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Why did world population double from 1800 to 1938? [1]

Social scientists have shown a lot of interest in historical demography in recent times, with extensive research on pandemic shocks and on the timing and causes of the demographic transition. However, the discourse so far has relied on data for a small and not representative sample of advanced countries. This paper extends the analysis to the rest of the world by using a newly compiled data-base of population by country from 1800 to 1938. We confirm that world population grew substantially, from about 1 to 2.2 billion but add two new results. First, volatility remained fairly high throughout the period and demographic crises were common and frequent, especially in Africa and Oceania. Second, population growth started substantially earlier than assumed so far and earlier than its alleged causes (progress in medicine, economic growth) developed. Thus, our results call for a reconsideration of causes of population movements in the last two centuries. We put forward some tentative hypotheses

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1. Introduction

World population exceeded 8 billion on Nov 15 2022 – i.e. it has increased about eight times in the last two centuries. This epochal change has been interpreted, since the pioneering work by Notestein (1945), as a 'temporary' disequilibrium during the transition from a Malthusian regime of high mortality/high fertility to modern one, low mortality and low fertility. In recent times demographic history has enjoyed a revival of interest among economists, especially within the framework of the Unified growth theory (Galor 2011 and 2012). On top of this, the COVID 19 epidemics has rekindled the interest in demographic shocks, with extensive work on the Spanish flu (Athurokala and Athukorala 2020, Barro et al 2020, Beach et al 2022).

[1] We thank the participants to the Groningen Growth and Development Center 25th anniversary conference the Maddison project board workshop (Utrecht) the 14th EHES conference (Groningen) and to seminars in Yale NYUAD, South Denmark University.. for comments to earlier drafts. We also thanks Sara Pecchioli for her excellent research work

The results offer a lot of useful insights and we will review these works in more detail later, but they are far from sufficient. They almost exclusively deal with advanced countries, the only ones with long-run series of birth and death rates, and thus leave a major gap in our knowledge. What happened in the rest of the world, which by 1938 accounted for over four fifths of world population? When did population start to grow? How much did demographic crises affect the evolution of population? What did drive population growth and why?

Following a well established tradition (Chesnais 1992), we address these issues by replacing missing series of birth and death rates with population. We have estimated yearly series of total population by polity from 1800 to 1938 and, for a substantial number of countries, also population net of migration.. We sketch out the methods and sources of our reconstruction in the next section, with full details and robustness checks in a working paper (Federico and Tena Junguito 2022). We outline the long-term population changes in Section Three. Section Four shows that, contrary to the conventional wisdom, the volatility of population series did not decline worldwide and actually increased in quite a few areas. Two major shocks, the Tai'Ping civil war in China in the 1850s-early 1860s and the late 1910s world crisis (the combination of World War One, Spanish flu and Russian civil war and famine, were large enough to temporarily reverse the upward trend of world population. Then Section Five we explore the early pattern of transition, grouping polities in sixteen homogeneous macro-areas, plus India and China, and looking for breaks in the series of population. We adopt a very conservative criteria to date the start of the process, yet the population growth seems to have started earlier in most areas. Section Six contrasts this timing with the available historical evidence about the causes of transition according to the standard demographic model and the Unified Growth Theory. These models are tailored to experience of advanced countries and thus they need to be reconsidered to explain the population growth and we put forward some tentative hypotheses

2) The series of world population

The League of Nations started to publish yearly data on population for all polities, as a mix of official data and guesstimates, in 1925 (with retrospective figures for 1913) in her Statistical Yearbook. The United

Nations resumed the series after the wartime interruption (1938-1949) and has continued to present (United Nations 2019). However, estimates of world population are much older. The first, by the Italian Jesuit Riccioli, dates back to 1661 and since then many scholars, have published benchmark estimates of population for the whole world and for continents, relying on their own intuition with little or no evidence. The latest and most famous work in this tradition, the book by McEvedy and Jones 1978, reports benchmark population figures for some major countries and macro areas at different intervals from 400 BC to 1950. Yearly country series have been collected for the first time by Maddison (1995, 2010), as part of his work on comparative national accounts. The number of series in his data-base grows progressively from 23 in 1820 to 65 in 1938. Maddison integrated his data with guesstimates for missing countries to estimate world population in eleven benchmarks, five from 1 AD to 1700 and six from 1820 onwards (1820, 1870, 1900, 1913, 1920 and 1940) [2].

Unlike Maddison's , our data-base is complete - i.e. it includes yearly estimates for all polities from 1800 to 1938. We have relied on the obscure but highly praiseworthy work by historical demographers, who have painstakingly collected, assessed and, when necessary, corrected official data and any available information. We have collected all the estimates we have been able to find, from country-specific sources or area specific data-sets such as Rothenbacher (2002, 2012) for European countries. We have filled gaps with interpolations and have extrapolated backward the population from the earliest available figure to 1800 or forward from the latest one to 1938. We have taken also into account the population movements in neighboring or otherwise comparable polities and also the available information on demographic crises (most notably the Spanish flu).

Following the UN definition, our series refer to present (de facto) population at historical borders and always include natives, as their omission would bias upward the growth of population. When possible, we report population data mid-year. Overall, the data-base features 174 polity series, for a total of 21815 observations [3]. About a sixth of these polities existed only for part of the period and several other series

[2] The Maddison project has never updated the Maddison population series and has dropped the world total in the latest (2020) release

[3] We report aggregate series for Micronesia, Melanesia and Polinesia rather than separate series for islands or archipelagos. These latter are available upon request.

were affected by border changes, short range migrations and linear interpolations. Thus for the purpose of statistical analysis, we have aggregated the polities in 16 macro-areas, taking into account their geographical location, the level of development and the size of migration flows [4]. We consider separately only British India and China, the two most populous countries, which were not affected by major boundary changes and experienced limited migrations flows relative to their population. For three areas we have been able to extend the series back in time (1560 for Western Europe, 1690 for Central Europe and 1650 for Southern Europe), albeit with a incomplete geographical coverage (Appendix A).

Needless to say, our figures are of widely different quality, ranging from the almost perfect for Scandinavian countries to the mere guesswork for Sub-Saharian Africa and Oceania in the early 19th century. The amount of guesswork is the greater the less capable the administration was, and thus as a rule earlier data are less reliable than more recent ones. We assess the reliability of each observation, following Durand (1977), by classifying it from A (excellent) to E(conjecture). The share of the top category increases from 5% of world population in the early 19th century to about a quarter on the eve of World War Two, and most data are classified as fair or poor. We estimate the potential bias by attaching to each observation a margin of error and then we aggregate margins by continent and world as sum of variance of polity series, under the assumption that errors of these latter are independent (Feinstein and Thomas 2002).[5] The world range of error declines from 18.7% to 12.4% of total population, but about a half of this change is accounted by the spectacular improvement in the series for Oceania, a consequence of the collapse of the poorly counted native population. The range of errors is quite large, but even in the worst case, they are unlikely to alter the basic narrative. It is possible to compute counterfactual maximum (minimum) increase in world population as the difference between the lower (upper) bound of the range in 1800 and the upper

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[4] We divide America between North, Caribbean, South American immigration areas (Brazil, Argentina and Uruguay) and other countries, Oceania between Immigration countries (Australia and New Zealand) and the rest (Micronesia, Melanesia and Polynesia), Africa between North and Sub-Saharian Africa, Asia between Middle East (former Ottoman empire and Iran), China, India, South East Asia (Indonesia, Thailand, Malaya), East Asia (Japan and Korea) and Europe between North Western (United Kingdom, France, Scandinavia etc.), Central (Germany, Austria-Hungary and successor states), Southern (Italy, Spain, Portugal, Greece), Eastern (Russia and Poland after 1918) and Balkans.

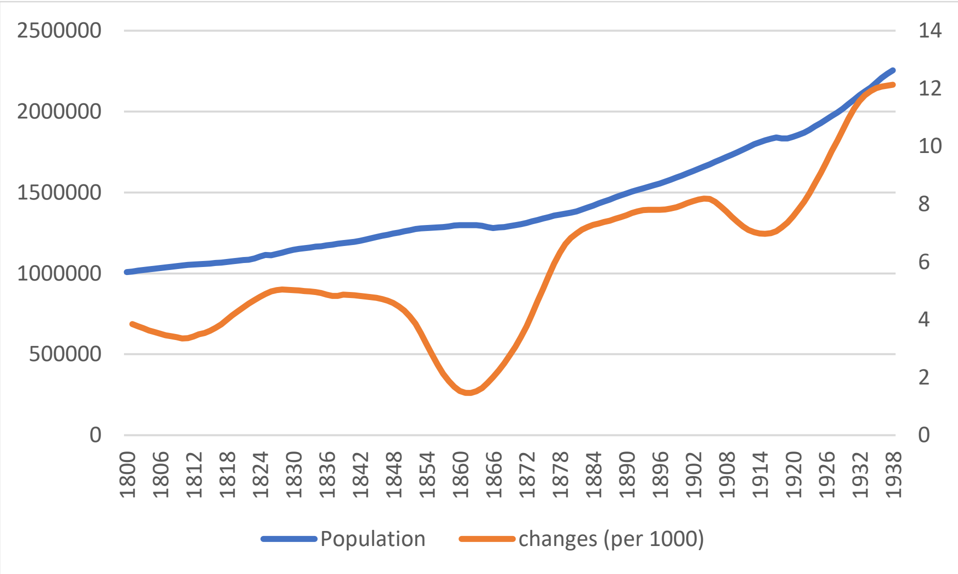
[5] We assume the margin of error to have been 2.5% for A estimates (± 1.25% around the 'true' value), 7.5% for Bs (±3.75%), 17.5% for Cs (±8.75%), 32.5% for Ds (±16.25%) and to have exceeded 40% for Es (with a band ±25%).

(lower) bound in 1938. Our baseline estimate yields a 123.7 % increase in world population, while the alternatives range from a minimum of 94.1% to a maximum of 159.5%.

3) The results: world population in the long run

3.1 The world population increased from just above 1 billion in 1800 to 2.2 billion, which corresponds to a log rate of 0.54%. A visual inspection (Figure 1, left axis) suggests an almost linear increase but the joint TS/DS model by Razzaque et al. (2007) fails to return a significant rate.[6] The yearly changes, smoothed with Epanechnikov kernel (Figure 1, right axis), show an upward trend interrupted by two massive crises, in the mid-19th century and in the second half of the 1910s.

Figure 1
World population and its yearly change 1800-1938



Sources: Federico and Tena-Junguito 2022

A Bai-Perron (2003) test singles out breaks in 1819, 1842 and 1867 but not in the early 20th century. [7] In Table 1 we report the rates of change for the corresponding intervals (left-hand column) and for a historical periodization which singles out the effect of the two main demographic crises (right hand column).

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[6] We run the regression $\Delta \ln POP = \alpha + \beta\, TIME + \psi \ln POP_{t-1} + \phi \ln \Delta \ln POP_{t-1} + \varepsilon$, and compute the rate of growth is computed as $-\beta/\psi=0$.

[7] We use the Stata xtbreak command (Ditzen et al 2021) which adopts a sequential approach. It tests progressively from the null of one break vs zero breaks to the null of nine vs eight breaks by splitting each interval, under the constraint that the length of segments between the breaks not to exceed a pre-determined proportion of the length of the series (or 'trimming'). For each break, the software returns an interval of coincidence in years at 95%, which for the world series is reassuringly narrow (three years). In the text we quote the results with a trimming 0.10, which

Table 1
Rates of change, world population, 1800-1938

	Short term °		Medium-term
1800-1819	0.33***	**1800-1850**	0.50***
1820-1842	0.50***	**1850-1870**	0.08**
1843-1867	0.27***	**1871-1913**	0.84***
1867-1938	0.89***	**1913-1920**	0.04**
		1920-1938	1.16***

* significant at 10%; ** significant at 5%: *** significant at 1%; underlined log linear

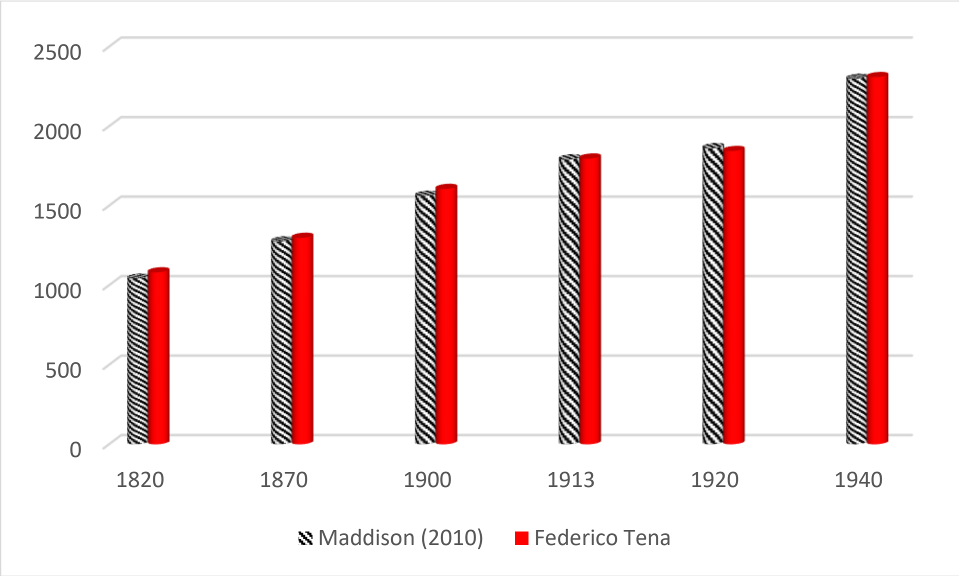
As expected, rates of change were very low (but still positive) during the two crises, while the other ones feature a progressive acceleration since the early 19th century. The rates in the early 19th century are somewhat higher than expected for an allegedly Malthusian world. In-fact the available evidence on population movements before 1800 (Appendix A) shows that the growth had started in Europe at least in the 17th century and, much more tentatively, also in other major Eurasian countries. We do not know enough on other continents, where total population movements were deeply shaped by slave trade, migration movements and European diseases on native population.

3.2 We compare our results with other available estimates and with the League of Nations and Gapminder series in the working paper (Federico and Tena Junguito 2022). Here we focuse on Maddison's estimate, the linchpin of all modern estimates (Figure 3) [8]

Figure 3
World population, 1820-1940: a comparison with Maddison

implies in the case at hand a minimum length of fourteen years –i.e. the first break cannot be earlier than 1813 and the last later than 1925. Using a 0.05 trimming increases the minimum length of each period to seven years but results are qualitatively similar. The routine finds five breaks instead of three, but all in the in the 19th century (1815, 1831, 1847, 1863 and 1881)..

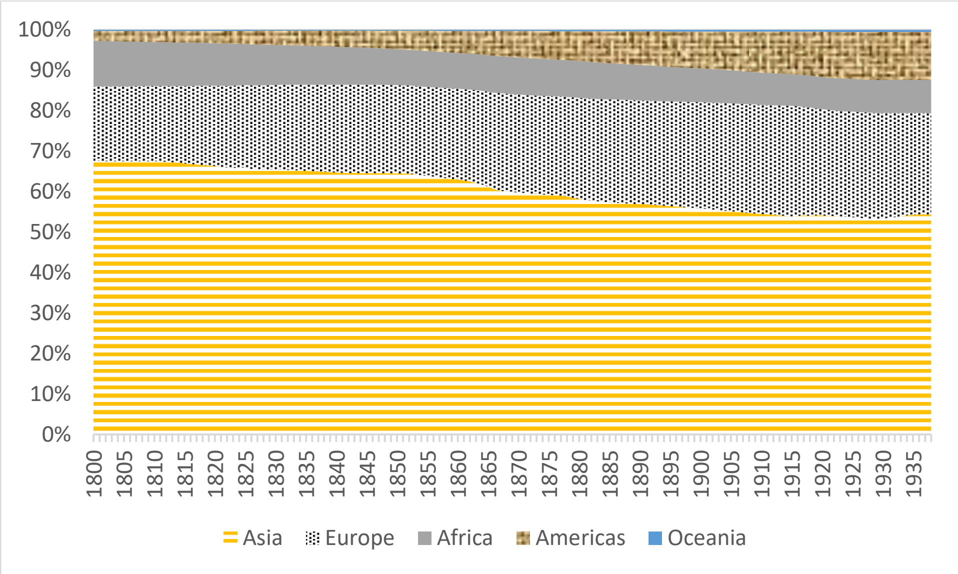
[8] For the purpose of this comparison, we extrapolate our series from 1938 to 1940 with the growth rates for the previous five years (1.3% for Asia and Africa, 1.2% for Americas and world population, 1.1% for Europe and Oceania). The result might be slightly overstated as it does not include an adjustment for war-time losses.



The difference in rates of growth over the whole period is small (0.63% the present estimate, 0.66% Maddison) and the Root Mean Square Error for the common yearly series, which refer mostly to advanced countries with good sources, is as low as 10%. Interestingly, the differences concentrate in the thirteen years before World War One: our estimate is 2.7% higher than Maddison's in 1900 and only 0.39% in 1913, so that our rate of growth is correspondingly lower by a couple of percentage points (0.87% per year vs 1.05%).

3.3 Our data-base allows geographically much more fine-grained analysis than the crude continent-based benchmarks. As a starting point, Figure 3 plots the distribution by continent

Figure 3
The distribution of world population by continent, 1800-1938



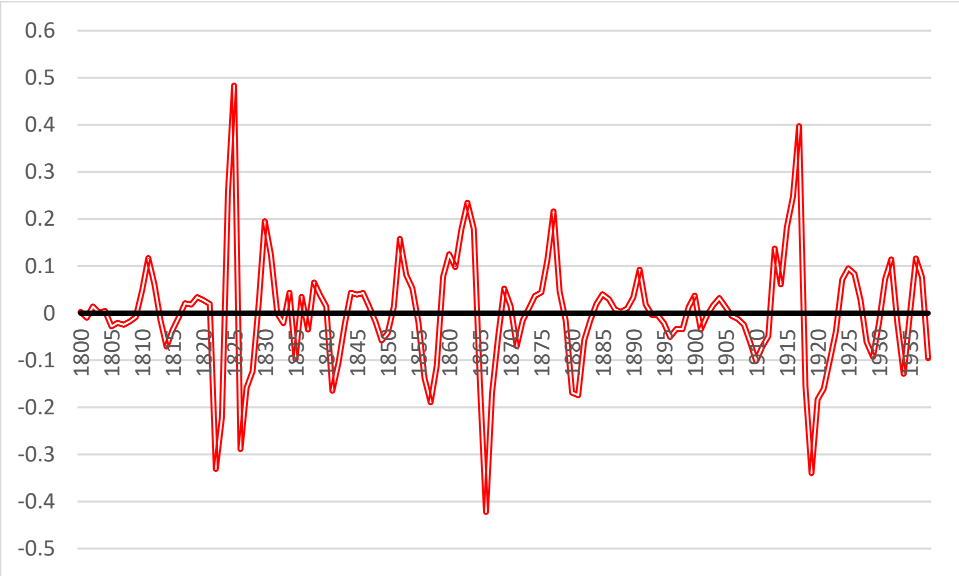
In relative terms, population declined in Africa and Asia, increased in Europe (here including the whole of Russia) and boomed in the Americas and Oceania. The changes were already massive by 1870 and were mostly over on the eve of World War One. Indeed, trends slowed down or even reversed in interwar years, but total changes were small in comparison with pre-war ones. The African share of world population fell by a fifth in the first half of the 19th century, from 11.3% to 8.9%, slid by a further percentage point to 7.8% in 1913 and in 1938 was roughly at the level of the mid-1900s. The Asian share declined over the whole period by 13 points, from 67% to 55% and a third of the change was cumulated in the 1850s and 1860s. Likewise, two thirds of the relative rise of Europe from 18% in 1800 to 27% in 1913 were cumulated before 1870. The European share fell during the war by one point and continued to decline afterwards. In contrast, the American share rose almost as fast from 1870 to 1913 (from 6.5% to 10.4%) than in the first seventy years of the century (from 2.5% to 6.5%) and rose further to 11.9% on the eve of World War One.

However continents are arguably not the right level of geographical aggregation. Indeed distribution by areas within continents show substantial variations, especially for the effect of migrations (Statistical Appendix Figure I). It boosted the share of Australia and New Zealand from a quarter to three quarters of Oceania and of North America from 26% to 52% of the Americas. Other changes within continents were less dramatic but still relevant: Eastern Europe increased from a fifth to a third of the European continent, and China decreased from 54% in the 1840s to 45% in the 1870s of Asia.

4) The results: volatility and demographic shocks

A visual inspection of the normalized residuals of the world population series from a Hodrick-Prescott filter (Figure 4) does not confirm the conventional wisdom about a long-term decline in volatility

Figure 4
Volatility of population, 1800-1938



The volatility seems stable and, again in contrast to the conventional wisdom, the average of the whole period was similar in the core countries (8.8%) than in the peripheral ones (8.5%)[9]. We test our impression by estimating rates of change in volatility with a (log-linear) regression, adding as a control the share of linearly interpolated series on total population (Federico and Tena Junguito 2022) [10].

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[9] The core includes North America (United States and Canada), North Western Europe (France, Germany, Scandinavia, Belgium and Netherlands), Australia and New Zealand. The ratios between absolute deviation and trend component over the whole period are 3.3% in Africa, 7.1% in the Americas, 10.9% in Asia, 9.1% in Europe and 8.1% in Oceania.

[10] The dependent variables are computed as logs of the ratios of squared numerator and denominator – i.e. the residuals and the trend component of the Hodrick-Prescott filters.

Table 2
Rates of change in volatility of population series, 1800-1938
a) Hodrick-Prescott filter

	1800-1938		**1800-1913**		**1800-1938**		
	Time	Share	Time	Share	Time	Share	Dummy 1910s
Africa	2.62***	-0.18	2.94***	0.01	2.24***	-0.20	2.77**
America	-0.46	-1.07**	-1.85**	-1.76	-1.23**	-1.41**	4.46***
Asia	-0.40	-0.13	-0.77	0.26	-0.30	-0.02	2.19
Europe	2.13***	0.00	2.17**	0.02	1.65**	-0.04	2.22*
Oceania	-0.56	-0.15	-0.50	-0.12	-1.47*	-0.25	5.06***
Core	-0.54	0.01	-0.94	-0.01	-1.12	-0.06	3.83**
Periphery	-0.81	-0.85**	-1.80**	-0.79**	-0.97	-0.86	1.11
World	-0.83	-0.96**	-2.34**	-1.22**	-1.21*	-0.96**	3.01***

b) Hamilton measure

	1800-1938		**1800-1913**		**1800-1938**		
	Time	Share	Time	Share	Time	Share	Dummy 1910s
Africa	7.46***	-0.29	8.07***	-0.23**	7.62***	-0.28	-1.19
America	-0.21**	-0.13	0.28**	-0.01	-0.17*	-0.11*	-0.24
Asia	1.13*	-0.26*	0.83	-0.29	1.09	-0.30**	-0.90
Europe	-0.19	-0.08**	1.04***	0.01	0.10	-0.06	-1.32***
Oceania	2.53***	-0.63***	4.59***	-0.37**	2.75***	-0.60**	-1.25
Core	-0.31**	-0.09	0.55***	0.08	-0.43***	-0.29	-0.71***
Periphery	2.14***	0.29*	1.74***	-0.05	2.28***	0.30	-1.02*
World	2.02***	0.30***	1.41***	-0.18	2.14***	0.30*	-0.93**

* significant at 10%; ** significant at 5%: *** significant at 1%

The time trend in the baseline estimate is negative but not significant, in stark contrast with the fast decline of volatility after 1950 (-5.7% yearly, significant at 1%). The only two significant continent-level coefficients are positive – i.e. volatility increased. Positive coefficients are also more common than negative ones at area level (Statistical Appendix Table I) and only one negative coefficient, for Australia/New Zealand, is strongly significant. As a robustness check, as suggested by Hamilton (2018). we measure volatility with five-year lag difference between observations divided by the five years lagged observation. The results (Table 2b) are even farther from the conventional wisdom, with increasing volatility as the norm.

One might surmise that the increases in volatility reflect the exceptional severity of the shocks of the late 1910s. We test this hypothesis by running the regressions for the period 1800-1913 and by adding a dummy for the crisis years 1914-1919. The results do change much. The decline before 1913 is faster and the rate becomes significant because of strong downward trends in Western and Southern Europe and in Immigration Latin America. As expected, the 1910s dummy is positive and significant in most cases, but its addition to the regression for 1800-1938 does not change the baseline results to any meaningful extent. Likewise, results do not differ much with the Hamilton measure [11].

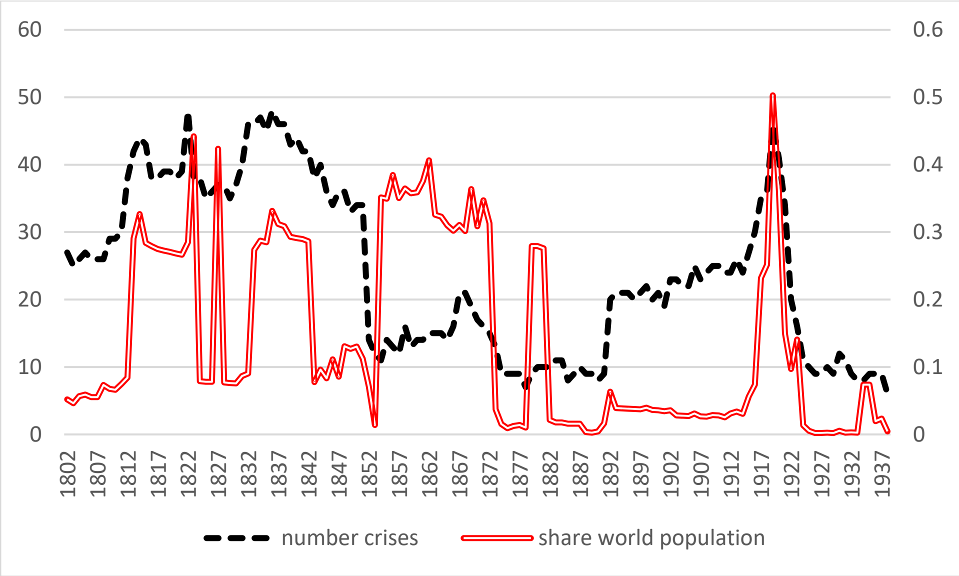
Our results imply that the frequency and/or severity of demographic crises has not changed. Without data on death rates for most countries, we cannot compute excess deaths and thus we define, quite conservatively, a crisis as an absolute decline in population. Crises hit at least once two thirds of the polities (121 out of 174), for about a sixth of the years (3324 years out of 21641). These figures may undervalue the true number of crisis. In all likelihood the number of deaths exceeded the normal in the 811 years of zero population growth and possibly in many others and by construction we miss all years of decline when population is obtained with upward linear interpolation [12].

Crises were more frequent in the first half of the 19th century, became fairly rare in the 1870s and 1880s (about ten polities per years) and then increased again since the early 1890s, peaking predictably, in 1918, when population declined in 49 countries out of 158 (Fig 5, black line).

Figure 5
Number of countries affected by demographic crises and their share of world population

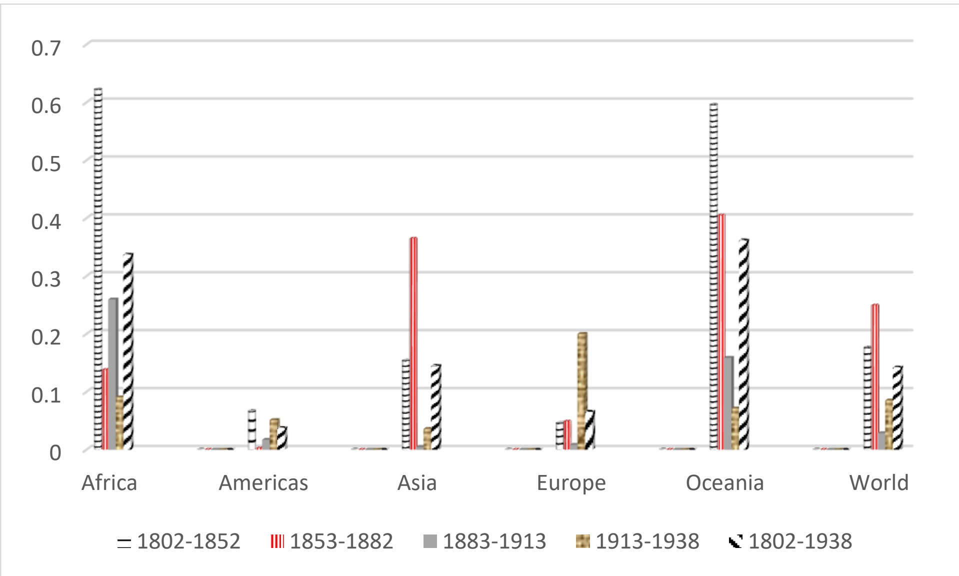
[11] We have also re-run the regression with a dummy for the years 1910 to 1923 which include at least one war year in the computation of the 'Hamilton' volatility measure. Results are almost identical.

[12] This effect is not compensated by the neglect of years of population growth in linearly interpolated downward trends: these latter ones accounted for only 31% of observations in interpolated trends.



The picture is somewhat different if one considers the number of affected people rather than the number of affected polities (Figure 5, red line). The total share is marginally lower (13.8% vs. 14.5%) and the time profile is dominated by crises in India (as in the 1810s and 1830s) and China (the 1850s and early 1860s). The differences emerge clearly from the distribution by period/continent (Figure 6).

Figure 6
Share of population affected by demographic crises, by period/continent



There were few crises in the Americas, where fluctuations were dampened by immigration, and in Europe, outside the war years. Crises were frequent in Asia before 1880, Oceania in the 19th century and in Africa almost for the whole period.

Table 3 distinguishes three types of crises according to the length of the decline [13].

Table 3
Duration and severity of demographic crises

	Short term (1 to 3 years)	Medium term (4 to 9 years)	Long term (over ten years)	All crises
Number crises	210	53	101	365
Number years of crises	310	301	2700	3311
Average length of crises	1.5	6	27	9
Average rate of yearly decrease	-2.2	-1.2	-0.6	-0.6
Shares years of crisis on world total				
Africa	14.5	8.6	56.3	48.0
Americas	18.7	31.9	26.8	26.5
Asia	16.8	31.9	5.3	8.8
Europe	44.8	25.7	1.2	7.5
Oceania	5.2	13.8	10.4	10.2

The short-term crises fit best the definition of demographic shock: a sharp drop in population determined by famines or epidemics [14]. The tiny island of Cabo Verde, which, in spite of its name, was subject to disastrous droughts, was hit by five such crises, and in the worst one, in 1831-1833, population collapsed from 76K to 47K – i.e. by 45%. The devastating famine of North China 1877-1878 claimed between 9 and 13 million lives (Aird 1968 p.265) and the worst affected province, Shanxi, lost 5.5 million lives, about 15% of its population. Also some medium-length crises were determined by famines: the potato blight and the ensuing mass migration caused the population of Ireland to collapse from 8.3 million in 1845 to 6.3 in 1852 and the population of the United Kingdom to decline for five years in a row, in spite of the fast rise in the rest of the country, from 28.0 in 1846 to 27.4 million in 1851 (Mitchell 1988). However most medium-term crises were determined by wars, such as the 1864-1870 war against Brazil and Argentine which wiped out about a quarter of the population of Paraguay, from 350K to 276K. About sixth of medium-length crises

[13] The table omits 13 observations, relative to polities subject to massive territorial losses – the Ottoman Balkans in 1830, 1859, 1879, 1881, 1897 and 1912, France in 1871, Germany in 1919, Greece in 1924, Hungary in 1923, Russia in 1919 and Turkey in 1919. In Figure 5 we substitute the actual change with the average change in the two neighbouring years.

[14] There is no good independent source on demographic shocks. The EMDAT data-base (https://www.emdat.be/) covers only natural disasters since 1900 and it seems to underestimate the number of deaths. It lists 387 events, but in only eight cases the death toll exceeds one million people.

years concentrated in the period 1914-1921, when the effects of war were worsened by the Spanish flu (cf. Table 4).

Over four fifths of crisis observations belong to long term negative trends, which hit Africa (35 long term crises, with a median length of 41 years), Oceania (5 long term crises, 51 years) and the Caribbean (11 crises, 31 years). [15] The exact timing, speed and duration of these long crises is highly uncertain as the population estimates are, at best, informed guesses. The linear interpolation assumes a steady decline rather than a succession of collapses and modest rebounds, and thus it may overestimate the number of crisis years and underestimate the yearly losses [16]. However, the existence of long-term crises, as consequence of slave trade and diseases, is beyond any doubt. In the first half of the 19th century, slave trade reduced the population of Sub-Saharian Africa (except its Southern tip) by about 4%, or by 0.07% per year [17]. In the last decades of the century, Africa suffered for a series of calamities, including droughts, locust, the European conquest and the rinderpest, which killed a large proportion of cattle and disrupted the livelihood of large swathes of the population (Sunseri 2018) [18]. By 1800, the European infectious diseases had already ravaged the native population in South America in Mexico, were still killing them in North America and had just started to spread in Oceania. The size of the decline depended on nature of diseases (some were more lethal than others) and on the patterns of transmission, which in turn depended on location and population density. The length of trips from Europe to Oceania might have prevented some transmission of some diseases (Bushnell 1993) and the wide spaces of North America reduced contacts between infected native groups (Thornton 2000). Yet, our source suggests a 62% decline of native

[15] According to the estimates by Bulmer Thomas (2012), the population of the Danish Virgin island (since 1917 US Virgin Islands) declined in 91 years out of 139 – i.e. in all years but the initial ones (1800-1835), the final ones (1930-1938) and a short period of stagnation from 1846 to 1850.

[16] As said, the overestimation might compensate the underestimation from the omission of crisis years during periods of linearly interpolated population growth. However, this case would not change the overall assessment of the demographic conditions of the country and anyway linearly interpolated downward trends account for 10.6%% of all crises. The share is high (and thus the issue potentially relevant) only in Africa, where they account for 22.2% of crisis observations in the whole period and for 51.4% in the first half of the century.

[17] Population declined from 1800 to 1850 by 1.7% (0.03% per year) in West Africa and by 14% in Central Africa (0.3% per year), from 1810 to 1850 in East Africa by 3.7% (0.1% per year), from 1820 to 1850 by 1.4% in NorthEast Africa (0.05% per year). Rates are computed between benchmarks by Manning-Nickleach 2014.

[18] Rinderpest appeared in 1887 and ravaged the continent until the 1930s. From 1891 (the first benchmark year in Frankema and Jerven 2014) onwards, 12 polities experienced long term decline, for a total of 330 years (a tenth of the world total) years and an average rate 0.65%

population of North America 1800 to 1890 (Thornton and Marsh-Thornton 1981). In Oceania the decline of the native population was as large as in the Americas and there was very little or no rebound before World War Two. According to the best estimates, the total aboriginal population of Australia collapsed from 575K in 1815 to 74K in 1933 (i.e. by 87%).

These demographic catastrophes were terrible for the affected people, but their impact on world population was small and sometimes negligible. Deaths during the 1878-79 Chinese famine were equivalent to a third of the population of the United Kingdom but accounted for only 0.6-0.9% of world population. If the native population of Oceania had been growing at 0.5% yearly since 1800 rather than declining, the total population of the continent would have been 2.3 million higher in 1938 and the world total only 0.1% greater. [19] In the extreme and somewhat implausible case that the 1800 native population were ten times the historical minimum, as hypothesized by Stannard (1989) for Hawaii the world population in 1938 would have been only 0.5% higher. The world population decreased only eight years out of 139, in 1826, 1862-1866 in 1918-19. The first of these falls is somewhat puzzling. It was determined by a sudden fall in Chinese population, from 392 to 385 million, which however does not coincide with any known catastrophe. The second coincided with the most intense period of the Tai'ping civil war. From the beginning of the war, in 1852 to 1871, when the last Tai'ping army was defeated, the Chinese population declined from 438.9 million to 357.8 million, and a half of these losses was suffered in 1862-1866 [20]. In contrast, the 1917-1919 crisis affected the whole world, as the cumulated outcome of three different shocks, the Great War, and the Spanish flu and the Russian post revolution troubles (the civil war, war communism and famine). Table

[19] For Australia and New Zealand we compute our counterfactual series as sum of natives and white population with data from Historical Statistics Australia and Historical Statistics New Zealand. For Hawaii we rely on data from Schmitt (1968 tab 16 and 26). We estimate the counterfactual series for full-blood natives only, while we include 'part Hawaiians in the series for 'others' (mostly Japanese immigrants), assuming there were 100 'others' in 1800. For other islands the sources do not distinguish between natives and immigrants, who anyway were much fewer than in Hawaii or, a fortiori, Australia and New Zealand. Thus, we implicitly assume that all population was native-born and we select for the counterfactual the period of absolute decline -i.e. 1800-1885 for Polynesia (a total decline of 50%), in Micronesia 1830-1913 (37%) in 1820-1901 Melanesia, without Papua New Guinea (-29%). We extrapolate the population in the final year of the period with the actual growth rate.

[20] It is possible to estimate the total death toll, including deaths from other rebellions and war-related diseases and famines and missing births by extrapolating the population in 1852 to 1871 with the growth rate of the late 1840s (0.4% year). This computation yields a total of up to 110 million, above the estimates of war losses (Aird 1965 p.265) but not much higher than some independent Chinese estimates (Platt 2012 p.308).,

4 focus on the most affected areas, reporting the actual change, our estimate of excess mortality and the available data on deaths from the flu and the war [21].

[21] We compute excess mortality as the difference between actual and counterfactual population in 1918 and 1919. We estimate this latter by extrapolating the actual population with the 'normal' rate of change, as proxied by the 1909-1913 rate. The population of Russia in 1919 at pre-war borders is computed by extrapolating the figure for 1918 with the rate of change for Russia at interwar borders (without Finland and Congress Poland) from Markevitch and Harrison (2011 Appendix tab A8 and A9). The estimates for Spanish flu exclude the deaths from the third (and minor) wave in 1920.

Table 4
Population changes 1917-1919 (thousands)

	Actual change		Estimated excess mortality		War losses 1918	Spanish flu
	1917 to 1918	1918-1919	1917 to 1918	1918-1919		
China	1404 (0.32%)	761 (0.17%)	-1147 (0.26%)	-1800(0.41%)		4000-9500
India	-7328 (2.36%)	-1431(0.45%)	-8965(2.77%)	-3031(0.93%)	44	6200-18500
Indonesia	-1072 (1.97%)	523(0.98%)	-1690 (3.11%)	-82(0.15%)	-	450-4300
Russia	-811(0.85%)	-2023(1.21%)	-4275 (2.56%)	-5470(3.20%)	584	450-2760
European belligerents *	-1903 (0.78%)		-3917 (1.60%)		2596	1300-2440
Western offshoots **	118(0.10%)	1759(1.50%)	-2147(1.83%)	-508(0.42%)	202	233-716
World	-6255(0.34%)	1259(0.07)	-23309(1.27%)	-15736(0.84%)		

* Austria-Hungary, France, Germany, Italy and United Kingdom: ** Australia, Canada, New Zealand and United States

Sources: war deaths (military) estimated as deaths 1914-1918 from War office (1922) and Becker (1999:90) times the share in 1917-1918 from Barro et al (2020) Tab. 2; Spanish flu maximum and minimum from Johnson and Mueller (2002) Athukorala and Athukorala (2020), Barro et al (2020) Tab. 1, plus country specific sources for India and Indonesia (cf. Appendix I

Deducting war losses from the excess deaths (39 millions) one gets a total of 35 million deaths from the for the Spanish flu [22]. There is some suspect that the figure is underestimated. The series for about sixty polities, accounting for 5-6% of world population, are estimated with linear interpolation, and thus assume by construction the impact of the flu to have ben nil. On top of this, the number of excess deaths in China, where anyway the flu might have been more benign than elsewhere (Chen and Leung 2007), is lower than all available estimates. On the other hand, the estimate include missing births and the figures for war-related losses are very conservative, as they refer to lower bounds of ranges and exclude civilians. Factoring both biases, it seems highly unlikely that the total world losses from Spanish flu reached 40 million. This latter figure is close to the upper bound of the range of the scientific estimates, from 17-24 million (Spreeunwenberg et al 2018) to 35-44 million deaths (Athukorala and Athukorala 2020)[23]. Our estimate implies that the Tai'ping civil war, or more in general the mid-19th century Chinese crisis, was the largest demographic shock in the whole period. Total losses were comparable to deaths in World War Two, when world population was double a century earlier.

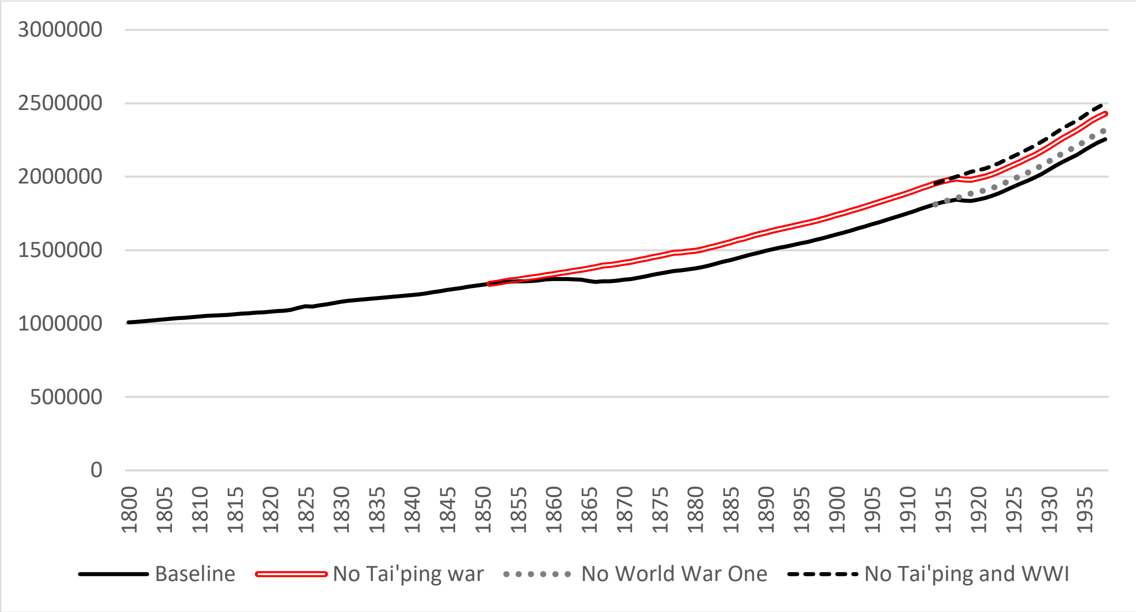
The impact of these two world-wide crises can be measured with a simple back of the envelope counterfactual exercise. We hypothesise that the Chinese population had been growing from 1851 to 1871 as fast as in 1830-1850 and that the world population had been growing from 1914 to 1919 as fast as in 1890-1914 [24]. It is thus possible to estimate population growth without the Tai'ping war, without the 1917 crises and without both crises (Figure 7).

Figure 7
Counterfactual, no-crisis series of world population

[22] The total war losses include the deaths of other belligerents (the Ottoman Empire and Balkans countries Greece, Japan, Portugal, South Africa and Turkey) but not civilian deaths. We also assume that the Russian civil war caused 1.5 million deaths in 1919. Our estimates of excess mortality are not totally independent from the data on deaths, as some population series incorporate the best guess estimates of losses from the flu.

[23] This figure of 100 million deaths, which is often quoted in the historical literature, is a highly speculative guess by Johnson and Mueller (2002). They report country estimates totalling between 33 and 43 million deaths, increase the figure to 50 million to take into account missing countries, and add that even this figure 'may be substantially lower than the real toll, perhaps as much as 100% understated' (p.115).

[24] We extrapolate the post crisis trend with the actual rate, which in theory could exceed the steady state one to compensate for the losses. However, there is no much evidence of such an acceleration. The rates for China were marginally higher in the mid-1870s than in the 1840s but the increase was short lived. As said, the worldwide rate of growth rose gradually from 1921 to the eve of World war rather than jumping after the end of crisis and then returning to the normal.



The Tai'ping war affected world population much more than the late 1910s crisis: without it, the world population in 1938 would have been 2429 million, rather than 2254 million (or 7.7% higher) while it would have been 2137 without the late 1910s crisis (2.8% higher). Without both major crises, the population in 1938 would have been about 244 million higher than the actual one (10.8%): if one factors in also the 'minor crises' the total missed growth might well have exceeded 300 million.

5) The results: dating the beginning of the demographic transition

The world-wide series suggests that population had started to increase before 1800 and that the growth has been gaining speed throughout the period (but for event-related setbacks). It reached the top speed after World War Two, with a 20‰ rate in 1965-1970, and since then growth has slowed down to 11‰ in 2015-2020 (a whisker below the pre-war maximum – 13‰ in 1929-1933). However, as said in Section II, the world-wide growth is the sum of quite different area trends: we will explore systematically these differences by looking for structural breaks in the series of rates of change of population by area with a Bai-Perron (2003) test. We consider three sets of series, the total population of the eighteen areas in 1800-1938, total population of Western, Southern and Central Europe in early modern period and counterfactual series of population net of migration for eight areas. Unfortunately, the gap in series between 1938 to 1950 prevents an analysis of the whole process and thus we will focus on its beginning and early stages.

As a first step, we let the routine find as many breaks as possible ('unconstrained' estimates). For the main set, test returns a total of 117 breaks, with ten area series featuring nine breaks, the maximum set by the 0.10 trimming percentage. However, quite a few of these breaks feature implausibly large intervals of confidence at 95%. Thus, in a second run we focus on breaks with a narrow interval of confidence in the initial run and we constrain the total number not to exceed their number ('precise' estimate) [25]. Finally, we select among the 'precise' estimates the most plausible dates for the beginning of transition, with very prudential criteria in order to avoid false inferences. We exclude breaks before or after major demographic crises as they might be determined by short-run Malthusian reactions. As a second step, we compute the rates of change of series of total population and, when available, no migration counterfactual one [26].For instance, the 'unconstrained' estimate for North Africa yields nine breaks, which the 'precise' estimate whittles to two breaks, in 1830 and 1876. The rate of growth in 1831-1876 is high (0.96%) but not significant and the null of equal rate to 1800-1831 is rejected only at 10%. Furthermore, the estimates in the first half of the century are highly uncertain (Federico and Tena Junguito 2022 Appendix I) and the year 1830 coincides with the French invasion of Algeria. So, in this case we prefer to play safe and consider the transition to have started only in 1876.

The results (table 5) highlights five stylized facts:

[25] As a further robustness check, we have also re-run the routine constraining the number of breaks not to exceed five ('constrained' estimates). And also 0.05 trimming

[26] When possible, we compute the rates of change with the Razzaque et al (2007) model. If it does not return significant results or the number of observations is too small, we use a log-linear trend. Almost all log-linear series features auto-correlated residuals, partly for the nature of population change and partly for the use of linear interpolations. We prefer not to correct in order to avoid further distortions, given that autocorrelated residuals do not bias the coefficient of trend variable, the result of interest, and that t-statistics are very high.

Table 5

Dating demographic transition: yearly rates of growth

a) total population	**Long-term**		**Before the first break**		**After the first break**		**After the second break**	
North Africa	1800-1938	0.64***	1800-1876	-0.13	1876-1938	1.15***		
Sub-Saharian Africa	1800-1938	0.23***	1800-1920	0.27***	1920-1938	1.36***		
North America	1800-1938	3.28***	1800-1845	2.78***	1845-1912	1.99***	1912-1938	1.24***
Caribbean	1800-1938	2.08**	1800-1830	0.87***	1830-1881	1.25***	1881-1938	1.85***
Immigration Latin America	1800-1938	2.28***	1800-1853	1.60***	1853-1938	2.30***		
Latin America	1800-1938	1.16***	1800-1891	0.99***	1891-1938	1.27***		
Middle East	1800-1938	0.49***	1800-1830	0.19***	1830-1922	0.55***	1922-1938	1.63***
India	1800-1938	0.62***	1800-1873	0.37***	1873-1920	0.47***	1920-1938	1.11***
China	1800-1938	0.15***	1800-1925	0.12	1925-1938	1.47***		
South-East Asia	1800-1938	0.80***	1800-1844	0.85***	1844-1938	0.74***		
Far East	1800-1938	0.39***	1800-1860	0.03	1860-1938	1.64***		
Western Europe	1800-1938	0.52***		No breaks				
Southern Europe	1800-1938	0.80***	1800-1862	0.68***	1863-1920	0.87***	1920-1938	1.03***
Central Europe	1800-1938	0.46*	1800-1923	0.84***	1923-1938	0.56***		
Balkans	1800-1938	1.59**	1800-1829	0.44***	1829-1920	0.63***	1920-1938	1.39***
Eastern Europe	1800-1938	1.27***	1800-1857	1.08***	1857-1909	1.55***	1909-1938	0.98***
Australia New Zealand	1800-1938	2.70***	1800-1831	-1.57**	1831-1892	3.77***	1892-1938	1.73***
Pacific Islands	1800-1938	-0.01	1800-1920	-0.38**	1920-1938	1.46***		
b) no migration series								
North America	1820-1938	1.66***	1820-1867	2.20***	1867-1927	1.32***	1927-1938	0.84***
Immigration Latin America	1800-1938	1.48***	1800-1852	0.94***	1852-1912	1.74***	1912-1938	1.40***
Caribbean	1800-1938	5.02	1800-1858	1.03***	1859-1938	2.15***		
Western Europe	1838-1938	0.89***		No breaks				
Central Europe	1817-1913	0.45		No breaks				
Southern Europe	1862-1938	0.95***	1862-1921	0.91***	1921-1938	1.06***		
Eastern Europe	1867-1914	1.65***		No breaks				
Australia New Zealand	1852-1938	1.80***	1852-1892	2.02***	1892-1938	1.71***		
c) early modern period								

Western Europe	1560-1913	-0.02	1560-1613	0.19***	1614-1730	0.11***	1730-1913	0.61***
Central Europe	1690-1913	0.42**	1690-1757	0.55***	1757-1871	0.84***	1871-1913	1.63**
Southern Europe	1650-1913	0.54*	1650-1685	0.15	1686-1814	0.26***	1814-1913	0.66***

Sources: own elaborations from Federico and Tena-Junguito 2022 and Appendix A; * significant at 10%; ** significant at 5%: *** significant at 1%; underlined rates estimates with log-linear specification

i) Over the whole period, the total population (panel a) increased in all areas but the islands of the Pacific, ravaged in the early 19th century by European diseases. As expected, the highest rates of growth are registered in the areas of destination of European immigration, followed by the Caribbean, where population growth was boosted by the inflow of slaves and indentured servants (Northrup 1995). Rates for the no-migration series (panel b) are, as expected, lower in the Americas and higher in Southern Europe, the major area of origin of migrants. A comparison of rates for the same periods show that most differences are substantial and significant, but they do not change qualitatively the main story.

ii) the test returns at least one upward break in total population series in all areas but Western Europe, with dates ranging from 1830 to 1925. The four comparable no migration series (panel b) broadly confirm this result [27]. The early modern series for European countries (panel c) shift the start of population growth to the 18th century. The series for Central Europe refers to (part of) Germany only and thus in all likelihood the population grew fast in the early years to fill the gaps of the Thirty Years'War [28].

iii) In contrast with the stylized description of the Malthusian world, stagnation before the first break is the exception, not the rule. The population grew significantly in the majority of areas and in quite a few cases the rates exceed 5‰, which in a century corresponds to an increase by two thirds.

iv) The first break was followed in all areas but two, Central Europe and North America, by a significant increase in the rate of growth. The slowing down in North America around mid 19th century is confirmed also by the no migration series and is followed by a further decline after a second break [29]

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[27] The comparison is impossible for Central, Southern and Eastern Europe and Australia/New Zealand because the dates of the first break of population series are outside the time coverage of the no migration series.

[28] Pfister (2022) estimates the population to have been 13.5 million in 1618, 7.9 in 1650, 10.6 in 1690 (rate of growth 7.4‰) and to have recovered the pre-war level in 1723

[29] The rates are 24.3‰ (log linear) in 1820-1845 and 1.05‰ in 1845-1912. Both are significant at 1% and they are significantly different at 1% as well

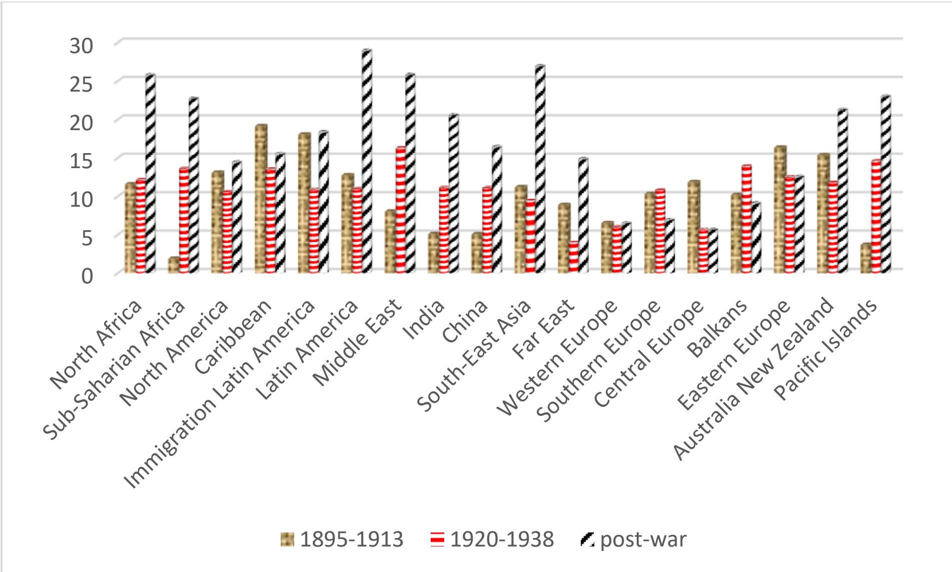
v) Only a minority of series, eight out of eighteen, show a second break in the covered period. The sharp decrease in Australia/New Zealand after 1892 is not confirmed by the no migration series and the slowing down in Eastern Europe is likely to have been determined by the war and the loss of territory and collectivization/famine of the 1930s [30]. Only North America shows a clear deceleration, which however dates to the mid-19th century. In contrast, the population growth seems to have accelerated in Southern Europe (possibly as a consequence of the end of mass emigration from Italy), India, Balkans, the Caribbean and Middle East.

Our statistical procedure might be biased by the gap in series from 1939 to 1950. Not only it is impossible by definition to detect breaks during these years but, given trimming, the routine cannot date breaks later than 1925 or earlier than 1957. Furthermore, it is also possible that in some cases the fall in population in the late 1910s causes the routine to miss an upward break in the late 19th century and thus to misdate the start of transition. We address these concerns by comparing the rates of population growth in 1895-1913, 1920-1938 and in the period between 1950 and the first break in the post-war series (Figure 9) [31].

Figure 9
Rates of population growth in the 20th century

[30] The rate of natural increase for the Soviet Union was quite high in the 1920s, in all likelihood as a rebound after the crisis late 1910s) but then sharp slowdown (Rothenbacher 2002 tab. ??). Adding a dummy for 1919 in the regression lowers the growth rate to 0.93% and the difference is not significant.

[31] We aggregate countries from the population data-base of the United Nations (2019) to match as well as possible the pre-war areas. We do not report here the full results of our statistical analysis of post 1950 trends because data UN make it possible a more insightful separate analysis of trend in fertility and mortality



Source: data-base and United Nations

The comparison between trends in 1920-1938 and after the war strongly downplays the impact of the so called baby boom of the 1950s and 1960s in advanced countries but confirms the acceleration of growth in all peripheral areas, with significantly higher rates in all areas but immigration Latin America and the Balkans. The war-time gap prevents to date more precisely the start of this acceleration – one might suspect it preceded the war. The differences between 1895-1913 and 1920-1938 are evenly distributed between positive and negative ones and all significant. However, there is no support for an error in the three cases of break in the 1920s, Sub-Saharian Africa, China and the Pacific Islands. In all these areas, the rate in 1895-1913 is lower than in the interwar years and it is not particularly high also relative to the 19th century. In China it is comparable to rates in the 18th and first half of the 20th century and in Africa it is lower than the long-run rate 1800-1920. It is higher only in the Pacific Islands, but the first decades of the century were, as said, a demographic catastrophe for the area [32].

[32] Population grew less than in 1875-1895 (0.37% per year vs 1.04%), which marked the beginning of recovery from the disaster. The total population was 15% lower in 1875 than 1800 and still 8% lower in 1913 and recovered the 1800 level only in 1925. These trends are not affected by migration flows. We have estimated a no migration series by combining the data on net migration of indentured servants from Northrup 1995 (tab A1 and A2) for the period 1851-1920 and on immigration in the Hawaii from 1911 to 1924 (Ferenczi and Willcox 1929). The difference with the total population is minimal (a coefficient of correlation 0.99).

Table 6 wraps up our analysis. Col 1 reports our best guesses, using whenever available the no immigration series and adding brackets to the more tentative dates. The other columns aggregate the polity-specific dates suggested by Riley (2005b) and Delventhal et al (2021) according to our eighteen series by weighting with the shares of each polity on the population of the area in the initial year of the transition[33]. Riley (2005b) singles out one (or more, up to four for Mexico) decade as the most plausible period for each country and we simply report the mid-point of the corresponding period. Delventhal et al (2021) use a more elaborate statistical inference. They collect the available series of crude birth and death rates, fill any gap with linear interpolation and model the transition, separately for birth and death rates, as a linear downward trend between two periods of constant rates selecting the initial and final dates of this trend with a grid search procedure [34]. This latter returns a starting date of mortality decline and thus for the transition in their framework, only in about a quarter of the cases ('modeled'). In all other, the authors project backwards the trend in death rates until the difference with the estimated birth rate hits 8.86‰ ('projected') [35]. Table 6 reports their results, separately for the 'modeled' (or core) polities and the full sample (including the 'modeled' ones). In the bottom row we compute the implicit starting date of world transition weighting the area dates with the shares on world population in 1913

Table 6

[33] Was a preliminary step, we adjust as much possible the list of polities by Riley and Delventhal (mostly at present-day borders) to our list (at borders of the time) by weighting with the shares at the closest date. For instance, we get a 'Delventhal' date for Austria-Hungary by weighting their dates for Austria (start of decline in 1881), Czechoslovakia (1867) and Hungary (1875) with the percentages of the three countries on the sum of their population in 1919. We do not consider Reher (2004) as he dates the start of transition with the decline in fertility, and relies on officially available series, which in a majority of countries begin in 1950-54

[34] Their data-base (available at https://sites.google.com/view/demographic-transitions accessed June 2022) includes 181 polities, with a total of 16197 observation for CBR and 16206 for CDR. However, 34 of these polities were established after World War Two and three quarters of observations refer to 1939 and following years. There are 606 observations for crude death rates before 1800, starting as early as 1541 for England (Wrigley and Schofield 1989), and 3428 (2128 for European countries), plus 616 interpolated ones, from 1800 to 1938.

[35] Delventhal et al (2021) obtain this figure as 'the average observed starting gap between CBR and CDR, 8.86 per thousand, the unweighted arithmetic mean across the 23 countries for which we observe the start of the fertility transitions and the fertility transition before 1950'.

Alternative dates of start of the demographic transition

	This paper	Riley 2005b	Delventhal et al 2021	
			Core	Full
North Africa	1876	1935	1935	1922
Sub-Saharian Africa	1920	1946	1963	1913
North America	[before 1800 ?]	1881	1796	1712
Caribbean	1860	1921	1916	1914
Immigration Latin America	[before 1800 ?]	1922	1870	1860
Latin America	[before 1800 ?]	1916	1910	1905
Middle East	1830	1939	1938	1932
India	1873	1932	1918	1919
China	1925	1925	NA	NA
South-East Asia	[1844]	1931	NA	1923
Far East	1860	1897	1946	1947
Western Europe	1730	1805	1765	1772
Southern Europe	[1810]	1890	1886	1886
Central Europe	[1760]	1883	1874	1877
Balkans	1829	1921	1902	1902
Eastern Europe	[1859]	1900	1892	1892
Australia New Zealand	[1852]	1870	NA	1852
Pacific Islands	1920	1938	NA	1928
World	1820	1910	NA	1921

Riley (2005b) and Delventhal et al (2021) suggest similar dates for the start of transition (the coefficient of correlation is 0.70), which differ substantially from our estimates in the vast majority of areas and also for the whole world. This divergence cannot be explained by the effect of migrations or by divergence in data. Our hypotheses in Table 5 are based on no migration counterfactual series for several areas and the flows into the other areas would have had to be huge to account for the difference. For instance, total immigration in the Far East should have been 2.2 times the 1860 population. Nor the differences can be explained by data issues: our series of natural increase and the ‘core’ data in Delventhal et al (2021) largely overlap and the two methods return fairly consistent results for Western Europe [36]. One would conclude that differences depends on their choice of a positive and fairly high rate of growth of population rate as threshold for the choice of the starting date of the transition.

6) Discussion: the causes of population growth

6.1. The demographic transition has been modeled in two different ways. Both describe the pre-transition situation as a Malthusian world, featuring in the steady state zero population growth (equal crude birth and death rates) and wages at subsistence level. Population would grow after an income-increasing shock but any increase cannot be but temporary, as mortality from famines and epidemics (positive checks) and/or by household decisions about fertility (preventive checks). The 'standard' transition model (Kirk 1996, Lee 2003, Reher 2004) hypothesizes that the demographic transition started with a decline of mortality, determined by progress medicine and/or by economic growth. This latter reduced mortality by increasing food supply in normal times via technical progress in agriculture and in distress thanks to market integration and by making it possible to invest in aqueducts and waste disposal. Whatever its cause, the decline in crude death rates was followed in due time by a decrease in fertility as households realize that they can achieve the desired number of surviving children with a lower number of births (Becker 1960). During the adjustment, the gap between birth and death rates caused population to grow.

In the Unified Growth Theory (Galor 2011 and 2012 Madsen and Strulik forthcoming), population growth is a component of the transition from the Malthusian to the post-Malthusian stage. The rise of income from technical progress increases fertility and population growth accelerated technical progress,

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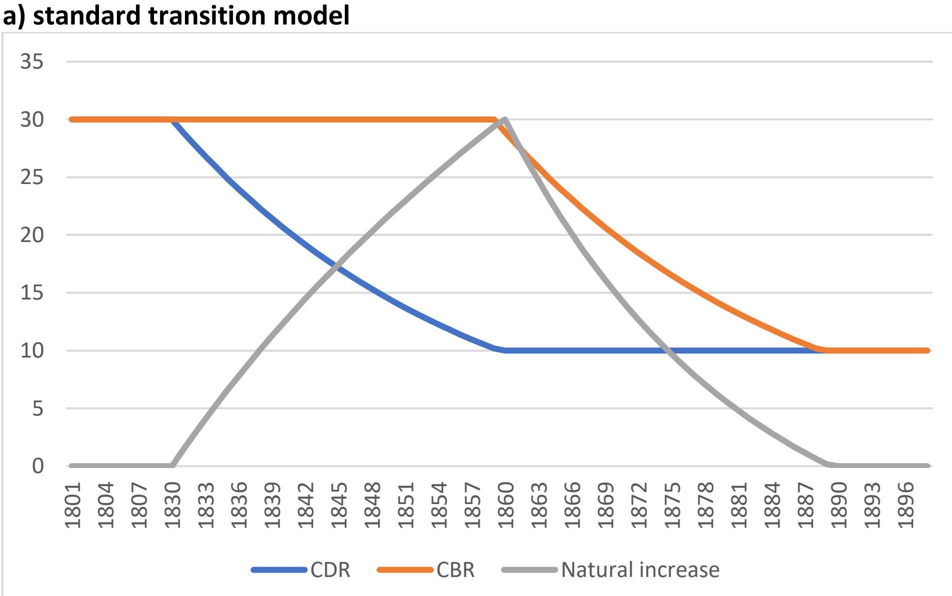
[36] The number of series common to both data-bases rises from six in the 1800s (France, England and the four Scandinavian countries) to twenty since the early 1880s. For each of them, we compute the population series implicit in natural increase from Delventhal et al (2021) extrapolating our figure for population in the initial year of their series. The aggregate difference (Root Mean Square Error) is negligible in the first half of the 19th century, rises to about 10% in the 1880s and then to 20% after World War One. Unfortunately, it is not possible to analyze the differences with Riley (2005b), as his list of references was published only on line and it is no longer available on the web (as of July 2022).

until the transition to the Modern Growth Regime. Fertility declines as households decided to reduce the number ('quantity') of their children in order to increase their human capital ('quality') to match the demand of skills from technical progress. The model assumes as an historical fact the decline in (infant and child) mortality, arguing that it could affect fertility only under specific conditions (e.g. uncertain number of surviving children for strongly risk-averse households) [37]

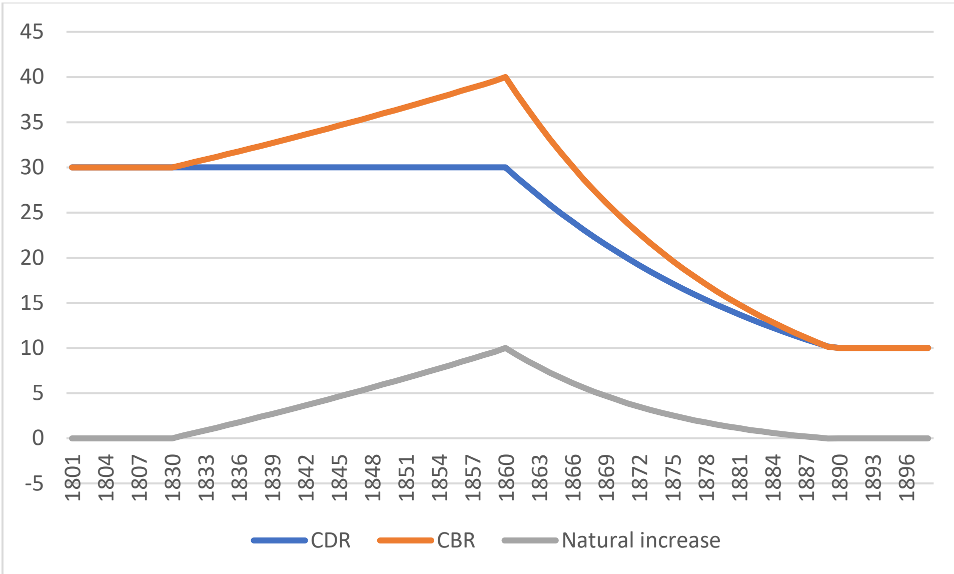
We sum up the predictions of the two models about population growth in Figure 10. It simulates the changes in rate of natural increase over a one hundred year period in a ultra-simplified scenario, with breaks in CDR and CBR coinciding in time and linear changes between them

Figure 10
Models of demographic change
a) standard transition model



b) Unified Growth Theory

[37] The increase in 'quantity' of children could accelerate the decline in fertility. Ceteris paribus, it reduces resources per child and thus, if not matched by a parallel decrease in demand for skills, strengthens the incentives to change the reproductive behaviour.



The timing of breaks in the population series coincide by construction, and thus the two models cannot be distinguished. The UGT does return lower population rates but only because we assume zero effects of growth/technical on mortality in the post-Malthusian stage and fertility is physiologically constrained. The figures purposely show three breaks but the number can be much higher if trends CBR and CDR not linear or breaks in the series do not coincide.

These stylized models suggest three historical questions

i) which combination of changes in CDR and CBR drove population growth?

ii) why did mortality decline? Was it a consequence of modern economic growth or of other exogenous factors?

iii) why did fertility change? How did changes in mortality or in labour market affect the households' reproductive behaviour

The economic history and demography literature on these issues is huge but not fully suitable to answer to these questions , for two reasons. First, it deals with different research questions

a) was the pre-industrial demographic regime Malthusian?

b) how much did modern economic growth reduce mortality?

c) is the quality-quantity trade off a realistic representation of the determinants of demographic behavior?

Second, its coverage across time and space is severely constrained by the lack of data. The existence of Malthusian check has been tested almost exclusively for preindustrial Europe, and the determinants of mortality and fertility mostly for advanced countries since the second half of the 19th century. But advanced countries, even in an extensive definition, accounted for only 13.6% of world population in 1800 and one cannot extend mechanically any result to other areas and periods [38]

6.2 Estimate the contribution of mortality and fertility to population growth would need series of crude birth and death rates over the whole period of transition[39]. Unfortunately, these series are available only for very few cases. Most country series for Europe start only in mid=19th century (Rothenbacher 2002 and 2012) and there almost no series for the rest of the world before WWII. As far as we know, before 1800, there are series of vital statistics for only seven European countries, and only two of them, for England and Centre-North Italy, the data extend back in time beyond 1700 (Figure II Appendix). Furthermore, the series for France are not suitable for time series analysis as they refer to five-years averages until the 1810s. We explore systematically the changes in birth and death rates of the remaining five series from their start to 1913 with procedures outlined in Sections Four and Five. We first single out break points with a Bai Perron test and then we estimate the corresponding rates of change of the series and also of volatility of death rates [40]. In most cases, the break points of the two series coincide or are close in time – seven out of nine breaks are less than 25 years apart, but patterns differ quite markedly among countries (cf. Table III Statistical Appendix). In England, (Centre-North) Italy

[38] The figure refers to Western, Southern and Central Europe, North America and Australia/New Zealand. Adding Far East (Japan and Korea) the share would increase by about one percentage point.
[39] In the case at hand, the crude birth rate is more representative than marital fertility (or age specific birth rates) because it captures all birth, including illegitimate children
[40] The Danish series cover two separate periods, 1705-1800 and 1800-1850. Given the gap 1800 to 1850, we estimate separately rates of changes for the two periods

fertility started to rise about a century earlier than mortality to decline (respectively in 1633 and 1727 in England and in 1753 and 1857 in Italy). In England, fertility rise accounted for most population growth until the 1830s In Sweden and Norway fertility started to rise and mortality to decline roughly at the same time, respectively since 1770 and since the early 19th century (1814 for birth rates and 1807 for death rates). Only in Germany the pattern followed the standard model, with a significant mortality decline since 1729 followed by a significant decline in fertility since 1795. The result for Norway, Germany and Denmark are somewhat uncertain because the series are too short [41].

In short the long-term series for Europe does not tally with the standard model – if any the two longer series would lend some support to the UGT model. This hypothesis is buttressed by some historical evidence for other countries. The life expectancy at birth in the area around Moscow was low (24 years) and stable from mid-18th to mid-19th century(Blum and Troitskaya 1997) and the nationwide crude death rate remained high from 1867 to the early 20th century (Natkhov and Vasilenok forthcoming). Mortality remained stable, although on slightly lower level, from the 18th to the 20th century also in China (Lee and Wang 1999). But the evidence is still insufficient for drawing a firm conclusion. Thus, in the following we use the econometric literature on causes of trends in fertility and mortality as source of insights to match with the historical evidence on not covered periods and countries

6.3 The negative correlation between mortality and GDP per capita first suggested by the seminal paper by Preston (1975) and it has been confirmed by several recent works in historical perspective. For instance, Prados (2022) runs cross section regressions for a large number of countries from 1870 onwards and finds that the relation between GDP per capita and life expectancy is positive, non linear and shifting in time (a higher life expectancy for the same level of GDP) and that it accounts for 63% of

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[41] The significant trends in Norway and Germany coincide with the start of the series and thus it is not possible to date their start. The series for Denmark show no significant trends in 1705-1800 and a significant decline for both fertility and (faster) mortality from 1850 onwards but the gap in the first half of the century prevents any inference on their start.

improvement in life expectancy and in 1870-1913 and for 26% in 1913-1950. The price for a large sample of countries is the wide resort to proxies for both GDP and life expectancy (e.g. heights in Africa for life expectancy [42]. The positive effect of growth on mortality is confirmed for a smaller sample of countries with good demographic data by Murtin (2013): GDP per worker is negatively associated with infant mortality (from 1870 to 2000) and positively, with a non linear relation, with life expectancy (1930 to 2000). On top of this, the relation is highly plausible as GDP per capita reduced mortality via with several mechanisms. Greater agricultural production and higher incomes allow food consumption to exceed minimum requirements for the whole population, with a positive effect on infant mortality, resistance to diseases and workers productivity, as forcefully argued by Fogel (1986, 1991, 1997). Better nutrition of English mothers reduced the share of stillbirths (Wrigley 1998). Market integration is often said to have contributed by making easier to provide relief in remaining crop failures. Last but not least, higher incomes make it possible to improve housing and afford more heating (and thus reduce risk of pulmonary diseases) and make it possible to invest in sanitation, subject to political decision-making process. Thus, modern economic growth reduced demographic shocks from famines and epidemics and for this reason, as said, conventional wisdom expected demographic shocks to have become less severe.

The results of the extensive literature on Malthusian hypothesis in pre-industrial Europe are not clear-cut and in some cases, most notably England, the characterization of demographic behavior as Malthusian is controversial. For instance, Moeller and Sharp (2014) title their paper *Malthus in cointegration space: evidence of a post-Malthusian pre-industrial England* while Madsen et al (2019 p.67) conclude that 'the Malthusian era lasted until the 19th century, when accelerating technological change led to rapid population growth'. Arguably, these different opinions depend on econometric techniques

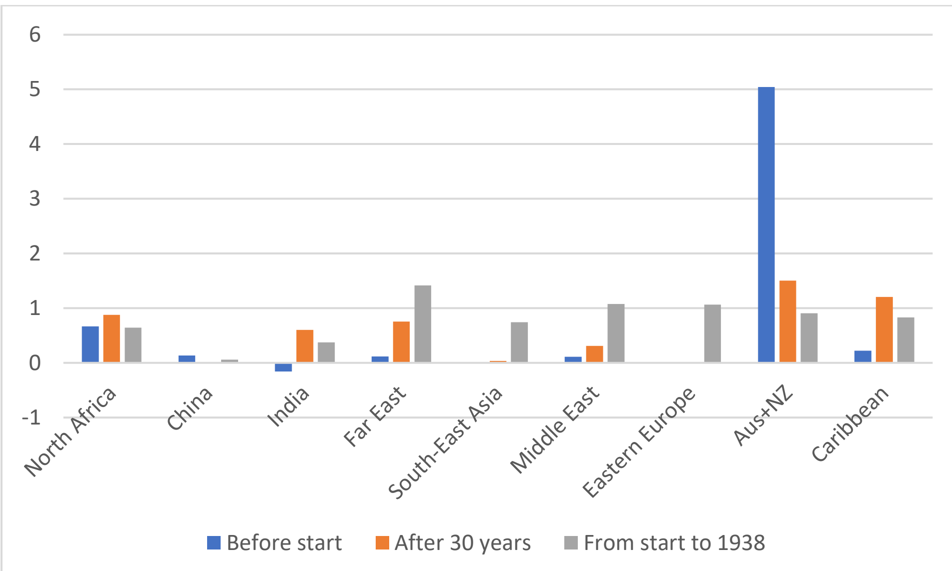
[42] Cf for the data base .. Two other recent papers arrive to similar conclusion but they suffer of even more serious data problem. Jetter et al (2019) extract series of death rates and GDP capita for 197 countries over 213 years from Gapminder which does not report any source. As said in Section Five, Delventhal et al (2021) estimate birth and death rates with an econometric exercise under the assumption of a standard model of transition and gets GDP series (for 47 countries) with extensive interpolations.

and definitions of 'Malthusian', but we need not to dwell on this here. From our point of view, key result is that elasticity of fertility to wages was positive and high enough so that growth in GDP per capita, if not stifled by Malthusian constraints, would explain the increase in fertility. This seems to have been the case in England (Moller and Sharp 2014 tab 5) but not necessarily for Centre-North Italy. Fernihough (2013) finds a positive but small elasticity (0.13) of birth to wages, possibly declining over time, in 1650-1881, while the elasticity was negative according to Pedersen et al (2021) and Chiarini (2010), who covers the period 1370-1870 with decadal averages.

In the historical literature about fertility and reproductive behavior there is no counterpart of the Preston equation. Most recent works deal with the causes of fertility decline, with a substantial literature on late 18th / early 19th century France, which experienced early parallel decline in fertility and mortality since 1he 1740s (Appendix Figure..), and several test of the UGT quantity/quality trade off. Both research agendas focus on the effects of education and culture rather than GDP and anyway the results on causes of fertility decline have to be used with caution to understand its rise. Yet some insights can be obtained from works which add GDP as control. For instance, Murphy (2015) estimates an elasticity 0.05 of marital fertility to income. The above mentioned paper by Murtin (2013) shows also a positive, non linear effect of GDP per worker on birth rates from 1870 to 2000, after controlling for education and mortality. In contrast Madsen and Strulik (forthcoming), for 21 advanced countries 1750-2000 find that income variable either not significant or negative but with 'minuscule' effect. This result is somewhat surprising, because children were a normal good.

6.4. Overall the evidence, although incomplete, suggests increase GDP per capita caused population growth via declining mortality and, at least in an early stage of modern economic growth, increasing fertility. Alas, this conclusion is not much helpful to explain the start of transition. In 17th century England, the rise in fertility and/or decline mortality coincided with an upward trend in GDP per capita, but this seems to have been an exception in Europe (cf Table… ??). In the 18th century GDP per capita was declining in China (Broadberry et al 2021) and at best stagnant in India (Broadberry et al 2015b), where real wages were declining (De Zwart and Lucassen 2020). The data from the Maddison project make it possible to compare rates of growth in GDP per capita before and after the start of transition (as defined as the thirty years after the dates from Table 6) for nine out of eighteen areas (Fig 11)[43]

Figure 11
Rates of growth in GDP per capita, before and after the start of the transition, 1820-1938



In most cases, the differences between rates before and immediately after the transition are small and the latter are very low. Substantial differences appear only if the period is extended to 1938. Actually, it has been argued that population growth explained the decline in GDP per capita in 18th century Italy (Malanima 2010) and Russia (Broadberry and Korchmina 2022). If not modern economic growth, what else? More precisely, which exogenous factors can explain the decline in mortality and rise in fertility?

The archetypal exogenous cause for the decline in mortality is progress in medicine. Much of the decline in mortality after World War Two was determined by new drugs such as sulfa drugs or antibiotics (Riley 2001, Acemoglu and Johnson 2007 Jayachandran et al 2011 Floud et al 20111) but

[43] For the other nine areas, the Maddison project does not report GDP data at all (Pacific Islands, Sub-Saharian Africa) or for the period before transition (e.g. Latin America or Europe).

there was no comparable breakthrough in cure in the 18th and early 19th century. The major innovations were the inoculation and then vaccination against smallpox (Crosby 2008, Kotar and Gessler 2013, Davenport et al 2016) and the germ theory. Mortality from smallpox was sharply reduced in Europe, even if epidemic of smallpox hit London (Guy 1882) and Germany and neighbouring countries (Kotar and Gessler 2017 pp.175-179) as late as the 1870s. Its early introduction boosted the population of Java, where it started in 1804, relative to other islands, where the campaign took off only in the 1860s (Bosma 2015). The germ theory arrived later. Snow first put forward hi hypothesis of a link between infected water and cholera in 1849 and the theory was fully developed by Pasteur and Koch in the second half of the 19th century. Micro analysis document the large positive impact of availability of running water and waste disposals on urban mortality in England Chapman 2019, Aidt et al forthcoming), Paris (Kesztenbaum and Rosenthal 2017) and Boston (Alsan and Goldin 2019). However, the wave of investment was limited to advanced countries, which could afford to pay for them and anyway it is too late to explain early decline mortality. The situation was different in the first half of the century: the declining heights in the United States (Komlos and A'Hearn 2017), England (Cinnirella 2008) and Western Europe (Komlos 1998) suggests that health conditions in Western cities, if any, were deteriorating in the early stages of modern economic growth. Urban life expectancy increased clearly only in the 19th century in advanced countries (Chaudhary and Lindert 2021, Davenport and Saito 2021, Davenport et al 2020, Haines 2000b). We know much less on rest of the world but at least in Greece it remained high until the end of the century (Raftakis forthcoming).

The increase in agricultural production and market integration were surely related to GDP growth (actually the increase was a major driver of it), but one might argue that they were partially exogenous. Market integration was determined by abolition trade barriers and by technical progress in shipping (Federico 2019). Chevet and O' Grada (2002) argue that French market, although not well integrated, helped to reduce the impact of famines 1693/4 and 1709-10. Overall, Europe modest gains 18th century, which were anyway reversed during Napoleonic period (Federico et al 2021). Massive process of integration after 1815 so at best it reinforced the trend. Railroads in India reduced famines, (Burgess and Donaldson 2011). The most relevant agricultural innovation was the introduction of American crops. – i.e. potatoes, maize and cassava. They increased quantities of calories per unit of land without affecting much GDP as they cost less than traditional cereals [44]. Nunn and Qiang (2011) argue that introduction of potatoes (proxied by alleged land suitability rather than by actual cultivation) account for a quarter of increase European population (measured by the McEvedy Jones 1978 data) from 1750 to 2000. The spread of maize cultivation increased food availability and population in 18th century Northern Italy (Malanima 2006). Deng and Shenmin (2019) list maize among the causes of the 'extraordinary' population growth in 18th century China, jointly with the decreasing taxation, the settlement of farmers in frontier areas (Sichuan, Mongolia etc) and the public provision of famine relief via public granaries. The real game changer was the availability of fertilizers. Chilean nitrates and Peruvian guano started to be imported in Europe since the 1830s and chemical fertilizers were massively adopted in advanced countries towards the end of the century (Federico 2005). On the other hand, in a Malthusian world the effects of innovations are bound to be temporary and the benefits in terms of reduction of mortality crises are clear only for Europe in the 19th century (cf. Statistical Appendix tables I and III).

Whatever the exact mix of causes of decline of mortality and the contribution of modern economic growth, they cannot explain the fertility rise which preceded it. Can it be explained by some exogenous factor? Reproductive behavior is heavily affected by cultural factors: recent research stresses their role in determining the timing and geographical diffusion of decline in France (de la Croix and Perrin 2018, Perrin 2022, Daudin et al 2019) and all over Europe (Spolaore and Waczjarg 2022). It seems however

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[44] VA agriculture computed as gross output less purchased inputs (e.g. fertilizers), which very limited or not-existent in traditional agriculture. Gross output quantity net of seeds and re-uses times price. Note that also more work

more difficult to hypothesize a cultural change which caused an increase in birth rate. The literature on 18th century Western Europe suggests two possible causes for higher fertility, the industrious revolution and the deskilling effect of early technical progress. The term industrious revolution (De Vries 2008) refers to a substantial increase in supply of labour, especially by women and children, as a reaction to the exogenous widening of tropical products on offer {Hersch and Voth ??)[45]. It is possible that the prospects of higher income pushed people to marry earlier and thus have more children (Birdsall 1983). Indeed, the age at marriage female decreased from 26.3 years in 1710s to a minimum 23.2 years in 1830s (Wrigley et al 1997 tab 5.3). Deskilling technical progress would reduce the need for apprenticeship training for manufacturing jobs and thus the incentives to prefer quality. The existence and strength of deskilling trend during the industrial revolution has long been debated but recent work suggests a complex pattern, with deskilling for former artisans, some increase in skills for former agricultural workers employed in factories and a growing role for an elite of 'mechanics' (Feldman and van der Beek 2016, de Pleijt et al 2020, Kelly et al 2023). The aggregate estimates show a decreases in the share of skilled workers (de Pleijt and Weisdorf 2017) and in the average number of years of education (de Plieji 2018). The industrious revolution and deskilling are unlikely to have been really relevant elsewhere in the 19th or early 20th century. Thus, we conclude by putting forward two more general, admittedly tentative, explanations, land abundance and changes in income distribution.

If land abundant, the Malthusian constraints were not binding: with constant land per worker productivity does not decline and opportunity cost of rearing children are very low. Land abundance is usually associated with Western settlement countries (Haines 2000a) but many countries expanded in previously lightly populated areas. – e.g. the Russian empire expanded southwards since the in the 18th century, increasing cropland by about a half in the first six decades of the 19th century with stable cereal

[45] The increase in labour supply increased GDP but we still include it as a potential autonomous cause because the labour share grew (Federico et al forthcoming)

yields (Broadberry-Korchmina 2022). However, land was abundant also before the 18th century: why did population not start growing earlier? Possible speculative answer, First, population growth was stifled by (exogenous) shocks, such the pandemics (e.g. the Black Death), the spread of European diseases in the Americas and wars (e.g. the Mongol and Manchu invasions in China). Second, the lack of organized states in sparsely populated areas is likely to have prevented settlement.

The effect of changes in income distribution on birth rates are quite complex. From one hand, in pre-transition world, fertility, but not necessarily mortality, was positively related to wealth or income (e.g. Chen 2011, Cummings 2020, Saleh forthcoming). Thus, in theory, worsening in distribution could increase fertility, if it reflected an increase in the number of 'rich' high fertility households, but not if a higher income of the same top households. On the other hand, an improvement in distribution would affect positively fertility if it gave the really poor to means to marry. The two effects are not necessarily compensating, as they affect different segments of the distribution. The Fertility maximizing change in distribution would follow a U-pattern, with increases of income at the left tail, especially around or below poverty line, and at the right one. Testing this effect needs data on change income by decile, as Milanovic (2016) elephant curve, but unfortunately, as far as we know there are no such historical data of income changes (cf. for an exception Vecchi 2017).

7) Conclusion

Our work has confirmed the conventional wisdom about world-wide long run trends in population. It did grow in the long run and the growth accelerated in the early 20th century, as a harbinger of the post war population boom. On top of this, it has established two new stylized facts. First volatility remained fairly high and demographic crises were widespread and frequent. Second, in most areas the population growth featured an upward break at different periods in time from the 18th century to around 1920 at the latest. In quite a few cases, however, population was increasing, albeit slowly, also before that break. Immigration boosted population growth in some areas but reduced it in others – worldwide the effects compensate.

These results do not tally well with the conventional wisdom on demographic transition, as inspired mostly by a stylized view of the historical experience of advanced countries. The most recent data on Europe show a rise in fertility jointly or before the start of decline in mortality. The limited evidence on death rate in the rest of the world is scarce but seems to rule out a massive fall in mortality before the 20^{th} century. Indeed, the literature suggests that mortality could be reduced by economic growth or by progress in medicine and neither was much present in the periphery before 1938. Thus, we infer that population growth was driven also, if not mostly, by an increase in fertility. We have also discussed possible causes of the hypothesized increase in fertility, such as changes in political situation which made it possible to exploit unused land or changes in income distribution. These are only tentative suggestions, but our results highlight the need to explore population history beyond the strictures of the standard models of transition.

References

Acemoglu Daron and Simon Johnson (2007) 'Disease and development: the effect of life expectancy on economic growth', *Journal of Political economy* 115, pp. 925- 985

Aidt Toke S. Romola Davenport Felix Gray (forthcoming) 'New perspectives on the contribution of sanitary investments to mortality decline in English cities' *Economic History Review*

Aird John S. (1968) 'Population growth' in Alexandr Eckstein, Walter Galenson and Ta-ching Liu (eds) *Economic trends in communist China* Edinburgh: Edinburgh University Press 1968 pp.183-327

Alsan Marcella and Claudia Goldin (2019) 'Watersheds in Child Mortality: The Role of Effective Water and Sewerage Infrastructure, 1880–1920' *Journal of Political Economy*, 127 (2) pp.588-638

Alter George and Gregory Clark (2010) 'The demographic transition and human capital' in Stephen Broadberry and Kevin O'Rourke (eds) *The Cambridge Economic History of Modern Europe. Vol I: 1700-1870* Cambridge: Cambridge University Press pp.44-69

Athukorala Prema-Chandra and Chaturica Athukorala (2020) The Great Influenza Pandemic of 1918-20: an interpretative survey at the time of covid-19 Centre for economic history the Australian National University Discussion paper series 2020-09 October 2020

Bai, J. and Perron, P. (2003) 'Computation and analysis of multiple structural change models', *Journal of Applied Econometrics*, 18, pp.1-22

Barro Robert J. Jose F. Ursua and Joanna Weng (2020**) '**The coronavirus and the great influenza pandemic: lessons from the Spanish flu for the coronavirus's potential effects on mortality and economic activity' NBER WP 26866 (March)

Beach Brian, Karen Clay and Martin Saavedra (2022) 'The 1918 influenza pandemic and its lessons for COVID 19' *Journal of economic perspectives* 60 (1) pp. 41-84

Becker Jean-Jacques (1999) 'Les deux guerres mondiales et leur consequences' in Jean-Pierre Bardet and Jacques Dupâquier (eds.) *Histoire des populations de l'Europe* Fayard Paris Vol II pp. 73-92

Becker Gary (1960) 'An economic analysis of fertility' in G.Becker (ed) *Demographic and Economic Change in Developed Countries* Princeton: Princeton University Press for NBER pp.219-240

Birdsall Nancy (1983) 'Fertility and Economic Change in Eighteenth and Nineteenth Century Europe: A Comment' *Population and Development Review* 9(1), pp. 111-123

Blum Alain and Irina Troitskaya (1997) Mortality in Russia During the 18th and 19th Centuries: Local Assessments Based on the Revizii *Population: An English Selection* , Vol. 9, pp. 123-146

Burgess Robin and Dave Donaldson (2010) **‘**Can openness mitigate the effect of weather shocks? Evidence from India’s famine era’ *American Economic Review* 100 (May 2010) pp.449-453

Bushnell Andrew (1993) ‘The “Horror” reconsidered: an evaluation of the historical evidence for population decline in Hawai‘i, 1778-1803’ *Pacific studies* 16 pp. 115-161

Bosma Ulbe (2015) ‘Smallpox, Vaccinations, and Demographic Divergences in Nineteenth-Century Colonial Indonesia’ *Bijdragen tot de Taal-, Land- en Volkenkunde*, Vol. 171 (1) pp. 69-96

Broadberry Stephen, Bruce M.S. Campbell, Alexandr Klein, Mark Overton and Bas van Leeuwen (2015) *British economic growth* Cambridge: Cambridge University Press

Broadberry Stephen, Johann Custodis and Bishnupriya Gupta (2015) ‘India and the great divergence: an Anglo-Indian comparison of GDP per capita 1600-1871 *Explorations in economic history* 56 (2015) pp.58-75

Broadberry Stephen, Hanhui Guan, and David Daokui Li (2021) **‘**China, Europe, and the Great Divergence: A Restatement’ *Journal of Economic History* 81 (3) pp.958-974

Broadberry Stephen and Elena Korchmina (2022) ‘Catching-up and falling behind: Russian economic growth 1690s-1880s’ Oxford Social and Economic History Working papers 197 (June 2022)

Camps Enriqueta and Stanley Engerman (2014) ‘World Population Growth: The Force of Recent Historical Trends’ *Journal of Interdisciplinary History,* 44(4) pp.509–526.

Cervellati Matteo and Uwe Sunde (2011) ‘Life expectancy and economic growth: the role of the demographic transition’ *Journal of economic growth* 16 pp. 99-113.

Chapman, Jonathan (2019) ‘The contribution of infrastructure investment to Britain’s urban mortality decline, 1861-1900’ *Economic history review* 72 (1) pp.233-259

Chaudhary, Latika and Peter Lindert (2021) ‘Healthy, Literate, and Smart: The Global Increase in Human Capital’ in Stephen Broadberry and Kyoij Fukao (eds) *Cambridge Economic History of Modern World vol II 1870 to present* Cambridge: Cambridge University Press pp. 329-355

Cheng K.F. and P.C. Leung (2007) ‘What happened in China during the 1918 influenza pandemic?’ *International journal of infectious diseases* 11, pp.360-364

Chesnais Jean-Claude (1992) *The demographic transition* Oxford: Clarendon Press

Chiarini Bruno (2010)’ Was Malthus right? The relationship between population and real wages in Italian history, 1320 to 1870’ *Explorations in economic history* 47 pp.460-475

Cinnirella Francesco (2008) **‘**Optimist or pessimists? A reconsideration of nutritional status in Britain 1740-1865’, *European Review of Economic History* 12 (3) pp. 325-354

Crombach, Lamar, Jeroen Smits and Christian Monden (2021) 'Life expectancy and length of life inequality in the long run' in OECD *How Was Life? Volume II New Perspectives on Well-being and Global Inequality since 1820* Paris: OECD, pp.124-148

Crosby Alfred (2008) 'Smallpox' in Kenneth Kiple (ed) *The Cambridge World History of Human Disease* Cambridge: Cambridge University Press pp.1008-1014

Cummins Neil (2020) The micro-evidence for the Malthusian system. France, 1670–1840 European economic review 129

Cutler David, Angus Deaton and Adriana Lleras-Muney (2006) 'The determinants of mortality' *Journal of economic perspectives* 20 (3) pp.97-120

Daudin, Guillaume, Raphaël Franck and Hillel Rapoport (2019) 'Can internal migration foster the convergence in regional fertility rates? evidence from 19th century France' *Economic journal* 129, pp.1608-1692

Davenport Romola (2020) 'Urbanization and mortality in Britain, c. 1800–50' *Economic History Review*, 73, (9), pp. 455–485

Davenport Romola and Osamu Saito (2021) 'Population and Human Development since 1700' in Stephen Broadberry and Kyoij Fukao (eds) *Cambridge Economic History of Modern World vol I 1700-1870* Cambridge: Cambridge University Press pp. 289-311

Davenport Romola,. Jeremy Boulton, and Leonard Schwarz (2016) 'Urban inoculation and the decline of smallpox mortality in eighteenth century cities—a reply to Razzell' *Economic History Review*, 69 (1), pp. 188–214

De la Croix David and Faustine Perrin (2018) 'How far can economic incentive explain the French fertility and education transition?', *European Economic review* 108, pp.221-245

Delventhal, Matthew Jesús Fernández-Villaverde and Nezih Guner (2021) 'Demographic Transitions Across Time and Space' CEPR Discussion Papers 16078 November

Deng Kent and Shun Shengmin (2019) 'China's extraordinary population expansion and its determinants during the Qing period 1644-1911', *Population review* 58 pp. 20-77

De Pleijt Alexandra (2018) 'Human capital formation in the long-run: evidence from average years of schooling in England, 1300-1900' *Cliometrica* 12 (1) pp.99-126

De Plejit Alexandra and Jacob Weisdorf (2017) 'Human capital formation from occupations: the 'deskilling hypothesis' revisited' *Cliometrica* 11 (1) pp.1-30

De Pleijt Alexandra, Alessandro Nuvolari and Jacob Weisdorf (2020) 'Human capital formation during the first industrial revolution: evidence from the use of steam engines' *Journal of the European Economic Association* 18 (1) pp. 829-888

De Zwart Pim and Jan Lucassen (2020) ‘Poverty or prosperity in Northern India? New evidence on real wages’ *Economic History Review* 73, n 2 (2020) pp. 644-667

Ditzen, J., Karavias, Y. & Westerlund, J. (2021) ‘Testing and Estimating Structural Breaks in Time Series and Panel Data in Stata’. arXiv:2110.14550

Durand, J.D. (1977) ‘Historical estimates of world population’, *Population and Development Review* 3, pp. 253-296

Feinstein, Charles H. and Mark Thomas, (2002) ‘A Plea for Errors’, *Historical methods,* 35 pp. 155-165

Federico, Giovanni (2005) *Feeding the world: an economic history of world agriculture, 1800-2000*, Princeton: Princeton University Press

Federico, Giovanni (2019) ‘Market integration’ in Claude Diebolt and Mike Haupert (eds.) *Handbook of cliometrics* 2nd editions, Berlin-Heidelberg: Springer pp.633-65**8**

Federico, Giovanni Max-Stephan Schulze and Oliver Volckart (2021) ‘European Goods Market Integration in the Very Long Run: From the Black Death to the First World War’ *Journal of Economic History* 81 (1) pp.276-308

Federico Giovanni and Antonio Tena-Junguito (2022) ‘How many people on earth? World population 1800 1938’, Maddison project Working paper

Federico Giovanni, Alessandro Nuvolari and Michelangelo Vasta (forthcoming) ‘Inequality in pre-industrial Europe (1260-1850): new evidence from the labour share’ *Review income and wealth*

Feldman Naomi and Karine van der Beek (2016) **‘**Skill choice and skill complementarity in eighteenth century England’ *Explorations in economic history* 59 (2016) pp.94-113

Fernihough Alan (2013) ‘Malthusian Dynamics in a Diverging Europe: Northern Italy, 1650–1881’ *Demography* 50 pp.311–332

Floud Roderick, Robert W. Fogel, Bernard Harris and Sok Chul Hong (2011) *The changing body. Health nutrition and human development in the Western World since 1700* Cambridge Cambridge University Press

Fogel, Robert W.(1986) ‘Nutrition and the decline in mortality since 1700: some preliminary findings’ in Engerman, Stanley L. and Gallman Robert E. (eds) *Long term factors in American economic growth* University of Chicago Press Chicago and London 1986 pp.439-526 [Dip 330.973 LON]

Fogel Robert W. (1991) The conquest of high mortality and hunger in Europe and America: timing and mechanisms, in Patricia Higonnet, David Landes, Henry Rosovsky (eds), Favorites of fortune. Cambridge (Mass) Harvard University Press 1991 pp. 33-71

Fogel Robert W. (1997) 'New findings on secular trends in nutrition and mortality: some implications for population theory' in Mark Rosenzweig-Oded Stark (eds) *Handbook of population and family economics* Amsterdam Elsevier North-Holland pp. 433- 481

Ferenczi Imre and Walter Willcox (1929) *International migrations Vol I Statistics* on line NBER https://www.nber.org/books-and-chapters/international-migrations-volume-i-statistics (Accessed 30 October 2021).

Frankema Ewout and Morten Jerven (2014) 'Writing history backwards or sideways: towards a consensus on African population, 1850-2010', *Economic history review* 67, pp.907-931

Galor, Oded (2011) *Unified growth theory* Princeton: Princeton University Press

Galor, Oded (2012) 'The demographic transition: causes and consequences' *Cliometrica* 6(1) pp.1–28

Guinnane Timothy (2011) 'The historical fertility transition: a guide for economists', *Journal of Economic Literature* 49 pp. 589-614

Guinnane Timothy (2021) 'We Do Not Know the Population of Every Country in the World for the past Two Thousand Years', CESIFO Working paper 9242 August 2021

Haines Michael (2000a) 'The white population of the United States, 1790-1920' in Michael Haines and Richard H. Steckel (eds.) *A population history of North America* Cambridge: Cambridge University Press pp.305-371

Haines Tom (2000b) 'Malthus and North America: was the United States subject to economic-demographic crises?' in Tommy Bengtsson and O. Saito (eds.) *Population and economy. From hunger to modern economic growth* Oxford University Press pp. 165-182

Hamilton, J. D. (2018) 'Why you should never use the Hodrick-Prescott filter', *Review of Economics and Statistics* 100(5), pp. 831-843.

Jayachandran, Seema, Adriana Lleras-Muney, and Kimberly V. Smith (2010) 'Modern Medicine and the Twentieth Century Decline in mortality: Evidence on the Impact of Sulfa Drugs' *American Economic Journal: Applied Economics* 2 (1) pp.118–146

Jetter Michael, Sabine Laudage and David Stadelman (2019) 'The intimate link between income levels and life expectancy: global evidence from 213 years' *Social Science quarterly* 100 n.4 June 2019 pp. 1387-1403

Johnson, Niall P.A.S. and Juergen Mueller (2002) **'**Updating the accounts: global mortality of the 1918-1920 'Spanish' influenza pandemic', *Bulletin of the history of medicine* 76, pp. 105-115

Kelly Morgan and Cormac Ó Gráda (2012) The Preventive Check in Medieval and Preindustrial England The Journal of Economic History , Dec 2012, Vol. 72, No. 4 pp. 1015-1035

Kelly Morgan, Joel Mokyr and Cormac O Grada (2023) 'The mechanics of the industrial revolution' *Journal of political economy* 131 (1) pp. 59-94

Kesztenbaum Lionel and Jean-Laurent Rosenthal (2017) 'Sewers' diffusion and the decline of mortality: The case of Paris, 1880–1914', *Journal of urban economics* 98, pp.174-186

Kirk Dudley (1996) 'Demographic Transition Theory', *Population Studies* 50 (3), pp. 361-387

Klein Goldewijk, K. , A. Beusen, and P. Janssen (2010) 'Long term dynamic modeling of global population and built-up area in a spatially explicit way, HYDE 3 .1' *The Holocene,* **20(4)**, pp.565-573.

Komlos, John (1998) 'Shrinking in a growing economy? The mystery of physical stature during the Industrial Revolution'**,** *Journal of economic history* 58 (3)**,** pp. 778-795

Komlos John and Brian A'Hearn (2017) 'Hidden negative aspects of industrialization at the onset of modern economic growth in the U.S', *Structural change and economic dynamics* 41, pp.43-52

Kotar S.J.and J.E. Gessler (2013) *Smallpox. A history* Jefferson (NC) and London: Mac Farland Co

Kumo Kazuhiro (2016) 'Population statistics of Russia: the Russian empire, the Soviet Union and the Russian federation' in Karbchuk Tatiana, Kazuhiro and Ekaterina Skoglund**,** (eds.) *Demography of Russia : From the Past to the Present*, Basingstoke: Palgrave Macmillan pp.11-58.

League of Nations Statistical Yearbook available on line at https://wayback.archive-it.org/6321/20160901220258/http://digital.library.northwestern.edu/league/otcgi/digilib/llscgi60-ae97.html 1926 – 1944. (accessed April 2019)

Lee, Ronald (2003) 'The Demographic Transition: Three Centuries of Fundamental Change', *Journal of economic perspectives* 17(4), pp.167-190

James Lee and Wang Feng (1999) 'Malthusian Models and Chinese Realities: The Chinese Demographic System 1700-2000' *Population and Development Review* 25 (1) pp. 33-65

Maddison Angus (1995) *Monitoring the world economy* Paris:OECD

Malanima, Paolo (2006) **'**An age of decline. Product and income in Eighteenth-Nineteenth century Italy *Rivista di Storia Economica* n.s. 22 (1) pp. 91-133

Malanima Paolo (2010) **'**The long decline of a leading economy: GDP in Central and Northern economy, 1300-1913' *European Review of Economic History* 15 pp.169-219

Manning Patrick and Scott Nickleach (2014) 'African Population, 1650-1950: The Eras of Enslavement and Colonial Rule' Unpublished manuscript dataverse.harvard.edu/dataverse/WH_AfricanPopMigration (accessed June 2021)

Markevich Andrei and Mark Harrison (2011) 'Great War, civil war and recovery: Russia's national income, 1913 to 1928', *Journal of Economic History* 71, pp.672-703

McEvedy, C. and Jones, R. (1978) *Atlas of World Population History*, Middlesex, England: Viking Penguin.

Milanovic Branko (2016) *Global inequality. A new approach for the age of globalization* Cambridge (Mass) Belknap for Harvard University Press

Mitchell Brian (1988) *British historical statistics* Cambridge: Cambridge University Press

Møller Niels Framroze ·and Paul Sharp (2014) Malthus in cointegration space: evidence of a post-Malthusian pre-industrial England *Journal of economic growth* 19 pp.105-140

Murtin Fabrice (2013) 'Long-term determinants of the demographic transition, 1870-2000', *Review of Economics and Statistics* 95, pp.617-631

Natkhov Timur and Natalia Vasilenok (forthcoming) 'Ethnic-specific infant care practices and infant mortality in late Imperial Russia' *Economic History Review*

Northrup David (1995) *Indentured labour in the age of imperialism 1834-1922* Cambridge: Cambridge University Press

Notestein Frank (1945) 'Population- the long view' in Theodore Schulze (ed.) *Food for the world*. Chicago: University of Chicago Press pp.36-57

Nunn, Nathan and Nancy Qian (2011) 'The potato's contribution to population and urbanization: evidence from a historical experiment' *Quarterly journal of economics* 126 pp.593-650

O'Grada Cormac and Jean-Michel Chevet (2002) **'**Famine and market in Ancien Régime France', *Journal of Economic History* 62, pp.706-733

Perrin Francoise (2022) 'On the origins of the demographic transition: rethinking the European marriage pattern', *Cliometrica* 16(3), pp.431-475

Platt Stephen R. (2012) *Autumn in the Heavenly Kingdom. China the West and the epic story of the Taiping civil war*, New York: A.Knopf

Prados de la Escosura Leandro, Carlos Alvarez Nogal and Carlos Santiago Caballero (2022) 'Growth recurring in pre-industrial Spain?', *Cliometrica* 16, pp.215–241

Prados de la Escosura Leandro (2022) 'Health, Income, and the Preston Curve: A Long View' CEPR Discussion papers 17151

Pfister Ulrich (2022) 'Economic growth in Germany, 1500-1850' *Journal of Economic History* 82 (4) pp.1071-1106

Pedersen Maja Uhre Claudia Riani and Paul Sharp (2021) 'Malthus in Pre-industrial Northern Italy?' *Journal population economics* (34) pp. 1003–1026

Preston, S H (1975) The Changing Relationship between Mortality and the Level of Economic Development" *Population Studies* 29(2): 231-248.

Raftakis Michail (forthcoming) Urban mortality in Greece: Hermoupolis (1859–1940) *Economic History Review*

Razzaque, Mohammad, Philip Osafa-Kwaako and Roman Grynberg (2007) 'The problems of commodity dependence' In Roman Grynberg and Samantha Newton (eds) *Commodity prices and development* Oxford University Press Oxford pp. 7-16

Riley James (2001) *Rising life expectancy: a global history* Cambridge: Cambridge University Press

Riley James (2005a) 'Estimates of regional and global life expectancy', *Population and development review* 31(3), pp.537-541

Riley James (2005b) 'The timing and pace of health transition around the world', *Population and development review* 31(4), pp.741-764

Rothenbacher Franz (2002) *The European population* Basingstoke: Palgrave

Rothenbacher Franz (2012) *The Central and East European Population Since 1850* Basingstoke: Palgrave Macmillan

Saleh Mohammed (forthcoming) 'The Middle-Eastern Marriage Pattern? Malthusian Dynamics in Nineteenth-Century Egypt' *Economic History Review*

Spolaore Enrico and Roman Wacziarg (2022) 'Fertility and modernity', *Economic journal* 132 (1), pp. 796-833

Spreeunwenberg, Peter, Madelon Kroneman and John Paget (2018) 'Reassessing the global mortality burden of the 1918 influenza pandemic, *American journal of epidemiology,* 187 pp.2561-2567

Sunseri Thaddeus (2018) 'The African Rinderpest Panzootic, 1888–1897' *Oxford Research encyclopedia African History on line* (accessed August 2022)

Thornton, Russel (2000) 'Population history of native North Americans' in Haines Michael and Richard H. Steckel (eds.) *A population history of North America* Cambridge: Cambridge University Press pp.9-50

Thornton Russell and Joan Marsh-Thornton (1981) 'Estimating Prehistoric American Indian Population Size For United States Area: Implications of the Nineteenth Century Population Decline and Nadir', *American Journal of Physical Anthropology* 55, pp. 47-53

United Nations (2019) Population Division Department of Economic and Social Affairs *World Population Prospects: The 2019 Revision* POP/DB/WPP/Rev.2019/POP/F01-1 (accessed August 20 2021)

Van der Vleuten. Lotte and Jan Kok (2014) ‘Demographic trends since 1820’ in Jan Luiten Van Zanden et al (ed) *How was life? Global well-being since 1820*, Paris: OECD pp.37-55

Vecchi Giovanni (2017) *Measuring wellbeing. A history of Italian living standards* Oxford: Oxford University Press

War Office (1923) "Statistics of the military effort of the British Empire during the Great War, 1914–1920". London H.M. Stationery Office

Wrigley Edward Anthony and Roger Schofield (1989) *The population history of England 1541-1871: a reconstruction*. Cambridge: Cambridge University Press 2nd edition

Statistical Appendix

Table I
Rates of change in volatility, Hodrick-Prescott filter, by area

	1800-1938		**1800-1913**		**1800-1938**		
	time	share	time	share	time	Share	dummy 1910s
North Africa	2.14***	0.53	3.17***	1.12**	2.29***	0.56	-1.03
Sub-Saharian Africa	3.82***	0.06	3.30***	0.07	3.47***	0.13	3.36***
North America	0.98	-0.26	0.93	-0.21	0.51	-0.22	3.80***
Caribbean	0.22	-0.14	0.04	-0.17	0.07	0.00	1.56***
Immigration Latin America	-0.39	-0.18**	-1.37***	-0.28**	-0.46	-0.18*	0.52
Latin America	-0.53*	-0.65***	-0.54	-0.61**	-0.52*	-0.65***	-0.07
Middle East	4.00***	0.03	4.50***	0.23	3.91***	0.10	1.32***
India	0.18	-0.02	-0.17	0.06	0.04	0.03	2.31***
China	0.89**	-0.57***	0.67	-0.69***	1.03***	-0.57***	-0.99
South-East Asia	-0.57*	-0.13	-0.64*	-0.14	-0.73**	-0.10	1.42**
Far East	-0.37	-0.15*	-0.78	-0.17**	-0.34	-0.15*	-0.15
Western Europe	-0.52	0.12	-2.12*	0.03	-1.01	0.11	3.28***
Southern Europe	-1.79*	-0.01	-3.71***	-0.09	-2.70***	-0.07	4.74***
Central Europe	1.33*	NA	-0.82	NA	0.59	NA	5.85***
Balkans	4.25***	0.17	4.71***	0.01	3.78***	-0.10	5.65***
Eastern Europe	3.11***	NA	3.11***	NA	2.86***	NA	2.20
Australia New Zealand	-2.54***	0.11	-3.13***	0.07	-3.27***	0.05	4.91***
Pacific Islands	1.69***	-0.17	1.38**	-0.21*	1.59***	-0.18*	0.50

Table II
'Modeled' and 'projected' samples Delventhal et al 2021

	Number polities	Share population reference year	Share potential observations	Number polities	Share population first year	Share potential observations
North Africa	1	45.1	4.0	5	100.0	23.2
Sub-Saharian Africa	3	10.5	1.2	35	93.1	22.5
North America	1	92.4	33.5	2	99.7	79.9
Caribbean	4	23.9	8.4	13	94.3	20.3
Immigration Latin America	1	15.1	25.7	3	100.0	53.0
Latin America	4	58.6	12.2	15	98.4	34.0
Middle East	2	42.1	1.6	13	99.1	11.0
India	3	94.2	21.6	5	100.0	26.9
China	NA			4	98.7	9.0
South-East Asia	NA			6	100.0	29.0
Far East	1	75.5	24.1	2	100.0	24.1
Western Europe	8	91.6	78.9	10	100.0	79.3
Southern Europe	5	92.8	39.4	6	100.0	45.2
Central Europe	1	28.9	78.2	3	100.0	79.0
Balkans	3	63.5	47.5	4	64.6	65.6
Eastern Europe	1	100.0	14.8	2	100.0	18.9
Australia New Zealand	NA			2	100.0	61.9
Pacific Islands	NA			3	0.8	12.0
World	38	51.326655	15.3	133	87.6	31.3

In Statistical Appendix (number polities – at pre-1938 borders, coverage population in the years of beginning transition and share of observations (modeled or projected) out of the total potential
In Table 6 we keep separate the results for the actual data ('core sample') from the total ones ('full sample'), reporting for each the number of polities (col. 1), their coverage on population in the starting year of the transition (col.2) and the implicit starting date of transition (col.3)[46].

Table III

[46] The number of potential observations for each polity is equal to the number of years of its existence before 1938– i.e. 139 in most cases and 20 (1919-1938) for polities established after World War One (Poland etc.)

Rates of change in fertility, mortality and GDP per capita, Europe 1560-1913

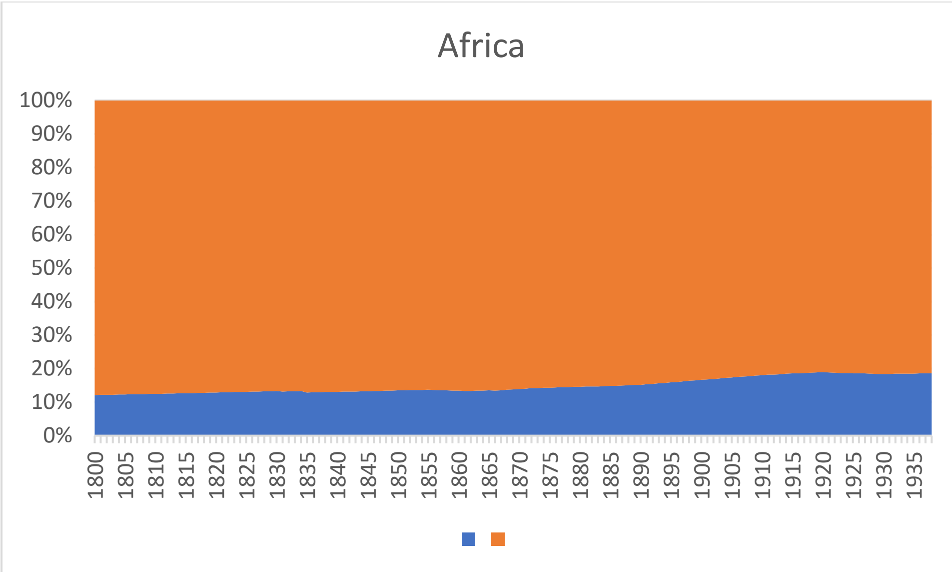
	Fertility	GDP		Mortality Rates	Volatility	GDP
Denmark						
1705-1800	0.01	NA	1705-1800	-0.07	-2.85***	NA
1850-1913	-0.29***	1.26	1850-1913	-0.76***	-2.27	1.26
England						
1541-1633	-0.16***	-0.10	1541-1656	-0.08	-0.74	0.08
1633-1739	0.16**	0.48	1657-1726	-0.13	-1.58	0.44
1739-1834	0.23***	0.38	1727-1833	-0.19***	0.61	0.34
1834-1913	-0.89	0.98	1833-1913	-0.74***	1.72	0.99
Germany						
1729-1795	2.96	0.04	1729-1833	-0.24***	-2.01**	0.2
1795-1856	-0.17***	0.47				
1856-1913	-0.77**	1.48	1833-1913	-0.78***	-2.72***	1.21
Italy						
1650-1753	-0.28***	0.10	1650-1728	-0.09	0.89	0.21
1753-1839	0.35***	0.08	1728-1857	0.05	-0.38	-0.13
1839-1913	-0.18***	0.53	1857-1913	-0.89***	-0.02	0.78
Norway						
1770-1815	0.23*	NA	1770-1850	-0.52***	-2.41**	NA
1815-1913	0.28**	1.47a	1850-1913	-0.52***	-3.81**	1.52
Sweden						
1749-1814	-0.18	-0.09	1749-1807	-0.21	1.49	-0.13
1814-1914	-0.38***	1.16	1807-1914	-0.62***	-3.41	1.11

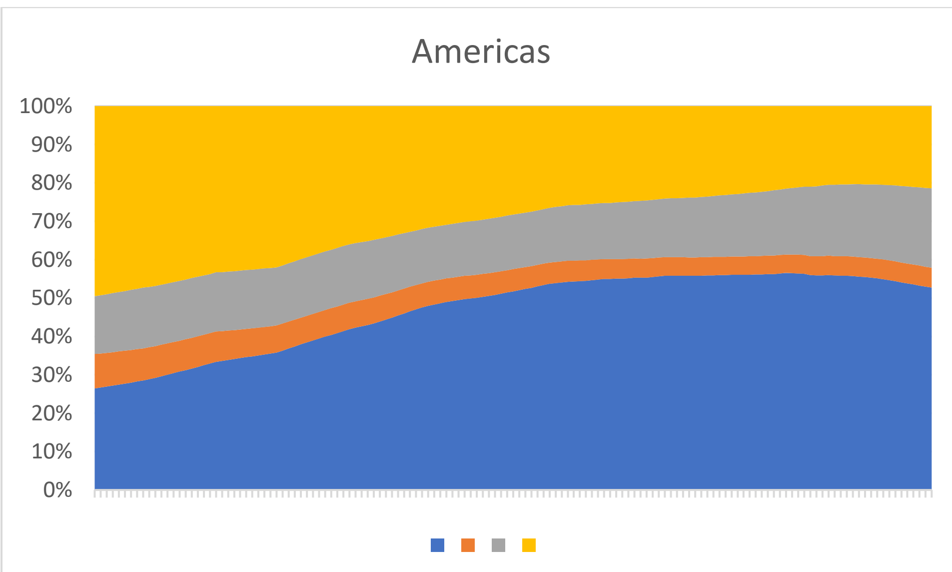
a 1830 Significant * 10%,** 5% *** 1%
Sources: fertility and mortality Appendix A, GDP per capita Maddison project DB (three years average) except Germany Pfister-Fertig 2022

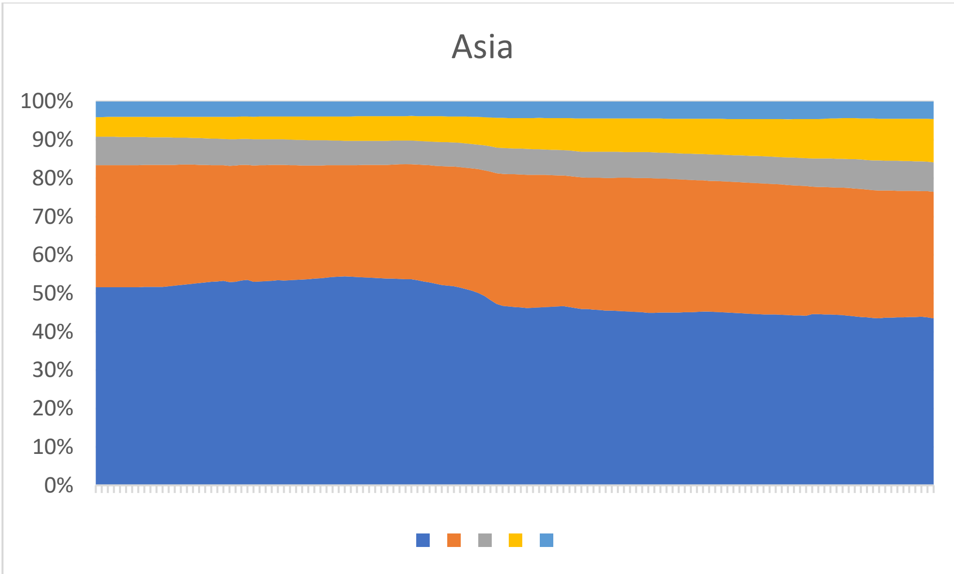
Appendix Figures

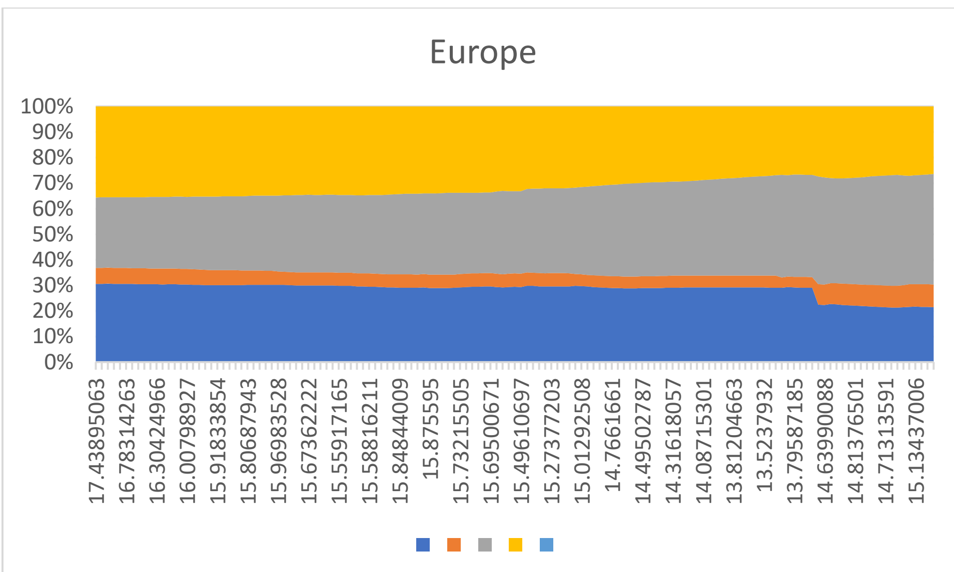
Fig I

Shares of areas by continent


Africa
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1800
1805
1810
1815
1820
1825
1830
1835
1840
1845
1850
1855
1860
1865
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915
1920
1925
1930
1935


Americas
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%


Asia
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%


Europe
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
17.43895063
16.78314263
16.30424966
16.00798927
15.91833854
15.80687943
15.96983528
15.67362222
15.55917165
15.58816211
15.84844009
15.875595
15.73215505
15.69500671
15.49610697
15.27377203
15.01292508
14.7661661
14.49502787
14.31618057
14.08715301
13.81204663
13.5237932
13.79587185
14.63990088
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14.71313591
15.13437006

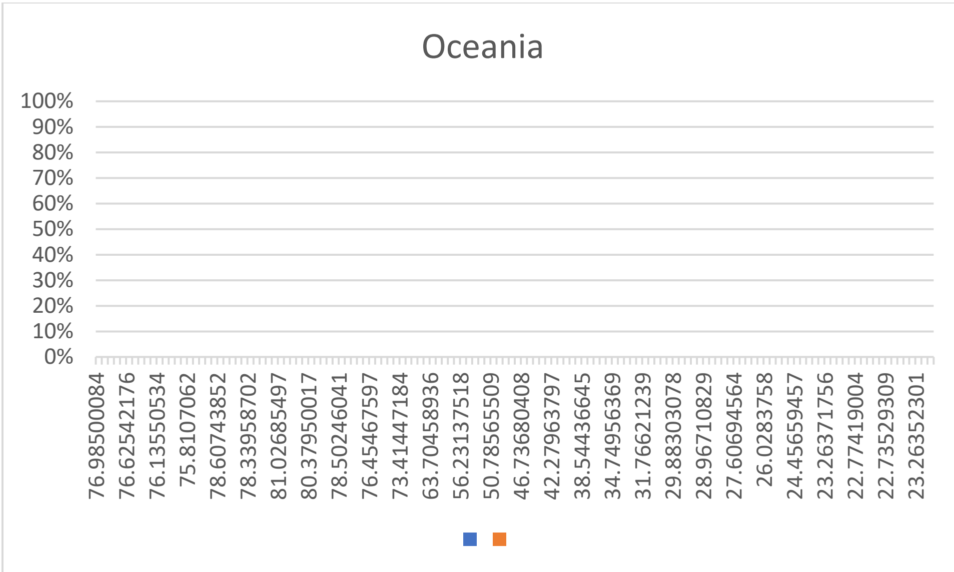
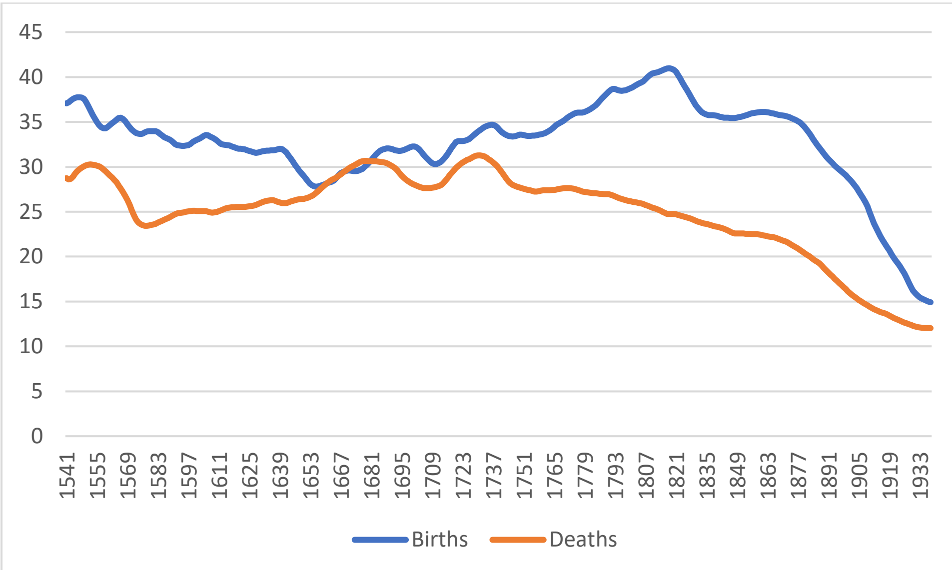

Oceania
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
76.98500084
76.62542176
76.13550534
75.8107062
78.60743852
78.33958702
81.02685497
80.37950017
78.50246041
76.45467597
73.41447184
63.70458936
56.23137518
50.78565509
46.73680408
42.27963797
38.54436645
34.74956369
31.76621239
29.88303078
28.96710829
27.60694564
26.0283758
24.45659457
23.26371756
22.77419004
22.73529309
23.26352301

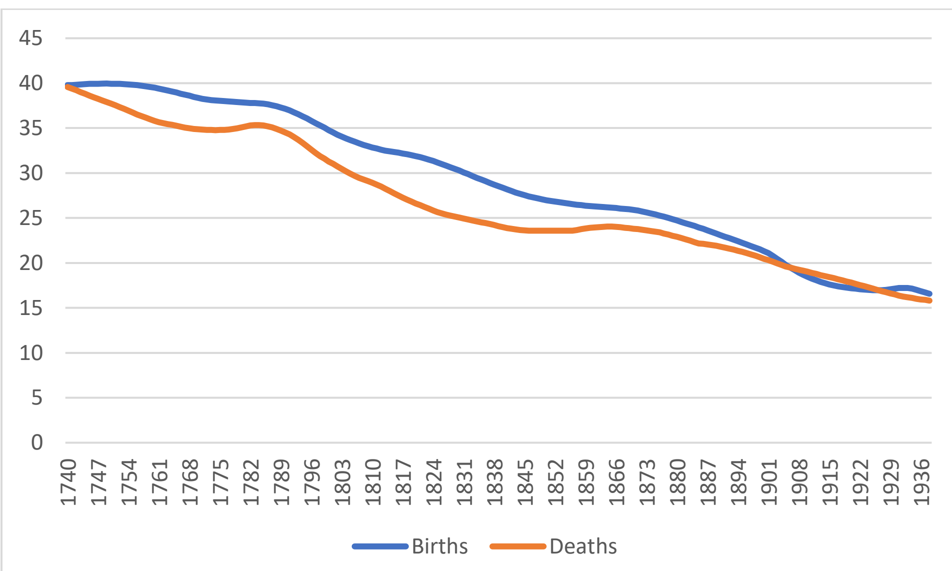
Fig II Crude Birth and death rates (kernel Epanechnikov). Vertical lines Germany and Italy mark major changes in territorial coverage

a) England and Wales



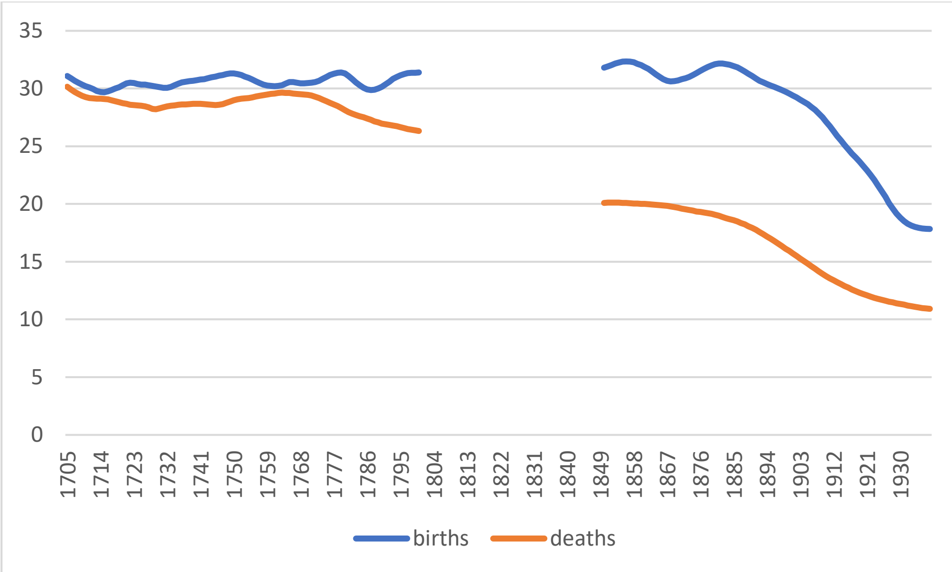
Source: Mitchell 1988 pp.40-52

b) France



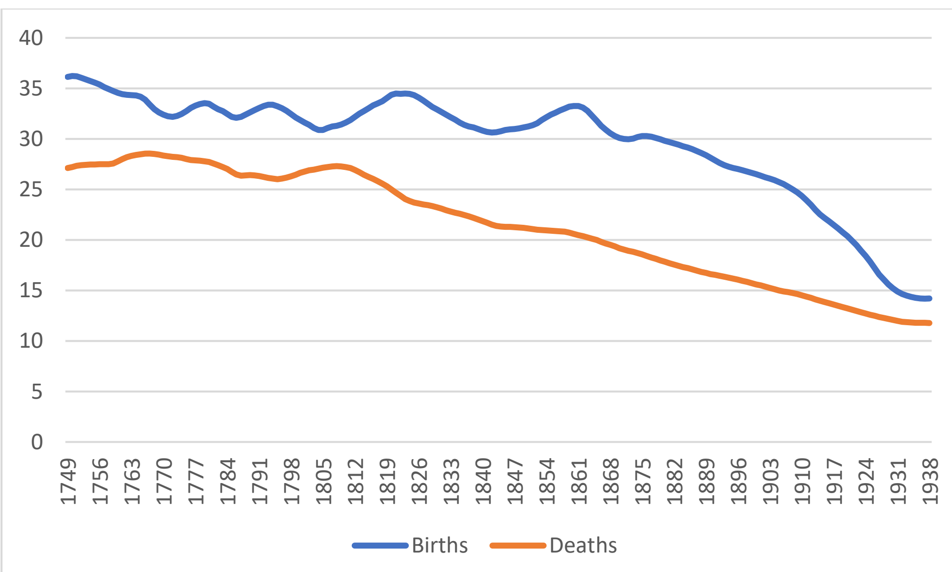
Sources: 1740-1830 Henry and Blayo 1975; 1830-1850 Statistical Yearbook France 1850-1938 Rothenbacher (2002)

c) Denmark



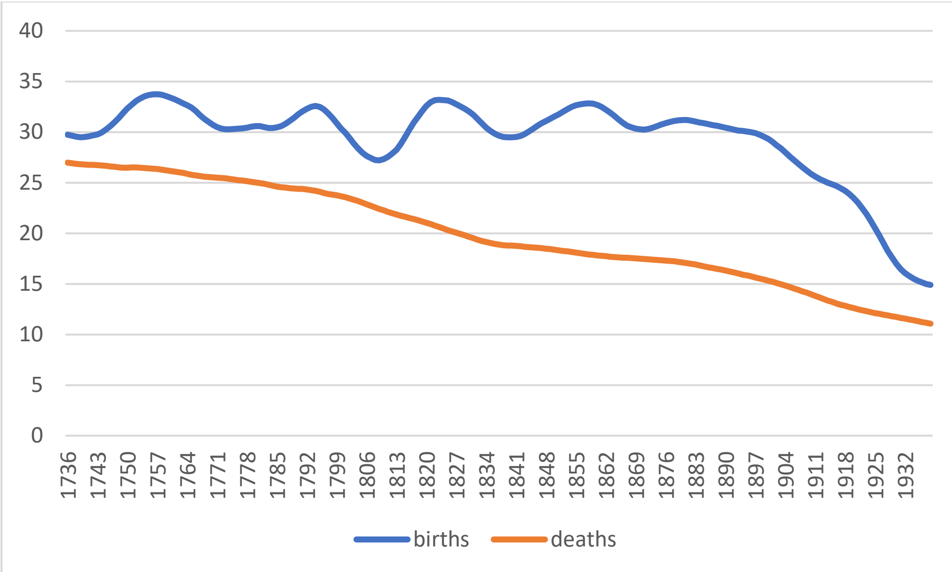
Source: 1705-1800 Sandholt Jensen et al 2020; 1850-1938 Rothenbacher 2002

d) Sweden



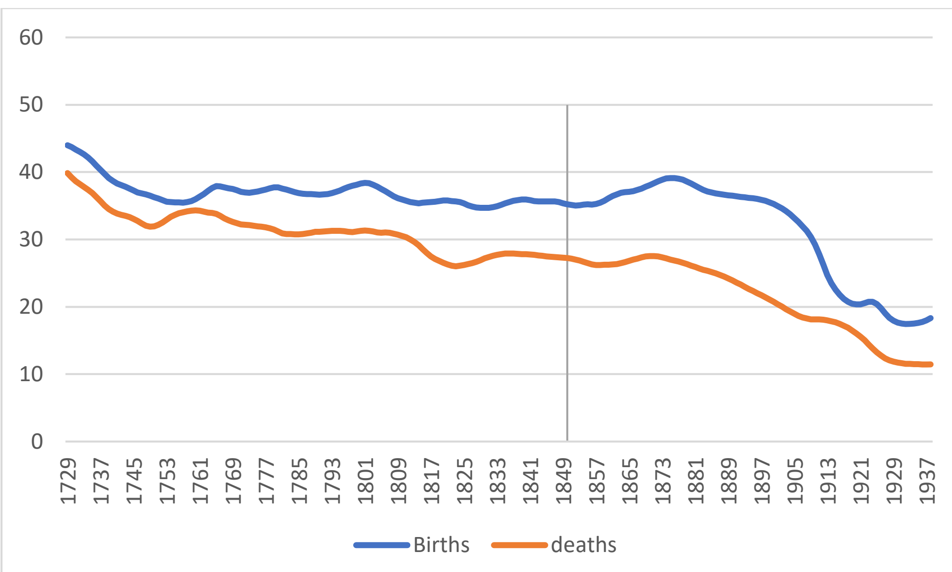
Source: Sveriges officiella statistik https://www.scb.se (accessed November 2022)

e) Norway



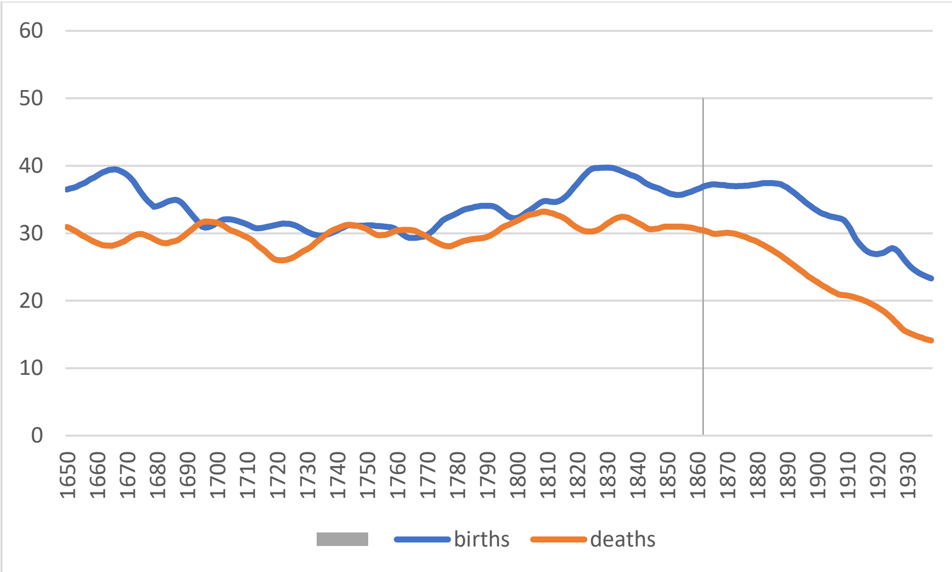
Source Statistikk centralbirà (1969)

f) Germany



Source: 1729-1849 Pfister and Fertig 2020, 1850-1938 Rothenbacher 2002

g) Italy



Source 1650-1861 Galloway 1994 1862-1938 Rothenbacher 2002

Appendix A

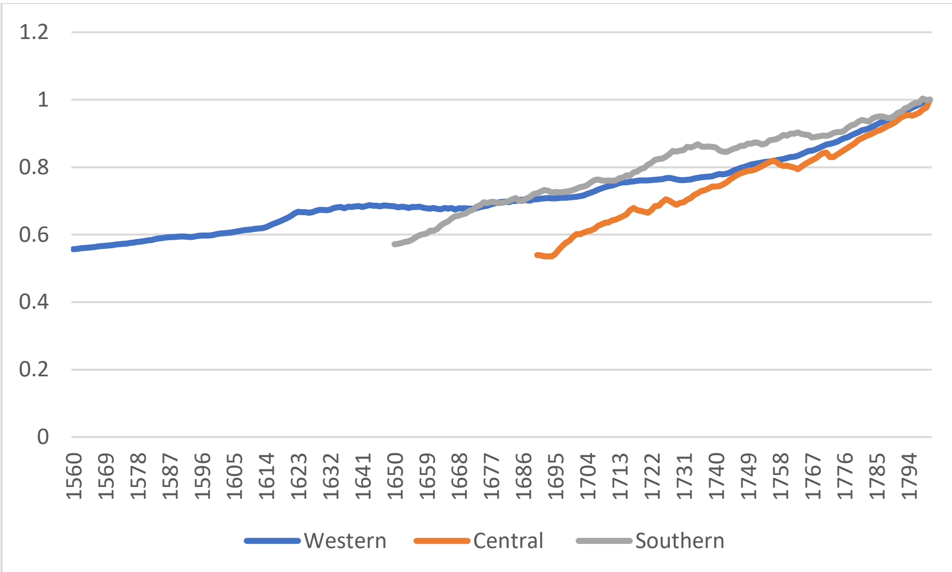
Population before 1800

This Appendix deals with population trends before 1800. We have not made any original effort to cover the world. We have collected series for European countries and China plus benchmark estimates for Russia, India and Japan and we also report the figures for world population from major estimates.

We have been able to build series for three macro-areas, Western, Central and Southern Europe, with a somewhat limited geographical coverage. The series for Western Europe starts in 1560 and includes England/United Kingdom (Broadberry et al 2015), France, joining data by Dupaquier (1995) for 1550-1739 and by Henry and Blayo (1975) for 1740-1799, Sweden (Schon and Krantz 2012) and Netherlands (Paping 2014)[47]. These four countries total accounts for 87.2% of the total population of Western Europe in 1800. We have not included series for Finland (Voutilainen et al 2020), Denmark (Sandholt Jensen et al 2020) and Norway (Historik Statistikk 1968) start later (1647, 1735 and 1736) but correlated with series respectively 0.898, 0.990 and 0.986. The series for Central Europe starts in 1690 and covers (most of) Germany (Pfister and Fertig 2020). In 1800 these areas accounted for 88.5% population of Germany in her 1871 boundaries and for 41.4% of population of Central Europe, including Austria-Hungary and Swtzerland. The series for Southern Europe begins in 1650 and features Centre-North Italy (Galloway 1994), Portugal (Palma and Reis 2019) and Spain (Prados de la Escosura et al 2022). The covered areas accounted for 71.9% of population of the three countries in 1800, and for 71.3% of Southern Europe. We have computed a series for Italy by projecting backwards the total country population with an index for the population of the Centre-North – assuming trends to be similar. We report the result in Figure A.1

[47] Series for France Netherlands report only ten or five years intervals. We compute the series by attributing the average to the mid-period year and then interpolating from mid period (e.g. 1560-1569 attributed to 1564)

Figure A.1
European population, 1800=1



Source: see text

The demographic history of China has attracted much attention and controversies, especially abut the reliability of the official bao-jia statistics (Deng 2004 and Federico and Tena-Junguito 2022). Figure A.2 reports two series, a linear interpolation between benchmarks from Maddison (1998), who revised the estimate by Liu and Hwang (1979) and Perkins (1968) and we the official statistics, as reported by Ho (1959 Appendix I).

Figure A2

Chinese population, 1650-1800 (million)

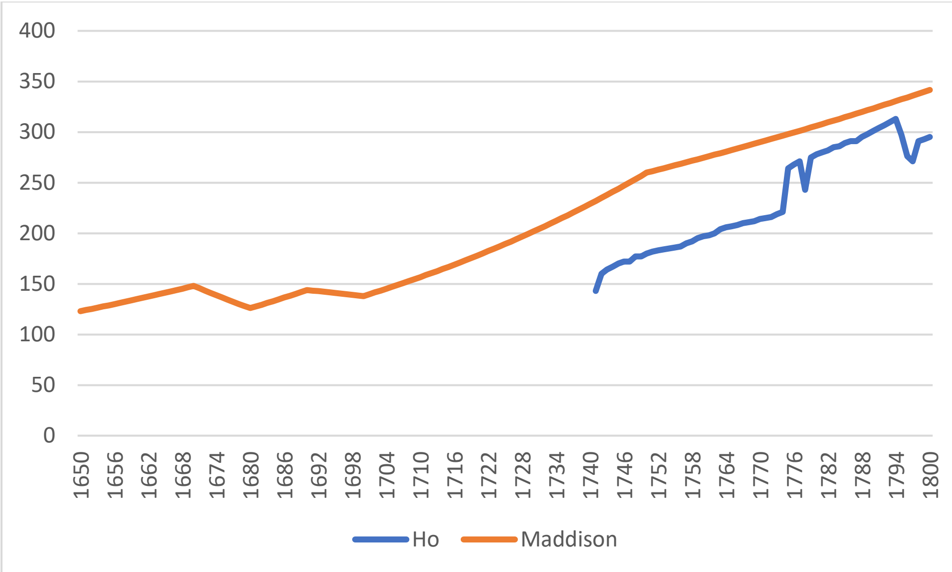


Table A.1 reports two recent, independent estimates

Table A.1
Chinese population (millions)

	Shi 2020 Appendix I		Cao 2000, inner	Cao, total empire
1661	120	1680	183	186
1683	139			
1727	175			
1766	278	1776	307	312
1812	367	1820	376	383

In both cases, we focus on the period following the Manchu invasion (1644), which caused a sharp fall in population. The initial growth thus includes the recovery from the shock, but the population in the Qing period exceeded by far any previous maximum

The data for other countries are more scattered (Table A.2)

Table A.2
Population other countries (millions)

	Russia			India		Japan
	1646 borders	Empire				
					1600	17
1646	7.0	7.0	1650	55.5		
1678	9.6	11.2				
			1700	64.1		
1719	13.6	15.6			1721	31.3
					1732	31.5
			1750	74.2	1750	30.3

1762	18.1	23.2			1768	30.7
1796	23.8	37.4			1792	29.1
1815	28.6	46.3	1801	80.9	1804	30.7

Sources Russia Broadberry and Korchmina 2022 Tab 1, India Broadberry et al 2015 Table 3, Japan 1600 Bassino et al 2019 Table 1 and 1721- 1804 revised official enumerations Biraben 1993

Last but not least, Table A3 reports selected estimates of total world population

Table A.3
World population, 1500-1800 (millions)

	1500	1600	1650	1700	1750	1800
Willcox (1940)			470		694	919
Carr-Saunders (1936)			545		728	906
Bennett (1954)			518	617	749	919
Clark (1967)	428		498	641	731	890
McEvedy and Jones (1978)	425	545	545	610	720	900
Biraben (1979)	461	578		780	771	954
Klein Goldewijk et al 2010	461	554	603	814	990	461
Maddison (2010)	438	556		603		1042

References

Bassino Jean Pascal, Stephen Broadberry, Kyoji Fukao, Bishnupryia Gupta and Masanori Takashima (2019) 'Japan and the great divergence, 730-1874' *Explorations in economic history* 72 pp.1-22

Bennett M.K. (1954) *The world's food: a* study of the World Population, National Diets, and Food Potentials. Harper and Brothers New York.

Biraben Jean-Noel (1979) 'Essai sur l'evolution du nombre des hommes' *Population* 34 (1) pp.13-25.

Biraben, Jean-Noël (1993) 'Le point sur l'histoire de la population du Japon' *Population* (French Edition), 48 (2), pp. 443-472

Broadberry Stephen, Johann Custodis and Bishnupriya Gupta (2015) 'India and the great divergence: an Anglo-Indian comparison of GDP per capita 1600-1871 *Explorations in economic history* 56 (2015) pp.58-75

Broadberry Stephen and Elena Korchmina (2022) 'Catching-up and falling behind:Russian economic growth 1690s-1880s' Oxford Social and Economic History Working papers 197 (June 2022)

Broadberry Stephen, Bruce M.S. Campbell, Alexandr Klein, Mark Overton and Bas van Leeuwen (2015) *British economic growth* Cambridge University Press: Cambridge

Cao Shuji (2000). *Zhongguo Renko Shi Mingqing Shiqi* (A Demographic History of China, the Qing Period), vol. 5. Shanghai: Fudan University Press.

Carr Saunders, A.M. (1936) *World population. Past population and present trends* Oxford: Clarendon Press.

Clark Colin (1967) *Population growth and land use* New York: MacMillan.

Deng Kent G. (2004) 'Unveiling China's true population statistics for the pre-modern era with official census data', *Population review* 43(2), pp.32-69

Dupâquier Jacques (1995). *Histoire de la population française. Tom 2 De la renaissance a 1789*. Paris: Presses Universitaires de France.

Galloway Patrick R. (1994) 'A reconstruction of the population of North Italy from 1650 to 1881 using annual inverse projections with comparisons to England, France and Sweden' *European journal of population* 10, pp.223-274

Henry Louis and Yves Blayo (1975) 'La population de la France de 1740 a 1860', *Population* 30, pp. 71-122

Ho Ping-ti (1959) *Studies on the population of China* Harvard University Press: Cambridge (Mass.):

Klein Goldewijk, K. , A. Beusen, and P. Janssen (2010) 'Long term dynamic modeling of global population and built-up area in a spatially explicit way, HYDE 3 .1' *The Holocene,* **20(4)**, pp.565-573.

Liu K.C. and Kou-shu Hwang (1979) 'Population change and economic development in mainland China since 1400' in Chi-ming Hou and Yu Tzong-shian (eds.) *Modern Chinese economic history* Institute of Economics, Academia Sinica Taipei pp. 61-90

Maddison Angus (1998) *Chinese economic performance in the long run* OECD Paris

Maddison Angus (2010) *The world economy: a millennial perspective* Paris:OECD.

McEvedy, C. and Jones, R. (1978) *Atlas of World Population History*, Middlesex, England: Viking Penguin.

Palma Nuno and Jaime Reis (2019) 'From convergence to divergence: Portuguese economic growth, 1527-1850', *Journal of economic history* 79 (2), pp. 477-506

Paping, R. (2014). General Dutch Population development 1400-1850: cities and countryside. Paper presented at 1st ESHD conference, Alghero, Italy

Perkins Dwight (1969) *Agricultural development in China 1368-1968* Edinburgh University Press: Edinburgh:.

Pfister Ulrich and Georg Fertig (2020) 'From Malthusian Disequilibrium to the Post-Malthusian Era: The Evolution of the Preventive and Positive Checks in Germany, 1730–1870', *Demography* 57, pp.1145-1170

Prados de la Escosura Leandro, Carlos Alvarez Nogal and Carlos Santiago Caballero (2022) 'Growth recurring in pre-industrial Spain: half a millennium perspective' *Cliometrica* 16 (2022) pp.215–241

Sandholt Jensen, Peter Maja Uhre Pedersen Cristina Victoria Radu Paul Richard Sharp (2022) 'Arresting the Sword of Damocles: The transition to the post-Malthusian era in Denmark' *Explorations in Economic History* 84

Schon Lennart and Olle Krantz (2012) 'Swedish Historical national accounts 1560-2010' Lund papers in economic history n.123

Shi Zhihong (2020) *Agricultural development in Qing China: a quantitative study 1661-1911* Brill Leiden

Statistikk centralbirà *Historik statistikk* 1968 Oslo. https://www.ssb.no/a/histstat/hs1968.pdf (accessed August 2019)

Voutilainen, M., Helske, J., and Högmander, H. (2020). A Bayesian Reconstruction of a Historical Population in Finland, 1647–1850. *Demography*, 57, 1171-1192.

Willcox Walter (1940) *Studies in American demography* Ithaca NY: Cornell University Press