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Abstract

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1. Introduction

Over the past two millennia, how has China—historically home to roughly one quarter of the world’s population—performed economically? Despite China’s rich documentary record in politics and literature, evidence on long-run economic performance remains limited. Modern statistical surveys did not become widespread until the mid-twentieth century, implying that even observers living in China a few centuries ago likely knew little about contemporary economic conditions. After World War II, economists and historians began to address this gap systematically (Liu and Yeh, 1965; Perkins, 1969; Liu and Hwang, 1979; Rawski, 1989). Landmark contributions over the past half-century—most notably Angus Maddison’s (1998) global historical GDP estimates and Kenneth Pomeranz’s (2000) “Great Divergence” thesis associated with the California School—reinvigorated interest in historical development and living standards. Since then, new reconstructions of China’s historical growth have appeared, offering important insights into GDP for most years after 980 CE (Broadberry, Guan, and Li, 2018, 2021; Liu, 2009; Ma and de Jong, 2019; Xu et al., 2017). These estimates rely primarily on the standard output approach. However, given the scarcity of early data, traditional methods struggle to produce a continuous GDP series for China before 1000 CE; moreover, between 1000 CE and the advent of systematic official national accounts in the 1950s, GDP estimates are still missing for roughly half of all years.

Is it possible to construct a continuous, high-resolution GDP dataset for China spanning more than two millennia? Combining an output-based approach for agriculture with an indirect, structure-based method for non-agriculture, we produce—for the first time—decadal, continuous GDP estimates for China (within modern borders) from 220 BCE to 1949 CE. We then link these series to post-1949 GDP data adjusted from official surveys, yielding the first panoramic view of China’s GDP from the onset of the imperial era to the present.

China’s two-millennium GDP estimates reveal the following: (1) Aggregate GDP grew steadily over the long run, expanding eighteenfold between 220 BCE and the 1940s, indicating sustained enlargement of economic scale. (2) For the two millennia

before 1950, GDP per capita remained below 1,000–1,500 international dollars (1990 prices). (3) Rapid and sustained growth in GDP per capita appeared only after 1950, reaching the fastest pace in Chinese history: within 70 years it expanded twenty-fourfold. This marks the onset of the “modern economic growth” phase—over a century later than in Britain and core Western Europe. (4) Before 1950, GDP per capita followed two distinct phases: a period of slow, long-run growth before 1000 CE (rising from 382 international dollars in 220 BCE to 1,431 in 1000 CE), followed by a phase of prolonged stagnation and gradual decline after 1000 CE (falling from 1,124 in 1010 CE to 517 in 1940).

With the data in place, we evaluate China’s economic performance over the past two thousand years. We first use this unusually long-run series to assess whether the Malthusian characterization of premodern growth embedded in mainstream growth theory is warranted (Ashraf and Galor, 2011; Galor, 2005, 2011; Galor and Moav, 2002; Galor and Weil, 2000; Hansen and Prescott, 2002). Unified Growth Theory posits that, until roughly two to three centuries ago, human societies were Malthusian: any increase in income per capita was offset by population growth, leaving long-run per-capita income near zero growth. Much empirical work has noted that Malthus’s 1798 thesis appears to describe most of premodern history; some even argue that the Industrial Revolution was the only truly transformative economic event, with little of consequence occurring in the preceding centuries or millennia (Clark, 2007). In a second phase, economies gradually achieved modest gains in income per capita through sustained technological progress, while demographic behavior still followed the Malthusian “the poor perish, the rich reproduce” mechanism. In the third phase, fertility behavior changed decisively with the demographic transition—characterized by active fertility control—while human capital accumulation and technological progress accelerated, ushering in the modern era of rapid per-capita income growth (Galor, 2005, 2011). Nonetheless, the timing of humanity’s escape from the “Malthusian trap” remains contested (Ashraf and Galor, 2011; Clark, 2007; Crafts and Mills, 2009; Madsen, Robertson, and Ye, 2019), and scholarly communities outside economics have not fully embraced the Malthusian account for more than 90% of human history (e.g.,

Lee and Wang, 2001; Pomeranz, 2000).

Because historical data are limited, empirical tests of Malthusian predictions focus largely on the last millennium. In Europe, for example, relatively reliable economic evidence begins only around the thirteenth century (Bolt and van Zanden, 2024), leaving the earlier Malthusian narrative weakly evidenced. Moreover, the economies examined typically had small populations, raising concerns about external validity. By contrast, our Chinese GDP dataset spans a much longer horizon, covers periods previously unstudied empirically, and is based on what is likely the largest population sample used in Malthusian research. Whether such a large economy exhibits a Malthusian pattern thus has major implications for the explanatory power of this classic theory and for modern growth models built upon it.

Our findings are straightforward. Following the approach of Madsen, Robertson, and Ye (2019), who test Malthusian dynamics without direct information on fertility and mortality, we argue that China's growth pattern before 1950 broadly fits the Malthusian model. However, unlike a strict "iron law of wages" economy, we observe that during the first millennium CE, China's GDP per capita did not exhibit long-run stagnation. Instead, it nearly tripled, showing sustained growth. By contrast, in the second millennium, China's growth pattern closely resembles the "textbook" Malthusian case.

To understand this "anomaly" in the first millennium, we apply a growth accounting framework incorporating labor, land, capital, human capital, technology, and institutions. Specifically, we (1) estimate production functions for the two millennia and (2) decompose factor contributions using the fitted functions. Results show that the absence of stagnation in the first millennium was driven by rapid expansion of non-labor factors. Each factor alone—land, capital, human capital, or technology—could offset the negative contribution of labor and yield positive per capita GDP growth, even if the others made no contribution. Land per capita did not decline significantly, while capital accumulation, human capital, and technological progress were especially strong; together, these three accounted for 86% of GDP per capita growth.

In the second millennium, however, the combined positive contributions of non-labor factors fell short of the negative effect of labor growth. As a result, GDP per capita reversed its trend and declined at an average annual rate of 0.5%. The slowdown stemmed from weaker growth in land and capital relative to labor, indicating resource constraints, but the sharpest problem lay in human capital and technological progress, whose contributions turned deeply negative. Had these factors performed as they did in the first millennium, GDP per capita would not have entered decline. In other words, the resource pressures accompanying China's population surpassing 100 million were foreseeable, but the collapse of human capital and technological progress—key components of TFP—was the fundamental cause of economic failure in this period.

Viewed through the lens of Unified Growth Theory, China's first millennium resembles a "second-phase" economy, while the second millennium regressed to a classical first-phase Malthusian economy. Yet in both eras, the absence of a demographic transition meant China remained, in essence, a Malthusian world.

The structure of this paper is as follows. It is divided into two main parts: measuring economic growth and analyzing economic growth. *Measuring economic growth*: Section 2.1 discusses the methodology for estimating GDP based on historical Chinese sources, with detailed data and materials for constructing the GDP component series provided in the appendix. Section 2.2 then uses the constructed GDP data to present China's economic performance over two millennia and compares it with mainstream estimates. *Analyzing economic growth*: Section 3.1 evaluates China's economic growth patterns over two millennia from a Malthusian perspective. The findings suggest that the widespread use of Malthusian theory by social scientists to describe premodern economic growth is reasonable, at least when viewed through China's longer time span and much larger population base. Section 3.2 then applies growth accounting to examine the main drivers of China's economic growth over the two millennia. Finally, the paper concludes with a summary.

2. Measuring Economic Growth

2.1 GDP Data Construction

Macroeconomic data in Chinese historical records are relatively well preserved, particularly for the agricultural sector. Detailed surveys of population and cultivated land can be traced back more than two millennia. Rulers in imperial China generally attached great importance to such data, which explains their systematic preservation in official histories. A distinctive tradition emerged whereby each dynasty, soon after its fall, would see the compilation of encyclopedic histories by individuals or official bodies under the new regime. These “national histories (国史)”, including the renowned *Twenty-Four Histories*, official chronicles, institutional compendia, and geographic treatises, contain a wide range of reliable and continuous macroeconomic information in both quantitative and qualitative form. From the Song dynasty onward, local encyclopedic works modeled on the style of the “national histories” proliferated, most prominently the local gazetteers. In addition, personal notes and local archives, which began to spread widely from the fourteenth century, further enriched the available material. Together, these sources form the foundation for reconstructing China’s historical GDP.

In contrast to Western Europe, where abundant, high-quality, and continuous micro-level data such as wages and prices have survived, Chinese historical records provide relatively limited information at the micro level. Long-term, reliable wage data only began to emerge after the sixteenth century (Liu, 2024), while high-resolution price information, such as annual series, became available primarily from the early seventeenth century (Peng, 1965; Wang, 1992).

As a result, the reconstruction of China’s historical GDP has relied mainly on direct output-based methods (Broadberry, Guan, and Li, 2018, 2021). By contrast, approaches commonly applied in European studies—using wages and consumer theory to infer GDP—are extremely difficult to apply in the Chinese context (Álvarez-Nogal and Prados de la Escosura, 2013; Malanima, 2011; Palma and Reis, 2019). One of the few attempts to apply such indirect European-style methods to China is Xu et al. (2017), who estimated GDP for the eighteenth to early twentieth centuries. More broadly,

historical GDP reconstruction in China relies more heavily on macro-level than micro-level information, with agricultural data being both more abundant and of higher quality than those for the non-agricultural sector across most periods (Solar, 2021). To date, direct estimates of value added for the three sectors can be traced back only as far as around 1000 CE. For earlier times, historical records are generally insufficient to support long-term output series for the non-agricultural sector. By contrast, agriculture, supported by rich and reliable documentation, allows the construction of output series spanning over two thousand years.

Given these conditions, our study adopts a comprehensive approach that combines the classical output method with an indirect method similar to those employed in European historical national accounts to reconstruct China's GDP over more than two millennia. Our methodology can be summarized as follows:

- (1) Agricultural sector: We apply the classical output method to calculate agricultural value added. This requires data on population, cultivated land, grain yields, crop composition, sown area, and the share of non-grain agricultural output, etc.
- (2) Non-agricultural sector: We use an “economic structure” indirect method, analogous to approaches employed in European studies. This method assumes that the share of non-agricultural value added in GDP is closely correlated with indicators such as the urbanization rate or the occupational structure of the non-agricultural labor force. In practice, multiplying urbanization or occupational structure data by an appropriate parameter serves as a proxy for the non-agricultural sector's GDP share. This method has been widely applied in historical GDP research for Europe, Japan, and regional studies of China, and has proven effective (Álvarez-Nogal and Prados de la Escosura, 2013; Malanima, 2011; Palma and Reis, 2019; Bassino et al., 2019; Broadberry and Guan, 2022).

The details of our data construction are consistent with this methodological framework. We first present the calculation methods and data sources for the agricultural sector, then explain the estimation of non-agricultural value added, and finally aggregate the

results to obtain the reconstructed GDP series. Further details are provided in the appendix.

Population

Some main results divided into agricultural and non-agricultural sectors are presented in Figures 1 and 2. Figure 1 contains three subplots (A–C), which illustrate three key elements of the agricultural sector: population, cultivated land, and grain yield. Each subplot also includes other widely cited results from the past half century for comparison. Subplot 1A shows China's population from 220 BCE to 1940 CE at a decadal resolution (each data point represents a ten-year average). Overall, the population increased more than tenfold, from about 40 million in 220 BCE to 500 million in the 1940s. However, the pace of growth differed markedly across periods. In the first millennium, population growth was relatively slow. China's population did not surpass 100 million until the 1070s. If the population was around 50–60 million at the beginning of the Common Era, it took nearly a thousand years to double. In the second millennium, growth accelerated noticeably. By the early seventeenth century, the population had approached 200 million, but large-scale wars and epidemics during the Ming–Qing transition caused heavy losses, and the true breakthrough to over 200 million occurred only in the early eighteenth century. From then on, doubling occurred much faster: while it took 600–700 years to rise from 100 to 200 million, the population doubled from 200 to 400 million in just about a century. Still, the growth trajectory was not always smooth. Population change was closely linked to dynastic transitions: during periods of political stability, losses were limited, whereas major declines typically occurred at times of regime change.

The slower growth of the first millennium was largely the result of frequent dynastic upheavals. In fact, during stable periods, population growth rates were not lower than in the second millennium. For example, annual growth rates during the stable phases of the Western Han and Eastern Han were 7.5 per thousand and 6.6 per thousand respectively, while the Tang reached 9.2 per thousand and the Northern Song 8.5 per thousand. By contrast, the Ming and Qing recorded lower rates of 4.2 per

thousand and 5.8 per thousand. Considering that periods of dynastic stability in the first millennium were much shorter than those in the second—especially the Ming and Qing, each lasting nearly 200 years or more (longer stable periods may make the calculated average annual growth rate during stable periods appear lower)—the population growth rates during stable periods were in fact not very different between the two millennia. The main reason for the difference in average population growth rates across the entire two millennia is that dynastic transitions were less frequent in the second.

Comparing the Ming and Qing alone, population growth was indeed faster in the Qing. Yet relative to other dynastic stable periods, Qing growth does not appear exceptional. Thus, the long-standing question in Chinese economic history of whether Qing population experienced an “explosion” due to the introduction of New World crops appears, in our view, not to be evident, although we do not deny that such crops may indeed have contributed to population growth. Compared with other widely cited studies, we also note that scholarly disagreement over China’s macro-level population estimates remains limited.

Cultivated land

The pattern of cultivated land is broadly similar to that of population. During periods without major demographic losses (the so-called stable dynastic periods), cultivated land generally expanded continuously. In the first millennium, China’s cultivated area remained below 600 million mu for a long time, only surpassing 800 million mu in the Northern Song. In the sixteenth century, total cultivated land exceeded 1 billion mu and eventually passed 1.4 billion mu in the nineteenth century. Comparing population and cultivated land provides further insights. Figure 5B presents the long-run trend of land per capita. In the first millennium, cultivated land per capita was relatively stable, generally maintained at 8–10 mu per person. Assuming five persons per household, this equals about 40–50 mu per household, which closely matches the land allotment standards set by governments for peasant households or soldiers in regions where land was relatively abundant. This likely reflects the maximum area a household could manage in the absence of modern machinery and fertilizers.

From the second millennium onward, however, per capita land declined steadily. By the nineteenth and twentieth centuries, household landholdings had fallen to about 10–15 mu, or just 2–3 mu per person. This suggests that China may have faced a serious resource and environmental constraint in the second millennium, as population growth was no longer matched by the expansion of cultivable land. Still, research on cultivated land appears to be much less consensual than that on population. On the one hand, fewer studies exist; on the other, cultivated land figures are much less abundant in historical records than population numbers, making this research inherently more difficult. Although Figure 1B shows that our estimates broadly align with most earlier results, we do find some studies reporting lower absolute values for the Ming and Qing. Upon closer examination, our estimates appear more plausible. Research on Ming land is limited, and the continuous series by Broadberry, Guan, and Li (2018) is one of the few available, though their estimates are clearly lower. This may stem from their reliance on Perkins’s (1969) benchmark estimates for the Ming, which in turn appear to be based mainly on civil administration records found in official histories and local gazetteers, thus omitting the military land system (Zhai, 2024).

For the Qing, discrepancies across studies are smaller, but we believe most estimates are still likely to be biased downward. Many scholars have recognized the issue that if Ming–Qing land estimates are set too low in absolute terms (Perkins, 1969; Shi, 2017), it becomes difficult to reconcile them with the official figure of nearly 2 billion mu after the 1980s based on modern techniques such as remote sensing. In other words, if both the lower Ming–Qing estimates and the higher mid-twentieth-century figures are accepted, one must assume an implausibly sharp increase in cultivated land during the first half of the twentieth century. Taken together, we conclude that most existing studies may still underestimate Ming–Qing cultivated land, especially for the Qing. Assigning relatively higher absolute values is thus a reasonable and cautious choice, which is also the approach we adopt.

Grain yield

The results for grain yield are relatively straightforward. Across both millennia, grain yield followed a long-term upward trend, with only a modest decline in the twelfth to fourteenth centuries—likely driven by declines in northern dryland crops, which may reflect the prolonged warfare in North China at the time. Even so, the overall increase was not particularly large: by the early twentieth century, grain yield was only a little more than double its level at the beginning of the Common Era. Compared with population and cultivated land, this expansion was limited, but under premodern technological conditions such an improvement was still substantial.

It should also be noted that for a long time historical studies of China's grain yield were dominated by Wu (1985), one of the earliest contributors. However, Chen and Peng (2022), after comparing multiple estimates against early twentieth-century survey data, concluded that Wu's figures were consistently too high to be credible. We reach a similar conclusion. Wu's estimates align closely with the yields of rice—the highest-yielding crop in China—which is implausible for overall grain output. Thus, Wu's results are most likely problematic. Excluding Wu, our estimates are broadly consistent with those of most other scholars.

Performance of the agricultural and non-agricultural sectors

Figure 2, comprising subfigures 2A and 2B, presents the main computational results for the agricultural and non-agricultural sectors, based on the methodology outlined in this section. Subfigure 2A illustrates both the output of the constituent subsectors within agriculture and per capita agricultural value added. Broadly, agriculture is divided into crop production and other activities, with crop production further subdivided into grain crops (rice and dryland crops) and cash crops.

Over the course of more than two millennia, total agricultural output expanded nearly twentyfold, following a long-run upward trajectory. Grain crops accounted for roughly 60–70% of total agricultural output over the long term. In the second millennium, particularly during the Ming and Qing dynasties, the share of grain crops declined. This corresponds to historians' view that rural proto-industrialization in late imperial China was driven by the expansion of non-grain activities (Li, 1998, 2010).

Nonetheless, this structural change was less pronounced than often suggested. As Zhai (2023, 2024) shows for the Yangzi Delta, although non-grain crops such as cotton became increasingly significant after the fourteenth century, their absolute scale remained limited compared to staple grain production. Hence, the so-called “cash crop revolution” or “cotton revolution” may not have been as transformative as conventional wisdom suggests.

The per capita results provide further insights into agricultural development across the two millennia. Despite the sharp increase in aggregate output, population growth constrained the long-term rise in per capita agricultural value added. By the 1940s, per capita output was only marginally higher than in the third century BCE. Even so, the first millennium witnessed a remarkable rise in per capita agricultural value added, roughly tripling, which—under premodern conditions—represented a substantial improvement, equivalent to a threefold increase in food availability, assuming distributional patterns remained constant.

In contrast, the second millennium saw a gradual decline in per capita agricultural value added. Prior to the seventeenth century, this trend was not particularly pronounced: from the twelfth to the sixteenth centuries, per capita levels remained at roughly twice those of the third century BCE, showing no clear long-run trend. However, following a temporary increase in the mid-seventeenth century—likely associated with demographic and agrarian shifts during the Ming–Qing transition—per capita value added declined steadily throughout the eighteenth to twentieth centuries, returning by the early twentieth century to levels comparable with those two millennia earlier.

These results also suggest mounting food supply pressures during the Qing dynasty and bear directly on the historiographical debate over the existence of a “High Qing” (Huang, 1985, 1990, 2002; Rawski, 2025; Zhai, 2023). The central issue is whether per capita welfare declined in eighteenth- to twentieth-century China, leading to what some have termed “An Age of Prosperity Amid Hunger (饥饿的盛世)”. Our findings lend support to the view that this period exemplified what Elvin (1973) described as “quantitative growth, qualitative standstill”.

Figure 2B shows the share of the non-agricultural sector in total GDP. Over the long run, this share remained stable at 30–40%. As explained in the Appendix, the calculation is primarily driven by urbanization rates; thus, the persistence of this range also implies long-term stability in urbanization, which hovered around 10% for two millennia. While such results accord with the historical experience of premodern China, they are based on a rough indirect method and require further verification. Broadberry et al. (2018) provide a useful comparison using production-based estimates. Except for the Northern Song, where their figures are lower, both the trends and levels are close to ours. The discrepancy likely reflects their underestimation of non-agricultural activity. Mainstream historiography considers the Northern Song as possibly the peak of non-agricultural development in Chinese history. If urbanization reflects relative non-agricultural development, the Song’s rate of 12%—compared with below 10% in the Ming–Qing—suggests that its non-agricultural share was unlikely lower than in those later periods.

We also present Zhai’s (2023) output-based estimates for the Yangzi Delta, China’s most advanced region, from 1393 to 1953. In this region, the non-agricultural share exceeded 50% from the late fourteenth century and surpassed 70% by the early twentieth century, consistent with earlier claims of a high local share (Li, 2010). Moreover, Zhai’s results reveal a sustained rise during the Ming–Qing, consistent with historians’ view of proto-industrialization in the Yangzi Delta. In contrast with the long-run national stability, however, we caution against overstating Ming–Qing proto-industrialization. Its scale was modest relative to contemporary Europe (Broadberry et al., 2015), and geographically it was likely confined to the Yangzi Delta rather than extending to the rest of China.

2.2 Chinese Economic Growth Over the Past Two Millennia

Figure 3 presents our estimates of China’s GDP per capita from 220 BCE to the present. Subfigure 3A depicts China’s GDP per capita in 1990 international dollars¹. A

¹ The GDP we calculated is measured in units of unhusked rice. Following the purchasing power parity (PPP) standard of Broadberry, Guan, and Li (2018), we convert it into 1990 international dollars to facilitate intuitive

clear result is that, over more than two thousand years, China's GDP per capita shows a long-term stability followed by rapid growth in recent decades. This trend mirrors that of most global economies, which, after a long period of low GDP per capita, experienced unprecedented growth in the last two centuries (Galor, 2011). However, China's "take-off" came much later. Our data indicate that this growth began around 1949, following the establishment of the People's Republic of China.

China's economic trajectory over these two millennia aligns with the Malthusian view that "prior to the Industrial Revolution or the last two centuries, human society remained in a long-term state of stagnation over millennial or even ten-thousand-year scales". This is also consistent with the famous assertion that, in human history, only one major event—namely, the Industrial Revolution—has fundamentally transformed human society (Clark, 2007).

However, when we exclude the exceptionally high data of the last half-century from Subfigure 3A, the narrative seems less consistent with the classical Malthusian "iron law of wages", a point we will emphasize in the following sections. Subfigure 3B in Figure 3 displays China's GDP per capita prior to 1950. For the two millennia before 1950, China's GDP per capita was not confined to a narrow range; instead, it fluctuated between 400 and 1400 international dollars. According to the Maddison Project, GDP per capita in most economies prior to the last two centuries remained in the range of 500–800 international dollars. In comparison, premodern China's GDP per capita fluctuations were quite large.

More importantly, Subfigure 3B reveals two distinct phases: (1) sustained growth before 1000 CE, and (2) the disappearance of steady growth after 1000 CE. The sustained growth in the first phase is visually apparent without statistical tools: over roughly 12 centuries, China's GDP per capita rose from around 400 to over 1400 international dollars. In the early 7th century, during the Tang dynasty (618–907 CE), China's GDP per capita first surpassed 800 international dollars, doubling from the initial level of approximately 400 in the Qin dynasty (221–207 BCE) over eight

understanding for a broader audience. In our study, the conversion rate is 1 Chinese Jin of unhusked rice = 0.3178 international dollars (1990).

centuries. From the early 7th to the late 10th century, China's GDP per capita increased even more rapidly, rising by about 75% from the 800 level and reaching over 1400 international dollars by 1000 CE. However, after 1000 CE, this trend of growth spanning over a millennium did not continue. China's GDP per capita in 1000 CE marked the peak for the next thousand years, with no clear long-term growth trend observable in this period.

Creating separate graphs for the two growth phases yields Subfigures 3C and 3D in Figure 3. Subfigure 3C depicts GDP per capita before 1000 CE, while Subfigure 3D illustrates the period between 1000 and 1950 CE. In these subfigures, we also include indexed information on population and average grain yield alongside GDP per capita. During the time span covered in Subfigure 3C, China experienced a much higher degree of political fragmentation than in the second millennium. This era saw multiple successive regimes: the Qin dynasty (221–207 BCE), Western Han (202 BCE–8 CE), Xin (9–23 CE), Eastern Han (25–220 CE), Three Kingdoms (220–280 CE), Western Jin (266–317 CE), Eastern Jin and Sixteen Kingdoms (317–420 CE), Southern and Northern Dynasties (420–589 CE), Sui (581–618 CE), Tang (618–907 CE), Five Dynasties and Ten Kingdoms (907–979 CE), and Northern Song (960–1127 CE). The period from 220 to 589 CE is often regarded as one of the most politically turbulent times in Chinese history, typically characterized in traditional historical sources as an era of instability and hardship.

The purple dashed line representing population in the subfigures shows that China's population during this time was significantly lower than in more unified periods. Population growth was not sustained for long periods, and the annual population growth rate during fragmented rule (1.8 per thousand) was relatively low compared to periods under unified dynasties, such as the Western Han (7.5 per thousand), Eastern Han (6.6 per thousand), and Tang (9.2 per thousand) dynasties. Despite these conditions, GDP per capita still grew at an annual rate of 0.2 per thousand during this “darkest era in Chinese history”, without any negative growth. Although lower than the annual growth rates in other periods—such as 3.0 per thousand in the Western Han, 0.6 per thousand in the Eastern Han, and 2.3 per thousand in the Tang—

this period did not experience the prolonged negative growth seen in the second millennium.

Subfigure 3D illustrates China's GDP per capita over the second millennium, a period often considered the era in which China's state-building reached maturity (Wang, 2020). Political institutions, Confucius culture, and economic organizations became increasingly stable and mature, with a strong trend toward nationwide political unification. Most unified regimes in this period lasted around at least one century, and starting in the 15th century, unified rule extended even for over 250 years. China's population exceeded 100 million for the first time in the 11th century, reached approximately 200 million by the late 16th and early 17th centuries, surpassed 300 million in the 18th century, and reached 400 million in the 19th century. Population growth in Chinese historical narratives is typically associated with periods of societal flourishing. However, in contrast to the previous millennium, GDP per capita during much of this population expansion exhibited negative growth. The indexed data for population and average grain yield reveal a divergence not observed in the previous millennium: while land productivity, represented by grain yield, continued to grow, population growth accelerated in the second millennium and eventually far outpaced grain yield. This suggests that population growth led to a shortage of per capita resources, implying that land could no longer support a larger population without a decline in welfare levels.

Most research on China's historical GDP aligns with our data in describing China's growth processes. Subfigures 3C and 3D display widely referenced estimates from Maddison (1998), Broadberry et al. (hereafter BGL), and other recent studies. Maddison's classic data, often viewed as speculative due to its minimal reliance on concrete historical sources (Deng and O'Brien, 2017), may hold primarily historiographical value. However, the latest estimates show high consistency with our findings, both in absolute levels and overall trends.

3 Analyzing Economic Growth

3.1 Malthus or Not? Understanding the Pattern of Chinese Economic Growth over Two Millennia

The Malthusian growth model is widely regarded as the standard pattern of premodern economic growth prior to the last two centuries (Clark, 2007; Galor, 2011). China's two millennia of economic growth reflect a loosely Malthusian pattern. This pattern cannot be strictly classified as Malthusian—since economic growth before 1000 CE appears inconsistent with the “iron law of wages”—yet it cannot be dismissed outright. After 1000 CE, growth dynamics clearly conform to Malthusian predictions: population data show that “when population increases, GDP per capita declines; when population decreases, GDP per capita rises”. Similar patterns are evident in European GDP data from the 13th century onward (Bolt and van Zanden, 2024), suggesting that the period from 1000 CE until the past two centuries may reasonably be characterized as a “Malthusian world”. By contrast, China's GDP per capita data prior to 1000 CE deviate from the classic Malthusian prediction of long-term income per capita stagnation or the “iron law of wages”, with visible evidence of sustained increases in GDP per capita. These distinctive facts underscore the importance of determining whether China's two millennia of economic growth prior to the 1940s followed a Malthusian pattern, particularly given that China historically accounted for more than one-quarter of the world's population. A rigorous test is essential, not only for understanding the trajectory of China's premodern economic growth but also for assessing the validity of the Malthusian assumption within Unified Growth Theory. The following sections provide a systematic examination of the applicability of Malthusian theory to Chinese history.

In *An Essay on the Principle of Population*, published in 1798, Malthus explored the relationship between population growth and economic growth (Malthus, 1970 [1798]). His argument can be summarized into two main assumptions and one prediction:

1. Assumption 1: Population grows geometrically, while food supply grows arithmetically.

2. Assumption 2: An increase (or decrease) in income per capita raises (or lowers) the birth rate and lowers (or raises) the death rate.
3. Prediction: Based on these assumptions, long-term income per capita will stagnate. Any positive shock to income per capita is temporary and will only result in a larger population size.

Assumption 1 also implies that technological progress or growth in non-labor factors of production is quite limited, resulting in population growth outpacing food (or resource and technological) growth. Assumption 2 includes the possibility that cultural or institutional changes affecting fertility remain relatively constant over the long term. In other words, if an economy's fertility culture fluctuates significantly, Assumption 2 may not hold. However, because cultural and institutional changes are generally slow, and human reproduction has physiological limits (even the most unusual fertility norms or policies cannot push a woman's lifetime fertility into negative numbers or hundreds), culture or institutions can be considered relatively stable over time within the same economy.

Malthusians argue that prior to the last two centuries, economic growth in most global economies was constrained by population growth, consistent with the Malthusian model. Although considerable debate exists over when economies began to escape the Malthusian trap, no literature explicitly denies that human societies largely conformed to Malthusian predictions for an extensive period in the past. Testing this theory is challenging due to the lack of long-term historical data. Nearly all historical GDP data for European economies begins around the 13th century or later, while GDP data from other continents lags even further, with most starting only in the 18th century. Another issue is that individual European economies had relatively small populations, making it difficult to generalize whether one country's alignment (or misalignment) with the Malthusian model reflects global trends.

Our two-millennia GDP dataset can help address these issues. As discussed, China's GDP per capita prior to 1000 CE suggests a potential "deviation" from the Malthusian income stagnation. This raises two possible explanations: (1) The entire Malthusian framework might be incorrect, including the feedback mechanism of

population reproduction, thereby failing to predict long-term stagnation. (2) Malthus's mechanism of population reproduction remains valid, but an external force, such as technological progress, mitigated the negative impact of population growth on economic growth. In this case, while the Malthusian trap may not exist, Malthusian population theory might still hold true.

Standard Malthusian tests typically rely on demographic information such as fertility, mortality, and marriage (e.g., Lee and Anderson, 2002; Nicolini, 2007; Crafts and Mills, 2009; Cummins, 2020). Unfortunately, comparable demographic data for China are unlikely to match the scale of our GDP estimates. We therefore rely primarily on the relationship between population and GDP per capita to test the Malthusian hypothesis. However, when these two core variables are used, reverse causality complicates the analysis. To address this issue, Madsen, Robertson, and Ye (2019) developed a household fertility decision model and, by linearizing around its steady state, derived an error correction model (ECM) that can be employed to test Malthusian dynamics empirically. This framework allows population and income per capita to be examined separately, thereby helping to mitigate the problem of reverse causality between the two:

$$\begin{aligned} \Delta \ln GDP \text{ per capita}_t &= \beta_{10} + \beta_{11} \ln GDP \text{ per capita}_{t-\Delta t} + \beta_{12} \Delta \ln Scientists_t \\ &+ \beta_{13} \Delta \ln Epidemics_t + \text{Time fixed effects} + \varepsilon_1 \end{aligned}$$

$$\begin{aligned} \Delta \ln Population_t &= \beta_{20} + \beta_{21} \ln Population_{t-\Delta t} + \beta_{22} \ln Scientists_{t-\Delta t} \\ &+ \beta_{23} \ln Land_{t-\Delta t} + \beta_{24} \Delta \ln Scientists_t + \beta_{25} \Delta \ln Epidemics_t \\ &+ \text{Time fixed effects} + \varepsilon_2 \end{aligned}$$

The two equations form error correction models (ECMs) for GDP per capita and population. The dependent variables represent the average annual geometric growth rate of GDP per capita and population over the period Δt . The main independent

variables are initial values of GDP per capita and population. Key control variables include the stock of significant scientific figures, frequency of pandemics, cultivated land, and time fixed effects. The essence of this test is estimating β_{11} and β_{21} , which represent the rate at which GDP per capita or population returns to its initial state after a change. Both β_{11} and β_{21} are inherently negative. If the Malthusian hypothesis holds, these coefficients should exhibit both statistical and economic significance: they should be statistically significant and reflect a sufficiently rapid convergence rate to support the Malthusian feedback mechanism on population. To evaluate this, we can calculate the so-called half-life years, $h = -\ln(2) / (\frac{\ln(1+\beta\Delta t)}{\Delta t})$. If the half-life years is excessively long, such as several centuries, even statistically significant β coefficients would suggest a weak Malthusian mechanism. Generally, a half-life years within a single generation indicates the presence of the Malthusian population feedback mechanism.

Subfigure 4A of Figure 4 presents the estimated β coefficients from the two equations for per capita GDP and population, with Δt set at 30, 20, and 40 years. For each Δt we conducted three grouped regressions: the entire period before 1950, the period before 1000 CE, and the period after 1000 CE. Subfigure 4B displays the half-life years indicated by the β coefficients across all 18 regression equations. The results in Figure 4 show that, both statistically and economically, the estimated β coefficients are significant across all regression equations. Most of the half-lives indicated by these coefficients are within 30 years, consistent with findings from Madsen, Robertson, and Ye (2019) for major European economies from the 13th to 19th centuries. This suggests that the Malthusian population feedback mechanism was present throughout China's entire historical period under study.

Notably, the results in Figure 4 show that the estimated β coefficient before 1000 CE is greater than its value thereafter. This indicates that the Malthusian mechanism in China—that is, the pressure of population growth on income per capita—was stronger before 1000 CE. Put simply, China's growth pattern prior to 1000 CE still belonged to a Malthusian regime. However, the classical Malthusian conclusions for premodern

growth—“long-run stagnation” or the “iron law of wages”—are not fully reflected here. How should this apparent anomaly be understood?

According to the model of Madsen et al. (2019), the positive drivers of income per capita include non-labor inputs such as land, capital, and total factor productivity (TFP), whereas the Malthusian demographic feedback mechanism (“the poor perish, the rich reproduce”) imposes negative effects on income per capita. In other words, although China exhibited stable growth in income per capita before 1000 CE—seemingly less “Malthusian” than in later periods—our empirical results indicate that the Malthusian demographic mechanism was actually stronger during this era, with a shorter half-life and a more pronounced negative impact on income growth. This suggests that growth in non-labor inputs may have been faster in this period, thereby offsetting the downward pressure from Malthusian feedback. Put differently, the classical assumption of “geometric population growth versus arithmetic food growth” may not fully apply to China before 1000 CE. Growth of non-labor factors outpaced population, so even though a Malthusian fertility feedback persisted, the trend of GDP per capita did not exhibit long-run stagnation.

This does not invalidate Malthusian theory. From the perspective of unified growth theory (Galor, 2011), long-run stagnation is not a necessary condition of Malthusian dynamics. For example, Western European economies displayed signs of escaping stagnation in income per capita more than a century before the Industrial Revolution, but this was merely the second stage of the Malthusian world—the eve of modern growth driven by demographic transition. As long as fertility behavior remained governed by the rule of “the poor perish, the rich reproduce”, once the growth of non-labor inputs slowed relative to labor under certain conditions, the economy would still return to the classical Malthusian trap of long-run income stagnation, i.e., the first stage. Therefore, within the framework of unified growth theory, so long as a Malthusian fertility regime persisted in China before 1000 CE, rapid growth of non-labor inputs cannot negate its classification as part of the Malthusian world. Indeed, Madsen et al. (2019) make a similar claim in their study of major European economies over five centuries.

The results in Figure 5 corroborate the foregoing discussion. Figure 5A presents multifactor productivity (MFP)², representing growth drivers beyond labor and land. Before 1000 CE, MFP fluctuated but showed an overall upward trend; after 1000 CE, it displays a clear downward trend. In other words, after 1000 CE the diminished contribution of factors beyond the traditional ones—such as human capital, technology, organization, or institutions—may explain the emergence of the classical Malthusian trap of income stagnation. Figure 5B depicts both the total stock of “great scientists” in Chinese history and the stock per capita. After the seventh century CE, the total stock entered a phase of slow growth, while the stock per capita declined continuously beginning in 1000 CE. These trends indicate that factors beyond labor and land played a key role in making 1000 CE a historical turning point.

Given that slow land expansion is viewed in classical Malthusian theory as a primary cause of the trap, it is also necessary to consider land specifically. Figure 5B simultaneously presents the long-term evolution of arable land per capita. Before 1000 CE, cultivated land per capita remained broadly stable; but in the second millennium CE it declined persistently, reaching by 1940 CE roughly one-third of its level in 1000 CE. This indicates that, from 1000 CE onward, land as an input began to diverge markedly from population or labor growth.

Taken together, the stylized facts across the variables in Figure 5 suggest a plausible explanatory direction: the difference between China’s growth patterns before 1000 CE and in the subsequent millennium may primarily stem from resource constraints (land–population pressures) and weak productivity growth (MFP or TFP).

² We define MFP as multifactor productivity, based on a simplified Cobb–Douglas production function:

$$Y = AL^{\alpha}T^{\beta}$$

where Y denotes output, L represents labor (proxied by population), and T denotes land. Following standard assumptions, we set the output elasticities $\alpha = 0.6$ and $\beta = 0.2$. Multifactor productivity A is then obtained as the residual:

$$A = \frac{Y}{L^{0.6}T^{0.2}}$$

Thus, A captures the aggregate contribution of all other factors beyond labor and land.

The precise contributions of different factors, however, require more rigorous growth accounting, to which the next section turns.

3.2 Understanding the Drivers of Chinese Economic Growth over Two Millennia: A Growth Accounting Framework

3.2.1 Empirical strategies

China's economic growth over the two millennia prior to 1950 can broadly be understood within a Malthusian framework. However, as the previous section indicates, the classic "income stagnation" version of the Malthusian model cannot fully explain China's experience, since GDP per capita during the first millennium rose over the long run. To interpret this Malthusian-style growth, it is necessary to draw on Unified Growth Theory (Galor, 2011), which offers a framework for premodern economies. In brief, the theory posits three distinct phases: (1) the Malthusian trap of stagnant income, (2) a regime of sustained productivity growth combined with Malthusian demographic dynamics, and (3) modern growth characterized by a fertility transition.

Although China's first millennium does not fit the first phase, it corresponds to the second, and thus the overall growth pattern can still be regarded as Malthusian. Preliminary discussion further suggests that relatively rapid expansion of non-labor factors may have been the main driver of sustained increases in income per capita during this era. The question remains, however, which factors contributed most and to what extent. Addressing this requires a decomposition of the growth process.

In this section, we adopt a rigorous growth-accounting framework: (1) estimating a production function for the Chinese economy over the two millennia, and (2) decomposing growth based on this function to identify the roles of different factors across periods.

First, we estimate the elasticities of different factors based on the classical Cobb–Douglas production function,

$$Y = AL^{\alpha}T^{\beta}K^{\gamma}$$

where Y denotes output, L labor, T land, K capital, α the labor elasticity, β the land elasticity, γ the capital elasticity, and A total factor productivity. By taking logarithms on both sides of the function, we obtain the following empirical equation:

$$\ln Y_t = b_0 + b_1 \ln L_t + b_2 \ln T_t + b_3 \ln K_t + b_4 \ln \text{human capital}_t + b_5 \ln \text{innovation stock}_t + b_6 \ln \text{institutions}_t + \varepsilon_t$$

The definitions of Y , L , T , and K remain unchanged. *human capital* refers to the stock of human capital, *innovation stock* represents technology, *institutions* capture institutional factors affecting output, ε denotes the error term, and t indicates time.

We employ two estimation methods to identify the model parameters. First, following the framework of Madsen and Murtin (2017) in their analysis of six centuries of British economic growth data, we apply the Dynamic OLS (DOLS) approach (Stock and Watson, 1993). This method estimates long-run relationships by including two leads and two lags of the first differences of the regressors. For brevity, these lead and lag terms are omitted from the reported results.

Second, we use the Autoregressive Distributed Lag (ARDL) model (Pesaran, Shin, and Smith, 2001), which has been widely employed in recent years to analyze long-run equilibria in time-series data. This method derives long-run relationships by incorporating lagged values of the regressors and reformulating the model in an error-correction form. Notably, ARDL estimation allows for a mixture of stationary variables and variables integrated of order one. For brevity, we report only the long-run equilibrium results, omitting the short-run dynamics.

In the empirical analysis, we set the growth rate of labor equal to that of population, and the growth rate of land equal to that of cultivated land. Hence, the results for labor and land factors can be directly inferred from Figure 1 and are not reproduced here. Figure 6 presents the data and sources for the other factors employed in our study.

Capital, as a key traditional factor, lacks reliable direct measures. We therefore use major hydraulic projects—among the most significant fixed-capital investments in

Chinese history—as a proxy, drawing primarily on the classic study by Chi (1936). Although Perkins (1969) provides an updated dataset, we rely on Chi’s results because Perkins omits the repair and reconstruction of hydraulic projects, which are critical components of fixed-capital formation. Excluding them would underestimate capital accumulation. For depreciation, we assume a service life of 200 years for hydraulic projects. While direct evidence is scarce, this assumption is broadly reasonable: in premodern China, wooden residential structures typically had life spans of 60–100 years (Li, 2010: 415–418). Given their greater durability and slower deterioration, assigning a 200-year horizon to hydraulic works is acceptable. The growth rate of capital appears broadly consistent with GDP growth during the first millennium, but considerably higher during the second millennium. This divergence may reflect greater political stability and the increased frequency of state-led collective projects in the latter period.

Beyond the traditional production factors of labor, land, and capital, we focus on three additional factors widely recognized in mainstream economic growth literature: human capital, innovation stock, and institutions. Ideally, human capital would be measured using indicators such as years of schooling or literacy rates. Unfortunately, such data are not available for historical China. Therefore, we employ the age-heaping method as an indirect measure of historical human capital.

Specifically, we calculate age heaping using birth and death year information from the China Biographical Database (CBDB), jointly compiled by Harvard University and Peking University, which is the most comprehensive database of historical Chinese elites currently available. Age heaping refers to the proportion of ages ending in the digits 0 or 5. In large samples with accurate age reporting, this proportion should approximate 20%. If individuals lack basic arithmetic skills and cannot report their ages precisely, this share tends to exceed 20% (A’Hearn, Baten, and Crayen, 2009).

Since the CBDB primarily contains information on elites, age heaping may be less pronounced than among the general population. Indeed, studies on Qing China have shown that while age heaping levels in the 18th–20th centuries were not dramatically different from those in Northwestern Europe, the share of terminal digits 0 and 5 still

significantly exceeded 20% (Baten, Ma, Morgan, and Wang, 2010). Our findings are consistent with this pattern: for most historical figures in the CBDB, the proportion of ages ending in 0 or 5 is close to the expected 20%, with some periods showing higher levels. However, these deviations are smaller than those observed among ordinary people in Qing China.

We do not claim that CBDB-based age heaping perfectly captures human capital levels across the entire Chinese population. Rather, our measure is best interpreted as identifying periods of relatively low versus normal or high human capital. Even among elites, the degree of age heaping varies across time. If elites exhibit substantial age heaping (well above 20%), it is reasonable to infer even lower arithmetic abilities among the general population. Conversely, when elite age heaping aligns closely with the 20% benchmark, we cannot assume the broader population had higher human capital, but this likely reflects periods of relatively advanced human capital development compared to times when even elites struggled with basic numeracy. Figure 6B presents our results. Notably, age heaping during the Song dynasty is the lowest in the entire two-millennium span³, which aligns well with historians' consensus regarding cultural and human capital achievements in that period. The higher age heaping observed in the Ming and Qing periods, relative to the Song but lower than pre-Song levels, also accords with well-established historical knowledge. In sum, although our age-heaping measure is not perfect, it provides a plausible and useful approximation of major peaks and troughs in China's historical human capital over the long run.

To measure technological innovation, we follow the approach of Madsen and Murtin (2017) in their study of Britain, which relies on the cumulative number of great scientists or major innovations. We use the stock of great scientists in Chinese history as a proxy for innovation stock. Compared with records of technological products, biographical records of individuals in Chinese history are generally more accurate and quantifiable. This variable is consistent with the data and measures used in the

³ The figure presents the inverse of the age-heaping measure, so that higher values indicate higher levels of human capital.

Malthusian tests discussed earlier and is drawn from Li and Zha (2002). Because the number of great scientists recorded may mechanically increase over time due to the expanding stock of historical records, we correct for this by using the total number of biographies in the CBDB for each period as a measure of the available historical material. The logic is straightforward: periods with more extensive historical records are more likely to include not only major figures but also less prominent scientists, inflating the nominal count. Thus, we adjust the recorded number of great scientists to ensure comparability across periods. The results are shown in Figure 6C. The stock of great scientists in China increased markedly during the first millennium, but appears to stagnate in the second millennium. This finding aligns closely with the well-known “Needham Puzzle” in the history of Chinese science and technology, which highlights the apparent stagnation of technological progress in China during the second millennium (Lin, 1995).

Measuring institutions in the context of Chinese history poses significant challenges. Standard institutional measures typically focus on constraints on executive power and political competition (Acemoglu, Johnson, and Robinson, 2005). In many studies, such measures are primarily designed to distinguish between democratic and autocratic regimes over the past few centuries. However, China’s imperial system persisted until 1912, and even during the subsequent the Republic of China period, the country did not meet the conventional definitions of democracy used in Europe or the United States. As a result, typical democratic institutions akin to those in Europe did not exist for most of Chinese history, and it is difficult to identify clear periods in which imperial power was meaningfully constrained.

For an imperial polity of this kind, we adopt a political competition perspective to capture institutional variation. Although Chinese history is often characterized by long periods of “great unification”, during which a single regime controlled the majority of population, land, and resources, multiple regimes frequently coexisted, generating de facto political competition. A classic example is the Northern and Southern dynasties period (420–589 CE), when several stable regimes in the North and South coexisted for

an extended period. Dissatisfied elites could migrate between regimes, reflecting how political competition influenced talent mobility and governance outcomes.

Following Chen and Ma (2020), we measure institutional quality through the number of coexisting regimes within the same period, which serves as a proxy for the degree of political competition. Figure 6D presents this measure and illustrates a clear long-run trend from political fragmentation toward unification in Chinese history.

3.2.2 Results

Estimating the Production Function

Tables 1 and 2 report the estimated production functions based on the DOLS and ARDL models, respectively. Column (1) in both tables includes only the traditional production factors—labor, land, and capital—as the baseline specification. In both models, the estimated coefficients on land and capital are larger, while labor appears to have an insignificant impact on GDP. Columns (2) to (4) in each table present results from augmenting the baseline with human capital, innovation stock, and institutions, respectively. All three variables have statistically significant effects on output, with elasticities of approximately 0.1 each. The results for institutions are particularly noteworthy. As previously discussed, our institutional proxy primarily captures political competition, which is an admittedly imperfect but pragmatic choice for China’s long imperial history, where standard measures such as constraints on the executive are not applicable. To our knowledge, few empirical studies have tested this type of institutional measure. Our findings show that even in the absence of European-style representative democracy, political competition itself exerted a positive effect on output: periods with more coexisting regimes—hence greater political competition—are associated with higher output, consistent with the predictions of institutional theory (Acemoglu, Johnson, and Robinson, 2005).

Column (5) in both tables reports the results including all factors simultaneously. Once all variables are considered, all coefficients except for institutions remain significant and align with economic theory. The three traditional factors—labor, land, and capital—are all positive and significant, with land exhibiting the largest elasticity

(around 0.8). Labor becomes significant as well, though its elasticity remains modest, at just above 0.15. Capital's elasticity is slightly below 0.1. The sum of these three elasticities is slightly above one, broadly consistent with the constant returns to scale assumption of a Cobb–Douglas production function.

The contributions of human capital and innovation stock differ somewhat across models: in the DOLS specification, their elasticities are roughly similar, whereas in the ARDL model, the elasticity of human capital is slightly lower. In both cases, however, the combined elasticity of these two factors is slightly above 0.2. Importantly, once all controls are included, the institutional variable becomes statistically insignificant in both models. Compared to column (4), where institutions are included individually, its coefficient becomes very small, and even turns negative in the DOLS model. This suggests that political competition, as measured here, may not have played a major role in China's economic growth.

While this result should be interpreted cautiously, given the novelty and limitations of our institutional proxy in the Chinese context, it is consistent with findings from Madsen and Murtin (2017) for Britain (1270–1870): institutions matter when considered alone, but their effect disappears once other growth factors are included. We do not claim that institutions are unimportant for economic growth; rather, for the period and proxy we consider, political competition (measured by the number of coexisting regimes) does not show a robust positive effect. Consequently, in our final growth accounting exercises, we adopt the specification reported in column (6) of Tables 1 and 2, which includes only the factors that have statistically significant effects.

Growth accounting for GDP and GDP per capita growth

Tables 3 and 4 present the growth accounting results for aggregate GDP based on the DOLS and ARDL models, respectively. Since the decomposition focuses on aggregate GDP rather than GDP per capita, the contributions of all factors are positive. We use the elasticities reported in column (6) of Tables 1 and 2. For each factor, its contribution to GDP growth is calculated by multiplying its average annual growth rate

over each period by its estimated elasticity. The sum of these contributions equals the total contribution of all factors to GDP, as implied by the estimated production function.

The results show that the sum of factor contributions is very close to 100%, indicating that the selected factors capture the main drivers of GDP growth. Examining the distribution of contributions across periods reveals a striking contrast between the two millennia. During the first millennium, human capital and innovation stock account for the largest share of GDP growth, together contributing nearly 40%, while the remaining 60% comes from labor, land, and capital. In contrast, during the second millennium, the contribution of human capital and innovation stock to GDP growth is close to zero.

Although we have not yet decomposed GDP per capita, the results from the aggregate GDP decomposition already offer a clear explanation: the relatively favorable economic performance in the first millennium appears to have been driven largely by total factor productivity components, particularly human capital and innovation stock. As discussed earlier in the Malthusian model analysis, if GDP per capita exhibited a long-term upward trend during the first millennium (albeit modest), this implies that the growth rates of non-labor factors exceeded that of labor. The growth accounting results presented here suggest that among these non-labor factors, knowledge-related factors—human capital and innovation stock—played a central role.

To better examine the determinants of GDP per capita, Tables 5 and 6 present the growth accounting results for GDP per capita. Starting from column (6) of Tables 1 and 2, we apply a simple identity transformation by subtracting the logarithm of labor from both sides of the estimated production function⁴. On the left-hand side, the variable becomes GDP per capita, while on the right-hand side, the factors correspond to the determinants of GDP per capita. Since the estimated coefficient on labor (b_1) is

⁴ This allows us to decompose GDP per capita growth as follows:

$$\ln(Y_t/P_t) = (b_0 - \ln\theta) + (b_1 - 1)\ln L_t + b_2 \ln T_t + b_3 \ln K_t + b_4 \ln \text{human capital}_t + b_5 \ln \text{innovation stock}_t + b_6 \ln \text{institutions}_t + \varepsilon_t$$

Here, θ is defined as P_t divided by L_t , which can be interpreted as the inverse of the employment rate. Since we assume that population and labor grow at the same rate in the long run, θ remains constant. The meanings of the remaining factors and parameters are consistent with the empirical specifications in Tables 1 and 2.

generally less than one, this transformation implies that labor now contributes negatively to GDP per capita growth, whereas all other factors contribute positively.

The average annual growth rate of GDP per capita during the first millennium was 0.7%, indicating that the negative contribution of labor to GDP per capita was more than offset by the positive contributions of other factors. Examining the contribution of each positive factor (calculated as the product of its average annual growth rate and elasticity) in Tables 5 and 6 shows that each factor individually exceeds the negative contribution of labor. In other words, even if all other factors had zero contribution, as long as one factor retained its actual value, GDP per capita growth would not have been negative.

Tables 5 and 6 also report the share of each positive factor in total positive contributions. Although land accounted for 34–37% of total positive contributions during the first millennium, this was still less than the combined contribution of human capital and innovation stock, which exceeded 40%. Overall, the main drivers of GDP per capita growth during the first millennium were relaxed resource constraints (land), a certain degree of capital accumulation, and—most importantly—productivity improvements stemming from knowledge (human capital and innovation).

The dominant role of knowledge is worth emphasizing. Historically, in economies with relatively small populations, assuming constant land is often unnecessary. classical Malthusian theory usually applies the fixed-land assumption only when populations are very large. As China's population expanded, it was inevitable that land would eventually become a binding constraint. Indeed, in the second millennium, the positive contribution of land was far below the negative contribution of labor, which became a major reason for the decline in GDP per capita. As population grew from under 100 million to over 400 million by the 19th century, natural resources became increasingly scarce, and cultivated land was no longer as abundant as in the first millennium. This created an underlying trend of declining per capita resources.

To prevent GDP per capita from falling under such conditions, other factors—especially capital, human capital, and innovation—would have had to compensate for resource scarcity. In practice, capital's contribution remained similar to that in the first

millennium but was insufficient to offset the negative impact of labor. The crucial difference lay in human capital and innovation stock, both of which contributed almost nothing to GDP per capita growth in the second millennium. Had these two factors maintained their first-millennium growth rates, GDP per capita would likely not have experienced negative growth.

In short, the second millennium diverged sharply from the first due to a combination of resource pressure (land constraints) and insufficient knowledge-driven growth. While resource constraints matter, the evidence suggests that knowledge was the decisive factor. If knowledge-based growth in the second millennium had matched or exceeded that of the first, sustained GDP per capita growth would have been feasible. Thus, although resource constraints were important, they were not the most critical issue. From both a quantitative and theoretical perspective, human capital and innovation stock determined the overall trajectory of economic growth across the two millennia.

Discussion: a Unified Growth Theory (UGT) perspective

The above growth accounting analysis aligns well with Unified Growth Theory (UGT), which posits that the transition from the Malthusian era to modern economic growth involves three stages—the classical Malthusian regime, the Malthusian technological growth phase, and the modern growth regime characterized by fertility transition—with human capital accumulation and technological progress playing the central role throughout. China's economic growth during the first millennium resembles the Malthusian technological growth phase observed in Northwestern Europe on the eve of the Industrial Revolution (Madsen, Robertson, and Ye, 2019). However, in the second millennium, China reverted to the classical Malthusian regime, with neither significant resource expansion nor sustained technological progress.

The reasons for this stagnation extend beyond the scope of this paper, but human capital accumulation and fertility transition likely played key roles. The civil service examination system, which matured during the second millennium, may have constrained both human capital formation and technological progress. Lin (1995) notes

that the examination content became heavily focused on literature and philosophy, shaping human capital accumulation toward non-scientific knowledge. Our data on the stock of great scientists also suggest that pursuing a scientific career became less attractive for top talents during this period.

Another crucial dimension is fertility transition. In Northwestern Europe, the shift away from the Malthusian fertility regime occurred after sustained technological progress, facilitating the move from the second to the third stage of unified growth. By contrast, extensive demographic research shows that China's fertility rate remained high and stable throughout the second millennium, without a significant transition (Cao, 2000, 2001; Dong, 2002; Ge, 2000; Hu, 2023; Wu, 2000).

This raises a counterfactual: if China had undergone a fertility transition during the second millennium, building on the first millennium's rising GDP per capita, could it have entered the path of modern economic growth earlier? If so, this would offer further support for UGT's explanation of comparative development and the Great Divergence. While further evidence is needed, this perspective highlights the critical role of knowledge and demographic dynamics in shaping China's long-run economic trajectory.

Conclusion

We provide the first decadal, continuous estimates of Chinese GDP from 220 BCE to 1940 CE. Based on these estimates, the broad contours of China's economic growth over the past two millennia are now clear—at least from the output perspective. We fully recognize that GDP is perhaps the single most important variable in the economic history of China, as in any other economy. Therefore, we do not claim our estimates to be the final word. Although we have sought to exhaust the available historical data to produce internally consistent series that align with established historical knowledge, our aim is more exploratory than definitive. In other words, while our GDP estimates may not convince everyone, we hope they can serve as a navigational chart—imperfect, like medieval maps from the modern perspective, yet sufficiently accurate to guide further exploration.

Following the construction of the GDP series, we focused on what these two millennia of data reveal about China's long-run growth dynamics. Our analysis shows that, despite fluctuations in GDP per capita over time, the overall pattern is essentially Malthusian. This finding provides both a coherent explanatory framework for China's economic growth over the last two millennia and an unprecedented long-run empirical test of both Malthusian theory and Unified Growth Theory (UGT).

Importantly, in the Chinese context, Malthusian growth does not necessarily imply a "trap". Even when population dynamics followed the classical Malthusian mechanism of "the poor perish, the rich reproduce", income per capita could still maintain a modest upward trend over the long run. Our findings, together with European historical experience, suggest that equating Malthusian growth with stagnation can be overly simplistic. The Malthusian world was not static.

Chinese history illustrates that knowledge-driven growth can mitigate Malthusian constraints. Fluctuations in human capital and technological progress shaped the contrasting growth patterns between the two millennia. While the second millennium indeed saw resource pressures, the more fundamental constraint likely lay in the failure to sustain human capital accumulation and technological innovation. In short, the evidence from two millennia of Chinese economic history suggests that human capital and technological progress have always been the most critical drivers of economic growth.

Tables

Table 1 Determinants of Chinese GDP (DOLS): -220 BCE to 1940 CE

Estimator	DOLS					
Est. period	-220 BCE to 1940 CE					
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: <i>log output</i>						
<i>Log labor</i>	0.027 (0.08)	0.123* (0.07)	0.083 (0.08)	0.201*** (0.07)	0.150** (0.06)	0.165*** (0.06)
<i>Log land</i>	0.981*** (0.15)	0.868*** (0.13)	0.981*** (0.15)	0.785*** (0.14)	0.882*** (0.10)	0.866*** (0.11)
<i>Log capital</i>	0.172*** (0.04)	0.116*** (0.03)	0.114*** (0.03)	0.185*** (0.03)	0.073*** (0.02)	0.077*** (0.02)
<i>Log human capital</i>		0.128*** (0.02)			0.111*** (0.03)	0.108*** (0.02)
<i>Log innovation stock</i>			0.102** (0.05)		0.112** (0.05)	0.115*** (0.04)
<i>Log total regimes</i>				0.093*** (0.02)	-0.011 (0.02)	
R square	0.981	0.986	0.985	0.985	0.989	0.989
N	212	212	212	212	212	212

Notes: Newey-West standard errors (Newey and West, 1994) in parentheses. The DOLS estimation (Stock and Watson, 1993) includes two leads and two lags of the first differences of the explanatory variables, as well as a constant term, which is omitted in the presentation. The labor variable is assumed to grow at the same rate as the population. *N* refers to the number of observations.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2 Determinants of Chinese GDP (ARDL): -220 BCE to 1940 CE

Estimator	ARDL					
Est. period	-220 BCE to 1940 CE					
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: <i>Log output</i>						
<i>Log labor</i>	0.065 (0.11)	0.108 (0.09)	0.116 (0.09)	0.218** (0.11)	0.181** (0.08)	0.147** (0.07)
<i>Log land</i>	0.922*** (0.17)	0.882*** (0.14)	0.887*** (0.13)	0.772*** (0.15)	0.823*** (0.11)	0.857*** (0.11)
<i>Log capital</i>	0.175*** (0.03)	0.134*** (0.03)	0.132*** (0.03)	0.188*** (0.03)	0.116*** (0.03)	0.102*** (0.02)
<i>Log human capital</i>		0.094*** (0.03)			0.063** (0.03)	0.077*** (0.03)
<i>Log innovation stock</i>			0.173*** (0.06)		0.144*** (0.05)	0.157*** (0.05)
<i>Log total regimes</i>				0.105*** (0.04)	0.030 (0.04)	
R square	0.699	0.709	0.708	0.709	0.721	0.720
N	213	213	213	213	213	213

Notes: Standard errors in parentheses. The cointegrating form of the ARDL estimation (Pesaran, Shin, and Smith, 2001) includes both long-run and short-run components; the short-run dynamics and the constant term are omitted from the presentation. For all six equations, the existence of a long-run relationship is confirmed by the ARDL bounds test (Kripfganz and Schneider, 2018). The labor variable is assumed to grow at the same rate as the population. *N* refers to the number of observations.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3 Accounting for GDP growth (DOLS): -220 BCE to 1940 CE

		Log GDP	Log Labor	Log land	Log capital	Log human capital	Log innovation stock	Total contribution
Annual growth rate	-220 to 1940	1.2%	1.0%	0.8%	2.2%	0.9%	0.5%	
	-220 to 1000	0.8%	0.1%	0.3%	2.0%	1.4%	1.3%	
	1010 to 1940	1.4%	1.9%	1.1%	2.3%	-0.2%	0.1%	
Elasticity			0.165	0.866	0.077	0.108	0.115	
Contribution to GDP growth and the share of observed growth (percent)	-220 to 1940		0.002	0.007	0.002	0.001	0.001	
			14.2%	55.5%	14.4%	7.7%	5.2%	97.0%
	-220 to 1000		0.0002	0.003	0.002	0.002	0.002	
			2.2%	33.1%	18.6%	18.5%	18.5%	90.9%
	1010 to 1940		0.003	0.009	0.002	-0.0002	0.0001	
			22.9%	67.1%	12.8%	-1.2%	0.6%	102.2%

Notes: The growth accounting results are based on estimates from the DOLS model. The *contribution to GDP growth* is calculated by multiplying the growth rate of each factor in a given year by its corresponding elasticity coefficient from the DOLS estimates. The *share of observed growth (percent)* refers to the ratio of this contribution to the actual annual GDP growth rate. The *total contribution* is the sum of these shares across all factors.

Table 4 Accounting for GDP growth (ARDL): -220 BCE to 1940 CE

		Log GDP	Log Labor	Log land	Log capital	Log human capital	Log innovation stock	Total contribution
Annual growth rate	-220 to 1940	1.2%	1.0%	0.8%	2.2%	0.9%	0.5%	
	-220 to 1000	0.8%	0.1%	0.3%	2.0%	1.4%	1.3%	
	1010 to 1940	1.4%	1.9%	1.1%	2.3%	-0.2%	0.1%	
Elasticity			0.147	0.857	0.102	0.077	0.157	
Contribution to GDP growth and the share of observed growth (percent)	-220 to 1940		0.002	0.007	0.002	0.001	0.001	
			12.7%	55.0%	19.1%	5.5%	7.1%	99.3%
	-220 to 1000		0.0002	0.003	0.002	0.001	0.002	
			1.9%	32.8%	24.8%	13.2%	25.4%	98.0%
	1010 to 1940		0.003	0.009	0.002	-0.0001	0.0001	
			20.5%	66.4%	16.9%	-0.9%	0.8%	103.8%

Notes: The growth accounting results are based on estimates from the ARDL model. The *contribution to GDP growth* is calculated by multiplying the growth rate of each factor in a given year by its corresponding elasticity coefficient from the ARDL estimates. The *share of observed growth (percent)* refers to the ratio of this contribution to the actual annual GDP growth rate. The *total contribution* is the sum of these shares across all factors.

Table 5 Accounting for GDP per capita growth (DOLS): -220 BCE to 1940 CE

		Log GDP per capita	Log Labor	Log land	Log capital	Log human capital	Log innovation stock	Total contribution
Annual growth rate	-220 to 1940	0.2%	1.0%	0.8%	2.2%	0.9%	0.5%	
	-220 to 1000	0.7%	0.1%	0.3%	2.0%	1.4%	1.3%	
	1010 to 1940	-0.5%	1.9%	1.1%	2.3%	-0.2%	0.1%	
Elasticity			-0.835	0.866	0.077	0.108	0.115	
Contribution to GDP per capita growth and the share of observed positive growth (percent)	-220 to 1940		-0.009	0.007	0.002	0.001	0.001	0.001
				67.1%	17.3%	9.3%	6.3%	
	-220 to 1000		-0.001	0.003	0.002	0.002	0.002	0.006
				37.3%	21.0%	20.8%	20.8%	
	1010 to 1940		-0.016	0.009	0.002	-0.0002	0.0001	-0.005
				84.7%	16.1%	-1.5%	0.8%	

Notes: The growth accounting results are based on estimates from the DOLS model. The *contribution to GDP per capita growth* is calculated by multiplying the growth rate of each factor in a given year by its corresponding elasticity coefficient from the DOLS estimates. The *total contribution* refers to the sum of all factors' contributions to GDP per capita growth. The *share of observed positive growth (percent)* indicates the proportion of each positively contributing factor (excluding labor) in the total contribution to GDP per capita growth from all positively contributing non-labor factors. It is calculated by dividing each factor's positive contribution (as reported in the previous line) by the sum of all positive contributions from non-labor factors.

Table 6 Accounting for GDP per capita growth (ARDL): -220 BCE to 1940 CE

		Log GDP per capita	Log Labor	Log land	Log capital	Log human capital	Log innovation stock	Total contribution
Annual growth rate	-220 to 1940	0.2%	1.0%	0.8%	2.2%	0.9%	0.5%	
	-220 to 1000	0.7%	0.1%	0.3%	2.0%	1.4%	1.3%	
	1010 to 1940	-0.5%	1.9%	1.1%	2.3%	-0.2%	0.1%	
Elasticity			-0.853	0.857	0.102	0.077	0.157	
Contribution to GDP per capita growth and the share of observed positive growth (percent)	-220 to 1940		-0.009	0.007	0.002	0.001	0.001	0.002
				63.4%	22.0%	6.3%	8.2%	
	-220 to 1000		-0.001	0.003	0.002	0.001	0.002	0.007
				34.1%	25.8%	13.7%	26.4%	
	1010 to 1940		-0.016	0.009	0.002	-0.0001	0.0001	-0.005
				79.7%	20.3%	-1.0%	1.0%	

Notes: The growth accounting results are based on estimates from the ARDL model. The *contribution to GDP per capita growth* is calculated by multiplying the growth rate of each factor in a given year by its corresponding elasticity coefficient from the ARDL estimates. The *total contribution* refers to the sum of all factors' contributions to GDP per capita growth. The *share of observed positive growth (percent)* indicates the proportion of each positively contributing factor (excluding labor) in the total contribution to GDP per capita growth from all positively contributing non-labor factors. It is calculated by dividing each factor's positive contribution (as reported in the previous line) by the sum of all positive contributions from non-labor factors.

Figures

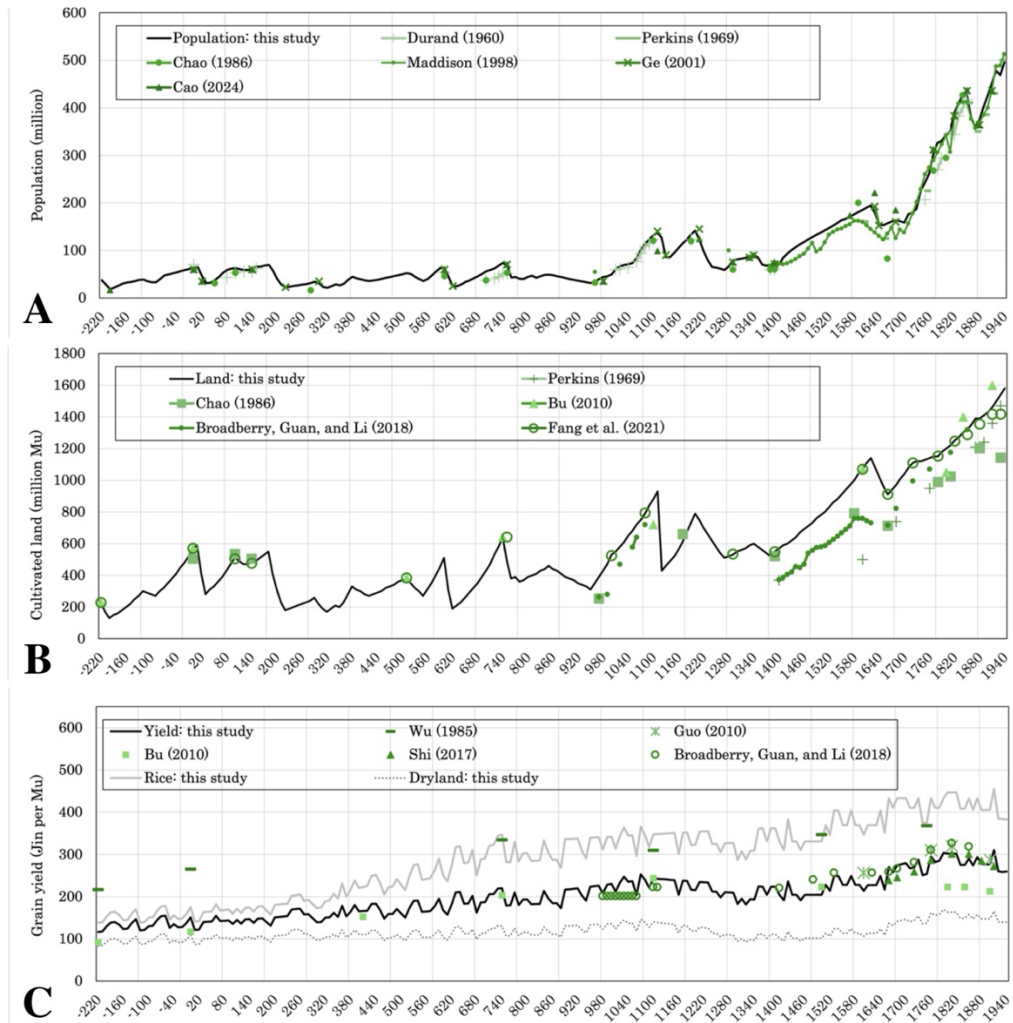


Figure 1 China's population, cultivated land, and grain yield: 220 BCE to 1940 CE

Notes: Subfigure 1A: China's population (220 BCE to 1940 CE). The data include results from this study as well as other widely cited findings over the past half century. Subfigure 1B: China's cultivated land (220 BCE to 1940 CE). The data include results from this study as well as other widely cited findings over the past half century. Subfigure 1C: China's grain yield (220 BCE to 1940 CE). This study's grain yield measure consists of two components: the main dryland staple crops of northern China (such as wheat and millet) and the main staple unhusked rice of southern China. For comparison, we draw on several widely used studies of grain yield. In the Chinese context, grain yield generally refers to the output of grain crops divided by the total cultivated area.

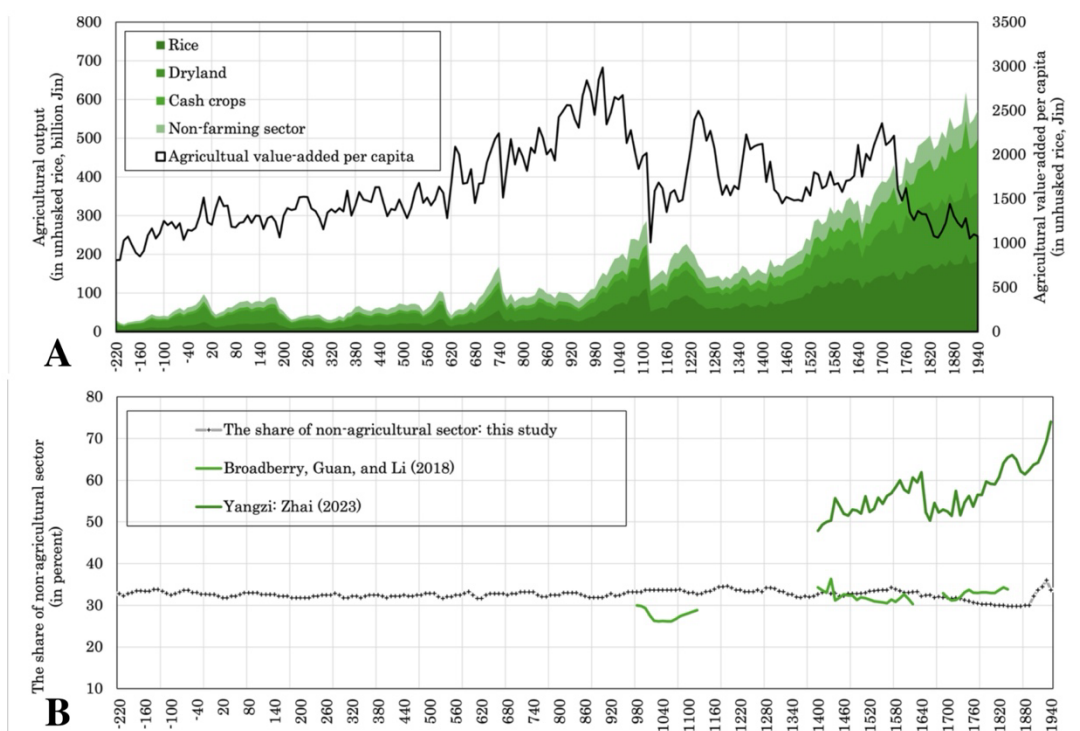


Figure 2 China's agricultural and non-agricultural development: 220 BCE to 1940 CE

Notes: Subfigure 2A: China's agricultural output (220 BCE to 1940 CE). Subfigure 2B: The share of non-agricultural output in China's GDP (220 BCE to 1940 CE). Broadberry, Guan, and Li (2018) provide alternative estimates of China's average GDP and the non-agricultural share. Yangzi (2023), by contrast, calculates the non-agricultural share for China's most developed region, the Yangzi Delta.

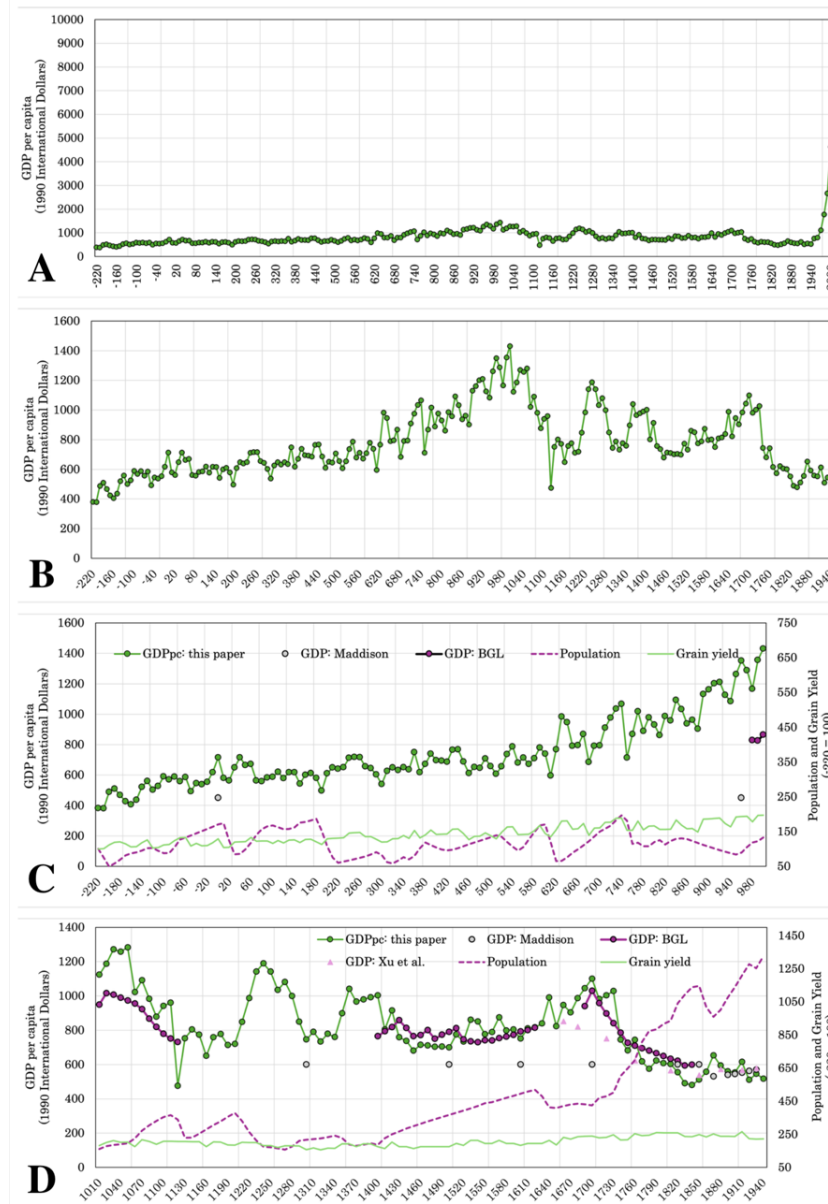


Figure 3 China's GDP per capita: 220 BCE to 1940 CE

Notes: Subfigure 3A: China's GDP per capita (220 BCE to 2010 CE). Subfigure 3B: China's GDP per capita (220 BCE to 1940 CE). Subfigure 3C: China's GDP per capita (220 BCE to 1000 CE). The green dotted line represents GDP per capita, the purple dashed line represents population, and the solid green line represents grain yield data from this study. Gray dots represent GDP per capita data from Maddison (2008), and purple dots represent data from Broadberry et al. (2021). Subfigure D: China's GDP per capita (1010 to 1940 CE). The green dotted line represents per capita GDP, the purple dashed line represents population, and the solid green line represents grain yield data from this study. Gray dots represent per capita GDP data from Maddison (2008), purple dots represent data from Broadberry et al. (2021), and light purple triangles represent data from Xu et al. (2017). The GDP values in the figures are converted to 1990 international dollars according to the methods of Maddison (1998) and Broadberry et al. (2018). Population and grain yield data are indexed (220 BCE = 100).

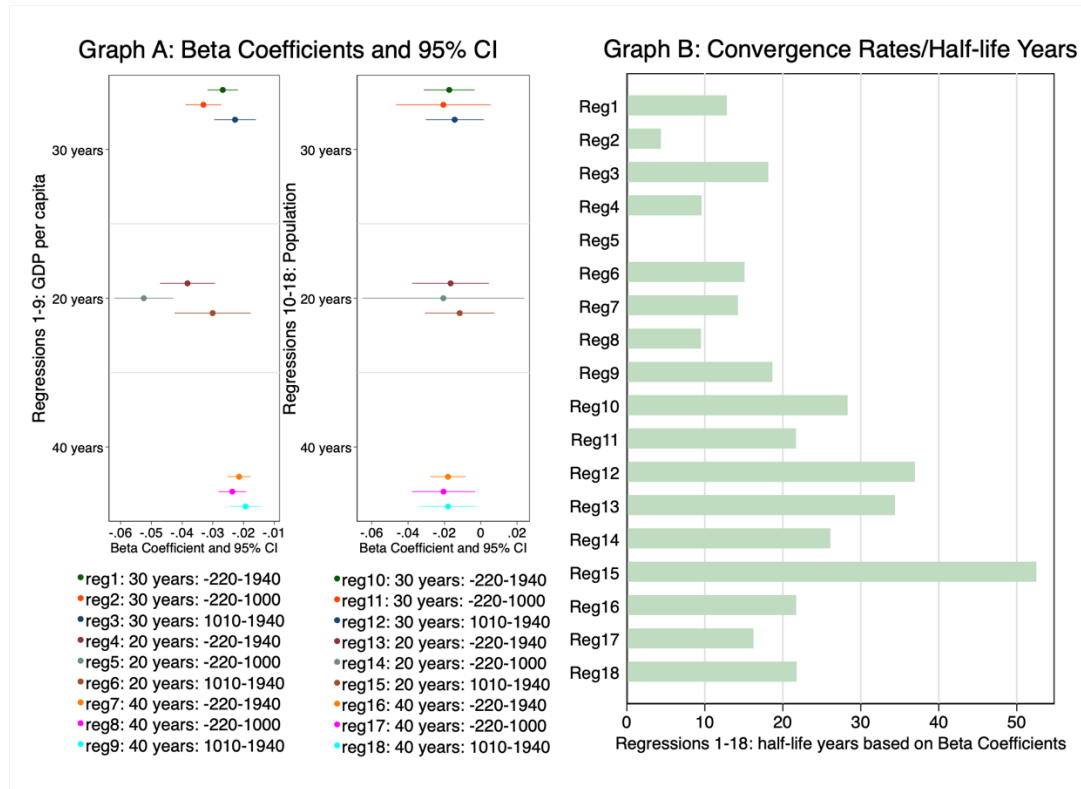


Figure 4 Malthusian test: error correction model of GDP per capita and population

Notes: Subfigure 4A: Beta coefficients and 95% confidence intervals from 18 error correction models. Models 1-9 primarily apply Newey-West regressions on GDP per capita with a maximum lag of 4. Models 1-3 use a 30-year interval for the full sample, the pre-1000 CE subsample, and the post-1000 CE subsample, respectively. Models 4-6 use a 20-year interval for the full sample, the pre-1000 CE subsample, and the post-1000 CE subsample. Models 7-9 use a 40-year interval for the same sample groupings. Models 10-18 apply Newey-West regressions on population with a maximum lag of 4, using the same intervals and sample groupings as for GDP per capita. Subfigure 4B: The beta coefficients from these 18 equations converted into half-life years. The half-life years for Regression 5 cannot be calculated, as the absolute value of the beta coefficient is too large, suggesting a half-life years of approximately zero.

The data for population and GDP per capita are from this study. Data on the stock of scientists are from Li and Zha (2002). As historical records become more complete over time, the original scientist data appear increasingly numerous in recent periods. To adjust for this, we use the number of biographies from CBDB as a denominator to calculate standardized counts of scientists across different periods. For example, if the biography number for Period A is 2 and scientists are 1, and for Period B the biography number is 10 and scientists are 5, a direct comparison would suggest Period B has more scientists than Period A. However, this could be due to a data preservation bias. By dividing scientists by biography number, we can estimate an “inflation-adjusted” number of “real” stock of great scientists. Data on epidemics are from *The Complete History of Natural Disasters in China*. The regression also controls for time dummies, with each cohort representing a 100-year interval.

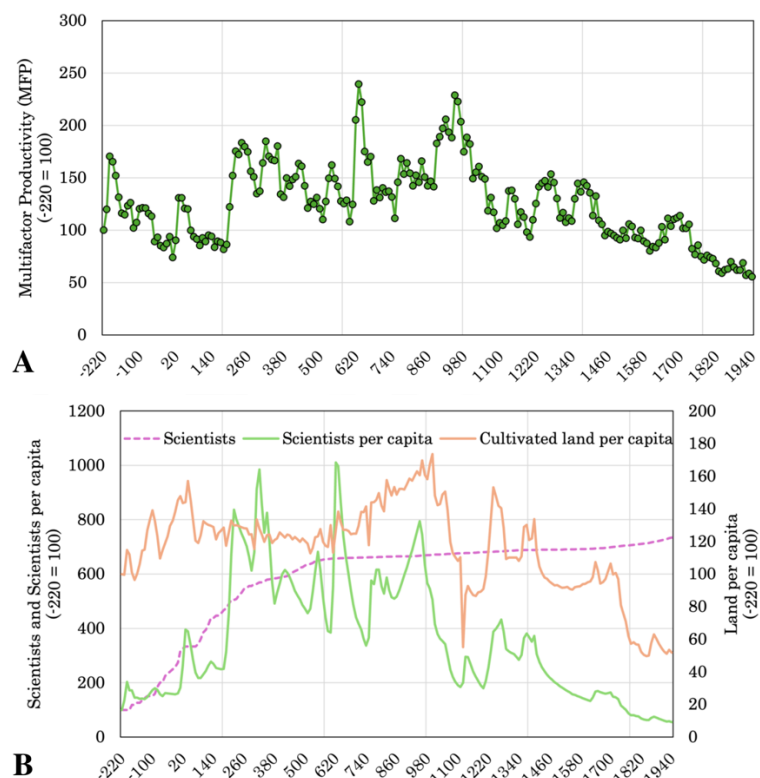


Figure 5 China's Non-Labor Input Factors: 220 BCE to 1940 CE

Notes: Subfigure 5A: China's historical Multi-Factor Productivity (MFP). MFP represents a composite index of input factors excluding labor and cultivated land (indexed to 100 in 220 BCE). Assuming a production function of the classic Cobb-Douglas form, with labor elasticity (proxied by population index) set at 0.6 and land elasticity at 0.2, we calculate the MFP index excluding labor and land. Subfigure 5B: Historical stock of great scientists, per capita stock of great scientists, and per capita cultivated land in China. Population and land data are from this study. Scientist data is referenced in the notes to Figure 4.

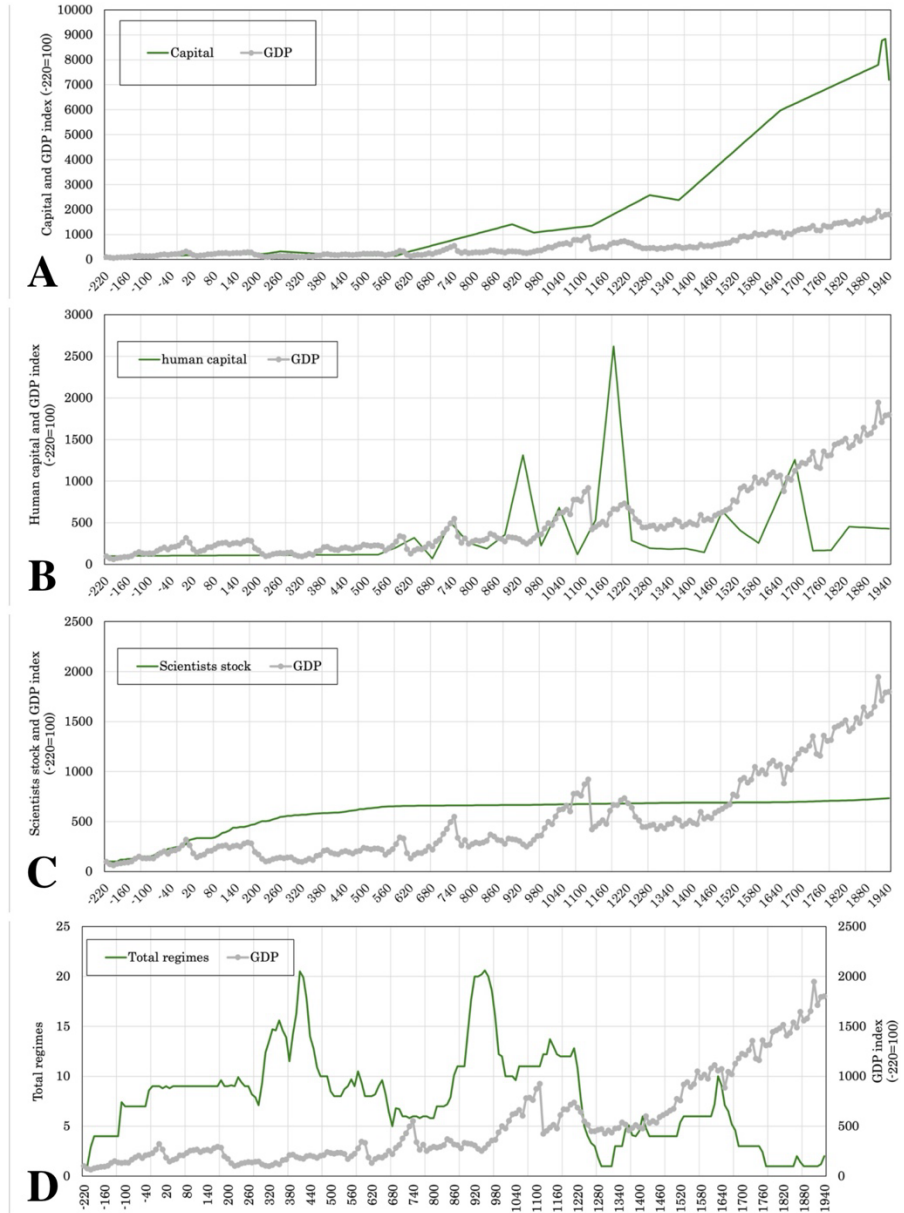


Figure 6 Capita, human capital, innovation stock, and institutions: 220 BCE to 1940 CE

Notes: Subfigure 6A: For capital accumulation, we use major hydraulic engineering projects—the largest fixed-capital investments in Chinese history—as a proxy. The data are drawn from Chi (1936), with a depreciation horizon set at 200 years. Subfigure 6B: For human capital, we employ age-heaping as a proxy, calculated from the distribution of ages of individuals with recorded birth and death years in the *China Biographical Database Project (CBDB)*. Data source: <https://projects.iq.harvard.edu/cbdb> Subfigure 6C: For innovation stock, we use the number of great scientists throughout Chinese history as a proxy, based on Li and Zha (2002). Subfigure 6D: For institutions, we use the number of regimes over different periods as a proxy for political competition, drawing on Chen and Ma (2020). Post-1911 data are supplemented according to the historical realities of modern China.

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