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Research Paper

Speed of convergence in a Malthusian world: Weak or strong homeostasis? ☆

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ABSTRACT

The Malthusian trap is a well recognized source of stagnation in per capita income prior to industrialization. However, previous studies have found mixed evidence about its exact strength. This article contributes to this ongoing debate by estimating the speed of convergence for a panel of 9 preindustrial European economies over a long period of time (14th–18th century). The analysis relies on a calibrated Malthusian model for England and β -convergence regressions. I find evidence of significant differences in the strength of the Malthusian trap between preindustrial European economies. The strongest estimated Malthusian trap is in Sweden, with a half-life of 20 years. The weakest estimated Malthusian trap is in England, with a half-life of about 230 years. This implies that some preindustrial economies were able to experience prolonged variations in their standards of living after a shock, while still being subject to Malthusian stagnation in the long run.

In four centuries [1300-1700], the [French] population only increased by 2 million persons in all! And some say less! [...] Thus, an extraordinary ecological equilibrium is revealed. Of course, it did not exclude possibly prodigious, but always temporary, upheavals and negative fluctuations in its time like those experienced by animal population.

Emmanuel Le Roy Ladurie (1977), Motionless History.

1. Introduction

One of the most fundamental and challenging questions in economics is to understand why the world was in a state of economic stagnation before industrialization and how it emerged from it. As postulated by Malthus (1798), preindustrial economic stagnation

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was due to the relationship between the standards of living and population. The Malthusian model posits that an increase in income will result in earlier marriage, higher fertility, and lower mortality, thereby stimulating population growth. As a consequence of the diminishing returns to labor resulting from land constraints, the initial increase in income is ultimately absorbed by the increase in population. Consequently, the Malthusian theory predicts that any increase in the technology level, for example the introduction of better cultivation techniques, will ultimately fail to raise the standards of living due to the counterbalancing effect of population growth. This is the so-called “Malthusian trap” mechanism, a central pillar in the interpretation of the forces that brought about the transition from stagnation to growth (Kremer, 1993; Galor and Weil, 2000; Hansen and Prescott, 2002; Clark, 2007; Galor, 2011).

While the existence of the Malthusian trap is widely recognized as a source of preindustrial economic stagnation, previous literature has found mixed evidence about its exact strength. For England, the most studied preindustrial economy, the estimated half-life of adjustment to shocks varies considerably, from half a century to more than four centuries (see Table 2). In addition, contrasting with much of the previous literature, Madsen et al. (2019) find evidence of a strong and widespread Malthusian trap across 17 countries, with estimated half-lives between one and three decades. This debate, between a strong or a weak version of the Malthusian trap, is referred to as a debate between strong and weak *homeostasis*.¹ Determining the exact strength of the Malthusian trap, or the exact degree of *homeostasis*, has important implications for our understanding of preindustrial economic dynamics and the emergence of sustained economic growth. Indeed, the existence of a weak Malthusian trap would imply that the main source of stagnation in preindustrial economies was their lack of technological progress. Conversely, a strong Malthusian trap would imply that the main source of stagnation was indeed their demographic behavior.

In this article, I reinvestigate the question of the strength of the Malthusian trap by examining the speed of convergence of Malthusian economies — i.e. how quickly they tend to return to their steady state following a shock. To do so, I develop a three level analysis. First, I build an overlapping-generations Malthusian model, in which the population adjusts to living standards through variations in fertility, marriage, and mortality. I derive the speed of convergence around the steady state, and show that the strength of the Malthusian trap depends on three structural parameters: the land share of output, the preventive checks elasticity (the elasticity of fertility and marriage with respect to income per capita), and the positive checks elasticity (the elasticity of mortality with respect to income per capita).

Second, I calibrate the model and perform quantitative simulations to see which degree of *homeostasis* is able to match the observed dynamics of GDP per capita in England before the start of the Industrial Revolution (1275–1700), as reconstructed by Broadberry et al. (2015). In particular, I consider three scenarios: a relatively strong Malthusian trap, a relatively weak, and a median one, based on the long-run elasticity values provided by the literature for the preventive and the positive checks. At each period, the three simulated economies are hit by the same population and technological shocks. I find that the simulation with the weakest Malthusian trap considered is the one that best matches the historical data. The half-life of adjustment to shocks is 230 years in that case, showing weak Malthusian dynamics in England after the Black Death.

Finally, I employ β -convergence regressions *à la* (Barro and Sala-i Martin, 1992) to provide empirical estimates of the speed of convergence for 9 European economies and a large part of the preindustrial period (14th–18th century). The data come from several studies reconstructing GDP per capita on an annual basis using detailed historical data and national accounting frameworks (eg. Broadberry et al. (2015) for England). These data are not derived from assuming a Malthusian model of the economy or a preindustrial economic stagnation. I find consistent evidence of a relatively weak Malthusian trap on average in the sample, with an estimated half-life of 90 years. Exploring the time heterogeneity in the speed of convergence, my results indicate no significant variations in the average strength of the Malthusian trap over time, from the 14th century up to the eve of the Industrial Revolution. However, I find evidence of significant differences in the strength of the Malthusian trap across preindustrial European economies over the same period. In particular, I find very strong Malthusian dynamics in Sweden, with a half-life of about 20 years; while I confirm the weakness of the Malthusian trap in England, with a half-life of 236 years. There are two main concerns in my empirical analysis: weak Malthusian dynamics may be the result of a serious attenuation bias due to omitted variables or classical measurement errors in the lagged dependent variable. I provide a series of additional estimations (detailed in Section 4.2), showing the robustness of my results to these concerns.

This article strongly connects to the growing literature examining the existence of Malthusian dynamics and the strength of the Malthusian trap in different countries and contexts (Lee and Anderson, 2002; Crafts and Mills, 2009; Møller and Sharp, 2014; Fochesato, 2018; Madsen et al., 2019; Cummins, 2020; Jensen et al., 2021; Attar, 2023). I contribute to this literature in two main respects. First, I confirm the particular weakness of the Malthusian trap identified by other studies for England (Crafts and Mills, 2009; Bouscasse et al., 2024). Moreover, I corroborate the findings of Bouscasse et al. (2024) that the particular weakness of the Malthusian trap can be traced back to the time of the Black Death, which is considerably earlier than highlighted by previous contributions. Finally, whereas the majority of the literature focuses exclusively on England, my empirical estimates allow for international comparisons. In particular, my results demonstrate that England has the weakest Malthusian trap in Europe.

My second contribution to this strand of the literature is to provide the first evidence of significant differences in the strength of the Malthusian trap across several preindustrial European economies. This is in contrast with the previous evidence provided by Madsen et al. (2019), who find a very strong Malthusian trap, and no significant differences between countries. My results indicate that only few countries are compatible with a strong Malthusian trap, with half-lives of about 30 years, as estimated by Madsen et al. (2019).

¹ *Homeostasis* comes from the Greek *homoiōs* “similar” and *stasis* “steady”, meaning “staying the same”. In demography, it refers to a population equilibrium maintained by density-dependent checks (Lee, 1987).

Finally, my findings contribute to the existing literature on the Little Divergence (Allen, 2001; De Pleijt and Van Zanden, 2016; Fochesato, 2018) by demonstrating that England and the Netherlands were able to maintain deviations from their Malthusian steady state for significant periods of time. In particular, I provide a more nuanced interpretation of the results presented in Fochesato (2018), demonstrating that the English and Dutch economies, as a whole, were still subject to the Malthusian trap, however weak.

The rest of this article is organized as follows. Section 2 presents my Malthusian growth model, derives the speed of convergence and discusses its potential determinants. Section 3 presents the calibration of the English economy, discusses the choice of the parameters and develops the implications of the results. Section 4 describes my empirical strategy and the data I use to estimate the speed of convergence. Section 5 presents and discusses my empirical results. Section 6 concludes.

2. The Malthusian model

This section presents a simple overlapping-generations Malthusian model with microeconomic foundations. The model is used to derive and discuss the dynamic implications and the speed of convergence. It builds on the previous contributions of Ashraf and Galor (2011) and Lagerlöf (2019). The main difference with respect to these previous versions is the introduction of marriage decisions, which enables the discussion of an additional channel through which population adjusts to shocks, as originally argued by Malthus (1798).² This extension of the Malthusian model is also motivated by recent empirical studies showing that marriage is a key element in understanding the preventive checks (Cinnirella et al., 2017; De la Croix et al., 2019; Cummins, 2020).

2.1. The basic structure of the model

I consider an overlapping-generations economy with time modeled as discrete and going from zero to infinity, and where agents live two periods. In the first period of their life, they are inactive children entirely supported by their parents; they make no decisions. In the second period of their life, they work, earn an income and make decisions about consumption, marriage and fertility.

Preferences and Budget Constraints. — The utility of a married agent i of generation t is defined à la (Baudin et al., 2015):

$$U_{i,t}^M = \ln c_t + \gamma \ln(n_t + \nu) - \ln \lambda_i, \quad (1)$$

where c_t denotes consumption, $\gamma > 0$ is a child preference parameter, n_t is the number of surviving children, $\nu > 0$ allows for childlessness as the individual utility remains defined when $n_t = 0$, and λ_i is the utility cost of marriage. This cost is specific to each individual with $\lambda_i \sim \mathcal{U}(1, b)$, and b being the maximum of a uniform distribution. The main difference compare to the preferences in Ashraf and Galor (2011) and Lagerlöf (2019) is the introduction of the constant ν and λ_i in order to model marriage decisions.

Consistent with historical studies for preindustrial Europe, I model childlessness and celibacy together, leaving the possibility to procreate only to married agents (Hajnal, 1965; Segalen and Fine, 1988; Wrigley et al., 1989). It follows that the utility of an unmarried agent of generation t is given by:

$$U_{i,t}^S = \ln c_t + \gamma \ln(\nu). \quad (2)$$

Agents allocate their income between consumption and child rearing such that we have the following budget constraint:

$$c_t = y_t - f(n_t), \quad (3)$$

where y_t is agent's income, and $f(n_t)$ is the cost of having n_t children in terms of goods.

A convenient functional form for $f(\cdot)$ capturing both the idea of childlessness for single individuals ($f(0) = 0$) and allowing for different types of returns to scale in the production of children for married agents is the following one:

$$f(n_t) = q(n_t + \nu)^{1/\delta} - q \nu^{1/\delta}, \quad (4)$$

with $q > 0$ being the unit cost of a child, and $\delta > 0$ a parameter influencing the degree of return to scale in child production as in Lagerlöf (2019). This formulation can be considered as a more general case as in Ashraf and Galor (2011), where the returns to scale are constant ($\delta = 1$). By setting $\nu = 0$ and $\delta = 1$, we would return exactly to the budget constraint considered by Ashraf and Galor (2011).

Fertility. — Maximizing (1) subject to (3), the optimal fertility behavior of a married agent of generation t is defined by:

$$n_t = \kappa \cdot (y_t + q \nu^{1/\delta})^\delta - \nu \equiv n_t(y_t), \quad (5)$$

where $\kappa = \left(\frac{q}{\gamma\delta} + q\right)^{-\delta}$. Thus, in accordance with Malthusian theory, the number of surviving children within marriage depends positively on income per capita ($\partial n_t / \partial y_t > 0$). This corresponds to the intensive margin of fertility — i.e. how the number of surviving children vary with means of existence, conditional on being married.

² Most of the previous contributions analyzing Malthusian dynamics use reduced-form models (Lee and Anderson, 2002; Fernihough, 2013; Möller and Sharp, 2014; Pfister and Fertig, 2020) instead of micro-founded models. The main difference between the two approaches is that the preventive checks coefficient is derived from agent optimization in the second case. Despite this difference, the dynamic implications between the two classes of models are similar.

Marriage. — Agents maximize their utility and therefore a marriage occurs only if the utility of being married is superior to the utility of being single. I define $\bar{\lambda}$ as the draw from the search cost distribution that makes an agent indifferent between being married and single. An agent marries if $\lambda_i < \bar{\lambda}$. Consequently, the probability for an agent of generation t to be married is:

$$p_t = P(\lambda_i < \bar{\lambda}) = \frac{\bar{\lambda}(y_t) - 1}{b - 1} \equiv p_t(y_t), \quad (6)$$

where b is the maximum of a uniform distribution and the threshold draw $\bar{\lambda}$ depends on an individual's income ($\partial p_t / \partial y_t > 0$).³ The intuition is that generations facing more favorable economic conditions will end up with a higher proportion of married couples everything else equals, following the idea of [Malthus \(1798\)](#). Since each period is a generation, I consider p_t as the marriage rate for generation t .

Mortality. — I model the survival rate of adult agents as directly depending on their income in the following way:

$$s_t = \underline{s} y_t^\phi, \quad (7)$$

where \underline{s} is a parameter calibrated to target an initial survival rate and ϕ is the elasticity of the survival rate to income per capita. Thus, in accordance with the Malthusian theory, adult's survival is increasing along income since $\underline{s} > 0$ and $\phi > 0$.

Production. — Total output in period t is given by:

$$Y_t = (A_t T)^\alpha L_t^{1-\alpha}, \quad (8)$$

where A_t is a land-augmenting technology factor, T is total land area, L_t is the size of the labor force that is equivalent to the adult population in my analysis and $\alpha \in (0, 1)$ is the land share of output.⁴

I assume that workers are self-employed and earn an income equal to the output per worker in t . Using (8) and normalizing land area to unity ($T = 1$), we obtain:

$$y_t = \left(\frac{A_t}{L_t} \right)^\alpha. \quad (9)$$

I consider sustained but constant growth in land productivity. The technological level in period t is given by:

$$A_t = A_0(1 + g)^t, \quad (10)$$

where A_0 is the initial technological level and g is an exogenously given and constant rate of technological progress.

2.2. The evolution of the economy

Population Dynamics. — The size of the population of the next generation $t + 1$ is given by:

$$L_{t+1} = n_t p_t s_t L_t. \quad (11)$$

This is the fundamental equation of the Malthusian economy: population size adjusts endogenously to income per capita via the number of children (n_t), marriage rate (p_t), and survival rate (s_t). According to [Malthus \(1798\)](#), population was kept in balance by the *preventive* checks, namely the adjustment of fertility and marriage to the standards of living, and the *positive* checks, the adjustment of the death rate to the standards of living. The preventive checks are depicted here by the effect of the standards of living on the marriage rate and on fertility within the marriage ($n_t \times p_t$). On the other hand, the positive checks are represented by the influence of income per capita on the survival rate of adults (s_t). Compared to [Ashraf and Galor \(2011\)](#), the dynamic of the population is richer, incorporating p_t and s_t as additional adjustment mechanisms, while maintaining the same qualitative predictions.

Income per capita Dynamics. — Forwarding (9) to period $t + 1$ and using (9), (10) and (11), I obtain a first-order difference equation giving the income per capita of the next generation:

$$y_{t+1} = \left(\frac{1 + g}{n_t(y_t) p_t(y_t) s_t(y_t)} \right)^\alpha \cdot y_t \equiv \psi(y_t). \quad (12)$$

Steady State. — The steady state of the economy is defined by a situation in which:

$$y^* \equiv \left(\frac{1 + g}{n(y^*) p(y^*) s(y^*)} \right)^\alpha = 1. \quad (13)$$

At the steady state, the rate of population growth equals the rate of technological progress, such that income per capita remains constant period after period.⁵

³ The full expression of $\bar{\lambda}$ is available in [Appendix A](#).

⁴ The considered production function does not include physical capital given its limited role in the Malthusian context compare to land. This is a standard assumption in Malthusian models (e.g. [Ashraf and Galor, 2011](#); [Lagerlöf, 2019](#)).

⁵ [Appendix A](#) of the Appendix shows that $\psi(y_t)$ has a unique and locally stable steady state $y^* > 0$, provided that y_t is not too low.

2.3. The speed of convergence and its determinants

Taking a first-order Taylor approximation of (12) around the steady state y^* , the speed at which GDP per capita converges to its steady state in a Malthusian economy is given by:

$$\beta^* = \alpha(\epsilon_{n_t} + \epsilon_{p_t} + \epsilon_{s_t}), \quad (14)$$

where ϵ_{n_t} , ϵ_{p_t} and ϵ_{s_t} are the elasticities of fertility, marriage and survival with respect to income per capita. Appendix C of the Appendix provides further details on the derivation of the speed of convergence.

Eq. (14) gives the general formula characterizing the strength of the Malthusian trap. Any society with a higher value for these elasticities will have a stronger Malthusian trap and will therefore return to its stationary state more quickly after a shock. The three structural parameters governing the speed of convergence in the model are: the land share of output α (see Eq. (8)), the degree of return to scale in child production δ (see Eq. (4)), and the survival-income per capita elasticity ϕ (see Eq. (7)). In particular, δ controls the two elasticities corresponding to the preventive checks ($\epsilon_{n_t} + \epsilon_{p_t}$). This is because, in the model, marriage is costly and does not yield utility as such; however, marriage is necessary to have children, who do yield utility, and whose cost depends on the parameter δ .⁶

There are good reasons to think that these three structural parameters varied substantially across preindustrial societies. First, family organizations, marriage markets, and women status varied substantially (Hajnal, 1965; Todd, 1985; De Moor and Van Zanden, 2010). As originally noted by Hajnal (1965), West of a line from Saint-Petersburg to Trieste, a European Marriage Pattern (EMP) was in place, where women married at a late age, a high proportion of women remained single and household were mostly nuclear. It has been argued that the EMP was a low pressure demographic regime, where fertility was less reactive to variations in living standards than elsewhere. This should translate into lower value of δ in the model for three main reasons. One first reason is that the reproductive possibilities of women decrease with age, and consequently a late age at marriage lowers the sensitivity of fertility to income per capita. A second reason is that a high proportion of women remaining single during their life reduces the pool of available partners and therefore lowers the sensitivity of the marriage rate to income per capita. Finally, nuclear households based on one single married couple could have lower returns to scale in child rearing compare to communitarian households, where several couples live with their parents in the same house.

A second element that can possibly varies a great deal between Malthusian economies and influence the speed of convergence is the land share of output α . In particular, one critical element influencing the value of α is the balance of power between landowners and laborers. Societies with more extractive feudal lords can be expected to have higher values of α , and therefore relatively stronger Malthusian traps. Investigating the evolution of the labor share of income in four preindustrial European economies, Federico et al. (2020) find non negligible differences between countries. The lowest long-run average of the labor share are found in Spain (44%) and Portugal (46%); while the highest are found in England (50%), France (52%) and Holland (53%).

Finally, the elasticity of the survival rate to income per capita ϕ can also potentially differ across preindustrial societies. We can think of factors such as the availability of sanitary conditions, nutrition, military technologies and threats as factors influencing the value of that elasticity across societies.

While I have previously outlined the reasons why the structural parameters governing the speed of convergence in a Malthusian economy may vary, the ultimate value of β^* and the existence of significant differences between two Malthusian economies remain empirical questions that I will address in the following sections.

3. Quantitative analysis

In this section, I calibrate the model to the English preindustrial economy and study how the strength of the Malthusian trap affects the simulated trajectories and matches the historical data. I start by discussing the identification of the parameters that I use to calibrate the English preindustrial economy. I then present the simulation results, compare them with historical data on per capita income, and discuss some of the implications for our understanding of preindustrial economic dynamics.

3.1. Identification of the parameters and initial conditions

In order to simulate the evolution of a Malthusian economy and study how its behavior is affected by the degree of *homeostasis*, I first set the value of some parameters *a priori*, while some others are set to match some target following an exact identification procedure. I focus on England for two reasons. First, the literature already provides a wide range of parameter values for this economy, as well as population and per capita income series spanning several centuries. Second, the English economy is also the first to have experienced sustained growth, giving us the occasion to investigate the role of the strength of the Malthusian trap in that process.

Table 1 summarizes and explains my calibration strategy. I start by fixing the length of a period or generation t at 25 years, meaning that an agent is living at most 50 years in my model.⁷ This is in line with life expectancy figures in preindustrial England as

⁶ This is also a convenient formulation to calibrate the model, as most of the literature provide long-run elasticity values for the preventive checks, rather than separately for the marriage rate and fertility within marriage.

⁷ De la Croix and Gobbi (2017) make a similar assumption in a modern context with developing economies.

reported by [Wrigley et al. \(1997\)](#). Life expectancy at the age of 20 was as high as 33–34 years on the period 1550–1799. Conditional on their survival until the age of 20, agents have therefore good chances to reach the age of 50. This is also in line with the evidence on the EMP from [Hajnal \(1965\)](#). Indeed, the EMP is characterized by a late age of first marriage for women (between age of 24 and 26) and low illegitimacy birth rates. In my setting, agents marry and procreate only in the second period of their life, that is to say between age of 25 and 50 as indicated by the EMP.

Table 1
Benchmark parameter values.

Parameter	Value	Interpretation, comments, and sources
Fixed <i>a priori</i>		
t	25	Number of years per generation (Wrigley et al., 1997)
γ	1	Preference for children
q	1	Unitary cost of a child
δ	0.068	Gives preventive checks-income per capita elasticity of 0.21. See Appendix B
ϕ	0.1	Gives positive checks-income per capita elasticity of 0.1. See Appendix B
α	0.5	Land share of output (Federico et al., 2020)
g	0.025	Rate of technological progress per generation
Calibrated		
\underline{s}	0.142	Minimum of the survival rate. To match $s^* = 0.71$
ν	0.859	Child quantity preference parameter. To match $n^* = 1.62$
b	2.91	Maximum of the search cost distribution. To match $p^* = 0.89$

Notes: See text for more details on the sources.

Next, I normalize γ and q , respectively the agent's preference for children and the cost of raising a child, to one.

Elasticity parameters δ and ϕ are particularly important in my setting, as they directly affect the speed of convergence (see [Section 2.3](#)). Since I am working at the generation level, I consider these parameters as representing respectively the long-run elasticity of the preventive checks (fertility and marriage) and the long-run elasticity of the positive checks (survival) to income per capita.⁸ The empirical literature testing the Malthusian model in England provides various estimates of these long-run elasticities based on wage, crude birth rate, crude marriage rate and crude death rate time-series ([Lee, 1981](#); [Lee and Anderson, 2002](#); [Nicolini, 2007](#); [Crafts and Mills, 2009](#); [Klemp, 2012](#); [Møller and Sharp, 2014](#)). I set $\delta = 0.068$ and $\phi = 0.1$ in my benchmark specification to match the median of the long-run elasticities provided by the aforementioned literature. This corresponds to a long-run elasticity of 0.21 for the preventive checks and 0.1 for the positive checks. [Table B.1](#) in the Appendix provides a complete list of studies, elasticity values, and details the method used to calibrate δ and ϕ .

Setting $\delta < 1$ means that my model consider decreasing returns to scale in the production of children, while most standard Malthusian models assume constant returns to scale ($\delta = 1$).⁹ As pointed out by [Lagerlöf \(2019\)](#), we may interpret decreasing returns to scale in the production of children as stemming from an implicit production function for child survival featuring two inputs: parental time devoted to each child and each child's food intake. More children automatically yields less time per child, leading to an increase in the per-child amount of the consumption good necessary to ensure the survival of each child. Furthermore, the aforementioned empirical literature consistently finds values well below unity for the long-term elasticities of the preventive and positive checks. For instance, using exogenous cross-county variations in Swedish harvest between 1816 and 1856, [Lagerlöf \(2015\)](#) finds long-run elasticities of fertility, marriage and mortality of 0.1, 0.16 and -0.09 , respectively.

The land share of output α for England is set at 0.5, corresponding to its long-run value for the preindustrial period, as estimated by [Federico et al. \(2020\)](#).

To set the rate of technological progress g , I calculate A_t using [\(9\)](#) and data from [Broadberry et al. \(2015\)](#) on population and per capita income. In particular, I calibrate g on the average growth rate of A_t between 1275 and 1500. The rationale behind focusing on this specific period is that, following 1500, there is a notable and gradual increase in the growth rate of A_t . This would imply to calibrate different levels of g after 1500, thereby signifying a transition to other Malthusian steady-states (see steady-state condition [\(13\)](#)). On the contrary, my goal is to see how much a fixed Malthusian system (based on pre-1500 characteristics), with different strength of the Malthusian trap, can match the observed dynamic of the preindustrial English economy.

Consider next the three remaining parameters, \underline{s} , ν and b that are calibrated to match respectively the steady-state survival rate for adults (s^*), agent's steady-state fertility (n^*) and the steady-state marriage rate (p^*) following an exact identification procedure. The first target s^* is set to 0.71 as in [Wrigley \(1968\)](#). This corresponds to the survival rate of population of 25 years old until the age of 50 for the period 1538–1624 in England. The second target p^* is set to 0.89, which corresponds to a percentage of never married women of 11% as reported by [Dennison and Ogilvie \(2014\)](#) for England. This figure is the average of the percentage of never married women for England across 45 historical studies and is also very close to the value reported in the seminal study of [Wrigley et al. \(1989\)](#). Knowing the two first targets, the third target n^* is given by the steady-state condition in [\(13\)](#). To find the value of these three remaining parameters, I also set the steady-state level of income per capita y^* to an arbitrarily high initial level to satisfy $\nu > 0$. In order to do so, I adjust the initial level of technology A_0 .

⁸ The long-run elasticity is the sum of elasticities at various time lags.

⁹ For instance, [Ashraf and Galor \(2011\)](#) are implicitly working with $\delta = 1$.

3.2. Simulation results and discussion

This section presents quantitative simulations of the Malthusian model, compares the simulations with per capita income data from Broadberry et al. (2015), and discusses some of the implications for our understanding of preindustrial growth.

Simulations are run for three model economies. The only difference across these three model economies is the long-run elasticity values used to calibrate δ and ϕ , the parameters that control the strength of the Malthusian trap through the preventive and the positive checks respectively. My benchmark is using the median of the long-run elasticity values found in the literature for the preventive and positive checks, while the two alternative specifications are using the 10th and 90th percentiles of the long-run elasticities (see Table B.1 for an overview of the long-run elasticity values I consider). This translates into significant differences in terms of the speed of convergence. Indeed, the half-life is about 112 years (4.47 generations \times 25 years) in the benchmark scenario, 64 years (2.55 generations) in the 90th percentile scenario and 230 years (9.21 generations) in the 10th percentile scenario.

My primary goal with this exercise is to see how much the simulations can fit the dynamics of GDP per capita, as shown in Broadberry et al. (2015). To do so, I estimate population and technology shocks using the residuals from an AR(1) process and data of Broadberry et al. (2015) for the period 1275–1700. I chose to stop in 1700 because the economy clearly ceased to be Malthusian around that date. Indeed, in Broadberry et al. (2015) data, growth in GDP per capita becomes positive from the second half of the 17th century onwards.

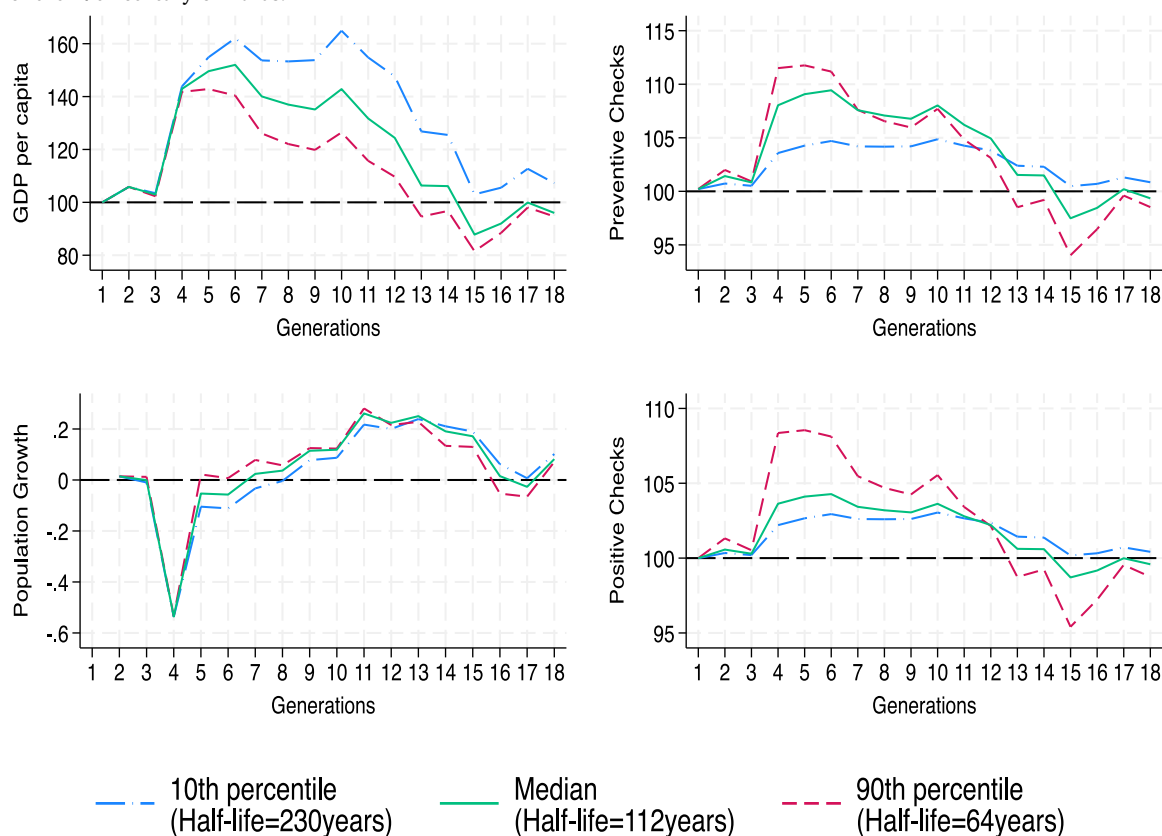


Fig. 1. Simulated paths for the preindustrial English economy.

Notes: This figure plots the simulated paths of per-capita income (top-left panel), the preventive checks (top-right panel), population growth (bottom-left panel) and the positive checks (bottom-right panel) of the calibrated English economy over 18 generations. At each period, the economy is hit by population and technological shocks, estimated with an AR(1) process and data from Broadberry et al. (2015). The solid green line indicates the benchmark scenario, using the median of the long-run elasticities of the preventive and the positive checks provided by the literature to calibrate the model (see Appendix B of the Appendix for more details). The longdashed and dotted blue line indicates an alternative calibration, using the 10th percentile of the long-run elasticities. The dashed red line indicates another alternative calibration, using the 90th percentile of the long-run elasticities. All series are normalized to their steady-state value (without shocks) in the first period.

Fig. 1 presents an overview of the simulations for the three model economies. In particular, it shows the evolution of income per capita (top left panel), population growth (bottom left panel), the preventive checks (top right panel) and the positive checks (bottom right panel), across 18 generations. As expected from the Malthusian model, there is a clear negative relationship between population and income per capita. This comes from the preventive and the positive checks; when income per capita is higher than its steady-state level, agents have better chances to survive, they marry more and are able to raise more surviving children inside marriage. This translates into faster population growth, which tends to push per capita income down towards its steady-state level. Every generation, the economy is hit by shocks, such that the observed level of GDP per capita almost never coincides with its

stationary level. However, the deviations observed from the stationary state are only temporary, since the model cannot generate sustained growth by construction. Among the estimated shocks, one is particularly significant for its magnitude: the Black Death. My estimates show that it killed 55% of the English population, which is within the bound given by the literature. Indeed, according to [Benedictow et al. \(2004\)](#), the upper mortality range caused by the Black Death is 62.5% while the lower mortality range is 45% ([Gottfried, 1983](#)).

Which degree of *homeostasis* best fits the per capita income dynamics of pre-industrial England? [Fig. 2](#) answers this question comparing the simulated paths of the three calibrations to per capita income data reconstructed by [Broadberry et al. \(2015\)](#) for England and years 1275–1700. It shows that the model with the weakest form of *homeostasis* considered is the one that best matches the data of [Broadberry et al. \(2015\)](#) overall. In particular, the weaker the *homeostasis*, the better the Malthusian model is able to replicate the long plateau of per capita income between the Black Death and the 16th century. This is because shocks become more persistent, and therefore GDP per capita can deviate from its steady state for longer. Consequently, my results show that the English economy was characterized by a rather weak Malthusian trap after the Black Death, with a half-life of about 230 years. This is towards the right-tail of the estimated half-life distribution in the literature (see [Table 2](#)), and supports previous studies finding slow Malthusian dynamics for England [Crafts and Mills \(2009\)](#). In particular, my results are close to [Bouscasse et al. \(2024\)](#), who find a half-life of 170 years for England before the Industrial Revolution using a calibrated model and [Clark \(2010\)](#) real wage series.

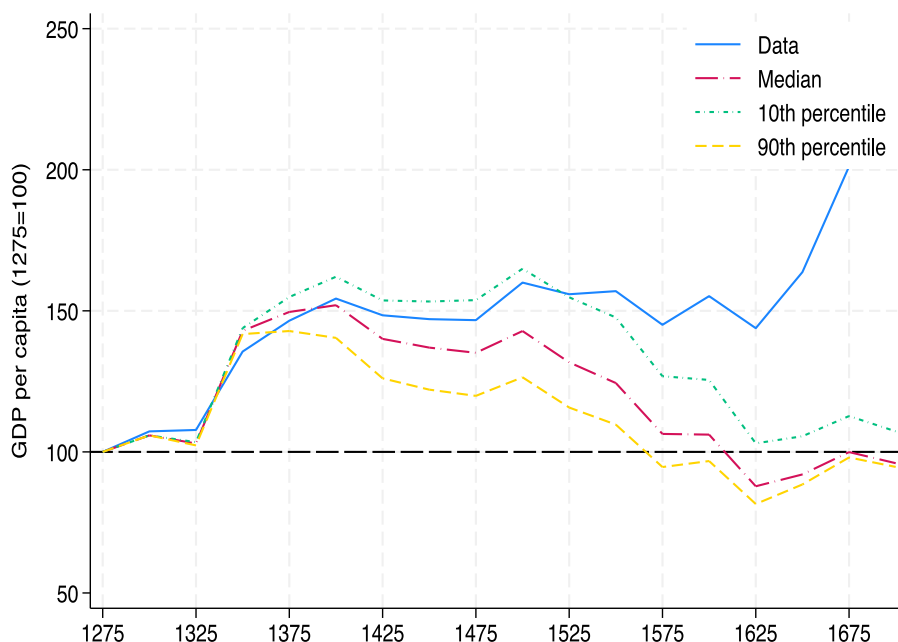


Fig. 2. GDP per capita dynamic in England: Simulated Paths vs. Data.

Notes: This figure plots GDP per capita from [Broadberry et al. \(2015\)](#) (solid blue line), and the simulated GDP per capita paths from the benchmark calibration using the median of the long-run elasticities (dashed and long dotted red line) and two alternative calibrations using the 10th percentile (dashed and short dotted green line) and the 90th percentile (dashed yellow line) of the long-run elasticities. Data are normalized on the period 1250–1275, the first period available in [Broadberry et al. \(2015\)](#) data. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

These results connect and complement with several important explanations from the economic history literature regarding preindustrial economic dynamics and the emergence of sustained growth in England, and elsewhere. A first question is what caused such a weak Malthusian trap in England and when did it prevail? Numerous scholars have argued that a particular low pressure demographic regime, labeled as the EMP, was present in Europe before the Industrial Revolution, and was perhaps particularly strong in England and Northwestern Europe ([Hajnal, 1965](#); [Wrigley et al., 1989](#)). As argued in [Section 2.3](#), a strong EMP is a plausible explanation for the weakness of the Malthusian trap, as it implies smaller quantitative reactions of fertility to income per capita. One remaining question, still debated in the literature, is whether the EMP emerged or have been reinforced by the Black Death? Some authors argue that the Black Death was indeed the shock that triggered the emergence or the spread of that particular demographic regime ([De Moor and Van Zanden, 2010](#); [Voigtländer and Voth, 2013](#)). On the other hand, [Bennett \(2019\)](#) finds evidence that the characteristics of the EMP were already present in rural England a century before the Black Death. Unfortunately, my results cannot help answer this specific question, since we do not have enough data points and shocks to test the Malthusian model convincingly before the Black Death. However, [Fig. 2](#) clearly shows that the Malthusian trap was already quite weak in England at the time of the Black Death.

Second, the above results have implications for the debate on when and why the English economy took off. [Fig. 2](#) shows that the Malthusian model is no longer able to fit the historical data from the mid-16th century onwards. This is because the rate of technological progress g started to accelerate after 1500, while it is set constant in my calibration to its pre-1500 average. This implies a take-off date during the second half of the 16th century for England. That date is consistent with the periodization

proposed by several other contributions. [Bouscasse et al. \(2024\)](#) show that English productivity growth was close to zero until 1600, then started to accelerated substantially. [Attar \(2023\)](#) finds the existence of a “technology-driven” Malthusian regime in England between 1550 and 1650, characterized by increasing productivity levels. Among the plausible factors proposed to explain the rise in productivity since 1550, [Attar \(2023\)](#) and [Bouscasse et al. \(2024\)](#) mention the Reformation, the printing press, the decline of feudalism and the expansion of international trade. On top of these factors, [Fig. 2](#) shows that the first significant deviation of the standards of living from their subsistence level was made possible due to the weakness of the English Malthusian trap. To sum-up, [Fig. 2](#) shows us that two ingredients were key for the success of the preindustrial English economy: (i) an early weak Malthusian trap and (ii) an acceleration in the rate of technological progress in the 1550s.

Table 2
Speed of convergence in my calibrations and in the literature.

Country	Period	Authors	Half-life (years)	Comments
England		Present study	112	Benchmark specification, calibrated using the median of the long-run elasticities reported in Table B.1 ($\delta = 0.074$; $\phi = 0.1$; $\alpha = 0.5$)
England		Present study	230	Alternative specification, calibrated using the 10th percentile of the long-run elasticities reported in Table B.1 ($\delta = 0.045$, $\phi = 0.06$ and $\alpha = 0.5$)
England		Present study	64	Alternative specification, calibrated using the 90th percentile of the long-run elasticities reported in Table B.1 ($\delta = 0.09$, $\phi = 0.23$ and $\alpha = 0.5$)
England	1646–1799	Crafts and Mills (2009)	431	Table 7, Clark real wages
England	1646–1799	Crafts and Mills (2009)	306	Table 7, Wrigley and Schofield real wages
England	1250–1800	Bouscasse et al. (2024)	170	
England	1540–1870	Lee and Anderson (2002)	107	
England	1548–1834	Lee (1993)	70	
England	1200–1700	Attar (2023)	40	
Sub-Saharan Africa	1990	De la Croix and Gobbi (2022)	198	
Northern Italy	1650–1881	Fernihough (2013)	112	
Developing countries	1990	De la Croix and Gobbi (2017)	100	
17 countries	1470–1870	Madsen et al. (2019)	29	Table 2 , income regression
17 countries	1470–1870	Madsen et al. (2019)	12	Table 3 , population regression
17 countries	1470–1870	Madsen et al. (2019)	11	Table 1 , wage regression

4. Empirical framework

In this section, I first present the data I use to empirically estimate the speed of convergence for several preindustrial European economies. Then, I detail my main estimating equation and discuss potential threats to my identification strategy.

4.1. Data

In the empirical analysis that follows, I use historical GDP per capita data series to estimate the speed of convergence across several preindustrial European economies. In particular, the countries, periods and sources included in the sample I consider are: England (1252–1799) ([Broadberry et al., 2015](#)), France (1276–1799) ([Ridolfi and Nuvolari, 2021](#)), Germany (1500–1799) ([Pfister, 2022](#)), Italy (1310–1799) ([Malanima, 2011](#)), Netherlands (1348–1799) ([Van Zanden and Van Leeuwen, 2012](#)), Poland (1400–1799) ([Malinowski and Van Zanden, 2017](#)), Portugal (1530–1799) ([Palma and Reis, 2019](#)), Spain (1277–1799) ([Prados de la Escosura et al., 2022](#)) and Sweden (1300–1799) ([Schön and Krantz, 2015](#); [Krantz, 2017](#)). All the data have been accessed through the Maddison Project data portal ([Bolt and Van Zanden, 2024](#)). I have chosen to stop the data before the 19th century, given the greater probability that countries have emerged from the Malthusian dynamics at this point in time.

These works represent a considerable improvement for the study of preindustrial economic dynamics compare to the original pioneering work of [Maddison \(2001, 2007\)](#). First, the per capita income reconstruction proposed by economic historians for these countries are now based on more comprehensive historical data and a national accounting framework. In the best case, as for England and the Netherlands, estimates are based on detailed information on real outputs by sector. For other countries, such as for Italy or Portugal, information is more limited and a consumption-based approach is used to estimate real GDP. One key improvement is that the new generation of historical per capita income estimates is available at a much higher frequency. GDP per capita figures are reported annually for all the countries in my sample, some series starting as far back as the 13th century. In contrast, [Maddison \(2001\)](#) reports only year 1000, 1500, 1600 and 1700 for the preindustrial period. Finally, and crucially for my analysis, the aforementioned per capita income estimates are not derived from assuming a Malthusian model. This is more likely to be the case in [Maddison \(2001\)](#), as the author assumes the Malthusian stagnation of some economies before the 19th century.

Further analysis and robustness check are performed using simulated GDP per capita data from [Lagerlöf \(2019\)](#) as an alternative source of data (see [Table D.3](#) in the Appendix). As demonstrated by [Lagerlöf \(2019\)](#), a Malthusian model with stochastic and accelerating growth in land productivity is able to generate per-capita income paths that match the moments (mean, standard deviation, and serial correlation) of the historical GDP per capita series presented in [Fouquet and Broadberry \(2015\)](#). In particular, [Fouquet and Broadberry \(2015\)](#) presents new-generation GDP per capita estimates for six European economies. Two

of these GDP per capita reconstructions are based on the same sources as those used in the main analysis (Italy and the Netherlands). The remaining four reconstructions are earlier versions of those considered in the main analysis (for England, Spain, Sweden and Portugal). These four countries were subsequently improved by the same authors, and using the same methodologies. The main advantage of using (Lagerlöf, 2019) simulated series compare to the original data is to gain in precision, since the simulated data are available for a wider cross-sectional and time dimensions, with 1000 model economies and 501 years.

4.2. Empirical strategy

To empirically assess the speed of convergence of Malthusian economies, I rely on a standard β -convergence model. Such models have been extensively used in the growth literature to quantify the speed at which modern economies converge to their steady state (Barro, 1991; Barro and Sala-i Martin, 1992; Islam, 1995; Caselli et al., 1996; Barro, 2015). More recently, this framework has also been used in the Malthusian context by Madsen et al. (2019).

My main specification is the following dynamic panel:

$$\ln(y_{i,t}) - \ln(y_{i,t-1}) = \beta \ln(y_{i,t-1}) + \delta_t + \alpha_i + \varepsilon_{i,t}, \quad (15)$$

where $i = 1, \dots, N$ indicates a country and $t = 1, \dots, T$ is a 25-year period. The left-hand side of Eq. (15) corresponds to the growth rate of GDP per capita.

My coefficient of interest is β , which gives the average annual speed at which Malthusian economies converge to their steady state. Obtaining unbiased estimates of the speed of convergence is challenging in many ways. First, endogeneity is a concern, as past levels of economic development and current economic growth may be jointly determined by omitted factors. To mitigate that issue, Eq. (15) includes country fixed effects α_i that control for time-invariant determinants of economic development, such as geography, climate and, to some extent, culture.

While partially solving the problem of omitted variables, country fixed effects are themselves recognized as a source of upward bias in the measurement of convergence speed in dynamic panels, known as the Hurwicz–Nickell bias (Hurwicz, 1950; Nickell, 1981). This is a potential problem, as it would constitute a systematic bias against a weak Malthusian trap in my analysis. However, as highlighted by Barro (2015), the Hurwicz–Nickell bias tends towards zero when the overall sample length in years tends towards infinity. This means that the risk of a sizeable Hurwicz–Nickell bias is strongly mitigated in my analysis by the length of the overall sample, which spans several centuries.¹⁰

To address the endogeneity issue arising from time-varying omitted factors, Eq. (15) also includes time fixed effects δ_t to control for common changes in the steady-state determinants, such as the spread of new technologies or global climatic changes.¹¹ Furthermore, Table D.2 in the Appendix demonstrates that my main results remain robust when controlling for the state history index of Borcan et al. (2018), namely a time-varying determinant of Malthusian steady-states.

Another source of concern is measurement error in the lagged dependent variable $y_{i,t-1}$. In presence of classical measurement error, i.e. random errors in the measurement of $y_{i,t-1}$, the β coefficient will be subject to an attenuation bias, driving the speed of convergence toward zero. This is a strong concern, as it would represent a systematic bias in favor of a weak Malthusian trap. To limit this possibility, I implement several strategies. First, as detailed in Section 4.1, I focus on European countries for which economic historians were able to reconstruct the GDP per capita based on detailed and comprehensive historical data. This constitutes a significant improvement compared to the pioneer work of Maddison (2001), and should therefore reduce the measurement error. Second, I follow the usual practice in the empirical macroeconomic literature and calculate 25-year averages of the dependent and lagged dependent variables. This allows me to smooth out short-term fluctuations and to reduce the influence of random errors. In addition, Table D.1 shows that my main results are robust to changes in the length of the data averaging window (to 35 years or 15 years). Finally, column 3 of Table D.3 performs a difference Generalized Method of Moments estimation (hereafter referred to as diff-GMM) (Arellano and Bond, 1991) of Eq. (15) using (Lagerlöf, 2019) simulated data. In particular, diff-GMM can help mitigate the bias arising from classical measurement error, as it uses lagged levels of the endogenous variables as instruments. In this case, I find that the diff-GMM results are not statistically different from their fixed effects counterparts, suggesting that classical measurement error is not an issue.

Nevertheless, there remains the possibility of non-classical measurement error, such as systematic and persistent differences over time in the measure of explanatory variables between countries. If this type of measurement error is highly persistent over time, it will be treated by the country fixed effects α_i . Similarly, if the errors are the same for all countries in a year, it will be captured by the year fixed effects δ_t . To account for less persistent measurement error across countries, my strategy is to run fixed effects regressions with year-interacted lagged dependent variables. Compare to specification (15), it adds a term $\sigma_t (y_{i,t-1} \times \delta_t)$, estimating the average differences in the speed of convergence compare to the baseline year. In this case, any time-varying differences in measurement correlated with initial GDP per capita levels will be taken into account. Reassuringly, I find that this approach yields similar results compare to my baseline fixed effects regressions (see Fig. 3).

¹⁰ On the contrary, Barro (2015) finds that the Hurwicz–Nickell bias on the speed of convergence coefficient is sizeable in the modern growth context, where the analysis runs typically over 50 years.

¹¹ For instance, my analysis spans from the 14th to the 19th century, the period during which certain global climatic events, such as the Medieval Warm Period or the Little Ice Age, occurred. Time fixed effects can control for these events, provided that they affected a large part of the sample.

5. Estimation results

In this section, I present my empirical estimates of the speed of convergence for various preindustrial European economies. I start by presenting my results on the estimation of the average strength of the Malthusian trap in my sample. Then, I explore the possible heterogeneity of the results across time periods and countries.

5.1. The strength of the Malthusian trap

In [Table 3](#), I report the estimations of specification (15) using OLS. The dependent variable is the average annual growth rate of GDP per capita. In column 1, I first present the relationship between the dependent variable and the initial level of GDP per capita, controlling for time fixed effects only. Then, I add country fixed effects in column 2.

Table 3
Speed of convergence in preindustrial Europe.

	OLS (1)	FE (2)
log(GDPpc)	-0.0003 (0.001)	-0.0077*** (0.002)
Time FE	Yes	Yes
Country FE	No	Yes
Observations	153	153
adj. R-sq	0.03	0.16
Half-life	2067	90
Half-life 95% C.I.	[286, -395]	[229,56]

Notes: This table presents estimates of the speed of convergence using GDP per capita reconstructions from various studies for a sample of 9 European economies over the period 1300–1799. See [Section 4.1](#) for more details on the data sources. Column 1 display the relationship controlling for time fixed effects only. Column 2 includes country fixed effects. Standard errors clustered at the country level are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Column 1 reveals an insignificant relationship between the lagged level of GDP per capita and its growth rate. This is not really surprising as the omitted variable bias is substantial in this case, driving the lagged dependent coefficient toward zero. Furthermore, according to my theoretical model, Malthusian economies are expected to exhibit conditional convergence rather than absolute convergence. This is because the steady-state position of each economy is dependent on its particular characteristics.¹²

Adding country fixed effects, column 2 shows a negative and significant relationship between GDP per capita growth and the initial level of GDP per capita, indicating conditional convergence and the existence of Malthusian dynamics. The estimated convergence dynamics are slow, as the half-life of the average Malthusian economy is 90 years ($\ln(2)/0.0077$). The 95% confidence interval is large, giving half-lives between 229 years and 56 years. This suggests potential heterogeneity within the sample, a question that I investigate further in the two next sections. These findings are consistent with other studies that estimate relatively weak Malthusian dynamics for certain countries or groups of countries in various contexts. [De la Croix and Gobbi \(2017\)](#) find similar slow dynamics for developing countries in the 1990s, with a half-life of 100 years. [Bouscasse et al. \(2024\)](#) and [Fernihough \(2013\)](#) find evidence of weak *homeostasis* for England and Northern-Italy, with half-lives of 170 and 112 years respectively. However, my results contrast with those of [Madsen et al. \(2019\)](#), who find a half-life of 29 years for per capita income in a panel of 17 Malthusian economies (900–1870) and conclude in favor of the existence of a strong and widespread Malthusian trap.

[Appendix D](#) of the appendix provides three robustness checks and one additional analysis on the results presented in [Table 3](#). First, I check the sensitivity of my results to the use of alternative observation intervals. Indeed, [Table 3](#) uses 25-year averages of the data as one time period (as in the rest of the paper), corresponding also to one generation in my calibration exercise (see [Section 3](#)). This could influence the estimated speed of convergence, as the signal-to-noise ratio is likely to vary with the length of the observation interval. In particular, I expect a lower estimated speed of convergence when the length of the observation interval is longer, as low-frequency data smooth out medium-term cycles. In [Table D.1](#), I perform the same analysis as in [Table 3](#), but using a 15-year window (columns 1–2) and a 35-year window (columns 3–4) as alternative time intervals. As expected, column 2 of [Table D.1](#) reveals a slightly higher speed of convergence with a half-life of 75 years, while column 4 shows a slower speed of convergence with a half-life of 119 years. In both cases, the estimated coefficients are not significantly different from the main results, indicating slow Malthusian dynamics on average.

The second robustness check investigates whether the weak Malthusian trap estimated is the result of a severe omitted variable bias. In particular, column 2 of [Table 3](#) does not control for any time-varying determinants of GDP per capita growth at the country level, as it controls only for time and country fixed effects. The challenge here is that very few time-varying data are available to control for determinants of the steady state for a large number of countries and a large part of the Malthusian period. One variable that qualifies as such a control is the state history index of [Borcan et al. \(2018\)](#). This index captures state presence for most today's countries, every half-century from 3500 BCE onward. [Borcan et al. \(2018\)](#) show that there is an hump-shaped relationship

¹² From the steady-state condition in (13), it is clear that two economies, with for instance different rates of technological progress g , will not converge to the same steady state.

between historical state presence and technology adoption in 1500 CE. Consequently, state presence could affect the steady state of Malthusian economies via its effect on the rate of technological progress (g in my model), and explain residual GDP per capita growth. Table D.2 shows the robustness of my results to the inclusion of the state history index of Borcan et al. (2018) and its square as controls. Strict comparison to the main results in Table 3 is limited by the fact that Borcan et al. (2018) data are available at a lower frequency than GDP per capita data. Nevertheless, this exercise is still informative on the extent of the potential bias provoked by potential omitted steady-state determinants.

Third, as an additional analysis, Table D.3 performs the same regressions as in Table 3 using simulated GDP per capita data from Lagerlöf (2019). Under plausible parameter values, Lagerlöf (2019) shows that a Malthusian model with stochastic and accelerating growth in land productivity can produce simulated GDP per capita paths that are similar to the historical data presented in Fouquet and Broadberry (2015) for several European economies between 1300 and 1800. In particular, the GDP per capita series presented in Fouquet and Broadberry (2015) are part of the data I use in Table 3 (e.g. Holland and Italy), or have been updated using a similar methodology (e.g. England and Sweden). Consequently, the main advantage of using this simulated series to estimate the speed of convergence is to gain in precision, since the simulated data correspond to the same empirical moments as the historical data while possessing a much greater temporal and cross-sectional dimension. As expected, Table D.3 shows that the speed of convergence is now estimated with much more precision. The fixed effects estimation in column 2 shows a half-life of 124 years, with a 95% confidence interval giving half-lives between 132 and 117 years. In particular, these results lie within the wide confidence intervals of Table 3 column 2. This provides additional confidence on the relative weakness of the Malthusian trap, on average.

Finally, the last robustness checks uses (Lagerlöf, 2019) simulated data and an instrumental variable approach to test the sensitivity of my results to the issue of classical measurement error. Indeed, it has been shown that instrument variable techniques can help to mitigate the bias arising from classical measurement error. In column 3 of Table D.3, I estimate Eq. (15) using a diff-GMM estimator (Arellano and Bond, 1991), a technique also widely used to estimate the speed of convergence in the context of modern economies. In particular, diff-GMM takes the first difference of regression Eq. (15), to eliminate country fixed effects, and uses lagged levels of endogenous variables as instruments. The estimated speed of convergence with diff-GMM is not statistically different from the fixed effects estimation in column 2, which provides reassuring evidence that classical measurement error is not an issue in the analysis.

5.2. The malthusian trap through time

Fig. 3 investigates whether the strength of the Malthusian trap varies across the studied period. To do so, I re-estimate the fixed effects specification of Table 3 column 2, adding an interaction term between the time period dummy variables and the initial level of GDP per capita. Consequently, Fig. 3 reports the estimated average speed of convergence for each period.

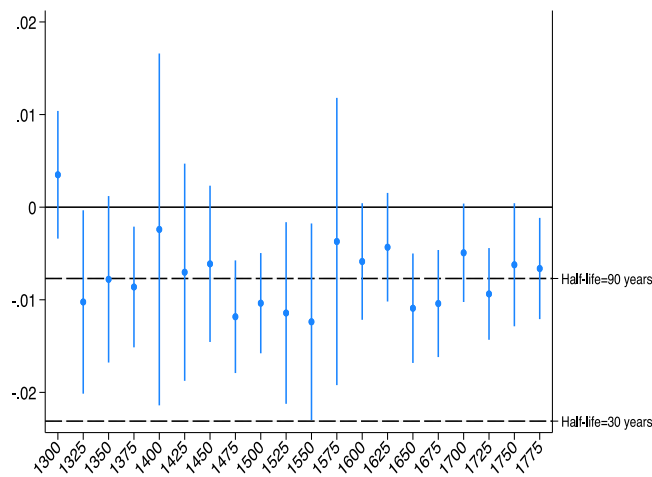


Fig. 3. Speed of convergence in preindustrial Europe over time.

Notes: This figure plots estimates of the evolution of the speed of convergence over time. It uses GDP per capita reconstructions from various studies for a sample of 9 European economies over the period 1300–1799. See Section 4.1 for more details on the data sources. In particular, the estimation corresponds to the FE specification in column 2, Table 3, adding year-interacted lagged GDP per capita levels as controls. Each reported coefficient indicates the average speed of convergence for the specified time period. 95% confidence intervals are reported.

Overall, I find evidence of a significant and stable Malthusian response over the period considered. The strength of the Malthusian trap has varied, but no specific trend can be noticed. In particular, the average strength of the Malthusian trap is not significantly different in the years around the Black Death (1325–1375) than in the 18th century, on the eve of the Industrial Revolution. Madsen et al. (2019) find similar results concerning the stability of the strength of the Malthusian trap from the Middle Ages up to the Industrial Revolution. Nevertheless, the most significant discrepancy between the two sets of findings is that my analysis points towards the existence of a relatively weak Malthusian trap on average, whereas Madsen et al. (2019) identify a strong Malthusian trap on average. The stability of the Malthusian trap until the 19th century is also consistent with the hypothesis of a gradual transition

out of the Malthusian regime via a post-Malthusian regime, as asserted by Galor and Weil (2000), Galor (2011). Furthermore, this result is based on an average speed of convergence and does not rule out the possibility that some countries escaped the Malthusian before the 19th century, as it is argued by some studies for England Nicolini (2007), Crafts and Mills (2009) and Møller and Sharp (2014).

As argued in Section 4.2, including interactions terms between the year fixed effects and the lagged dependent variable can also be a way to check for the influence of non-classical measurement errors. Indeed, if the errors in measurement are time-varying and correlated with initial GDP per capita levels, they would be taken into account in that case. Despite few exceptions, all the estimated coefficients in Fig. 3 are statistically significant and with a similar magnitude compare to the fixed effect regression in Table 3. This suggest that this particular type of non-classical measurement error is not a critical issue for my results.

5.3. The Malthusian trap across countries

In Table 3, I find a relatively slow average speed of convergence in my sample, with a large confidence interval. The analysis of the previous section shows that variations in the strength of the Malthusian trap over time cannot explain this pattern. In Table 4, I investigate the potential differences in the strength of the Malthusian trap across country. To do so, I re-estimate the fixed effects specification of Table 3 column 2, adding an interaction term between the country fixed effects and the initial level of GDP per capita. By that mean, I am able to estimate the speed of convergence for each country individually in my sample.

Table 4 shows that significant differences in the strength of the Malthusian trap existed across preindustrial European economies. The strongest estimated Malthusian trap is in Sweden, with a half-life of 20 years. This is in line with the results of Madsen et al. (2019), who identify a strong and widespread Malthusian trap with half-lives ranging from 10 to 30 years. Under these conditions, improvements in technology or population shocks hardly make income per capita deviate from its steady state for too long. However, in contrast with Madsen et al. (2019), my results also indicate several preindustrial economies with a significantly weaker Malthusian trap. It takes 40 years to absorb half of a shock in France; 57 years in Portugal. In particular, the two weakest and significant Malthusian trap estimated on the period are in the Netherlands and England, with a half-life of about 111 years and 236 years, respectively. The estimated half-life for England is consistent with my calibration results in Section 3.2, indicating a half-life of about 230 years for England.

Table 4
Speed of convergence in preindustrial Europe by country.

Country	Coefficient	Std. error	Half-life (years)	Half-life 95% C.I.
England	-0.0029	(0.001)**	236	[2840, 123]
Spain	-0.0059	(0.005)	118	[38, -106]
Netherlands	-0.0063	(0.001)***	111	[203, -76]
Italy	-0.0112	(0.005)*	62	[31, -9561]
Portugal	-0.0122	(0.002)***	57	[97, 40]
Poland	-0.0163	(0.006)**	43	[261, 23]
France	-0.0171	(0.003)***	40	[71, 28]
Germany	-0.0204	(0.009)**	34	[1090, 17]
Sweden	-0.0339	(0.003)***	20	[25, 17]

Notes: This table presents estimates of the speed of convergence per country. It uses GDP per capita reconstructions from various studies for a sample of 9 European economies over the period 1300–1799. See Section 4.1 for more details on the data sources. In particular, the estimation corresponds to the FE specification in column 2, Table 3, adding country-interacted lagged GDP per capita levels as controls. Each line reports the estimated speed of convergence for the specified country. Standard errors clustered at the country level are in parentheses.

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

One important implication of the above results is that some preindustrial economies were able to enjoy prolonged deviations from subsistence, while still being subject to the Malthusian stagnation in the long run. As noted by Bouscasse et al. (2024), a slow speed of convergence enable us to better understand why some preindustrial economies have experienced episodes of non-sustained economic growth in the past. This is what Goldstone (2002) calls “efflorescences” and include episodes such as ancient Rome or the golden age of Holland. On the other hand, some other preindustrial economies were unable to deviate from stagnation for too long, due to a stronger Malthusian trap. In that perspective, the results presented in Table 4 particularly relate to the Little Divergence. The Little Divergence is the process whereby the North Sea Area (the United Kingdom and the Netherlands) achieved significantly higher levels of economic development than the rest of Europe in the centuries leading up to the Industrial Revolution (Allen, 2001). Therefore, my results tend to confirm that a key factor behind the early economic success of England and the Netherlands in the preindustrial era was a relatively weak Malthusian trap, compare to the other European countries. As reviewed in Section 2.3, the argued particular prevalence of the EMP in these countries is one obvious plausible candidate to explain that pattern. Differences in political institutions, possibly affecting the land share of output α , could also have played a role in diminishing the strength of the Malthusian trap in the North Sea Area.

6. Conclusion

The Malthusian trap has long been identified as a significant obstacle to sustained economic growth prior to industrialization. However, consensus on its exact strength and prevalence is lacking. In this article, I estimate the strength of the Malthusian trap for 9 preindustrial European economies between the 14th century and the end of the 18th century. In particular, I focus on the

speed of convergence to the steady state as a measure of the strength of the Malthusian trap. The analysis relies on a calibrated Malthusian model for England and empirical estimates of the speed of convergence derived from β -convergence regressions. The data used are provided by the recent advancement in historical national accounting and represent the most accurate GDP per capita reconstructions available for the study of preindustrial economies.

My principal finding is that significant differences in the strength of the Malthusian trap existed in Europe long before industrialization. The strongest Malthusian trap is found in Sweden, with a half-life of 20 years. In contrast, the two weakest and significant Malthusian traps are identified in England and the Netherlands, with half-lives of 230 and 111 years, respectively. Other European countries exhibit intermediate values, with half-lives of 40 years, as observed in France, or 62 years, as in Italy. The main implication of the above results is that some preindustrial economies were able to sustain deviations from their Malthusian steady state for a longer period than others following a shock. This also implies that the absence of consistent technological progress during the preindustrial era was a crucial element in ensuring economic stagnation over the long run. My results also strongly supports the hypothesis that a particularly weak Malthusian trap in North Sea countries enabled them to diverge from the rest of Europe before the Industrial Revolution. This article, for the first time, highlights significant differences in the strength of the Malthusian trap between European countries. It thus invites future research to examine the precise factors, demographic or institutional, that could explain the strength or weakness of the Malthusian trap in certain countries.

CRedit authorship contribution statement

: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Appendix A. Uniqueness and stability of the steady state

In this section, I analyze in more depth the dynamic of the Malthusian economy described in Section 2. In particular, I show that the economy has a unique, locally stable, and positive steady state.

The dynamic of the economy is given by the first-order difference Eq. (12), that I further develop here:

$$\psi(y_t) = \left(\frac{1+g}{(\kappa^{-\delta} (y_t + q v^{1/\delta})^\delta - v) \cdot \frac{(\bar{\lambda}(y_t)-1)}{(b-1)} \cdot \underline{s} y_t^\phi} \right)^\alpha \cdot y_t,$$

with $\bar{\lambda}(y_t) = \exp\left(\ln(1 - \frac{q}{\kappa}) + (1 + \delta\gamma) \ln(y_t + q v^{1/\delta}) - \delta\gamma \ln(\kappa) - \ln(y_t) - \gamma \ln(v)\right)$.

Uniqueness of the Steady State. — The model admits a unique state $y^* > 0$ for all $y_t \in [0, +\infty[$. As stated by Eq. (13), the steady-state level of income per capita y^* is attained when:

$$y^* \equiv \left(\frac{1+g}{n(y^*) p(y^*) s(y^*)} \right)^\alpha = 1.$$

There is only one steady state for the economy because $n_t(y_t)$, $p_t(y_t)$ and $s_t(y_t)$ are increasing and monotonous functions of y_t , given $y_t > y > 0$. Therefore, there is only one value $y_t > 0$ that satisfies the steady-state condition (13) and equates $(1+g) > 0$.

To see this, lets first define \underline{y} , the minimum income per capita level for which $n_t(y_t)$, $p_t(y_t)$ and $s_t(y_t)$ start to have meaningful values – i.e. $(n_t, p_t, s_t) \in \mathbb{R}_{++}$. For $n_t(y_t)$, we have that:

$$n_t(\underline{y}) = 0 \Leftrightarrow \underline{y} = \frac{q}{\gamma\delta} \cdot v^{1/\delta} > 0,$$

since q , δ , γ and v are strictly positive.

Similarly, for $p_t(y_t)$, we have:

$$p_t(\underline{y}) = \frac{\lambda(\underline{y}) - 1}{b - 1} = \frac{1 - 1}{b - 1} = 0.$$

For $s_t(y_t)$, we have:

$$s_t(\underline{y}) = \underline{s} \left(\frac{q}{\gamma\delta} \right)^\phi \cdot v^{\phi/\delta} > 0,$$

since $\phi > 0$.

These functions are strictly increasing for all $y_t \in [0, +\infty[$, except p_t that is strictly increasing for all $y_t > \underline{y}$:

$$n'_t(y_t) = \delta\kappa(y_t + qv^{1/\delta})^{\delta-1} > 0.$$

$$p'_t(y_t) = \left(\frac{1 + \delta\gamma}{(y_t + qv^{1/\delta})} - \frac{1}{y_t} \right) \cdot \bar{\lambda}(y_t) > 0 \text{ if } y_t > \underline{y}.$$

$$s'_t(y_t) = \phi \underline{s} y_t^{\phi-1} > 0.$$

Therefore, it exists one and only one value $y_t > \underline{y}$ that solves Eq. (13), and that value is a steady state $y^* > 0$.

Levels of income per capita $y_t \in [0, \underline{y}]$ result in unbounded dynamics. To prevent such cases in the quantitative exercise of Section 3, I make the economy starts at an arbitrarily large steady-state level $y^* = 1 \cdot 10^7$. This is well above the value of \underline{y} in my simulations, which is $\underline{y} = 0.051$.

Stability of the Steady State. — The steady state y^* is locally stable. The steady state y^* is stable if the absolute value of the derivative of $\psi(y_t)$ evaluated at the steady state is in the unit circle.

The first derivative of $\psi(y_t)$ with respect to y_t gives:

$$\psi'(y_t) = \left(\frac{(1+g)}{n_t(y_t) p_t(y_t) s_t(y_t)} \right)^\alpha \cdot \left(1 - \alpha (\epsilon_{n_t} + \epsilon_{p_t} + \epsilon_{s_t}) \right),$$

with $\epsilon_{n_t} = n'_t(y_t)/n_t \cdot y_t$, $\epsilon_{p_t} = p'_t(y_t)/p_t \cdot y_t$ and $\epsilon_{s_t} = s'_t(y_t)/s_t \cdot y_t$ elasticities of the income per capita to fertility, marriage and survival respectively.

At the steady state, we have:

$$\begin{aligned} \psi'(y^*) &= \left(\frac{(1+g)}{n_t(y^*) p_t(y^*) s_t(y^*)} \right)^\alpha \cdot \left(1 - \alpha (\epsilon_{n_t}^* + \epsilon_{p_t}^* + \epsilon_{s_t}^*) \right) \\ &= 1 - \alpha (\epsilon_{n_t}^* + \epsilon_{p_t}^* + \epsilon_{s_t}^*). \end{aligned}$$

In the quantitative exercise of Section 3, $1 - \alpha(\epsilon_{n_t}^* + \epsilon_{p_t}^* + \epsilon_{s_t}^*) = 0.84$, ensuring that the steady state y^* is locally stable.

Appendix B. Calibration of elasticity parameters

In this section, I detail the sources and the method used to calibrate the elasticity parameters controlling the preventive checks (δ), and the positive checks (ϕ) in the model described in Section 3.

Since my model is written at the generation level, I focused on studies estimating the long-run elasticities of the preventive and positive checks for the English Malthusian economy. I considered the six studies listed in the first column of Table B.1. When available, I collected the long-run elasticity estimates by sub-period, in order to have more variation for the Malthusian period. I have avoided including data after 1800, as they are less likely to be representative of Malthusian dynamics (especially for the English economy). This was always possible in the studies considered except for Lee and Anderson (2002), where estimates are only available for the period 1540–1870. Unfortunately, elasticity estimates are not available for England before the 16th century. This is because all studies rely on the same demographic series (birth, death and marriage rates) compiled by Wrigley et al. (1989), and starting in the year 1540.

The two last columns of Table B.1 indicate the elasticity values taken into account to calibrate my model. I was able to collect 10 long-run elasticity estimates for the preventive checks and 7 for the positive checks. I have not included the positive check elasticity values if they were found with the “wrong” sign in the studies, which I indicate by a “+” in Table B.1. Table B.1 also provides information on the data and the model used to estimate the elasticities in each article, which could explain some of the differences in estimates across studies.

The value of the long-run elasticity of the positive checks is directly given by ϕ in my model, as Eq. (7) corresponds to the unit-elastic case. Therefore, I set ϕ directly to the median of the elasticities provided by the aforementioned studies for the benchmark specification – i.e. $\phi = 0.1$.

Table B.1
Preventive and positive checks elasticities considered for the calibration.

Article	Model	Data (Population/Wage)	Period	Preventive check elasticity	Positive check elasticity
Crafts and Mills (2009)	State space	WS/C	1541–1645	0.31	0.24
	State space	WS/C	1646–1799	0.22	^a
	SVAR	WS/C	1541–1645	0.09	0.03
	SVAR	WS/C	1646–1799	0.23	^a
Klemp (2012)	CVAR	WS/C	1701–1759	0.31	N.A.
Lee and Anderson (2002)	State space	WS/PBH	1540–1870	0.12	0.08
Lee (1981)	OLS	WS/PBH	1548–1834	0.14	0.1
Møller and Sharp (2014)	CVAR	WS/A	1564–1760	0.32	0.1
	CVAR	WS/C	1564–1760	0.21	0.22
Nicolini (2007)	SVAR	WS/A	1541–1640	0.03	0.11
	SVAR	WS/A	1641–1740	0.11	^a

Notes: This table presents the source I used to calibrate the elasticities parameters in my model in Section 4. Column 3 gives the source of the population and wage data used in each paper mentioned. WS indicates that the population data comes from Wrigley et al. (1989), C indicates that the wage data comes from Clark (2010), PBH indicates that the wage data comes from Hopkins (1957), and A indicates that the wage data comes from Allen (2001).

^a Indicates sub-period for which the positive checks were estimated with a counter-intuitive sign.

Table B.2

Estimated long-run elasticities from quantitative analysis of Section 3.

Dependent variable:	log(n_t)			log(s_t)			log(p_t)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
log(y_t) — Benchmark (Median)	0.1034***			0.1000***			0.1072***		
	(0.000)			(0.000)			(0.000)		
log(y_t) — Alternative specification (90th percentile)		0.1483***			0.2300***			0.1590***	
		(0.000)			(0.000)			(0.000)	
log(y_t) — Alternative specification (10th percentile)			0.0453***			0.0600***			0.0455***
			(0.000)			(0.000)			(0.000)
Observations	18	18	18	18	18	18	18	18	18

Notes: This table presents estimates of the long-run elasticities of fertility, survival rate and marriage rate with respect to income per capita, using the simulated data of Section 3. Standard errors robust against heteroskedasticity are in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Concerning the preventive checks, I fix δ such that the sum of the elasticities of fertility and marriage with respect to income per capita in my model is equal to the median of the long-run elasticity of the preventive checks provided by the aforementioned literature. In Table B.1, the median elasticity for the preventive checks is 0.21. Therefore, I solve $e_{n_t}^* + e_{p_t}^* = 0.21$ for δ to calibrate my model. It implies that $\delta = 0.068$ in my benchmark specification.

Table B.2 provides the elasticities e_{n_t} , e_{p_t} and e_{s_t} estimated using the data generated by model in the quantitative exercise of Section 3. This is a way of checking the accuracy of my calibration strategy. Table B.2 shows that the elasticities of the preventive and positive checks are successfully calibrated, both for my benchmark specification and for the two alternative calibrations considered. In particular, the sum of the elasticity of e_{n_t} in column 1 and e_{p_t} in column 7 gives $0.103 + 0.107 = 0.21$. This matches the target value for preventive checks, validating my calibration strategy.

Appendix C. Derivation of the speed of convergence

Taking a first-order Taylor expansion of $\psi(y_t)$ around y^* , we have:

$$\begin{aligned} \psi(y_t) &\approx \psi(y^*) + \psi'(y^*) \cdot (y_t - y^*) \\ y_{t+1} &\approx y_t - \alpha(e_{n_t} + e_{p_t} + e_{s_t}) \cdot (y_t - y^*). \end{aligned}$$

It follows that GDP per capita growth rate at the neighborhood of the steady state is:

$$g^y \equiv \frac{y_{t+1} - y_t}{y_t} \approx -\beta^* \cdot (\ln y_t - \ln y^*), \tag{C.1}$$

with $\beta^* = \alpha(e_{n_t} + e_{p_t} + e_{s_t})$ the speed of convergence to the steady-state.

In my model, population is not constant at the steady state but rather growth at the same pace as technology. To analyze the speed of convergence to the population steady state, I first need to express labor L_t in terms of effective units:

$$\widehat{L}_t \equiv \frac{L_t}{A_t}.$$

Recall Eq. (9), we can express effective units of labor as:

$$\widehat{L}_t = y_t^{-1/\alpha}. \tag{C.2}$$

Taking the logarithm of (C.2) and highlighting growth rates, we have:

$$g^{\widehat{L}} = \frac{\partial \ln \widehat{L}_t}{\partial t} = -\frac{1}{\alpha} \frac{\partial \ln y_t}{\partial t} = -\frac{1}{\alpha} g^y. \tag{C.3}$$

Using (C.3) and (C.1), we have:

$$\begin{aligned} g^{\widehat{L}} &\approx -\beta^* - \frac{1}{\alpha} \cdot (\ln y_t - \ln y^*) \\ g^{\widehat{L}} &\approx -\beta^* \cdot (\ln \widehat{L}_t - \ln \widehat{L}^*). \end{aligned} \tag{C.4}$$

It means that in a Malthusian economy, effective unit of labor converges to its steady state at the same pace than GDP per capita. Consequently, once technological progress and the size of land is hold constant, population data can be used to estimate the speed of convergence of a Malthusian economy.

Appendix D. Robustness checks and additional analysis

See Tables D.1–D.3.

Table D.1
Speed of convergence in preindustrial Europe — Robustness to alternative time intervals.

Time interval:	15 years window		35 years window	
	OLS (1)	FE (2)	OLS (3)	FE (4)
log(GDPpc)	−0.0006 (0.001)	−0.0093*** (0.003)	−0.0001 (0.001)	−0.0058*** (0.002)
Time FE	Yes	Yes	Yes	Yes
Country FE	No	Yes	No	Yes
Observations	261	261	115	115
adj. R-sq	−0.00	0.08	0.02	0.17
Half-life	1182	75	11 020	119
Half-life 95% C.I.	[254, −447]	[229, 45]	[366, −392]	[347, 72]

Notes: This table presents estimates of the speed of convergence. In particular, I test the robustness of my main results presented in Table 3, to a change of the time interval used to average the data. Columns 1 and 2 controls for time fixed effects. Columns 2 and 4, add country fixed effects. Standard errors clustered at the country level are in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Table D.2
Speed of convergence in preindustrial Europe — Robustness to time-varying control variables.

	FE (1)	FE (2)	FE (3)	FE (4)	FE (5)
log(GDPpc)	−0.0053*** (0.001)	−0.0052*** (0.001)	−0.0051*** (0.001)	−0.0051*** (0.001)	−0.0049** (0.002)
L.Statehist		−0.0196 (0.031)			−0.7573** (0.269)
L2.Statehist			−0.0078 (0.020)		1.3179*** (0.373)
L3.Statehist				−0.0037 (0.020)	−0.5790** (0.229)
L.Statehist squared		0.0286 (0.041)			1.1073** (0.444)
L2.Statehist squared			0.0514 (0.033)		−2.0834*** (0.463)
L3.Statehist squared				0.0667 (0.052)	1.0165** (0.409)
Time FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes
Observations	74	74	74	74	74
adj. R-sq	0.17	0.15	0.15	0.16	0.15
Half-life	132	133	135	137	142
Half-life 95% C.I.	[316, 83]	[334, 83]	[344, 84]	[367, 84]	[540, 82]

Notes: This table presents estimates of the speed of convergence. In particular, I test the robustness of my main results presented in Table 3, to the inclusion of the index of state history of Borcan et al. (2018) as control variable. Columns 1–5 control for time and country fixed-effects. From column 2 onward, I control for historical state presence, using different lagged and squared levels of the variable. Standard errors clustered at the country level are in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Table D.3
Speed of convergence in preindustrial Europe — Additional results and robustness using Lagerlöf (2019) simulated data.

	OLS (1)	FE (2)	diff-GMM (3)
log(GDPpc)	−0.0021*** (0.000)	−0.0056*** (0.000)	−0.0055*** (0.000)
Time FE	Yes	Yes	Yes
Country FE	No	Yes	Yes
Observations	20 000	20 000	19 000
adj. R-sq	0.05	0.10	.
AR(3)			0.75
Hansen			0.50
Instruments			37
Half-life	325	124	126
Half-life 95% C.I.	[357, 297]	[132, 117]	[150, 108]

Notes: This table presents estimates of the speed of convergence using simulated GDP per capita data from Lagerlöf (2019). See Section 4.1 for more details on Lagerlöf (2019) simulated data. Column 1 controls for time fixed effects only. Column 2 adds country fixed effects. Finally, column 3 performs a difference-GMM estimation. In particular the diff-GMM estimation uses the third and further lagged levels of GDP per capita as instruments. I use a collapsed matrix of instruments and report the number of instruments. The AR(3) row reports the p -value of a test for the absence of third-order correlation in the residuals. Standard errors clustered at the country level are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Data availability

Replication data and code are available at openICPSR: <https://www.openicpsr.org/openicpsr/project/209662/version/V1/view>.

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