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Abstract: Chinese GDP per capita fluctuated at a high level during the Northern Song and Ming dynasties before trending downwards during the Qing dynasty. China led the world in living standards during the Northern Song dynasty, but had fallen behind Italy by 1300. At this stage, it is possible that parts of China were still on a par with the richest parts of Europe, but by 1750 the gap was too large to be bridged by regional variation within China and the Great Divergence had already begun before the Industrial Revolution.

JEL classification: E100, N350, O100
Keywords**:** GDP Per Capita; Economic Growth; Great Divergence; China; Europe

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I. INTRODUCTION

As a result of recent advances in historical national accounting, estimates of GDP per capita are now available for a number of European economies back to the medieval period, including Britain, the Netherlands, Italy and Spain (Broadberry, Campbell, Klein, Overton and van Leeuwen, 2015; van Zanden and van Leeuwen, 2012; Malanima, 2011; Álvarez-Nogal and Prados de la Escosura, 2013). A number of recent studies have also extended this approach to Asian economies, including India and Japan (Broadberry, Custodis and Gupta, 2015; Bassino, Broadberry, Fukao, Gupta and Takashima, 2014). So far, however, the economy which has been at the centre of the Great Divergence debate, China, has been conspicuously absent from this approach.

This paper uses historical national accounting methods to estimate GDP for China during the Northern Song, Ming and Qing dynasties, and combines the resulting series with population estimates to produce GDP per capita. The indirect or short-cut method of Malanima (2011) and Álvarez-Nogal and Prados de la Escosura (2013), which estimates agricultural output from the demand side cannot be used here, since China has only very patchy real wage data before the nineteenth century. However, agricultural output can be estimated from the supply side using the direct sectoral approach of Broadberry, Campbell, Klein, Overton and van Leeuwen (2011; 2015) for Britain. This involves building on the pioneering work of Ho (1959), Perkins (1969) and others, who assembled data on population, cultivated land and grain yields, and also subsequent developments by Liu and Hwang (1979), Maddison (1998) and others, who have further refined the estimates. The indirect approach derives non-agricultural output from the urbanization rate, which is taken as an indication of an agricultural surplus to support industry and services production. Although Rozman's (1973) data on urbanization are available for China from the Northern Song to the

Qing dynasties, sufficient data exist to provide separate series for a number of industries and services, as in the direct approach of Broadberry, Campbell, Klein, Overton and van Leeuwen (2015). For industry, our estimates incorporate production data from official sources supplemented by individual industry studies produced in both English and Chinese.[1] For services, we make use of data on the size of the state and the volume of marketed output in the commercial sector as well as the urbanisation rate for housing and other services. These estimates of Chinese GDP per capita can be used to compare economic performance during the Northern Song, Ming and Qing dynasties. China's GDP per capita fluctuated at a high level during the Northern Song and Ming dynasties, before trending downwards during the Qing dynasty.

The results also shed new light on the timing of the Great Divergence. Our estimates indicate that Northern Song China was richer than Domesday Britain circa 1090, but Britain had caught up by 1400. Also, China as a whole was certainly poorer than Italy by 1300, but at this stage, it is quite possible that the richest parts of China were still on a par with the richest parts of Europe. By the seventeenth century, however, China as a whole was already substantially behind the leading European economies in the North Sea area, despite still being the richest Asian economy. Even allowing for regional variation within China, it is clear that the Great Divergence between China and Western Europe was already well under way by the first half of the eighteenth century, before the start of the Industrial Revolution. Although this clearly contradicts the early statements of California School writers such as Pomeranz (2000) and Wong (1997), it is broadly consistent with the later views of Pomeranz (2011), who accepts that his early claim of China on a par with Europe as late as 1800 was exaggerated,

[1] For example, Hartwell's (1966) pioneering study of the iron industry during the Northern Song dynasty has been substantially revised by Liu (1993).

and is now willing to settle for an earlier date between 1700 and 1750.[2] We think this is encouraging, because it shows how engagement between researchers using primarily quantitative methods and those who tend to put more weight on qualitative methods can result in a new consensus that challenges the original position of both sides in a major debate. The California School were right to claim that, taking account of regional variation, historical differences in economic performance between China and Europe were much less than was once thought. However, the early claims of the California School went a bit too far: China and Europe were already on different trajectories before the Industrial Revolution, as European economic historians have traditionally maintained. The Great Divergence did not begin as late as the nineteenth century.

II. CHINESE DATA SOURCES

Until recently, most accounts of economic growth before the mid-nineteenth century were largely qualitative. That changed with Maddison's (2001), *The World Economy: A Millennial Perspective*, published shortly after Pomeranz's (2000) *The Great Divergence*. However, Maddison's medieval and early modern estimates can best be described as controlled conjectures, rather than estimates derived from data collected at the time. This has had an unfortunate effect of leaving some historians with the impression that quantification of the Great Divergence is not possible because of the absence of useable quantitative data (Deng and O'Brien, 2016a; 2016b). In fact, however, medieval and early modern Europe and Asia were much more literate and numerate than is often thought, and left behind a wealth of data in documents such as government accounts, customs accounts, poll tax returns, parish registers, city records, trading company records, hospital and educational establishment

[2] This means that it was not simply the result of factors such as coal and ghost acres, as Pomeranz (2000) had argued, but was a longer run dynamic process, which can be seen as linked to the underlying institutional differences emphasised by western economic historians (Weber, 1930; Pirenne, 1939; Polanyi, 1944; Landes, 1969).

records, manorial accounts, probate inventories, farm accounts, tithe files and other records of religious institutions.

The absence of China from the new comparative work on the origins of the Great Divergence, noted in the Introduction, is surprising given the centrality of China to the debate. It is also surprising given the large amounts of quantitative data collected during the Northern Song, Ming and Qing dynasties. Indeed, China has a long and impressive tradition of recording history for the purpose of providing experience and lessons in national governance for future dynasties. To achieve this, governments usually established a special institution with responsibility for compiling and recording laws and policy, and these institutions collected important economic data. It would surely be an astonishing act of neglect to throw away this rich stock of data on the grounds that it does not provide a complete picture without making assumptions, as if the same issue of the representativeness of the surviving records does not affect the use of qualitative information (Deng and O'Brien, 2016a; 2016b). In addition to this official historical literature, there are two additional types of material that have been drawn on in the estimates provided below, a private historical literature and regional gazetteers.

The official historical literature includes *Shihuo zhi* (Treatise on Food and Money) for each dynasty, starting from the Han dynasty (202 B.C. to 220 A.D.). In a country with a highly centralised authority, local governments had to report information to the central government, and these sources contain much important economic data that are useful for a historical national accounting study, including the amount of arable land, the total population, fiscal revenue, and the output of salt and iron. Another important official historical source for the Ming and Qing dynasties is the *Shilu* (Veritable record), an annual commissioned by the

Emperors to record in detail, on a daily basis, events that happened in the royal palace and the whole country. The *Ming shilu* (Veritable records of the Ming dynasty) and *Qing shilu* (Veritable records of the Qing dynasty) were compiled by highly regarded contemporary scholars, and have been accorded high value in the historiography. *Huiyao* and *huidian* (Collected statutes) chiefly recorded laws and institutions. *Song huiyao (*Collected statutes of the Song dynasty*)*, for example, provides detailed information on the legal system of the Song dynasty, while *Ming huidian* (Collected statutes of the Ming dynasty) provides information on the administrative laws and regulations of the Ming dynasty.

The authors of private historical works were sometimes distinguished historians of their era. For example, Ma Duanlin, the compiler of *Wenxian tongkao* (Comprehensive examination of the literature) was a renowned scholar, who wrote a kind of Chinese encyclopaedia from ancient times to the Song dynasty. Li Tao, another historian living in the Song dynasty, wrote the historiographical work *Xu zizhitongjian changbian* (Extended continuation to "Comprehensive mirror in aid of governance"). Privately written historical works also sometimes recorded important economic data based on the investigative research of the authors.

A gazetteer is a kind of encyclopedia of a particular province, prefecture or county. It is known in Chinese as *Difang zhi*, which means "area record", and contains information about the natural, human and economic geography of the area. Gazetteers provide important economic data for this study, particularly where an industry was concentrated regionally. *Guangdong tongzhi chugao* (Provincial gazetteer of Guangdong), for example, is an important source of data for the iron industry around Foshan town, Guangdong province during the later stages of the Ming dynasty. These sources help to fill important gaps in the official historical literature at the national level.

There are both advantages and disadvantages with each of these three types of historical source. The official historical literature has full national coverage and is highly systematic, but there are sometimes good reasons to doubt its accuracy. Since these historical records were designed to meet the Emperor's need to govern the country, the writers sometimes had an incentive to distort reality. Thus, for example, at the beginning of the Ming dynasty, the population and land data were recorded in a register named *Huangce* (Yellow book of the Ming dynasty) since Emperor Hongwu wanted to know how much tax revenue could be raised from the people. Once this work had been completed, the Emperor set a fixed fiscal revenue, so that later data on land and population do not reflect real developments, which can only be tracked from other sources. The private historical literature is therefore more credible than some of the official historical literature, but since it is less complete, it should be seen as complementary to the official historical literature rather than as a substitute. Gazetteers are usually more credible than some of the official historical literature, but they are also less complete, since they are only available at the sub-national level. In some cases, it is possible to simply aggregate area level data to the national level, but in other cases, it is necessary to make assumptions about the relationship between areas for which data are available and the rest of the country.

It is worth noting that although some data from the official historical literature suffer from inaccuracies and biases, Chinese economic historians have drawn on other sources to publish adjusted data. In addition to referencing the primary sources used in the calculations, this study therefore also makes use of many studies from the existing secondary literature on the quantitative economic history of China.

Although some series are available on an annual basis, many others are not. In particular, although it is possible to track long run trends in grain yields, there are no data on annual fluctuations. Since this was the largest sector of the Chinese economy, and since grain yield fluctuations were the key driver of annual fluctuations in GDP even in Britain, where agriculture accounted for a much smaller share of GDP, a decision was taken to work towards obtaining data every 10 years, along the lines of Liu and Hwang (1979).

It is important to be clear about how territorial changes have been dealt with in this study, since the Northern Song dynasty covered a smaller area than the Ming dynasty, which in turn covered a smaller area than the Qing dynasty. This is shown clearly in Map A1 in the Appendix. Within each dynasty, however, the territorial coverage has been held constant. Although each dynasty did experience an initial period of territorial expansion, these years are not included in the data set. Thus the Northern Song is covered for the period 980-1120, excluding the territorial expansion of the period 960-980. Similarly, the territorial expansion of the Ming dynasty between 1368 and 1400 is excluded by restricting the Ming coverage to the period 1400-1620. The Qing dynasty is covered only for the period 1690-1840, excluding the period of territorial expansion between 1644 and 1690. Although the territorial changes were substantial, the changes in population and GDP were much smaller, since the new territories were thinly populated. Furthermore, discontinuities in GDP per capita were smaller still. This is similar to the British case used later for comparative purposes, where a change of territory from England to Great Britain in 1700 led to a significant increase in population and GDP but a relatively minor decline in GDP per capita (Broadberry, Campbell, Klein, Overton and van Leeuwen, 2015).

Detailed data sources are provided in Appendix 1. Inevitability, the results of our calculations must rest on the accuracy of the underlying data, and the above brief survey indicates some areas of potential error. To deal with this uncertainty, we build upon the subjective error margins approach used by Perkins (1969) for Chinese population and agricultural series. This approach has also been used in other historical national accounting studies (Feinstein, 1972; Feinstein and Thomas 2001).

III. CHINESE ECONOMIC GROWTH, 980-1840

1. Population

Before reconstructing GDP from the output side, it will be helpful to set out trends in population, which will be needed to derive estimates of GDP per capita, the key indicator of overall economic performance in this study. In China, population data were systematically recorded throughout the period covered here, in connection with taxation. Ho (1959) provides a detailed guide to the nature of the official population data in the Ming and Qing dynasties. It is generally accepted that the officials were capable of recording the number of people accurately (Perkins, 1969: 193). Furthermore, as Deng (2004: 36-37) points out, there were strong incentives for officials to correctly estimate population, since the neighbourhood watch unit was liable for punishment if individuals or households evaded tax or defaulted. Also, an individual village needed to keep an accurate record of population to prevent free-riding on crop-patrol duties, required to prevent plunder. Furthermore, incentives for individuals or households to avoid enumeration were weak, since tax rates were low and the state provided a wide range of services. The scale of disagreement between modern scholars is therefore limited.

Our estimates are taken from Wu (2000) for the Northern Song dynasty and from

Maddison (1998) for the Ming and Qing dynasties, apart from some small adjustments described below. Wu's (2000) Northern Song estimates agree broadly with the figures derived by Deng (2004: 43) for the Northern Song dynasty, obtained by multiplying the registered households by a family size of 5.77, the long term average from years when both household and population data are available. However, Wu suggests a slightly lower family size of 5.4.The Maddison estimates are close to those of Liu and Hwang (1979), who interpolated the data for a number of benchmark years from Perkins (1969), which provided a correction to the recorded census estimates for the Ming and Qing dynasties that has commanded widespread support. Our minor adjustments during the period 1480-1510 extend the corrections of Maddison (1998), who thought that Liu and Hwang's (1979) series included some observations with implausibly high decadal population growth rates, but did not consider large unexplained population declines to be a problem. We have dropped Liu and Hwang's estimates for 1490 and 1500 and log-linearly interpolated between 1480 and 1510, since there is no qualitative historical material to support a sharp drop of more than 15 percent in the population at this time.

The population data are plotted on a log scale in Figure 1, and show rapid growth during the Northern Song dynasty at an annual rate of 0.87 per cent. Following a substantial decline during the Mongol interlude, population growth returned during the Ming dynasty, but at the slower rate of 0.32 per cent per annum. After another population decline during the next dynastic change, the annual growth rate picked up to 0.70 per cent during the Qing dynasty. There seems to be a high degree of consensus about the trend of China's population over this period, but the foundational study by Perkins (1969: 216) provided a range of estimates for his benchmark years. This range, based informally on his working knowledge of the data, declines from around ±10 per cent in 1393 to ±6 per cent in the mid-nineteenth century, but with a greater range in the first half of the seventeenth century associated with the collapse of the Ming dynasty.

2. Agricultural output

Agricultural output is estimated mainly from data on the amount of land cultivated and crop yields per unit of land. This section provides an overview of the sources and methods, with more detail provided in Appendix A1. The direct output-based approach has previously been used by Perkins (1969) and Liu and Hwang (1979) for some parts of the Ming and Qing dynasties, and represents the only feasible quantitative method for Chinese long run economic history, due to the absence of reliable wage data needed for the alternative demand-based approach (Álvarez-Nogal and Prados de la Escosura, 2013; Broadberry, Custodis and Gupta, 2015). These estimates have been tested and improved by subsequent scholars, leading to important changes during the Qing dynasty in particular.[3]

The starting point for the estimation of output is the cultivated land area, which is derived ultimately from the official data, but also draws upon information obtained from gazetteers and private histories. We draw here upon Qi's (2009) adjustment of the official data for the Northern Song dynasty, while for the Ming and Qing dynasties, we use the adjusted figures of Shi (2011; 2015) and Wang (2003). These authors build upon the work of earlier scholars such as Perkins (1969) and Wang (1973), who in turn report and extend the work of Chinese and Japanese scholars to revise the official estimates for the Ming and Qing dynasties. This work was also incorporated into the estimates of Liu and Hwang (1979). Chao (1986: 80-86) discusses a number of possible reasons for under-reporting, including incentives provided by emperors to encourage peasants to bring marginal lands into

[3] This makes it very difficult to understand the dismissal by Deng and O'Brien (2016a: 106) of the work of subsequent scholars to improve upon the estimates of these classic works as merely recycling or fine-tuning without questioning their origins and accuracy.

cultivation without being properly registered. The figures provided here have been adjusted for these distortions. However, it should be borne in mind that although land data were kept primarily for tax purposes, and that people try to avoid taxes, biases arising from this are unlikely to be too large because people need to register their interest to retain ownership rights (Perkins, 1969: 217). Another serious worry concerns the lack of a consistent standard measure for the unit of land area, the *mu*, which varied between regions and over time. However, much effort has been devoted to documenting this variation and the estimates presented here work in terms of a standard *mu* that is 1/15th of a hectare or 1/6th of an acre (Perkins, 1969: 218-221).

Figure 1 plots on a log scale the cultivated land area for the Northern Song, Ming and Qing dynasties, together with the population series. As will become clear later, cultivated land per capita plays an important role in determining overall living standards, since agriculture was the largest sector of the economy. Although the cultivated land area grew substantially over time, albeit with a major decline between the Northern Song and Ming dynasties, ultimately it did not keep pace with the growth of population so that cultivated land per capita declined over time from a peak of around 9 *mu* during the Northern Song dynasty to just 3 *mu* by the late Qing period. Much of this decline occurred during the Qing dynasty, as uncovered by the careful work of Shi (2011; 2015).

Given the important role of cultivated land per capita in determining overall living standards, it will be useful to consider the orders of magnitude of potential errors in the estimates. Perkins (1969: 240) provides a range of estimates for his benchmark years, although as with his population estimates, they reflect subjective judgement rather than formal statistical criteria. The error range for cultivated area declines from just under ±20 per cent in 1400 to around ±10 per cent by the mid-eighteenth century and under ±5 per cent by the late nineteenth century.

Grain yield data are also taken largely from official sources and gazetteers, as set out in Appendix A1.2. As noted earlier, there are difficulties of interpretation associated with the variation in the size of a *mu* over both space and time, but painstaking work by historians to deal with this problem has produced a consensus that grain yields increased over time (Qi, 2009; Luo, 1999; Perkins, 1969). In addition, some of the grain yield observations are derived from land rent data. As noted by Perkins (1969: 312), however, there is much evidence to support the contention that the rent was around half the output, so that doubling the rent provides a good measure of crop yields. Grain yields are given in *jin per mu*, where the *jin* is equal to 1.102 lb. During the Northern Song, wheat yields were stable at 210 *jin per mu*, while husked rice yields increased from 195 to 230 *jin per mu* (corresponding to an increase in unhusked rice yields from 390 to 460 *jin per mu*), with the introduction of high yielding champa rice (Qi, 2009; Wu, 1985; Ho, 1956). Guo (2000) bases his average China-wide yields during the Ming dynasty on a sample covering 37 rice areas in the south and 8 wheat areas in the north, and covering 4 different grades of land (highest, high, middle and low quality). Average grain yields for wheat and husked rice rose during the Ming dynasty from 220 *jin per mu* in 1402 to 256 *jin per mu* by 1626. During the Qing dynasty, Shi (2015) derives average yields for the country as a whole as a weighted average of yields in northern China and southern China broken down into dry farming and paddy farming, with an allowance for multiple cropping. Average grain yields rose from 266 *jin per mu* in 1685 to 326 *jin per mu* in 1850. However, this upward trend in grain yields across the three dynasties was not sufficient to offset the decline in cultivated land per capita.

The grain yields used in the calculations are averaged across crops, and reflect the changing distribution of the cultivated land area between crops. These crop distribution data are also derived ultimately from official sources, and are shown for benchmark years in Table 1. Rice and wheat were the most important crops during the Northern Song and Ming dynasties, but other crops became more important during the Qing dynasty. In addition to corn and potatoes introduced from the New World, the share of land devoted to cash crops (including sugarcane, hemp, cotton, tobacco and peanuts) also increased significantly. The cultivated area multiplied by the average grain yield provides a measure of real agricultural output over time. Although separate allowance can be made for cash crops grown on uncultivated land, such as tea and fruit, and also for livestock, forestry and fishing when calculating the level of agricultural value added in 1840, our key benchmark year for deriving sectoral weights, we lack separate time series information on these subsidiary parts of the agricultural sector.

Figure 2 plots indices of the cultivated land area and grain yields used to derive the index of agricultural output. Grain yields increased over time, so that agricultural output grew faster than the cultivated land area. However, as Figure 3 makes clear, agricultural output did not increase as fast as population, so that agricultural output per capita declined over time, particularly during the Qing dynasty. Notice however, that the territorial expansion between dynasties was not an important driver of the overall downward trend in agricultural output per capita. Indeed, agricultural output per capita did not decline substantially across either of the dynastic changes in our sample, which might have been expected if territorial expansion had led to growing reliance on more marginal land. Rather, we see that output per capita increased between the later years of the Ming dynasty and the early Qing dynasty. Two periods stand out as worthy of comment, given the existing literature. First, although grain yields *per mu* did increase significantly during the later years of the Northern Song dynasty, with the introduction of high-yielding champa rice, as noted by Ho (1956), this did not lead to any substantial increase in living standards. Indeed, these higher yields were needed just to dampen the negative effects of the decline in cultivated land per capita arising from the rapid population growth of the period. Second, the decline in agricultural output per capita from the eighteenth century is broadly consistent with Huang's (1985; 2002) process of involution. Population growth outstripped the increase in the cultivated land area, and grain yields did not increase sufficiently to offset the fall in land per capita.

3. Industrial output

Industry is divided into four main sectors: metals and mining; food processing; textiles and other manufacturing; and building. The basic approach is to obtain indicators of the volume of output in each main branch of industry and to aggregate these into an index of industrial production using value added weights for the benchmark year of 1840. Detailed data sources for industry are provided in Appendix A2.

The output of the metals and mining sector is tracked using volume data for iron, copper and salt, taken largely from official sources, supplemented by information from gazetteers and private historical sources, particularly where an industry was regionally concentrated. Many economic historians have worked on the original data to provide cross-checks and make up for the shortcomings of individual sources. There have been numerous studies of the iron industry since the strong claims of Hartwell (1962) that China produced as much as 150,000 tons of iron in 1078. Many subsequent researchers argue that Hartwell seriously overestimated iron production in the Northern Song dynasty, and the estimates used here are taken from the work of Liu (1993), obtained by aggregating the annual quantities of iron used for coining and government purchases.[4] According to Liu, peak iron output in 1078 was around 13,500 tons rather than the 150,000 tons claimed by Hartwell. For the Ming dynasty, the state-run iron industry was based mainly in Zunhua City and the output estimates are based on the official records. The private iron industry is tracked during this period using tax revenue, with the tax rate set at one-fifteenth of output. For the Qing dynasty, iron industry output is based on regional data for Guangdong, which became the centre of the iron mining and metallurgical industry. Li (1979) added data from all other iron-producing provinces to the Guangdong data to estimate the total volume of iron production.

Copper output for the Northern Song dynasty is estimated from official sources. Because copper was used in minting, the industry was strictly regulated by the government, so that few adjustments to the tax quota or *ke (er)* were needed (Wang, 2005; Wang, 1995a). Copper output was much lower during the Ming dynasty, but can be gleaned from official sources for a number of benchmark years. During the Qing dynasty, copper output data are taken from Peng (1962), drawing on detailed information for Yunnan province, an important centre of copper mining, and more fragmentary information for other regions. For the Northern Song and Qing dynasties, salt output is based mainly on the work of Guo (1997), who collected data on salt production in different regions and then aggregated the regional estimates to arrive at national salt output. For the Ming dynasty, salt tax data recorded in *Ming shilu* are supplemented with demand-based estimates using information on consumption per capita.

The data in Figure 4 suggest a good deal of volatility in the output of the iron and copper industries. The boom in these industries during the later years of the Northern Song

[4] Hartwell (1966: 39) appears often to have multiplied government quotas of iron by a factor of 10, on the assumption that these quotas represented only 10 per cent of the output.

dynasty is clearly visible, consistent qualitatively (although not quantitatively) with the views of Hartwell (1962; 1966; 1967). The lower level of activity in these industries during the Ming dynasty was largely the result of developments in the state-owned sector, where there was a temporary decline in the production of weapons and a more dramatic and long lasting reduction in the minting of coins. A famous politician and historian of the Ming dynasty, Qiu Jun, estimates that the Ming output of metals was about one to two tenths of the level of the previous dynasty (*Daxue yanyi bu, Vol. 29,* Shanze Zhili (profits from metals and mining)). The private sector only managed to offset these developments fully during the Qing dynasty, when the government gave up its prohibition of private production, and officials met imperial demand by purchasing metal products in the market. However, although iron and copper have received a great deal of attention in the literature, the value of their output was dwarfed by that of the much larger salt mining industry, which was less volatile.[5]

Figure 5 presents production indices of the other three main branches of industry, together with the index of output in the metals and mining branch. Food processing is assumed to grow in line with agricultural output, following the approach of Broadberry, Campbell, Klein, Overton and van Leeuwen (2011; 2015) for England. Building is assumed to grow in line with population, but with an allowance for urbanization. This also follows the procedure of Broadberry, Campbell, Klein, Overton and van Leeuwen (2011; 2015) in the estimation of English economic growth, 1270-1700. Data on the urbanization rate are taken from Rozman (1973: 279-283), as suggested by Maddison (1998: 35).[6] Although the building

[5] Value added weights are given in Table 2.

[6] Because Rozman's (1973: 279-283) urbanization rates are based on different population estimates and do not vary within dynasties, we have also experimented with alternative estimates based on the urban data of Wu (2000) and Cao (2000; 2001). Although this raises the urbanization rate during the early Northern Song period from 6 per cent to 11 per cent, the maximum effect of this change is to raise GDP per head above our baseline estimate by 5.7 per cent in 980, with most of the effect coming through services rather than industry, since the building industry accounted for just 14.7 per cent of industry, with industry accounting for just 8.1 per cent of GDP in 1840.

of the Great Wall must have accounted for a significant share of construction activity during the Ming dynasty, most of the construction was completed before 1400. During the period covered by our Ming dataset, 1400-1620, house building accounted for the bulk of construction sector activity. The textile industry, which is taken as representative of other manufacturing, is assumed to grow in line with population, consistent with evidence on cloth consumption per capita (Li, 2005; Xu, 1992). The food processing, textiles and other manufacturing, and building industries all grew rapidly within the Northern Song, Ming and Qing dynasties, but with some setback across the dynastic changes. Output in metals and mining followed a more volatile path, as noted above.

Figure 6 plots the overall index of industrial production, aggregated using value added weights from Table 2, which will be discussed later. The aggregate index was dominated by the largest sectors, textiles and other manufacturing, and building. Food processing grew more slowly in line with agricultural output, while metals and mining showed slightly faster trend growth, but with a greater degree of volatility. Figure 6 also shows the index of Chinese industrial output per capita. Over the long run, industrial production grew at about the same rate as population, so that industrial output per capita exhibits no trend. The boom in the early fifteenth century was due largely to developments in metals and mining, and coincides with the famous voyages to the western oceans which demonstrated to the world China's technological precocity (Maddison, 2001: 67-69; Fairbank, 1992: 137-140).

4. Service sector output

Services have received much less attention from economic historians than agriculture and industry (Broadberry, 2006). Here, the service sector is broken down into three subsectors: commerce; government; and housing and domestic services. Volume indicators are used to construct real output indices for each subsector. Detailed data sources for services are provided in Appendix A3.

The output of the commercial sector is estimated from data on the volume of agricultural and industrial goods to be distributed. We use 1840 weights of 58 per cent for agricultural output and 42 per cent for industrial output, despite the fact that agriculture was much larger than industry. This is because Wu (1998) finds that only approximately 17 per cent of agricultural output was marketed during the Northern Song, Ming and early Qing dynasties, before rising to 20.7 per cent during the later Qing period after 1840, whilst all industrial output was assumed to be marketed.

For government services, output is calculated from the numbers of civil servants and soldiers and their salaries, derived from official sources. This yields nominal output, which is deflated by a price index to obtain real government services. The GDP deflator used for this purpose will be described in the next section. Following Broadberry, Campbell, Klein, Overton and van Leeuwen (2015), it is assumed that housing and domestic service grew in line with population, with an allowance for urbanization from Rozman (1973), as for the building sector.

Output indices of the main service sub-sectors are shown in Figure 7. The most significant long term trend was the sharp rise in the real size of the government sector during the later years of the Northern Song dynasty, which was maintained during the Ming dynasty, but declined sharply during the Qing dynasty. This appears to be a result of the peak level of government revenue being reached in nominal terms already by the late Northern Song period. As population and the price level both increased above their Northern Song peak levels during the Qing dynasty, the real value of government services on a per capita basis declined sharply. This provides a strong contrast to the rise of the fiscal state in early modern northwest Europe, with growing tax revenues as a share of GDP funding the provision of public goods (Karaman and Pamuk, 2010; O'Brien, 2011). As Figure 8 shows, this pattern of an increase during the Northern Song and a decline during the Qing dynasty is also visible in the overall index of service sector output per capita.

5. Gross Domestic Product

Indices of real output in the agricultural, industrial, and service sectors are plotted together in Figure 9. Over the period as a whole, industry was the fastest growing sector, keeping pace with population, while agriculture grew more slowly. Services grew at about the same rate as agriculture over the long run, but with more of the growth occurring during the Northern Song dynasty. The next step is to combine these sectoral indices into a series of real Gross Domestic Product, which requires a set of value added weights for the benchmark year of 1840. These weights are presented in Table 2. The sectoral shares are taken from the work of Zhang (1987), who estimated Chinese GDP for the 1880s, but the absolute level of GDP in 1840 is established by first calculating value added in agriculture for that year, and then applying the shares from the 1880s to calculate nominal value added in industry and services. This seems reasonable, given the huge dominance of agriculture in the Chinese economy and the stability of the sectoral shares between the 1880s and 1933, when another estimation of Chinese GDP broken down by sector is available from the work of Wu and Wang (1947).

The level of nominal GDP in agriculture in 1840 is established in Part A of Table 2. The starting point is the data on crops grown on cultivated land that have already been used to track the growth of agricultural output over time. The volume of grain output is obtained by multiplying the cultivated land area devoted to grain crops by the average grain yield. This is then multiplied by the average grain price, taking account of the distribution of crops in Table 1, to obtain gross output. Gross output is converted to a net output basis by subtracting the value of agricultural inputs such as seed and fertiliser. Fang (1996) and Luo (1999) suggest that these inputs amounted to 15 per cent of gross output during the Qing dynasty, a figure which also applies to 1933 (Wu and Wang, 1947). These figures are also very consistent with the findings of Sivasubramonian (2000: 87-90) for the case of Indian agriculture, where the share of value added in gross output was around 85 per cent during the first half of the twentieth century. The net output of cash crops is set at 25.2 per cent of the net output of grain crops, with the ratio taken from Zhang (1987). The same source yields a ratio of 10.4 per cent for the net output of livestock, forestry and fishing compared to the net output of grain crops.

In Part B of Table 2, the values of net output in the industries that have been used in the construction of the index of industrial production are derived using the sectoral shares from Zhang (1987), taking the 1840 level of agricultural output from Part A of the same table. Within metals and mining, salt was much larger than the iron and copper industries, as noted earlier. Within industry as a whole, metals and mining was larger than food processing and building, but smaller than textiles and other manufacturing, (considered together in our production index). Turning to services in Part C of Table 2, levels of net output are again arrived at using the sectoral shares from Zhang (1987) and taking the 1840 level of net output in agriculture from part A of Table 2 as given. Commerce was approximately double the size of government services and also housing and other private services. For the total economy, agriculture accounted for 66.1 per cent of net output, industry for 8.1 per cent and services for the remaining 25.8 per cent.

Combining the 1840 weights from Table 2 with the output indices underlying Figures 3 to 9 yields the index of constant price GDP shown in Figure 10. This can be combined with the population index from Figure 1 to yield the index of GDP per capita which is also plotted in Figure 10. These series will be used in the next section to evaluate the performance of the Chinese economy both domestically across the Northern Song, Ming and Qing dynasties, and internationally, compared with other nations in Europe and Asia.

To complete the picture, it will be helpful to establish China's GDP and GDP per capita in nominal as well as in real terms. To do this, it is necessary to provide a price index that covers both agricultural and non-agricultural prices. Following the approach of Broadberry, Custodis and Gupta (2015) for India, we establish a GDP deflator for China using a grain price index and a cloth price index, with weights of 67 and 33 per cent, respectively, in line with the shares of agriculture and non-agriculture in GDP in Table 2. Detailed data sources are provided in Appendix A4. This price index is plotted in Figure 12, together with the index of real GDP from Figure 10. Multiplying real GDP by the GDP deflator yields an index of nominal GDP, which can be used to project back in time from the 1840 benchmark in Table 2 to obtain nominal GDP in taels. Nominal GDP increased from 128.6 million taels in 980 to 5,379.6 million taels by 1840. This increase in nominal GDP by a factor of 41.83 was split fairly evenly between an increase in the price level by a factor of 5.41 and an increase in real GDP by a factor of 7.73.

6. Reliability of the estimates

It is worth adding a note of caution, given our earlier references to uncertainties about the accuracy of the underlying data. We have already reported subjective error margins provided by the compilers of some of the most important original series, based on their informed impressions of the reliability of the primary data. To this can be added information gleaned from the range of estimates made by others, as well as the underlying volatility and extent of interpolation in the individual series. Assessments of this type have often been made for official national accounts, and were also adopted in Feinstein's (1972: 21) historical national accounts for the United Kingdom. The reliability grades, set out in Appendix Table A1, fit quite well with the scale of error margins reported by Perkins (1969) for the key variables used in our reconstruction of China's historical national accounts. For firm figures (grade A), the margin of error around the reported series is judged to be ± less than 5%. For good estimates (grade B), the margin of error is ± 5% to 15%, while for rough estimates (grade C) the margin of error is ± 15% to 25% and for conjectures (grade D) it is ± more than 25%. For the UK historical national accounts, Feinstein (1972: 22) judged the probability of the true values lying within the error margins for each grade as 90 per cent. For the less well documented Chinese case, it may be more appropriate to follow the suggestion of Perkins (1969: 216) of an 80 percent confidence interval, although neither has a precise statistical justification. Information on the range and volatility of the underlying series is presented in Appendix Table A2, while Table A3 describes the number of observations and methods of interpolation for dealing with missing data.

Although the error margins attached to each series in Table 3 inevitably contain a subjective element, the exercise is helpful in a number of ways. First, it highlights where the strengths and weaknesses of the estimates lie. Thus prices and nominal values are generally less reliable than real magnitudes, the cultivated land area is less reliable during the Northern Song than during the Qing dynasty, while iron and copper are less reliable during the Ming than in the Northern Song or Qing dynasties. Second, since it is likely that some series will be biased upwards and others downwards, some offsetting errors may be expected in the real aggregates derived as the sum of individual series, so long as those series are derived independently (Feinstein and Thomas, 2001; Bowley, 1911-12). This explains the B, B and A grades for GDP during the Northern Song, Ming and Qing dynasties, respectively, despite some of the component series receiving lower grades. Third, error margins for ratios may also be lower than suggested by the accumulation of error margins for the component series where the errors are positively correlated (Feinstein and Thomas, 2001; Bowley, 1911-12). This may be expected to apply to GDP per capita, which is heavily influenced by the ratio of cultivated land to population. Since the population and cultivated land data were collected by the imperial authorities, it is likely that an under-estimate of one was accompanied by an under-estimate rather than an over-estimate of the other.

IV. CHINESE ECONOMIC PERFORMANCE

1. Comparing the Northern Song, Ming and Qing dynasties

This section sheds light on the long term evolution of the Chinese economy between 980 and 1840 by comparing the growth rate of GDP and the level of GDP per capita during the three dynasties for which data are available. Although China's territory expanded between the Northern Song and Ming dynasties, and expanded further between the Ming and Qing dynasties, it is nevertheless useful to compare these three dynasties. First, most of the newly extended territory was sparsely populated, so that it did not have a particularly large effect on the aggregate volume of economic activity. Second, our main concern is with GDP per capita, which was affected even less by territorial changes. The average annual growth rate of real GDP during the Northern Song, Ming and Qing dynasties was 0.88%, 0.25%, and 0.36%, respectively, although there was also a sharp fall in the level of real GDP (and population) between the end of the Northern Song and the beginning of the Ming dynasties. Real GDP more or less kept pace with population during, as well as between, both dynasties, so that GDP per capita fluctuated without trend around a high level. During the Qing dynasty, however, GDP per capita trended downwards strongly at an annual rate of -0.34 per cent. As a result, GDP per capita in 1620 was about the same as it had been in 980, but by 1840 had fallen to around 70 per cent of its 980 level.

This general pattern of fluctuations without trend around a high level during the Northern Song and Ming dynasties, followed by decline during the Qing dynasty, is broadly consistent with much of the largely qualitative literature on Chinese economic performance over the very long run. The early good performance during the Northern Song and Ming dynasties is most obviously consistent with the work of Hartwell (1966), who was impressed by China's development of coke smelting of iron in the eleventh century, and Elvin (1973), with his idea of China being caught in a high-level equilibrium trap. The idea of an early peak is also consistent with the view of Chinese science expressed by Needham (1954), who asked why China was overtaken by the West despite its early scientific successes, such as the development of gunpowder, the magnetic compass and paper and printing. It also fits with the emphasis of Wittfogel (1957) on the early development of irrigation works, leading to high levels of agricultural productivity, but also a bureaucracy that stifled later development.

The idea of a decline in GDP per capita during the Qing dynasty is also most obviously consistent with the work of Huang (1985; 2002), who argues that the rapid population expansion at this time led to a growing division of land holdings into ever-smaller plots. Given the decline in the cultivated land per capita (shown in Figure 1), and the failure of grain yields to rise sufficiently to offset this over time (shown in Figure 2), this led inevitably to a decline in living standards. This pattern of Qing decline is also captured in a number of recent quantitative studies, which draw upon a range of indicators. First, Allen, Bassino, Ma, Moll-Murata and van Zanden (2011: 28) find falling real wages in China, with welfare ratios declining from 1.7 to 0.8 in Suzhou/Shanghai between 1738 and 1818 and from 1.7 to 1.0 in Beijing over the same period, and continuing to decline further until the 1850s. Second, Baten, Ma, Morgan and Wang (2010: 351-352, 355) also find evidence of declining heights and numeracy in China, although their evidence on these indicators begins only in the nineteenth century. Third, Bernhofen, Eberhardt, Li and Morgan (2016) show growing grain price divergence in Chinese regions from the 1740s, while European grain prices continued to converge, so that a large gap opened up between Western Europe and even the most advanced regions of China, the Lower and Middle Yangzi.[7] Fourth, the comparative study by Li and van Zanden (2012) showed GDP per capita in the Lower Yangzi to be only around half the level of the Netherlands already by the 1820s. Fifth, recent estimates of Chinese national income produced by Shi, Xuyi, Ni and van Leeuwen (2014) for the period 1661-1933 show a similar percentage decline in GDP per capita during the Qing dynasty as in our study.

Note that this pattern of high levels of per capita income during the Northern Song and Ming dynasties, followed by decline during the Qing dynasty differs substantially from the path of Chinese GDP per capita proposed by Maddison (1998), whose "controlled conjectures" showed an increase from $450 in 1990 international prices to $600 during the Northern Song dynasty, before a long period of stagnation at $600 until the mid-nineteenth century. Our data-based estimates show only a temporary boom in per capita GDP during the Northern Song dynasty rather than Maddison's (1998) assumed 33 per cent permanent

[7] Although Shiue and Keller (2007) are often quoted in support of the idea that there was no significant difference in the extent of grain market integration between China and Western Europe before the nineteenth century, it is worth emphasising that they also pointed to the higher level of market integration in England.

increase. And as noted above, our data also indicate a steady decline during the Qing dynasty in contrast to Maddison's assumed constancy of living standards.

This picture of falling living standards during the Qing dynasty is also very different from the view of Chinese economic performance painted by California School authors, who see the eighteenth century as a period of economic success for China. On its own terms, the Chinese state would clearly have seen this as a successful period, with new territory and a rapidly expanding population. However, in the modern world which was just emerging during the eighteenth century, economic success was beginning to be measured in terms of rising productivity and living standards. Careful analysis of the cultivated land area and grain yields reveals a decline in per capita food availability, which was not compensated for by an increase in industrial production or service sector output.

We will conduct some sensitivity analysis in the final part of this section. However, at this stage, it is worth noting an important implication of rejecting this pattern of decline in GDP per capita during the Qing dynasty. Few would now dispute that China had a low level of GDP per capita by the early nineteenth century. If there was no decline during the Qing period, then this must necessarily mean that China was also very poor during the Ming and Northern Song dynasties, so that any idea of China having once been a dominant economic force would disappear. For, as we shall see below, levels of GDP per capita in Europe were already well above bare bones subsistence levels in the late medieval period.

2. Comparing China and Britain

It is possible to compare the new GDP per capita estimates for China with the British estimates from Broadberry, Campbell, Klein, Overton and van Leeuwen (2015). However, to do so requires converting the estimates for both countries into a common currency. Following the work of Maddison (2001, 2010), this is usually done in terms of 1990 international dollars. As well as presenting their series for British GDP per capita in terms of constant 1700 pounds sterling, Broadberry, Campbell, Klein, Overton and van Leeuwen (2015) also report figures in 1990 international dollars. This is done by splicing the series in 1700 pounds sterling to Maddison's (2010) figure for the United Kingdom in 1850 (but converted to a Great Britain basis) as the benchmark. If we can establish Chinese GDP per capita as a proportion of British GDP per capita in the mid-nineteenth century, we can thus arrive at a figure for Chinese GDP per capita in 1990 international dollars.[8]

We have data for nominal GDP per capita in 1840 in both countries and prices for a number of important commodities, which can be used to convert the nominal GDP per capita comparison to real terms. Table 4 sets out the 1840 price data for seven commodities, which can be grouped into categories covering food and non-food items, with the former divided between unprocessed grain products (wheat and rice) and more processed foods (sugar, tea and salt). The non-food commodities cover textiles (cotton cloth) and metals (bar iron). Sources are listed in the notes to the table. Weights are based on Feinstein (1995) and Horrell, Humphries and Weale (1994) for Britain, adapted for China to reflect the importance of rice production. Details are again given in the notes to the table. Using British weights, the appropriate price ratio or purchasing power parity (PPP) in 1840 is £1 = 2.11 tael, while at Chinese weights the PPP is £1 = 1.96 tael. Taking the geometric mean of British and Chinese weights, the Fisher index PPP is £1 = 2.03 tael. The nominal exchange rate in 1840, given by the silver weight of the tael compared to the pound sterling was £1 = 3.20 tael. The PPP was

[8] Deng and O'Brien (2016a) are critical of studies which rely on a single benchmark to pin down comparative levels of GDP per capita over long periods. Although our results are expressed in terms of 1990 international dollars, we also incorporate a mid-nineteenth century benchmark which is consistent with extrapolation from 1990.

therefore substantially below the exchange rate, as found by Allen (2009: 540-543) for the Yangzi Delta in 1820. Note, however, that the PPP was substantially lower for food (£1 = 1.53 tael) than for non-food commodities, where the PPP was close to the exchange rate (£1 = 3.04 tael). This is again something which Allen (2009: 541) found for the Yangzi Delta in 1820, and is explained by the possibility of arbitrage in tradable commodities. Food was less easily tradable than cloth because of the high cost of transporting low value but bulky items, which reduced the possibilities of arbitrage.

Table 5 provides an estimate of Chinese GDP per capita in 1840 benchmarked on Great Britain. Nominal GDP and population are taken directly from this study for China and from Broadberry, Campbell, Klein, Overton and van Leeuwen (2015) for Britain. At the silver exchange rate, Chinese GDP per capita was only 15.04 per cent of the British level. However, allowing for the lower price level in China by using the PPP suggests that Chinese GDP per capita was 23.76 per cent of the British level. Taking the 1840 level of British GDP per capita in 1990 international dollars as $2,521, from Broadberry, Campbell, Klein, Overton and van Leeuwen (2015) and Chinese GDP per capita in that year as 23.76 per cent of the British level, suggests a figure for Chinese GDP per capita in 1990 international dollars of $599. This is reassuringly close to the figure of $600 suggested by Maddison (2010) for 1850.

Table 6 presents the GDP per capita series for both China and Britain for the long period 980-1850. These estimates suggest that Northern Song China was substantially richer than Britain at around the time of the Domesday Survey in the late eleventh century. However, per capita incomes then fluctuated without trend in China until the end of the Ming dynasty. With per capita incomes rising in Britain from the mid-fourteenth century, following the mortality crisis of the Black Death, Britain had caught up with China by the beginning of the fifteenth century, and edged ahead during the sixteenth century. China then fell further behind during the Qing dynasty as Chinese per capita incomes declined while incomes started to grow rapidly in Britain from the mid-seventeenth century. By the mid-nineteenth century, Chinese per capita GDP was just 20 per cent of the British level.

3. Asia-Europe comparisons

So far, we have compared China only with Britain. However, Britain was a relatively poor part of Europe in the eleventh century and a relatively rich part by 1850, as can be seen in the recent estimates of GDP per capita presented in Table 7. Before the Black Death struck in 1348, per capita incomes were substantially higher in Italy and Spain than in England and Holland. There then followed a substantial reversal of fortunes between the North Sea area and Mediterranean Europe, so that by 1750, just before the Industrial Revolution, per capita incomes were substantially higher in Britain and the Netherlands than in Italy and Spain. This "Little Divergence" within Europe accompanied the "Great Divergence" between Europe and Asia.

Table 8 also suggests a "Little Divergence" within Asia, with a reversal of fortunes between China and Japan. Japan had very low levels of per capita GDP until 1450, but then experienced episodic growth of the kind seen in Britain and Holland. A phase of positive growth between 1450 and 1600 was followed by a plateau before a second phase of growth from the 1720s. Japan's more rapid growth after the Meiji Restoration of 1868, which marked the first transition to modern economic growth in Asia, was built on this earlier period of dynamism. This upward trajectory in Japan contrasts with the downward trend in Chinese per capita GDP. On these estimates, Japan overtook China during the eighteenth century. Like

China, India experienced declining GDP per capita from the Mughal peak under Akbar, circa 1600. Japan also pulled decisively ahead of India only during the eighteenth century.

The GDP per capita figures presented here suggest that China was the richest country in the world during the Northern Song dynasty. China was certainly richer than England in 1090, some time after its peak, although England had caught up with China by 1400. However, England was a relatively poor part of Europe at this time, and comparing China with the richest part of medieval Europe, it is likely that Italy was already ahead by 1300, and perhaps even earlier. By 1500, Holland and Italy were both substantially ahead of China. However, we need to be careful here before concluding that the Great Divergence began in the sixteenth century, since China was much larger than any individual European country, as emphasised by Pomeranz (2000) and Wong (1997). While the GDP per capita gap between the leading North Sea area economies and the whole of China remained small, as it did until the eighteenth century, it is quite possible that a smaller region of China, such as the Yangzi delta, may still have been on a par with the richest parts of Europe.

4. Sensitivity analysis

The most important result in this study is the finding of a substantial decline in Chinese GDP per capita during the Qing dynasty, largely as a result of a widely accepted large increase in population, without an equivalent expansion of the cultivated area or crop yields. This coincided with positive growth of GDP per capita in the leading regions of Europe, producing a clear divergence in the eighteenth century, so that the gap between Europe and China became too large to be bridged by regional variation within China. In this section we explore whether it would be possible to restore Pomeranz's (2000) original finding of a delayed divergence beginning only in the nineteenth century by taking error margins into account. The answer must surely be no.

Li and van Zanden (2012) have produced a comparison of GDP per capita in the Yangzi delta and the Netherlands in the early nineteenth century, finding per capita incomes in the Yangzi delta to be 53.8 per cent of the level in the Netherlands during the 1820s. This suggests a per capita GDP figure of $1,050 for the Lower Yangzi, in 1990 international dollars, or about 75 per cent higher than in China as a whole. A high estimate for GDP per capita in the Yangzi delta in earlier years would apply this ratio to our estimates of per capita GDP for China as a whole. This produces our Yangzi (H) series in Figure 13, which also plots the GDP per capita data for the richest part of Europe. The European frontier is based on Italy until the 1540s, followed by the Netherlands until the 1800s and then Great Britain. Although the Netherlands enjoyed a significant lead over the Yangzi delta in the early seventeenth century, this could be discounted as a very small part of Europe, with no other North Sea area economies enjoying a significant advantage over the Yangzi delta. But once Great Britain, the Netherlands and Belgium had all forged ahead of the Yangzi delta during the first half of the eighteenth century, this is too large an area to be ignored. By 1750, Dutch GDP per capita was 42 per cent higher than in the Yangzi delta, rising to a 90 per cent lead by 1770. This is well outside the 5% error margins for a grade A series such as GDP per capita during the Ming dynasty, and indeed even beyond the error margins for a grade B or C series.

Figure 13 also includes an alternative low estimate of GDP per capita in the Yangzi delta, shown by the dashed line Yangzi (L). This is derived by rebasing the Yangzi (H) series on an alternative mid-nineteenth century benchmark from Shi, Xuyi, Ni and van Leeuwen

(2014). Their figure for China’s GDP per capita in 1850 in 1990 international dollars is obtained by accepting Maddison’s (2010) estimate for 1933 and projecting backwards using a different series. Instead of our figure of $600 in 1850, this yields an alternative estimate of $472, which is getting quite close to bare bones subsistence of $400, thus providing an effective lower bound. Note that even with this lower bound series, although western Europe appears to start forging ahead in the sixteenth century, GDP per capita in the Yangzi delta remains 93 per cent of the level of the leading European country as late as 1700, and the first half of the eighteenth century remains a critical juncture.

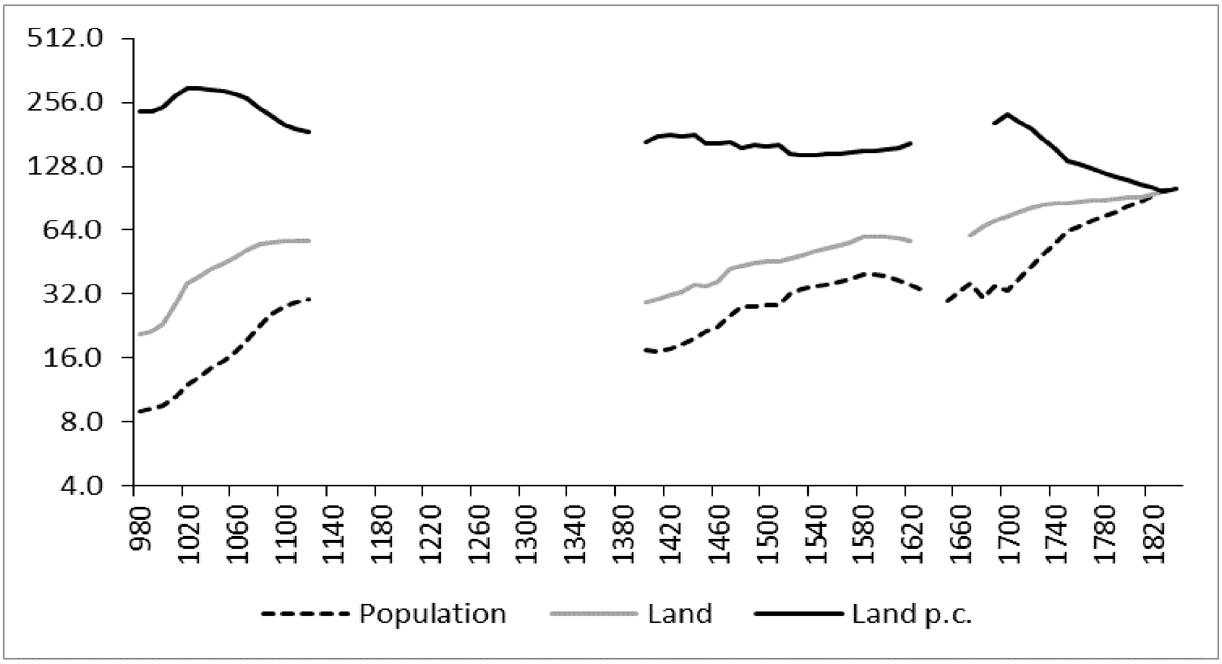
It is reassuring that the historical national accounting evidence suggests the first half of the eighteenth century as the point in time when the gap between Europe and Asia became too large to ignore, since this seems to be the new consensus that is emerging from both California School authors such as Pomeranz (2011) and from economic historians using other quantitative indicators such as real wages and urbanization rates (Broadberry and Gupta, 2006; Allen, Bassino, Ma, Moll-Murata and van Zanden, 2011). Furthermore, as noted earlier, it is important to realise that without a decline in Chinese GDP per capita of the order of magnitude shown by our series, China must always have been poor, since there have been no revisionists to suggest that China was anything other than very poor in the nineteenth century. If this were the case, then there would have been no reason for the Great Divergence debate to have occurred.

V. CONCLUSIONS

This paper provides estimates of Chinese GDP and relative standing in the world constructed from the output side between 980 and 1840, covering the Northern Song, Ming, and Qing dynasties. These GDP estimates are combined with population data to track the path of GDP per capita. China's GDP per capita fluctuated around a high level during the Northern Song and Ming dynasties, before trending downwards during the Qing dynasty, falling to around 70 per cent of its 980 level by 1840.

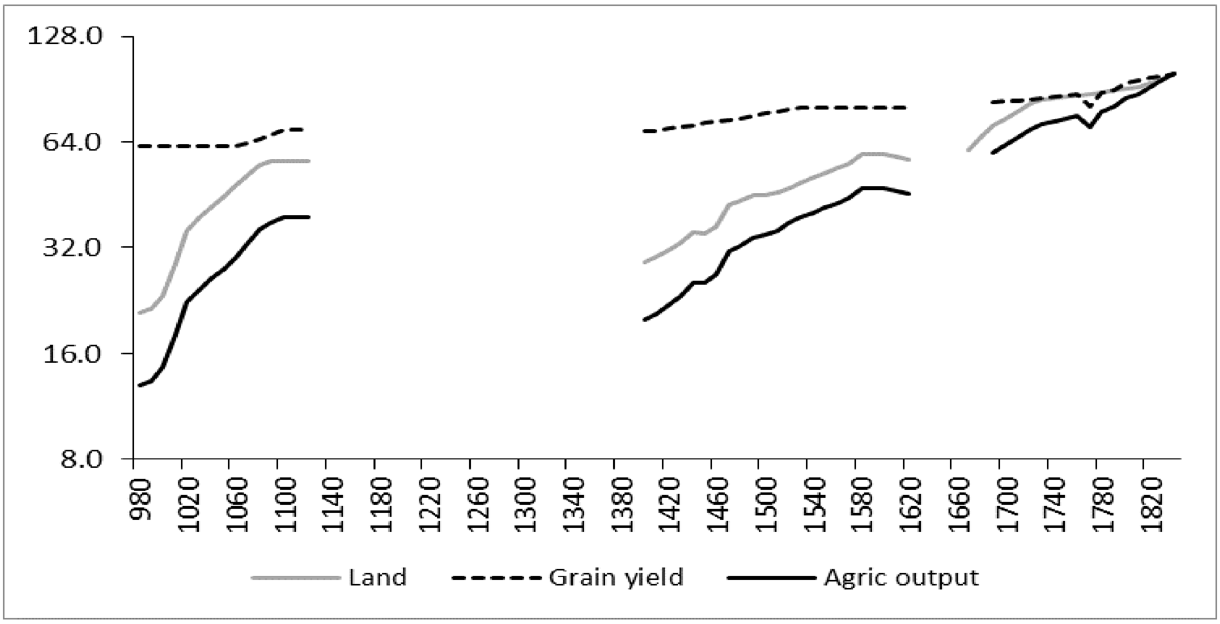
From an international perspective, Northern Song China was richer than Domesday Britain in 1090, but Britain had caught up with China by the fifteenth century. Although China had the highest standard of living in the world during the Northern Song dynasty, Italy had already forged ahead by 1300. At this point, however, and even until the eighteenth century, it is quite possible that a relatively rich Chinese region such as the Yangzi Delta was on a par with the most developed parts of Europe. But Chinese GDP per capita declined sharply during the Qing dynasty, so that by the middle of the eighteenth century, the gap between China and the most developed parts of Europe was too large to be bridged by regional variation within China. Since China was still the richest Asian country at this time, it is therefore likely that Western Europe was significantly ahead of Asia not just by the early nineteenth century, but already by the mid-eighteenth century, before the Industrial Revolution. This suggests that the Great Divergence had deep institutional roots, rather than springing up suddenly as a result of factors such as coal or ghost acres.

FIGURE 1: Chinese population, cultivated land area and land per capita, 980-1840 (1840=100, log scale)



Sources: See Appendix A1 for a detailed discussion of sources and methods.

FIGURE 2: Chinese cultivated land area, average grain yield and agricultural output, 980-1840 (1840=100, log scale)



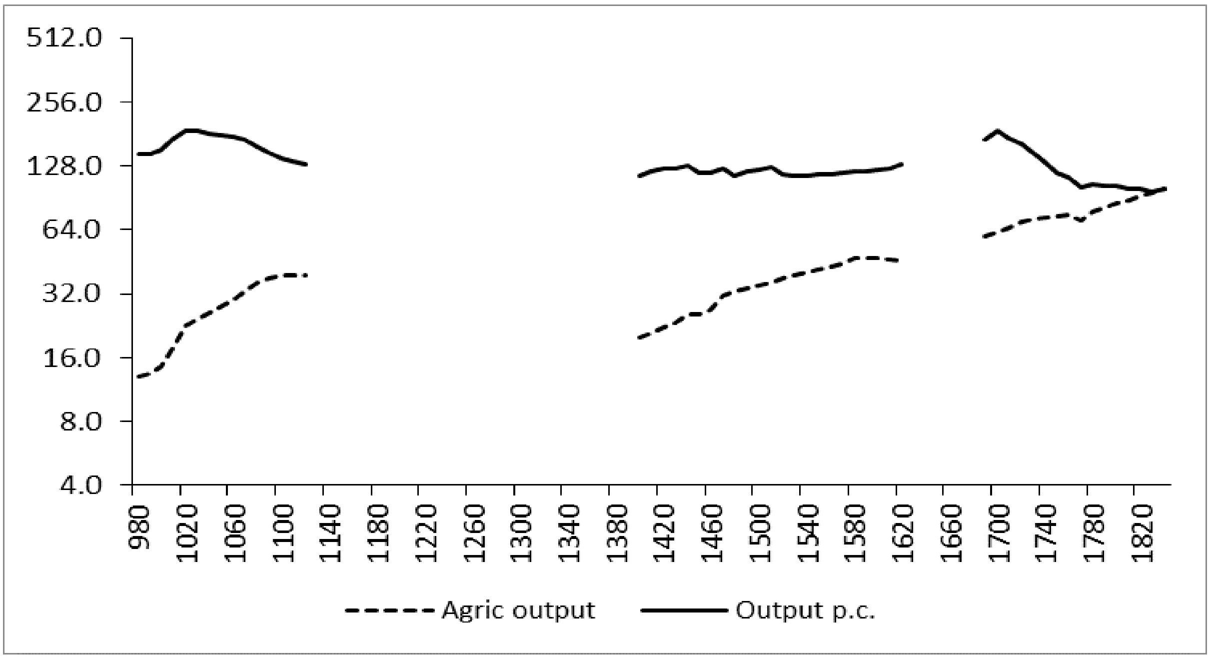
Sources: See Appendix A1 for a detailed discussion of sources and methods.

TABLE 1: Distribution of cultivated land area in China by major crops, 1000-1850 (%)

	1000	1400	1700	1750	1800	1850
Rice	60.0	50.2	33.0	31.0	29.0	27.0
Wheat			23.0	22.0	21.0	20.0
Barley			7.0	7.2	7.3	7.2
Millet			8.0	8.2	8.4	8.2
Corn			0.0	1.2	2.3	3.5
Potatoes			0.5	0.5	0.8	1.2
Sorghum			8.1	8.3	8.4	8.3
Other crops	34.0	42.1	9.4	9.7	9.8	9.6
Cash crops	6.0	7.7	11.0	12.0	13.0	15.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

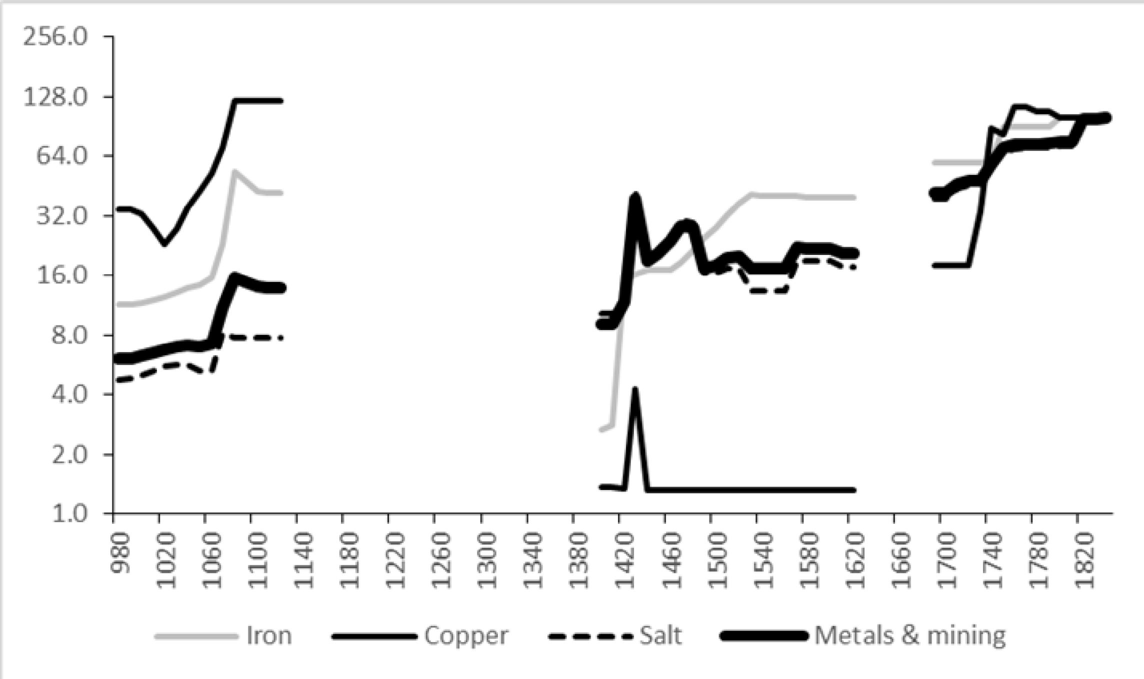
Sources: Wu (1985); Guo (2000); Luo (1999).

FIGURE 3: Chinese agricultural output and output per capita, 980-1840 (1840=100, log scale)



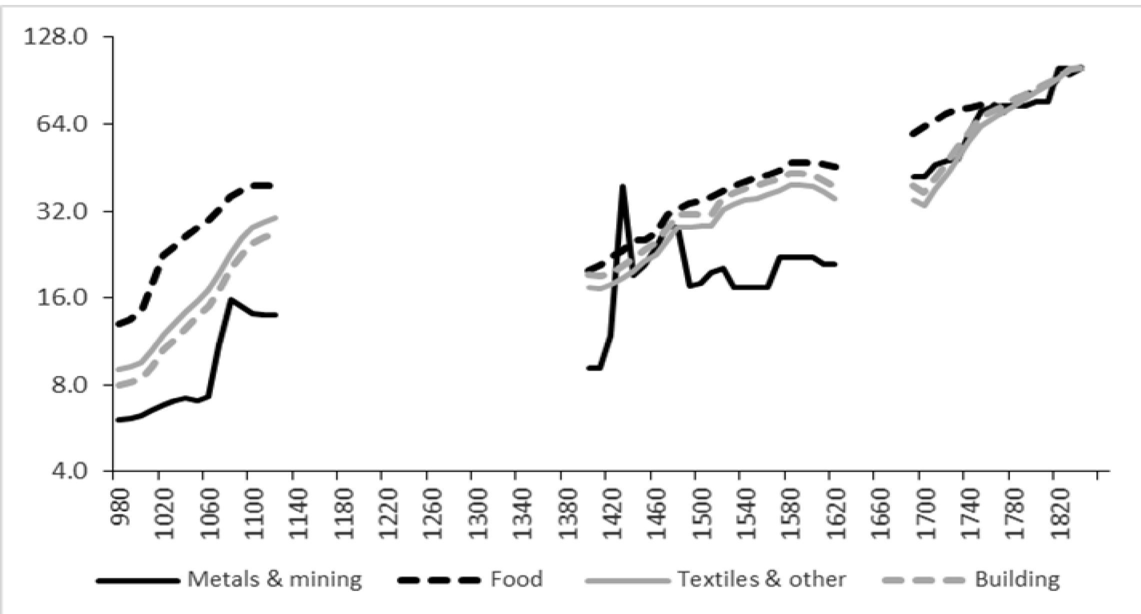
Sources and notes: See Appendix A1 for a detailed discussion of sources and methods.

FIGURE 4: Indices of Chinese metals and mining production, 980-1840 (1840=100, log scale)



Sources: See Appendix A2.

FIGURE 5: Indices of Chinese industrial output by major branch (1840=100, log scale)

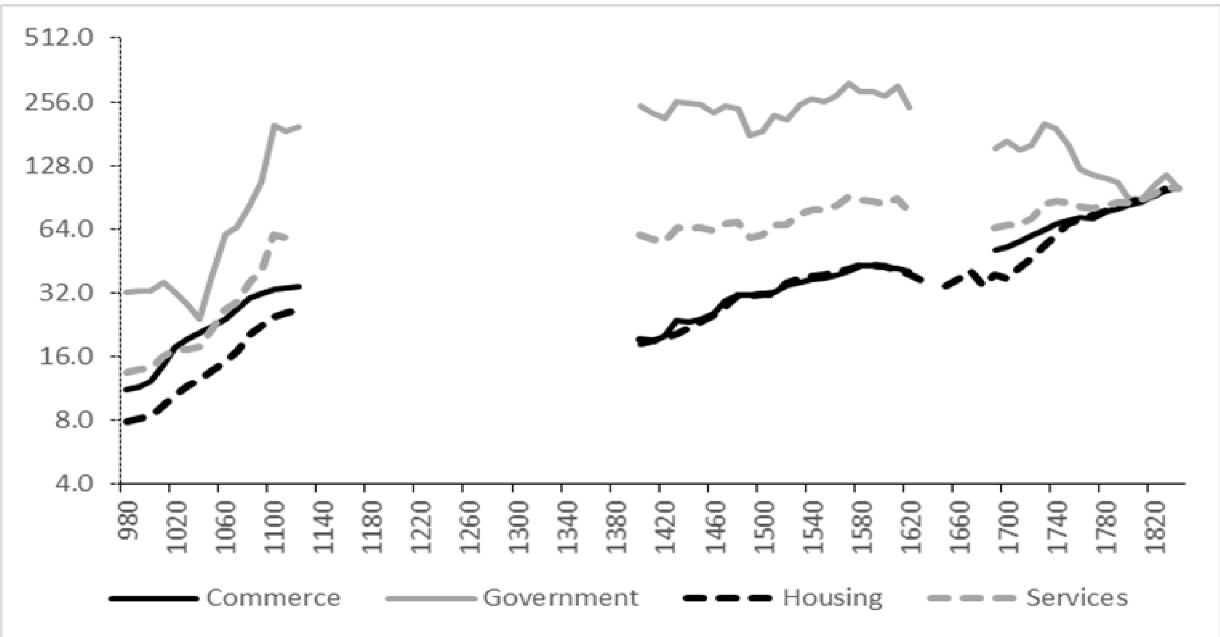


Sources: See Appendix A2.

FIGURE 6: Chinese industrial output and output per capita, 980-1840 (1840=100, log scale)

Sources: See Appendix A2.

FIGURE 7: Indices of Chinese service sector output by major branch, 980-1840 (1840=100, log scale)

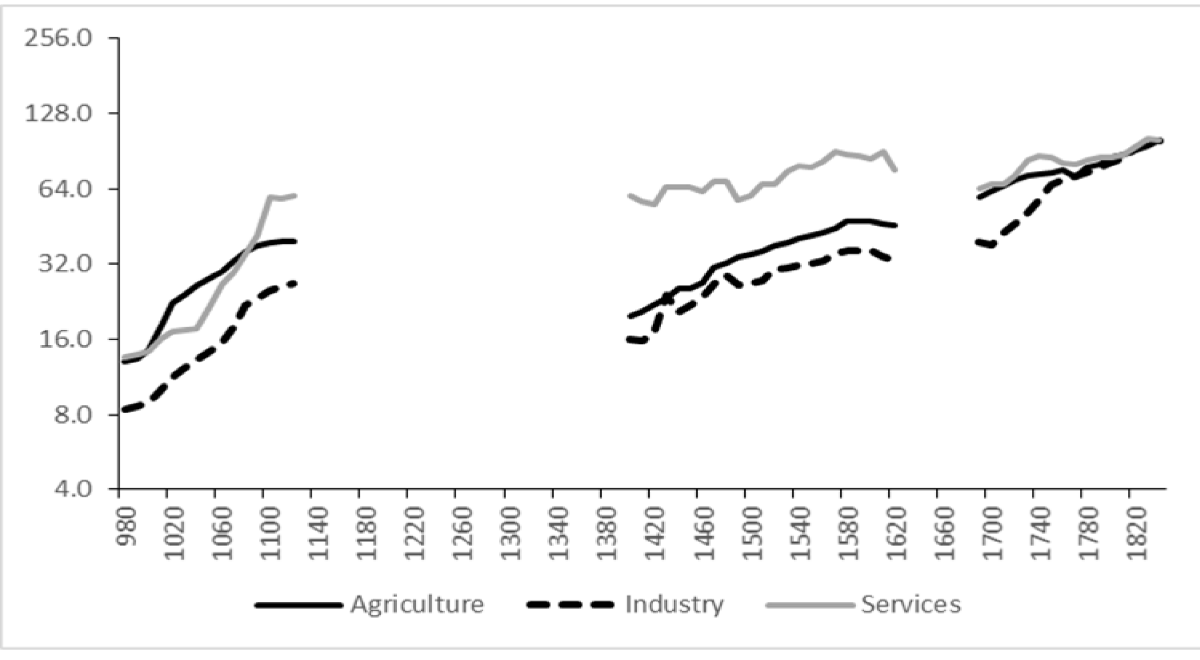


Sources: See Appendix A3.

FIGURE 8: Chinese service sector output and output per capita, 980-1840 (1840=100, log scale)

Sources: See Appendices A1 to A3.

FIGURE 9: Chinese agricultural, industrial and service sector output, 980-1840 (1840=100, log scale)



Sources: See Appendices A1 to A3.

TABLE 2: Chinese current price GDP in 1840 (000 tael)

A. Agricultural GDP

	Volume (000 jin)	Price (tael per jin)	Gross output (000 tael)	Net output (000 tael
Grain crops	296,502,281	0.0104	3,087,106	2,624,040
Cash crops				661,258
Livestock, forestry, fishing				272,900
AGRICULTURE				3,558,198

B. Industrial GDP

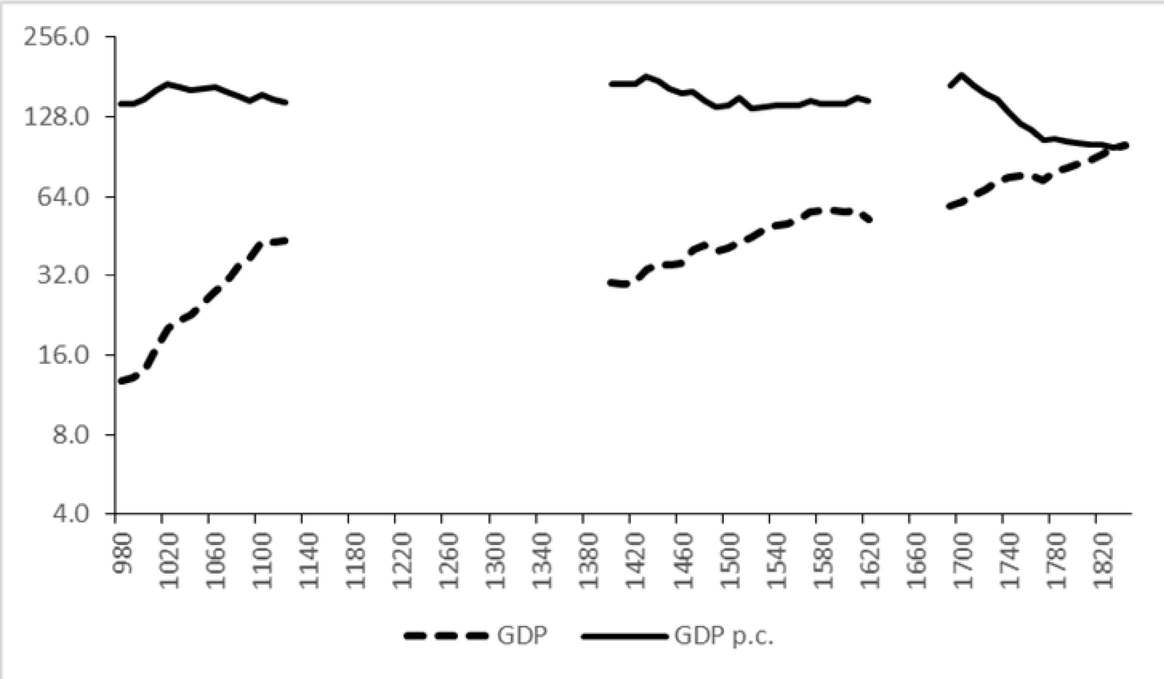
	Net output (000 tael)
Iron	7,663
Copper	427
Salt	42,578
Other metals & mining	51,096
METALS AND MINING	101,764
Food processing	31,895
Textiles	197,605
Other manufacturing	38,076
MANUFACTURING	267,577
Building	63,692
TOTAL INDUSTRY	433,033

C. Service sector and total economy GDP

	Net output (000 tael)
Commerce (transport, trade, finance)	690,290
Government	349,059
Housing & other private services	349,059
SERVICES	1,388,409
TOTAL ECONOMY	5,379,640

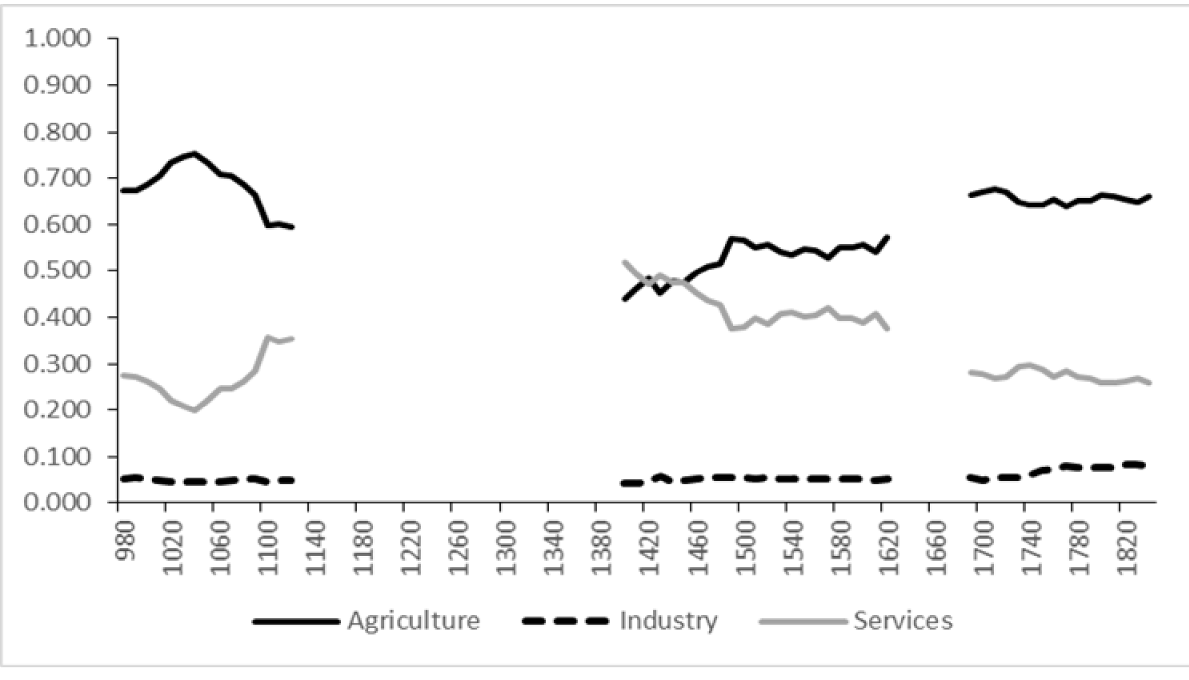
Sources: Agriculture: See Appendix A3. Industry and services: derived from agriculture using sectoral shares from Zhang (1987).

FIGURE 10: Chinese constant price GDP and GDP per capita, 980-1840 (1840=100)



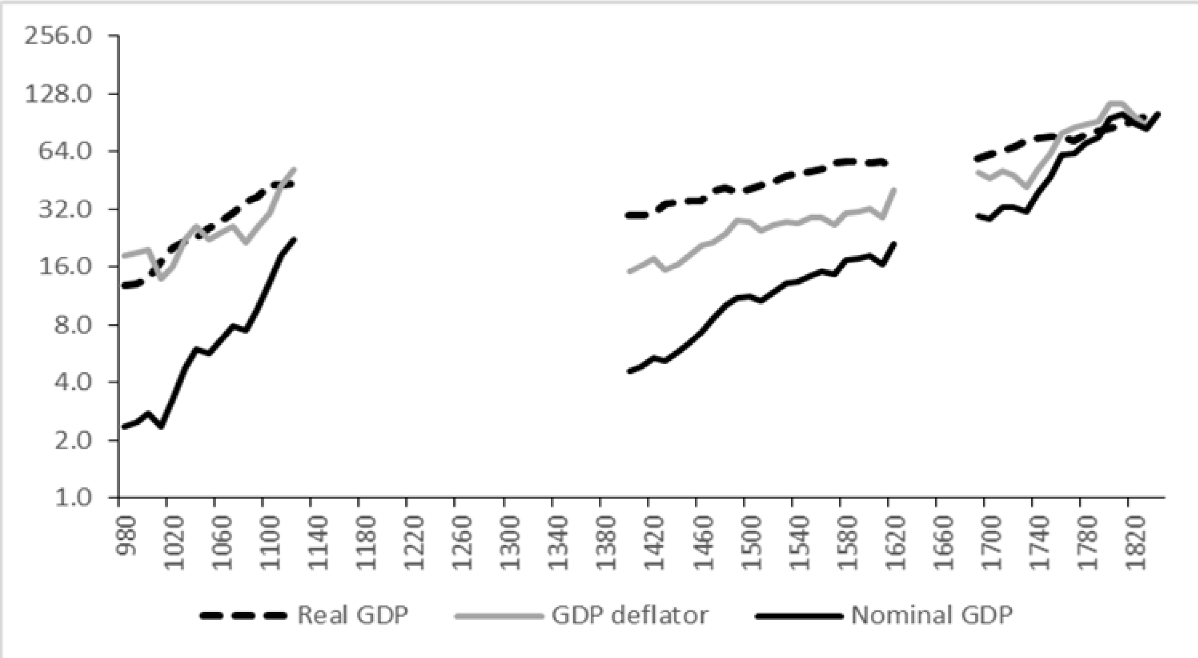
Sources: See Appendices A1 to A3.

FIGURE 11: Chinese sectoral shares of constant price GDP, 980-1840



Sources: See Appendices A1 to A3.

FIGURE 12: Real GDP, the GDP deflator and nominal GDP in China (1840=100)



Sources: See Appendices A1 to A4.

TABLE 3: Data reliability assessments

	Northern Song	Ming	Qing
Agriculture			
Cultivated land	C	B	A
Crop yields	B	B	A
Industry			
Iron	B	C	B
Copper	B	C	B
Salt	B	B	B
Food processing	C	B	A
Textiles	B	B	A
Building	B	B	A
Services			
Commerce	B	B	A
Government	B	B	B
Housing & domestic service	B	B	A
Real aggregates			
GDP	B	B	A
Population	B	B	A
GDP per capita	B	B	A
Nominal aggregates			
GDP deflator	D	C	B
Nominal GDP	C	C	B

Sources: based on error margins from Perkins (1969), comparisons with alternative series produced by other authors and the volatility of the underlying data, as described in the text. See Appendix Table A1 for a statistical interpretation of the reliability grades.

TABLE 4: A China/GB PPP for 1840

	China tael/lb	GB £ per lb	PPP Tael per £	Chinese weights	British weights
Rice	0.01407	0.02500	0.56	0.201	0.000
Wheat	0.00900	0.00691	1.30	0.134	0.335
Sugar	0.04900	0.02191	2.24	0.134	0.134
Tea	0.09347	0.13021	0.72	0.134	0.134
Salt	0.00544	0.00134	4.07	0.067	0.067
Iron	0.04195	0.00402	10.44	0.046	0.046
Cotton cloth	0.20690	0.11301	1.83	0.284	0.284
FOOD			1.53		
OTHER			3.04		
TOTAL			2.03		

Sources and notes:
GB:
Rice: Beveridge (1939: 433). The figure of 6s per 12 lb from the Lord Steward's Department actually refers to 1830.
Wheat: UK Board of Trade (1903: 70). The figure of 66s 4d per imperial quarter is taken originally from the *London Gazette*.
Sugar: UK Board of Trade (1903: 162). The average price per cwt unrefined sugar exclusive of duty.
Tea: UK Board of Trade (1903: 177). Average price per lb in bond.
Salt: UK Board of Trade (1903: 188). Data originally from Greenwich Hospital.
Iron: Mitchell (1988: 762). English merchant bar iron at Liverpool.
Cotton cloth: Mitchell (1988: 761). Average value of cotton piece goods exported, converted from yards to lb using 1840 ratio from Robson (1957: 331).
Weights: Based on Feinstein (1995) for the mid-nineteenth century. Food and non-food items have weights of 0.67 and 0.33, respectively. For the breakdown within food, Feinstein (1995) suggests that grain based products (wheat flour and bread) accounted for around half of expenditure on food. Thus wheat is given a weight of 0.335 and rice, which was prohibitively expensive, has a weight of zero. The remaining expenditure on food has been allocated across sugar, tea and salt, with equal weights for sugar and tea and a smaller weight for salt, again broadly consistent with budget studies. Within non-food, the breakdown between cotton and iron is in proportion to the value added in these two industries, from Horrell, Humphries and Weale (1994).
China:
Rice: Peng (1965: 850).
Wheat: *Yiban lu*.
Sugar: Fu (1987).
Tea: Yao (1962, vol. 1: 582), based on export prices.
Salt: *Qingshi gao (Shihuozhi: Yanfa).*
Iron: Kong (1981: 509, 527), wrought iron.
Cotton cloth: Yao (1962, vol. 1: 557, 616), based on export prices.
Weights: The weights are the same as for Britain, apart from an allowance within food for rice, based on the late-Qing ratio between wheat and rice production (30:20). Within non-food, the breakdown between cotton and iron is broadly consistent with the late-Qing shares of value added in textiles and metals production.

TABLE 5: A benchmark estimate of China/GB GDP per capita in 1840

China	
Nominal GDP (million tael)	5,379
Population (million)	412
GDP per capita (tael)	13.05
England	
Nominal GDP (£ million)	496.30
Population (million)	18.332
GDP per capita (£)	27.07
Exchange rates	
Silver exchange rate (tael per £)	3.20
PPP (tael per £)	2.03
Comparative China/GB GDP per capita (%)	
At silver exchange rate	15.04
At PPP	23.76
GDP in 1990 international dollars	
GB	2,521
China	599

Sources and notes: Nominal GDP and population from Figures 1 and 7 for China, and from Broadberry, Campbell, Klein, Overton and van Leeuwen (2015) for Britain. Silver exchange rate derived from the silver weight of the tael and pound sterling from von Glahn (1996: 133) and Craig (1953), respectively. PPP from Table 3. GDP for Britain in 1990 international dollars from Broadberry, Campbell, Klein, Overton and van Leeuwen (2015).

TABLE 6: GDP per capita levels in China and Britain (1990 international dollars)

	China ($1990)	GB ($1990)	China/GB (GB=100)
980	853		
1020	1,006		
1060	982		
1090	878	754	116.4
1120	863		
1270		759	
1300		755	
1400	1,032	1,090	94.7
1450	990	1,055	93.8
1500	858	1,114	77.0
1570	885	1,143	77.4
1600	865	1,123	77.0
1650		1,110	
1700	1,103	1,563	70.6
1750	727	1,710	42.5
1800	614	2,080	29.5
1840	599	2,521	23.8
1850	600	2,997	20.0

Sources and notes: GB: Broadberry, Campbell, Klein, Overton and van Leeuwen (2015); Walker (2014). China: Figure 10.

TABLE 7: GDP per capita levels in Europe (1990 international dollars)

	England/ GB	Holland/ NL	Italy	Spain
1270	759			957
1300	755		1,482	957
1348	777	876	1,376	1,030
1400	1,090	1,245	1,601	885
1450	1,055	1,432	1,668	889
1500	1,114	1,483	1,403	889
1570	1,143	1,783	1,337	990
1600	1,123	2,372	1,244	944
1650	1,100	2,171	1,271	820
1700	1,630	2,403	1,350	880
	1,563			
1750	1,710	2,440	1,403	910
1800	2,080	2,617	1,244	962
		1,752		
1820	2,133	1,953	1,376	1,087
1850	2,997	2,397	1,350	1,144

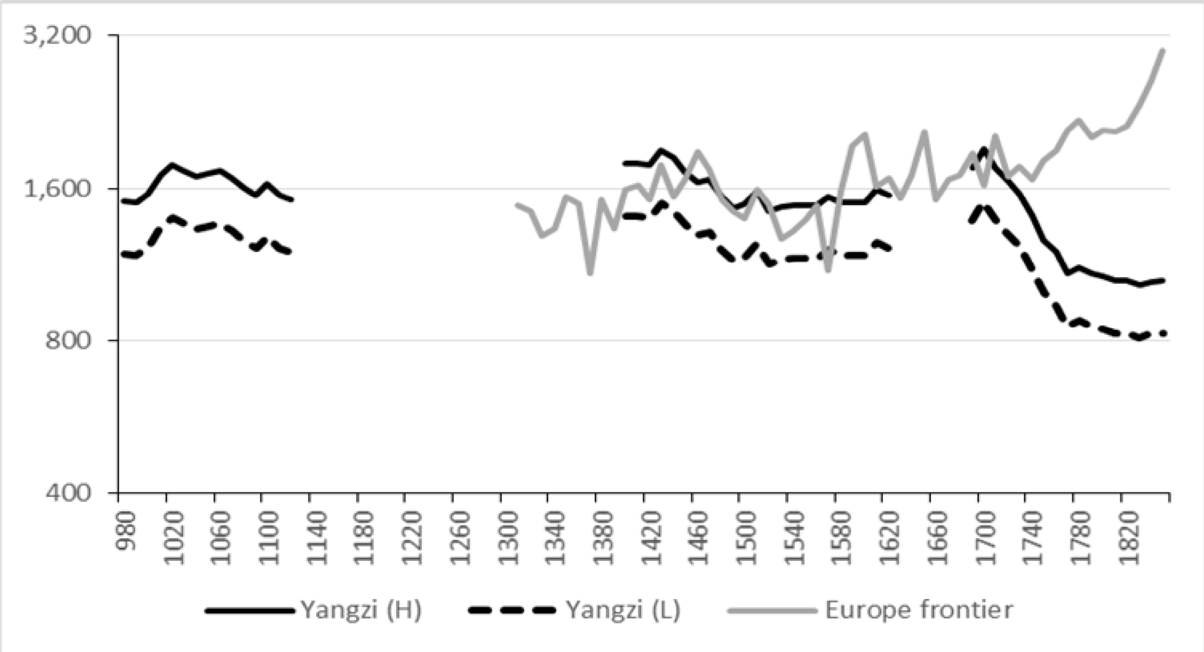
Sources and notes: England/Great Britain: Broadberry, Campbell, Klein, Overton and van Leeuwen (2015). The data refer to the territory of England before 1700 and Great Britain after 1700; Holland/Netherlands: van Zanden and van Leuwen (2012). The data refer to Holland before 1800 and the Netherlands after 1800; Italy: Malanima (2011); Spain: Álvarez-Nogal and Prados de la Escosura (2013).

TABLE 8: GDP per capita levels in Europe and Asia (1990 international dollars)

	England/ GB	Holland/ NL	Italy	Japan	China	India
725				551		
900				476		
980					853	
1020					1,006	
1060					982	
1090	754				878	
1120					863	
1150				508		
1280	679			552		
1300	755		1,482			
1400	1,090	1,245	1,601		1,032	
1450	1,055	1,432	1,668	552	990	
1500	1,114	1,483	1,403		858	
1570	1,143	1,783	1,337		885	
1600	1,123	2,372	1,244	605	865	682
1650	1,110	2,171	1,271	619		638
1700	1,563	2,403	1,350	597	1,103	622
1750	1,710	2,440	1,403	622	727	573
1800	2,080	1,752	1,244	703	614	569
1850	2,997	2,397	1,350	777	600	556

Sources: GB: Broadberry, Campbell, Klein, Overton and van Leeuwen (2015); Walker (2014); Holland/Netherlands: van Zanden and van Leuwen (2012); Italy: Malanima (2011); China: Table 6; Japan: Bassino, Broadberry, Fukao, Gupta and Takashima (2014); India: Broadberry, Custodis and Gupta (2015).

FIGURE 13: GDP per capita in the leading regions of Europe and China (1990 international dollars)



Sources and notes: Europe frontier is derived as: 1300s to 1540s: Italy from Malanima (2011); 1540s to 1800s: the Netherlands from van Zanden and van Leeuwen (2012); 1800s to 1860s: Great Britain from Broadberry, Campbell, Klein, Overton and van Leeuwen (2015). Yangzi (H), the high estimate for the Yangzi delta, is derived as 1.75 times the level of GDP per capita in China as a whole from Table 8. Yangzi (L), the low estimate for the Yangzi delta is derived as the same series benchmarked on $472 in 1850 from Shi, Xuyi, Ni and van Leeuwen (2014).

APPENDIX 1: DATA SOURCES AND METHODS FOR TIME SERIES, 980-1840

A1 AGRICULTURAL OUTPUT

A1.1 Cultivated land

Northern Song dynasty

The cultivated land area is derived for the years 976, 997, 1021, 1051, 1066 and 1083 from the official literature: *Wenxian tongkao (Tianfu kao; Lidai Tianfu Zhizhi)* and *Songshi, (Shihuo Zhi, Nongtian)*, with other years obtained by interpolation. However, the official figures have been adjusted in line with the work of Qi (2009: 65), who finds that the actual amount of cultivated land was substantially greater than the officially recorded amount after 1051.

Ming dynasty

The amount of cultivated land after 1400 has been estimated at a 10-year frequency by Liu and Hwang (1977: 81-82). Here, we use the adjusted figures of Shi (2011: 97; 2015: 21) and Wang (2003: 10), which correct for an under-recording of land during the period 1520-1620.

Qing dynasty

The amount of cultivated land is taken from Shi (2011: 96; 2015: 9) for 1661, 1685, 1724, 1766, 1812 and 1850, with other years obtained by interpolation. As during the Ming period, these estimates include a correction for under-reporting, obtained by comparing independent estimates with official estimates in particular regions.

A1.2 Crop yields

Northern Song dynasty

Grain yield per *mu* is available from the following official literature and private historical works: *Song huiyao jigao (Shihuo) (Shihuo zhi buzheng*) and *Wenxian tongkao (Tianfu kao, Tuntian).* Here, we use the average country level estimates from Qi (2009: 154) and Wu (1985: 19). Average grain yields for the years around 1020, 1060 and 1100 are based on 286 local observations. Although Perkins (1969: 315-332) worked with 261 observations, they were restricted to Zhejiang and Jiangsu provinces, while Qi (2009) and Wu (1985) provide a more geographically representative sample. Grain yields were generally higher in Southern China than in Northern China, while Eastern China had higher yields than Western China. Looking at the entire Northern Song period, the grain yield per *mu* increased gradually.

Ming dynasty

Grain yield per *mu* is derived by Guo (2000: 385) from a sample of land rent rate data. Guo (2000: 375-380) added 92 observations to the 87 local grain yields collected by Perkins (1967: 315-332) for the Ming dynasty. He aggregated the local yields on the basis of four different grades of land (highest, high, middle, and low), covering both southern rice areas and northern wheat areas. Country-wide averages for the years around 1402, 1482, 1530 and 1626 are obtained using weights for the different qualities of land (10, 30, 40 and 20 per cent, respectively).

Qing dynasty

Grain yield per *mu* for the Qing dynasty is derived by Shi (2015: 12) from 3,000 local observations based around the six years 1661, 1685, 1724, 1766, 1812 and 1850. This represents a considerable increase over the 497 observations reported by Perkins (1967: 315-332), as a result of Shi's (2015) use of additional gazetteers and private historical sources. Average yields are calculated for dry farming and paddy farming in northern China, with weights of 52.7 and 0.5 per cent in China's total cultivated land area. For southern China, dry farming paddy farming and multiple cropping on both types of land have weights of 23.4, 14.0 and 9.4 per cent, respectively.

A1.3 Agricultural net output in 1840

Grain crops

The total cultivated land area is first adjusted by the share of land devoted to grain crops, derived from Table 1. This is then multiplied by the average grain yield to obtain the volume of grain output. The volume of output is multiplied by the price of grain from *Yiban lu* to obtain gross output. Agricultural inputs are set at 15 per cent of gross output, in line with the findings of Fang (1996: 94) and Luo (1999: 38), and subtracted from gross output to arrive at the value of net output.

Cash crops

The net output of cash crops is set at 25.2 per cent of the net output of grain crops, in line with the ratio for the 1880s from Zhang (1987: 90).

Livestock, forestry and fishing

The net output of livestock, forestry and fishing is set at 10.4 per cent of the net output of grain crops, in line with the ratio for the 1880s from Zhang (1987: 90).

A2 INDUSTRIAL OUTPUT

A2.1 Metal and Mining Industries

A2.1.1 Iron

Northern Song dynasty

We use the estimates of Liu (1993: 90), which show a much lower peak level of iron production in 1078 than Hartwell (1962: 153-162).

Ming dynasty

The production of the state-run iron industry, which was based mainly in Zunhua City, can be derived from the official records. The production of the private iron industry can be calculated from the tax revenue, which can be found in *Ming shilu*; *Da Ming huidian, Vol.194*; and *Guangdong tongzhi chugao in the reign of the Jiajing Emperor* (Huang, 1989: 2-18).

Qing dynasty

Data from Li (1979: 116-126) are used to estimate the output of iron in Guangdong, the centre of the iron mining and metallurgical industry. Output is also estimated for other provinces to derive the total volume of iron production.

A.2.1.2 Copper

Northern Song dynasty

The volume of copper output is estimated from the *ke e(r)*, or tax quota, following the research of Wang (2005: 59-60) and Wang (1995b: 726), based on the original data from *Xu zizhi tongjian changbian, Wenxian tongkao, Song huiyao jigao*. Because of the government's strict regulation of the production of copper, which was used for minting, few adjustments to the *ke e(r)* were needed. For the period 1078-1125, the original data show too steep a decline because they cover only the southern area of Northern Song China, so output has been held constant after 1078.

Ming dynasty

Tax data on the private copper industry and production data on the state-run copper industry are available at infrequent intervals, and must be interpolated for other years.

Qing dynasty

Copper output data come from Xu and Wu (1985: 491-493). During the Qing dynasty, the government gave up the right to monopolize the mining of minerals. In some provinces, there are thus gaps in the data on copper production. Abundant data exist for Yunnan province, which was an important centre of copper mining, and to which estimates for other provinces are added, based on more fragmentary information,

A.2.1.3 Salt

Northern Song dynasty

Guo (1997: 647) collected data on salt production in different regions and then aggregated it to arrive at national salt output.

Ming dynasty

Salt tax data were recorded in *Ming shilu*, but have been supplemented with information from the demand side, making use of estimates of consumption per head, multiplied by population.

Qing dynasty

Salt output during the Qing dynasty is also taken from the research of Guo (1997: 727).

A.2.2 Food processing

Following Broadberry, Campbell, Klein, Overton and van Leeuwen (2015), we assume other food processing industries grew in line with agricultural output.

A.2.3 Textiles

Output is assumed to grow in line with population, which is consistent with the absence of a trend in cloth consumption per head (Li, 2005: 57-58; Xu, 1992: 215-216).

A.2.4 Building

Building is assumed to grow in line with population, but with an allowance for urbanization. This follows the procedure of Broadberry, Campbell, Klein, Overton and van Leeuwen (2015) in the estimation of English economic growth, 1270-1700. The urbanization data are taken from Rozman (1973), as presented by Maddison (1998: 35).

A3 SERVICE SECTOR OUTPUT

A3.1 Commerce

The output of the commercial sector is estimated indirectly from data on the volume of agricultural and industrial output. The 1840 weights of 58 per cent for agricultural goods and 42 per cent for industrial goods reflect the much lower share of agricultural output that was marketed. Wu (1998: 21) finds a commercialisation rate of 17 per cent for agriculture, whereas all industrial output was assumed to be marketed. The value of distributed output is thus derived as 17 per cent of agricultural GDP plus 100 per cent of industrial GDP in 1840 from Table 2.

A3.2 Government

Output of government services is derived from the numbers of civil servants and soldiers multiplied by their salaries. The numbers of soldiers and civil servants and their pay are taken from Li (1988: 78-103) and Wang (1995a: 774,778) for the Northern Song dynasty. For the Ming dynasty, data for all parts of government can be obtained from *Ming shilu* and *Wanli kuaiji lu*. For the Qing dynasty, data are taken from Chen (2008: 405-437) and from Shi and Xuyi (2008: 50). The nominal value of these services is converted to real terms by deflating with a price index. Details of the GDP deflator used for this purpose are given in Appendix A4.

A3.3 Housing and domestic service

Following Broadberry, Campbell, Klein, Overton and van Leeuwen (2015), it is assumed that housing and domestic service grew in line with population, with an allowance for urbanization from Rozman (1973), as detailed in section A2.4 on building.

A4 PRICES

A.4.1 Agriculture

Northern Song dynasty

The price series of grain crops are taken from Qi (2009: 1103-1105) and Quan **(**1991: 29-87, 235-265**),** both of whom estimate the prices of rice and wheat, and argue that the prices of other crops (such as millet and beans) moved in similar ways. Qi provides observations for 14 years between 1007 and 1117, with 7 observations drawn from *Xu zizhi tongjian changbian*, 2 observations from *Shihuo of Song huiyao jigao*, and the other 5 observations from private historical sources. Quan draws his observations from the same sources as Qi, but provides more historical analysis of the price changes during this period. The price series for grain is an unweighted average of the price of wheat and rice.

Ming dynasty

Peng **(**1965: 704**)** records the price series of rice measured in silver throughout the Ming dynasty based on a 10-year frequency. Data on the price of wheat are more limited for this period, but suggest a price of around 80 per cent of the price of rice. Ninety per cent of Peng's prices are drawn from *Ming shilu*, with the other ten per cent coming from private historical sources.

Qing dynasty

Rice prices during the Qing dynasty are taken mainly from the work of Peng (1965: 850), drawn from *Qing shilu* and *Qingshi gao*. Other crop prices are taken from Luo (1999: 32-33), based on Zheng Guangzu's *Yiban lu*.

A.4.2 Non-agriculture

Northern Song dynasty

The price series for cloth is an unweighted average of silk and hemp cloth prices. The silk cloth price is assumed to move in line with the price of raw silk, collected by Qi (2009: 1106) from *Song huiyao jigao* and *Xu zizhi tongjian changbian*. Cheng (2008: 251-254) collected hemp price data from *Shihuo of Song huiyao jigao, Wenxian tongkao (Vol.5, Tianfu Kao),* and other private historical sources. Some of the hemp prices were recorded in iron coin and thus needed to be converted to copper coin.

Ming dynasty

The price series for cloth is an unweighted average of silk and cotton cloth prices. The silk cloth price is assumed to move in line with the price of raw silk. The primary sources for both silk prices and cotton cloth prices are *Ming shilu* and *Da Ming huidian.* Peng **(**1965: 711**)** collected silk prices from the second half of the fourteenth century to the second half of the sixteenth century. Peng (1965: 712) also provided cotton cloth prices for 9 years between 1368 (the first year of the Hongwu Emperor) and 1643 (the sixteenth year of the Chongzhen Emperor). Additional cotton cloth price data covering 21 years are taken from Yu (2000: 801-802).

Qing dynasty

The price of cloth is assumed to move in line with the price of cotton, which was the dominant cloth during the Qing dynasty. The primary sources for cotton cloth prices are *Qufu kongfu dangan ziliao xuanbian* and other private price history books. Huang (2008:112-114) recorded cotton cloth prices from 1644 (the first year of the Shunzhi Emperor) to 1839 (the nineteenth year of the Daoguang Emperor), obtaining a total of 30 observations. Based on these observations, he derives a national level trend. Yu (2000: 926-927) provides the same trend but his benchmark years are different, so we combine these two studies to arrive at a single series for cotton cloth prices during the Qing dynasty.

TABLE A1: Reliability grades

Reliability grade	Margin of error
A. Firm figures	± less than 5%
B. Good figures	± 5% to 15%
C. Rough estimates	± 15% to 25%
D. Conjectures	± more than 25%

Source: Feinstein (1972: 21).

TABLE A2: Summary information on data series

	Range	Coefficient of variation		
		Northern Song	Ming	Qing
Agriculture				
Cultivated land	20.9 – 100.0	0.32	0.22	0.09
Crop yields	62.4 – 100.0	0.05	0.05	0.07
Industry				
Iron	2.7 – 100.0	0.65	0.46	0.22
Copper	1.3 – 123.0	0.65	0.43	0.52
Salt	4.8 – 100.0	0.21	0.40	0.31
Food processing	13.0 – 100.0	0.35	0.27	0.15
Textiles	9.0 – 100.0	0.43	0.27	0.34
Building	7.9 – 100.0	0.43	0.27	0.31
Services				
Commerce	11.2 – 100.0	0.37	0.25	0.21
Government	32.4 – 310.6	0.84	0.14	0.27
Housing & domestic service	7.9 – 100.0	0.43	0.27	0.31
Real aggregates				
GDP	12.8 – 100.0	0.41	0.21	0.15
Population	9.0 – 100.0	0.43	0.27	0.34
GDP per capita	98.3 – 182.9	0.06	0.09	0.24
Nominal aggregates				
GDP deflator	15.2 – 114.4	0.39	0.26	0.33
Nominal GDP	2.4 – 100.4	0.78	0.43	0.45

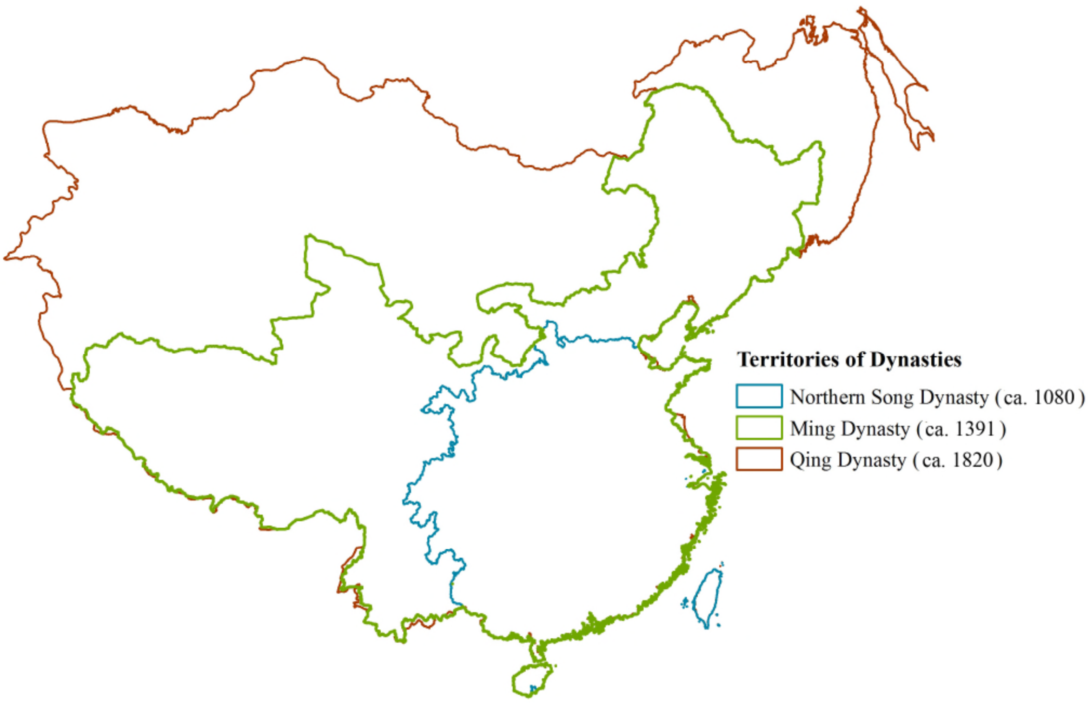
Sources: see Appendices A1 to A4.

TABLE A3: Recorded observations, benchmarks and methods of interpolation for independent component series

	Northern Song, 980 – 1120	Ming, 1400-1620	Qing, 1690-1840
Maximum possible number of decadal observations	14	22	15
Agriculture			
Cultivated land	6 observations with log-linear interpolation	22 recorded observations used to interpolate between 3 corrected benchmark years	6 observations with log-linear interpolation
Crop yields	Average grain yields for 3 years with log-linear interpolation	Average grain yields for 4 years with log-linear interpolation	Average grain yields for 6 years with log-linear interpolation
Industry			
Iron	8 observations with log-linear interpolation	5 observations with log-linear interpolation	3 observations with log-linear interpolation
Copper	6 observations with log-linear interpolation	3 observations with log-linear interpolation	15 observations for Yunnan and additional estimates for other provinces with log-linear interpolation
Salt	9 observations with log-linear interpolation	22 observations	13 observations with log-linear interpolation
Services			
Urbanisation	1 observation	1 observation	1 observation
Government	11 observations with log-linear interpolation	22 observations	15 observations
Real aggregates			
Population	9 observations with log-linear interpolation	22 recorded observations used to interpolate between 3 corrected benchmark years	15 recorded observations used to interpolate between 3 corrected benchmark years
Nominal aggregates			
Agricultural & non-agricultural prices	7 observations with log-linear interpolation	22 observations	15 observations

Sources: see text of Appendices A1 to A4.

MAP A1: Territories of the Northern Song, Ming and Qing dynasties



Sources: 1080 and 1391 territory maps are obtained from Robert Hartwell's "China Historical Studies" GIS dataset (http://www.people.fas.harvard.edu/~chgis/data/hartwell/);
1820 territory map is obtained from the China Historical Geographic Information System (https: www.fas.harvard.edu/~chgis)

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