale, comparing a region within China with the UK should be a more reasonable approach; the comparison between the Yangzi delta area and England, carefully designed by Pomeranz (2000), not only illustrates the timing of "the great divergence" but also indicates a future direction methodologically for comparative research in economic history. For instance, we can compare the labour productivity level in the lower Yangzi delta with that of the UK at the early stage of China's industrialisation.

Based on the new benchmark estimation, we can then describe pre-war China's industrialisation at regional levels. The estimation of labour productivity for the manufacturing sector as a whole may average out extreme values among the different branches, such as the industry of wearing apparel. Likewise estimating labour productivity for the whole economy may also average out extreme values among regions. We regrouped the 21 provinces and the capital city in the 1912 industrial census into nine regions and repeated the calculation of comparative labour productivity in Section 3. Note that regional comparative labour productivity indicates the difference between a region of China and the UK, in which way we provide a consistent comparison across regions within China.

Table 4 lists the estimated comparative labour productivity at regional levels. Northeast China and the Middle Yangzi region were more advanced in manufacturing among regions in 1912 China, with higher levels of comparative labour productivity than the national average level. The next follower in the ranking is the Lower Yangzi delta.[23] As we know from historiography, there were four centres of industrialisation in pre-war China in the 1920s–1930s: Northeast China, Middle Yangzi, Lower Yangzi and South China. According

23. Since the 1912 industrial census might fail to include industrial activities in concessions in China, we may underestimate the actual manufacturing labour productivity in the lower Yangzi delta relative to other regions, if labour productivity in the concessions in the lower Yangzi delta was significantly higher than in other concessions, for instance, in Northeast China and the Middle Yangzi region. We may underestimate labour productivity for the wearing apparel industry in the lower Yangzi delta because factories with a higher level of labour productivity might be concentrated in the concessions. To what extent this underestimation affects the ranking of regional manufacturing productivity will be decided by the share of the wearing apparel industry in manufacturing in the lower Yangzi delta relative to other regions.

to this study, at least two regions of the four were already at a leading position in 1912. Especially according to the estimated comparative labour productivity, the industrial performance in Northeast China in the 1910s was very close to the Japanese level of the same period (above 0.20, as shown in Table 3). As for the lower Yangzi delta, the status in 1912 was not as unique as considered in the literature. In terms of total output and the scale of industrial production, the Lower Yangzi region was known as the most advanced in the Chinese economy during the early twentieth century and also stood at the centre of the regional picture of China's industrialisation (Ma 2008).[24] This study otherwise intends to reveal the regional variation in China's early industrialisation in terms of output per worker. The differences in regional manufacturing productivity found in this study may be caused by regional differences in production structure between new factory industries and traditional handicrafts.[25] Following the discussion in Kubo and Grove (2022), further examinations of the relationship between new and traditional industries in regions within China should help to explain the regional productivity differences of the early twentieth century.

In labour productivity, Northeast China had an absolute advantage in the textile industry rather than in the lower Yangzi delta. In Middle Yangzi, the leading industry is food processing; it had a long history as one of the centres of China's agricultural production. A relatively low level of labour productivity in food processing seems to explain the position of the lower Yangzi delta in the ranking. Note that the involvement in international trade and the export-import pattern may also affect the determination of the leading industries in a given region, different from those regions emphasising domestic production.

To better illustrate the regional distribution of China's manufacturing in the 1910s, we also calculated comparative labour productivity at provincial levels based on regional manufacturing PPPs estimated above. Figure 2 shows the result and indicates that regional variation was an important feature of China's early industrialisation before WWII. The figure presents three provinces which had a level of comparative labour productivity similar to the Jap-

24. Ma (2008) estimated per capita GDP (NDP) of the Lower Yangzi region, offered a sectoral decomposition of the 1930s GDP estimate, and provided a comprehensive study of the economic and political institutions in early-twentieth-century China.

25. The 1912 industrial census contains both new factory industries and traditional small-scale handicrafts; however, based on the census data, it is not possible to calculate the output or productivity ratio at regional levels. To examine regional production structure in the 1910s, instead we calculated the proportion of factories in manufacturing including both factories and handicraft workshops at provincial levels. Northeast China had a higher proportion of factories in manufacturing in the 1910s, although the total number of factories and handicraft workshops was considerably larger in Jiangsu and Guangdong province. This calculation indicates that in the 1910s the leading region or province in terms of manufacturing productivity tended to have more factories in the manufacturing sector.

anese level (above 0.20): two provinces in Northeast China, Fengtian and Heilongjiang, and Shanxi province.[26] Shanxi province was famous for the Shanxi bankers and the cross-national financial services in the Qing period. In the 1912 industrial census, around 20 per cent of the manufacturing labour force was in the metal industry. This finding may imply a higher level of industrial development in Shanxi province. Besides the above mentioned three provinces, there were another five among the 21 provinces with a level of comparative labour productivity higher than the national average: Shandong province in north China, Hunan and Jiangxi province in central China, and one province in Northeast China, Jilin. The figure compares comparative labour productivity and GDP per capita at provincial levels in the 1910s. Among the five wealthiest provinces in terms of GDP per capita, only one also performed better in manufacturing. Therefore, in pre-war China, the connection between manufacturing industry and the overall economic performance seems to be less clear at provincial levels.

TABLE 4 ▪ *Comparative labour productivity in manufacturing, regions of China/UK, ca. 1910*

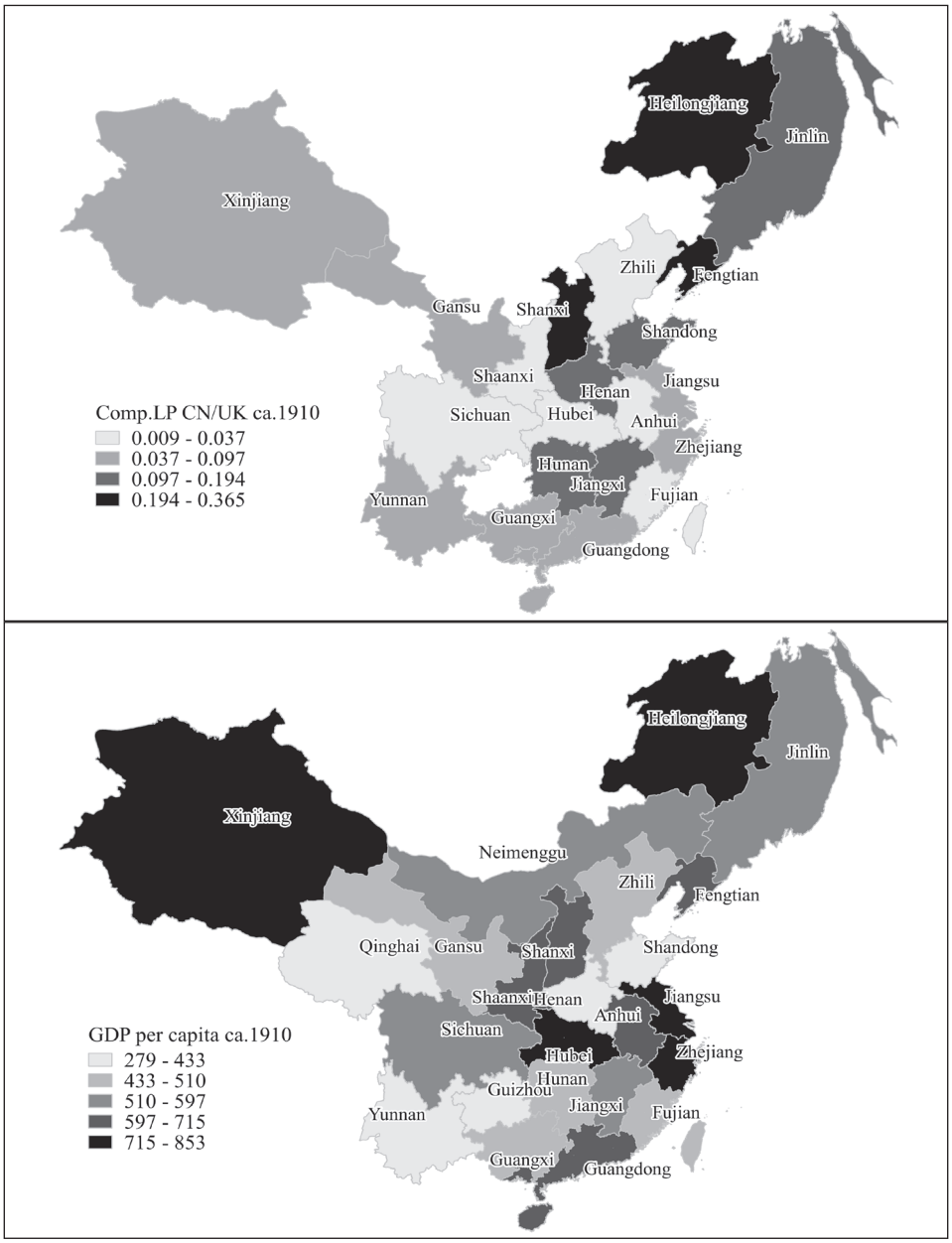
	China	Northeast China	North China	Northwest China	Lower Yangzi	Middle Yangzi	Upper Yangzi	Southwest China	South China	Southeast China
Manufacturing	0.097	0.239	0.045	0.060	0.066	0.132	0.009	0.053	0.054	0.013
Food	0.053	0.073	0.117	0.057	0.027	0.086	0.005	0.028	0.025	0.003
Textiles	0.028	0.377	0.008	0.016	0.044	0.050	0.007	0.035	0.055	0.057
Leather	0.049	0.063	0.014	0.010	0.004	0.018	0.018	0.006	0.052	0.028
Wearing apparel	0.153	0.388	0.305	0.020	0.144	0.254	0.156	0.315	0.240	0.470
Chemicals	0.023	0.063	0.004	0.017	0.036	0.009	0.011	0.005	0.036	0.014
Building materials	0.073	0.211	0.073	0.058	0.199	0.077	0.107	0.050	0.037	0.101
Paper	0.061	0.271	0.177	0.208	0.042	0.080	0.039	0.022	0.150	0.083

Sources: Estimated by the authors. The estimate of comp. *LP* for China as a whole is from Table 2.

"Northeast China" covers Fengtian, Heilongjiang and Jilin province; "North China" covers the capital city, Zhili, Shandong and Henan province; "Northwest China" covers Shanxi, Shaanxi, Gansu and Xinjiang province; "Lower Yangzi" covers provinces: Jiangsu, Zhejiang and Anhui; "Middle Yangzi" covers Jiangxi, Hunan and Hubei province; "Upper Yangzi" only covers Sichuan province; "Southwest China" covers only Yunnan province; "South China" covers Guangdong and Guangxi province; "Southeast China" covers only Fujian province. The map in Appendix 3 shows the regions and provinces within China. For the classification of "macroregions" in pre-war China, see section 2.2.

26. The three provinces, Fengtian, Heilongjiang and Shanxi, are the top three provinces in terms of the factory proportion in manufacturing.

FIGURE 2 ▪ *Regions within China: comparative labour productivity in manufacturing and GDP per capita*



Sources: Constructed by the authors. The two figures are based on the map of 1820 China, from China Historical GIS data V4 (CHGIS, Cambridge: Harvard Yenching Institute and Fudan Center for Historical Geography, January 2007). The figure on the left shows the distribution of provincial labour productivity relative to the UK estimated by this study. This figure only shows the provinces analysed in this study. The figure on the right shows regional GDP per capita of 1912/18 estimated by Caruana-Galizia and Ma (2016).

Conclusion

This study fits in the literature on long-term comparative economic performance by providing a new benchmark estimate between Chinese and UK manufacturing in the 1910s. Based on new quantitative evidence, the study adds new insights to the previous understanding of regional differences in China's early industrialisation. We summarise the findings and point out some limitations that need to be taken up in future research.

The benchmark estimation revealed a level of China's labour productivity in manufacturing in 1912 of around 9 per cent of the UK level in 1907. A higher level of comparative Chinese labour productivity was found in 1935. Comparing the two estimations leads to the conclusion that industrialisation in China during the years between 1912 and 1935 did narrow the gap in relative terms with the more developed economies. However, the catch-up in manufacturing in the 1910s–1930s relative to early industrialised Western economies was not unique to China. A faster catch-up process was found in Japanese industrialisation, which contributed to the divergence in the industrial sector between Asian economies. The estimated manufacturing labour productivity also indicates that the divergence between China and Japan may have already existed in the early 1890s and significantly enlarged in the early twentieth century.

By calculating regional labour productivity relative to the UK, this study provides a new indicator of industrial performance and presents a regional picture of Chinese industrialisation different from those derived from the comparison of total output. Concerning manufacturing output per worker in 1912, the lower Yangzi delta seemed to be not very different from other regions. In contrast, Northeast China and the vast central region already stood out in that year. We may underestimate the actual industrial performance in the lower Yangzi delta and leave it with a third place in the ranking. The data quality of the industrial census should be considered; sensitivity tests should be included to assess the extent to which the results will be affected by the availability and quality of historical data. Moreover, future research into the relationship between modern industries and traditional handicrafts at regional levels should help to explain regional differences in labour productivity.

This study compares the Chinese and UK economies based on the matched goods and branches in the manufacturing sector. Data coverage remains a concern in this type of quantitative historical studies. In comparing less-developed with more-developed economies, it is difficult to find a large number of identical goods necessary to make a reliable labour productivity comparison. Two improvements are now within reach. Japan can be set as the reference economy in comparing the catch-up process in pre-war industrialisation between Asian economies. Similarly, in comparing regional industrial development within China, the Yangzi delta region can be set as the reference economy. Quality differences in

product matching will be a challenge in a historical context. The comparison requires a product-level investigation into both economies, especially when the industries of the two economies were at different stages of development.

In this study, the comparison focuses on private manufacturing productivity. However, state intervention and direct investment formed an important part of the early industrialisation in Asia before WWII. For pre-war China, we would like to include the productivity performance of state-owned factories and state-directed investments in future research and then compare the industrial performance of the public sector with that of the private sector. This improvement would help us to get a complete understanding of China's early industrial development and help to interpret the policy-directed process of industrialisation in modern China.

Author contribution statement

Ye Ma: framework, methodology, software and code, formal analysis, investigation, dataset, writing, visualization.
Herman de Jong: framework, methodology, formal analysis, writing, supervision.
Yi Xu: framework, dataset, investigation.

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Appendix 1. Data and calculation procedures

TABLE A 1.1. ▪ *Gross output PPPs in manufacturing, China/UK, 1912/1907*

	China/UK	China *Weights*			UK *Weights*			*Paasche*	Laspeyres	Fisher average
	UVRs	I	II	III	I	II	III	CN *weights*	UK *weights*	
Manufacturing, matched products and sub-industries								5.7686	6.5441	**6.1441**
Food, drink, and tobacco		**0.6482**			**0.1920**			**4.6395**	**14.8137**	**8.2902**
flour	30.1230		0.0220			0.3530		0.0332	30.1230	
fruit, canned or bottled	1.5094		0.0484			0.0880		0.6625	1.5094	
sugar	20.1876		0.0395			0.0665		0.0495	20.1876	
beverage: alcohol	6.6826		0.8545			0.3634		0.1496	6.6826	
tobacco snuff	2.7035		0.0356	0.0004		0.1290	0.0131	1.4871	2.1376	
cigarettes	4.8445			0.0514			0.3494			
other	0.6422			0.9482			0.6375			
Textiles		**0.0978**			**0.2230**			**6.2736**	**6.6763**	**6.4718**
cotton: piece-good	6.3203		0.4531			0.5880		0.1582	6.3203	
woollen fabrics product	6.9788		0.0083	0.1235		0.2556	0.9239	0.0923	8.3058	
carpets	25.0896			0.3393			0.0730			
rug	8.7891			0.5372			0.0031			
Jute, hemp, linen: piece-good	2.7347		0.0701			0.1081		0.3657	2.7347	
silk	7.1494		0.4046			0.0176		0.1399	7.1494	
Hosiery: hose	13.5644		0.0639			0.0306		0.0737	13.5644	
Leather and leather products		**0.0087**			**0.0230**			**11.9792**	**11.9792**	**11.9792**

(Continued on next page)

		China/UK	China *Weights*			UK *Weights*			*Paasche*	Laspeyres	Fisher average
		UVRs	I	II	III	I	II	III	CN *weights*	UK *weights*	
skins: fellmongery		11.9792		1.0000			1.0000		0.0835	11.9792	
Wearing apparel			**0.0306**			**0.0720**			**5.0923**	**4.9095**	**5.0001**
boots and shoes		5.1576		0.6229			0.8173		0.1939	5.1576	
hats	hats: felt	3.1627		0.3771	0.0811		0.1827	0.5697	0.2005	3.7999	
	hats: straw	4.3893			0.0591			0.3138			
	hats: other (silk)	5.3279			0.8599			0.1165			
Chemicals			**0.0972**			**0.0500**			**16.7669**	**12.2639**	**14.3397**
seed oil		23.1251		0.8432			0.2700		0.0432	23.1251	
Acid	nitric	11.4223		0.0267	0.9958		0.5004	0.0956	0.0876	9.3389	
	sulphuric	9.1187			0.0042			0.9044			
soap	household laundry	5.7400		0.0050	0.8424		0.1845	0.8501	0.1907	5.4207	
	toilet	3.1621			0.1212			0.1298			
	polishing and scouring	6.5092			0.0364			0.0200			
candle		6.1275		0.1211			0.0425		0.1632	6.1275	
paraffin wax		33.2742		0.0040			0.0026		0.0301	33.2742	
Stone, clay, and glass products			**0.0330**			**0.0780**			**7.7544**	**7.7544**	**7.7544**
bricks		7.7544		1.0000			1.0000		0.1290	7.7544	
Paper and printing			**0.0127**			**0.0410**			**9.9111**	**8.8779**	**9.3802**
paper: fine		5.9710		0.0649			0.3417				
paper: printing		10.3865		0.9351			0.6583				

Sources: Constructed by the authors, from the Chinese census of 1912 and the UK census of 1907.

TABLE A 1.2 ▪ *PPPs in manufacturing, China/UK, 1912/1907*

		Gross output PPP (*Yuan*/Pounds)			
		Paasche	Laspeyres	Fisher	Relative to exchange rates
	Total manufacturing	5.77	6.54	6.14	0.62
1	Food	4.64	14.81	8.29	0.83
2	Textiles	6.27	6.68	6.47	0.65
3	Leather	11.98	11.98	11.98	1.20
4	Wearing apparel	5.09	4.91	5.00	0.50
5	Chemicals	16.77	12.26	14.34	1.44
6	Building materials	7.75	7.75	7.75	0.78
7	Paper	9.91	8.87	9.38	0.94

Sources: See text, constructed by the authors from the Chinese census of 1912 and the UK census of 1907. See Appendix Table A 1.1 for more information. Fisher PPP is a geometric mean of Laspeyres and Paasche PPPs for manufacturing PPPs and also for branch PPPs.

Relative to exchange rates: Fisher gross output PPPs/ official exchange rates. In 1912, 1 pound =9.99 Chinese *Yuan* (Hsiao 1974, p. 187).

Table A 1.3 ▪ *Gross labour productivity in manufacturing, China/UK, 1912/1907*

		China, 1912, *Yuan*		China, 1912, PPP-adjusted, Pounds		the UK, 1907, Pounds	
	Samples	**1**	**2**	**1**	**2**	**1**	**2**
	Manufacturing, Matched branches	186.0	163.1	30.3	26.5	353.6	272.4
1	Food	414.6	270.4	50.0	32.6	816.7	619.9
2	Textiles	47.7	48.8	7.4	7.5	276.5	266.2
3	Leather	240.4	240.4	20.1	20.1	1247.7	412.3
4	Wearing apparel	109.2	109.2	21.8	21.8	178.3	142.6
5	Chemicals	211.8	196.3	14.8	13.7	624.8	586.9
6	Building materials	93.7	91.8	12.1	11.8	119.6	161.3
7	Paper	107.1	107.1	11.4	11.4	332.6	188.4
	Non-matched branches		160.0				288.9
8	Wood						194.0
9	Metal		188.9				816.5
10	Iron and engineering						263.1
11	Miscellaneous		143.5				176.8

Sources: See text, constructed by the authors from the Chinese census of 1912 and the UK census of 1907. The new manufacturing PPPs estimated in this study are used to calculate PPP-adjusted labour productivity between China and the UK. Sample 1 covers only the 30 matched products and sub-industries. Sample 2 covers the seven matched manufacturing branches, including all the products both matched and non-matched in each branches.

Appendix 2. Comparisons between the economies of China and the UK in the early twentieth century

TABLE A 2.1 ▪ *Economic levels and structure, China/UK, the early twentieth century*

	China, 1907	China, 1912	China, 1935	UK, 1907	UK, 1911
Total GDP in mil., current prices (in national currencies) [a]	10,042	15,071	28,661	2,113	2,227
Total GDP in mil., Pounds (Converted by exchange rates *Yuan*/ pound)	2,237	2,263	1,943	2,113	2,227
Per capita GDP, current prices (in national currencies) [a]	24.14	34.86		48.32	49.20
Per capita GDP, current prices (in Chinese *Yuan*)	36.19	52.26	54.18		
Per capita GDP, Pounds (Converted by exchange rates)	3.62	5.23	3.67	48.32	49.20
Per capita GDP, constant prices (in 1990 int. dollars)	572	557	619 [b]	4,679	4,762
Structure of GDP (%)	100	100	100	100	100
Agriculture	71.2	71.8	62.5	7.2	7.0
Industry	6.3	5.7	12.7	38.1	36.9
Mining	0.9	0.3	0.9	6.6	
Manufacturing	4.7	4.7	10.1	26.3	
Construction [c]	0.6	0.6	1.7	5.2	
Services	22.6	22.6	24.8	54.7	56.2

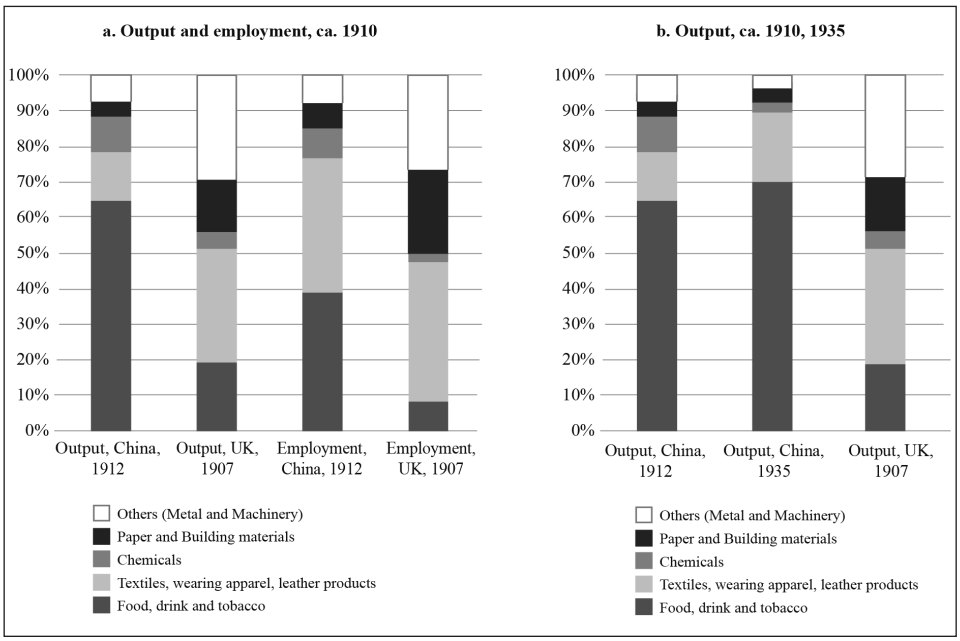
Sources: Constructed by the authors. The first two columns are from Ma and de Jong (2019). The levels of 1907 and 1912 GDP are in terms of silver *taels,* i.e. the currency of pre-war China. The third one is based on Yuan, Fukao and Wu (2010), Table 1, p. 327. The GDP levels of 1935 China are in terms of Chinese *Yuan*. The UK GDP and per capita GDP in current prices are from Officer and Williamson (2014). The UK per capita GDP in 1990 int. dollars is from the Maddison Project (Bolt and van Zanden 2014). The GDP structure for the 1907 UK is from Feinstein (1976), and the 1911 structure is calculated according to the index of sector output at constant factor cost (1913=100). The GDP structure for China is measured by the shares of value-added of the three sectors at current prices.

[a] In 1912, officially 1 Chinese *Yuan*= 0.667 *taels* (Agriculture and Industry Department, 1914); 1 pound =9.99 Chinese *Yuan* (Hsiao 1974, p. 187). In the 1930s, 1 *tael*= 1.5 Chinese *Yuan* (Perkins 1969, p. 2).

[b] From Fukao, Ma and Yuan (2007), Figure 1, p. 514.

[c] Including utilities and transportation construction.

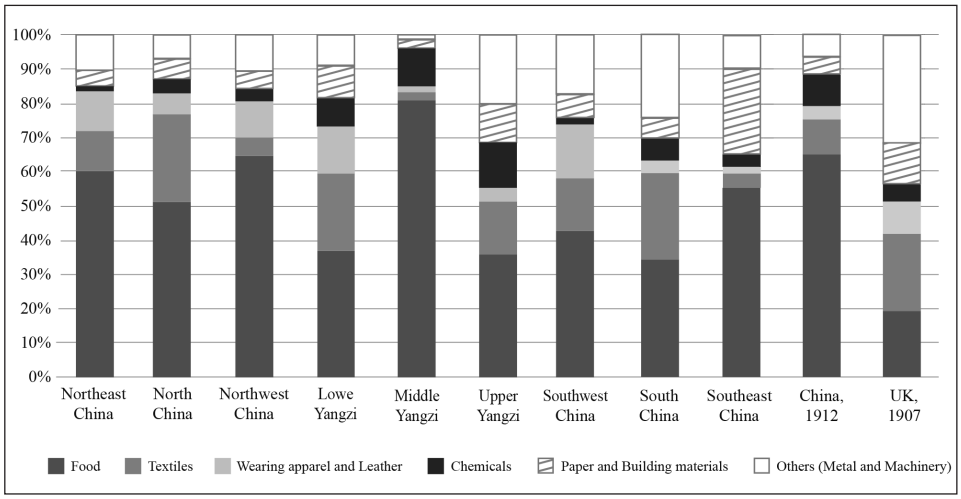
FIGURE A 2.1 ▪ *Manufacturing structure, China, 1912, 1935, and the UK, 1907*



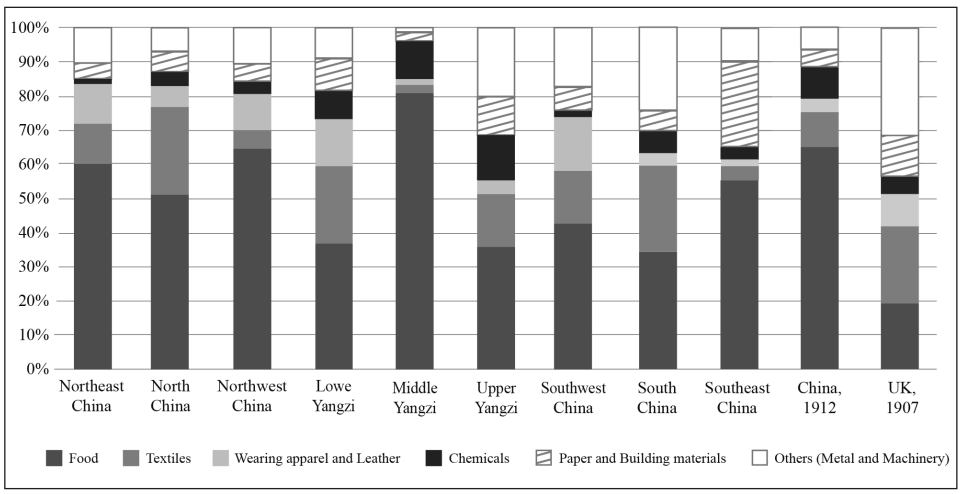
Sources: Constructed by the authors. The data for 1912 China and 1907 UK are from the two censuses used in this study. The data for 1935 China is from Yuan, Fukao and Wu (2010), Table 2. For China, the manufacturing data include both factories and handicraft workshops. Output shares are calculated from the output value in nominal terms of national currencies. Employment is defined as numbers employed rather than hours worked. The category, i.e. paper and building materials, also covers lumber and wood products. The category "others" includes metal products, iron, steel, engineering, shipbuilding and also the miscellaneous. Here, we grouped China's manufacturing industries into five categories from labour-intensive to capital-intensive industries.

FIGURE A 2.2 ▪ *Manufacturing structure, regions within China, 1912, and the UK, 1907*

a. Output Shares

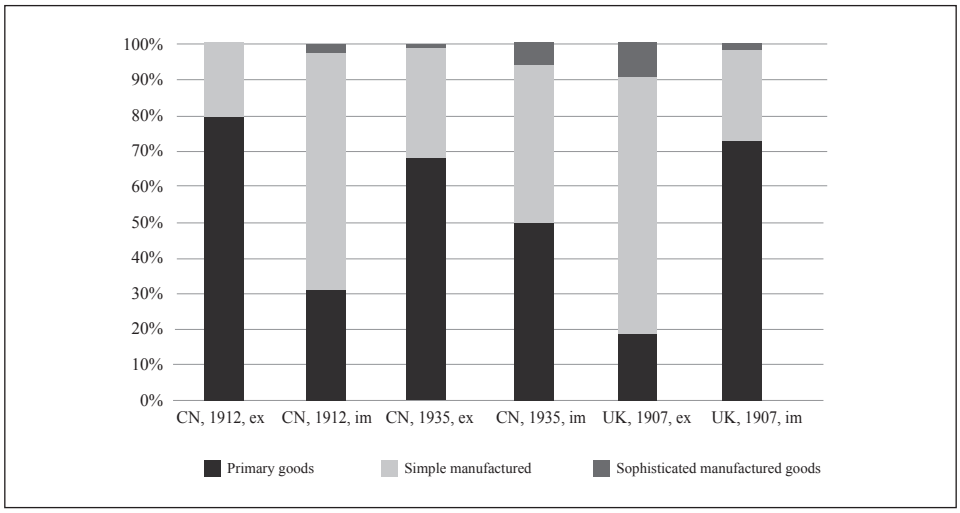


b. Employment shares



Sources: Constructed by the authors. The regional data of China are from the agricultural and industrial census of 1912 China. The 1912 census of China covers 21 provinces. "Northeast China" covers Fengtian, Heilongjiang and Jilin province; "North China" covers the capital city, Zhili, Shandong and Henan province; "Northwest China" covers Shanxi, Shaanxi, Gansu and Xinjiang province; "Lower Yangzi" covers provinces: Jiangsu, Zhejiang and Anhui; "Middle Yangzi" covers Jiangxi, Hunan and Hubei province; "Upper Yangzi" covers only Sichuan province; "Southwest China" covers only Yunnan province; "South China" covers Guangdong and Guangxi province; "Southeast China" covers only Fujian province.

FIGURE A 2.3 ▪ *Export and import shares, China, 1912, 1935, and the UK, 1907*



Sources: Constructed by the authors. The trade data for 1912 China are reorganised from Yang and Hou (1931). The trade data for 1935 China is from Yuan, Fukao and Wu (2010), Table 3. The trade data for 1907 UK are based on the annual reports from H. M. Stationery Office, London. Value shares are calculated in nominal terms of national currencies in millions.

APPENDIX 3 ▪ *Regions and provinces within China*

Sources: Constructed by the authors. The map shows the 21 provinces analysed in this study and the regions discussed in Table 4. This map is based on the map of 1820 China, from CHGIS (2007). See the grouping of provinces in section 2.2.

■

Measuring China's performance in the world economy. A benchmark comparison between the economies of China and the UK in the early twentieth century

Abstract

This study draws attention to China's industrialisation in the 1910s and gives a new starting point to review early industrial development before WWII. It provides the first estimates of purchasing power parity (PPP) converters for the early 1910s between China and the UK. Statistical indicators, comparative output and labour productivity, are then calculated to address queries regarding the relative level that China's early manufacturing had reached at the end of the Qing Empire (1911) – after half a century's attempt to catch up with the West since the 1860s. By comparing the new 1910s benchmark with that of the 1930s, we also for the first time present the development of China's early manufacturing in the inter-war period. We find that its growth in the inter-war period narrowed the gap with the early industrialised economies; however, the improvement was not unique for China. The new estimation of labour productivity also provides a regional picture of China's early industrial performance, different from those derived from the estimation of total output.

Keywords: China, early 20th century, industrialisation, labour productivity

JEL Codes: E23, E30, N15, N9

■

Midiendo el desempeño de China en la economía mundial. Una comparación entre las economías de China y el Reino Unido a principios del siglo XX

Resumen

Este estudio se centra en la industrialización de China antes de la Segunda Guerra Mundial y ofrece un nuevo punto de partida para revisar procesos de desarrollo industrial temprano. Proporciona las primeras estimaciones sobre factores de conversión de la paridad de poder adquisitivo (PPA) entre China y el Reino Unido para principios de la década de 1910. A continuación, presenta cálculos sobre indicadores estadísticos, producción comparada y productividad del trabajo, con el objetivo de dar respuesta a preguntas sobre el nivel relativo que, después de medio siglo de intento de convergencia con Occidente, había alcanzado la incipiente manufactura china al final del imperio Qing (1911). A partir de una comparación entre el nuevo año de referencia para la década de 1910 y los años de 1930, este trabajo también muestra, por primera vez, el desarrollo de la temprana actividad manufacturera china durante los años de entreguerras. Observamos que durante este período el crecimiento redujo la distancia entre China y las economías industrializadas; sin embargo, esta mejora no fue única para la China de preguerra, especialmente si se compara con el ritmo de industrialización del Japón de la era Meijí. La nueva información para 1911 también ayuda a mostrar el patrón regional del crecimiento industrial de la China de preguerra.

Palabras clave: China, principios del siglo xx, industrialización, productividad laboral

Códigos JEL: E23, E30, N15, N9

■

Mesurant el desenvolupament de la Xina en l'economia mundial. Una comparació entre les economies de la Xina i el Regne Unit a principis del segle xx

Resum

Aquest estudi se centra en la industrialització de la Xina abans de la Segona Guerra Mundial i ofereix un nou punt de partida per revisar processos de desenvolupament industrial primerenc. Proporciona les primeres estimacions sobre factors de conversió de la paritat de poder adquisitiu (PPA) entre la Xina i el Regne Unit per a principis de la dècada del 1910. A continuació, presenta càlculs sobre indicadors estadístics, producció comparada i productivitat del treball, amb l'objectiu de donar resposta a preguntes sobre el nivell relatiu que havia assolit la incipient manufactura xinesa al final de l'Imperi Qing (1911) després de mig segle d'intent de convergència amb Occident. A partir d'una comparació entre el nou any de referència per a la dècada del 1910 i els anys de 1930, aquest treball també mostra, per primera vegada, el desenvolupament de l'activitat manufacturera xinesa primerenca durant els anys d'entreguerres. Observem que durant aquest període de creixement es va reduir la distància entre la Xina i les economies industrialitzades; tanmateix, aquesta millora no va ser única per a la Xina de preguerra, especialment si es compara amb el ritme d'industrialització del Japó de l'era Meiji. La nova informació per a l'any 1911 també ajuda a mostrar el patró regional del creixement industrial de la Xina d'abans de la Primera Guerra Mundial.

Paraules clau: Xina, principis del segle xx, industrialització, productivitat laboral

Codis JEL: E23, E30, N15, N9