Inequality and the Industrial Revolution*

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Abstract. In this paper, we propose a new theory for why income inequality can be conducive to early industrial development. Technological advances in agriculture and population growth increase land rents relative to wages and as the landed elites become richer, demand for manufactured goods increases, which in turn facilitates industrialization. Using data for Britain over the period 1270-1940, we show that increasing inequality was a major contributor to the expansion of the manufacturing sector. Taking into account the more well-known drivers of modern growth, we find that inequality is a major contributor to the British Industrial Revolution, alongside foreign trade, education, technological knowledge and, to some extent, institutions.

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1. Introduction

Following in the footsteps of the classical economists, this study argues that increasing demand for manufactured goods by the landowning class contributed to the British Industrial Revolution. However, in contrast to the classical economists who emphasize an increasing preference for new luxury goods, we argue that demand by the landed class for manufactured consumer goods was fueled by rising land rents. When a sufficiently large part of the population works in agriculture, advances in productivity and population growth increase land rents and, therefore, the income gap between workers and the landed class. The increasing purchasing power of the landed class in turn results in an increasing demand for manufactured consumer goods; thus promoting industrialization by creating a larger market for manufactures.[1]

The evidence suggests that increasing land rents were not channeled into fixed investment and lending to urban entrepreneurs (Mokyr, 1977; Allen, 1994; Doepke and Zilibotti, 2008). The share of agricultural investment in total economy-wide income fluctuated around a relatively constant level of about 8% over the period 1210-1500 before declining gradually to a low of 1-2% by the end of the 19th century (Madsen, 2017); thus, suggesting that the increasing rent-wage ratio did not materialize in a higher investment ratio. Furthermore, the evidence indicates that only a marginal share of the income expansion in agriculture found its way to manufacturing enterprises during the 18th century (Allen, 1994). Finally, when the landed class moved into urban centers in the 18th century, they reduced expenses on 'hospitality' in order to further their consumption of manufactured goods (Brewer, 1998). This means that in the 18th and 19th centuries an increasing share of the budget of the landed class went into manufactured consumer goods.

In order to show the path from productivity advances in agriculture to industrialization through the channel of inequality, we develop a two-class two-sector unified growth model. Individuals are either landowners or landless workers and they obtain utility from consumption of agricultural goods and manufactured goods and from having children. Agricultural goods are also needed for child development. Due to limited land, workers face declining marginal labor productivity in agriculture and there exists an equilibrium where workers cannot afford luxury items from the manufacturing sector. Innovations in both sectors are driven by learning-by-doing and are thus scale-dependent. Labor is initially employed primarily in agriculture so that innovation-driven productivity grows mostly in agriculture, leading to falling relative prices of food that promote better nutrition and rising fertility and population growth.

Advances in land productivity gains and the induced increase in the labor force push up the rent-to-wage ratio and results in an increase in income inequality. The increasing income of landowners allows them to increase their demand for manufactured goods and, gradually, the manufacturing sector expands. As the manufacturing scale increases, so does the rate of innovation and productivity growth in manufacturing. Rising productivity in manufacturing eventually makes luxury goods affordable for everyone. A turning point of the inequality-driven growth process is reached when the rate of innovation in manufacturing exceeds that of agriculture

[1] The Industrial Revolution is defined as the process of change from a predominantly agrarian economy to one dominated by industry and machine manufacturing.

and the relative price of manufactured goods declines, which leads to the onset of the fertility transition. With the declining employment in agriculture and rising wages, the rent-wage ratio decreases and further economic advances are no longer positively associated with inequality. In this setup, early industrialization is fueled by the increasing income of the landed elite and, ceteris paribus, higher inequality leads to earlier and faster industrialization and modern growth.

Similar to the reasoning here, rising demand for manufactured goods was the leading explanation given by classical economists for industrialization in Britain. The demand hypothesis was suggested by Hume in the mid-18th century, then further developed by Adam Smith and Malthus in the late 18th century, and later by Gilboy and Keynes in the first half of the 20th century (for discussion and analysis, see Mokyr, 1977; Brewer, 1998; Fiaschi and Signorino, 2003). Hume argues that agriculture in the pre-industrial period was underperforming because of the indolence of the landed class, caused by a lack of attractive manufactures (Brewer, 1998). For Smith, the increasing taste for sophisticated manufactured goods induced landlords to relax the conditions of the lease of their tenants to allow them to implement more efficient agricultural techniques that, consequently, pay higher rents. In Smith's words; 'once luxury became fashionable, landlords cared more about maximizing rent than about maintaining their hold over their tenants and agreed to more secure tenancies in return for higher rents' (Smith, 1869, 158-9). In his analysis of the industrialization, Malthus extends the consumption possibility frontier to include leisure and considers consumption of processed manufactured goods as substitutes for leisure (Fiaschi and Signorino, 2003). Summarizing, although the hypothesis that increased consumerism fueled Britain's industrialization is old, our proposed mechanism, operating through increasing inequality and increasing demand from the landowning class, is new.

In the second part of the paper, we corroborate the predictions of the model with empirical evidence. Using novel data for Britain, we demonstrate that British industrialization prior to the fertility transition was preceded by increasing income inequality measured by the agricultural land rent-wage ratio, the land-labor-income ratio, and the ratio between operating surplus and labor income.[2]

We also consider the more well-known drivers of modern growth and find that inequality is a major contributor to the British Industrial Revolution, alongside foreign trade, education, technological knowledge and, to some extent, institutions.

Our study relates to the extensive literature on factors that contributed to the British Industrial Revolution (see, for example, North and Weingast, 1989; Acemoglu, et al., 2005; Galor, 2005, 2011; Clark, 2008; Allen, 2009; Crafts, 2011; Kelly et al., 2014; Mokyr, 2011, 2018; Fernihough and O'Rourke, 2021; Chu et al., 2022). Specifically, it relates to the classic literature on consumerism and agricultural development (as explained above) and to the literature emphasizing that productivity advances in agriculture enabled the increasing supply of labor to manufacturing and the expansion of manufacturing (Allen, 1994; Matsuyama, 1992; Koegel and Prskawetz, 2001; Strulik and Weisdorf, 2008; Chu et al., 2022). Our study shares with most theoretical expositions of long-run development that increasing population, driven primarily by

[2]Throughout the paper we refer to Britain as a generalization for England, Britain and the UK. The data are mostly for England before approximately 1700, Britain over the approximate period 1700-1810, and the UK thereafter. All data are scaled up to current UK borders.

productivity advances under the Malthusian regime, fuels economic growth through increasing returns to scale and learning-by-doing (Kremer, 1993; Goodfriend and McDermott, 1995; Galor and Weil, 2000; Jones, 2001; Strulik et al., 2013). Here, however, we emphasize that the increasing demand for manufactured goods runs through increasing inequality. Industrialization is initiated and driven by the increasing income of the elite that was not tied to Malthusian forces and is therefore able to convert increasing agricultural productivity into demand for manufactured goods.

Our model can be best conceptualized as a unified growth theory constructed from elements of the two-sector, one-class model of Strulik and Weisdorf (2008) and the one-sector, two-class model of Madsen and Strulik (2020). Since our focus is on the early industrialization period before the onset of the fertility transition, we deliberately neglect education and human capital in the model. Human capital and the child-quantity-quality trade-off and its interaction with technological progress is a major driver of industrialization after the onset of the fertility transition (Galor and Weil, 2000; Galor and Moav, 2002; Madsen and Strulik, 2023). For the first phase of industrialization, the consensus view ascribes a limited role to child quantity-quality considerations in families and to human capital in the production process (see, for example, the discussion in Clark, 2008, Ch. 11, and Galor, 2011, Ch. 2).

Of the many studies of unified growth theory, the model of Galor et al. (2009) is particularly related to our model since it derives, in a seemingly similar setting, an ostensibly conflicting conclusion to ours, namely that *less* inequality promotes industrialization. However, their focus is on the Second Industrial Revolution, their channel emphasizes human capital investments, and their theory is based on a political-economy mechanism. In contrast, we focus on the onset and first phase of industrialization when human capital played a minor role in production and workers' demand for manufactured goods was low. Our theory is also related to the model of Chu et al. (2020) on status-seeking behavior of individuals and how it facilitated the development of capitalism and an early industrialization.

The remainder of the paper is organized as follows. In Section 2, we set up the model and derive the theoretical results. We illustrate long-run development and the role of inequality with a parameterized version of the model in Section 3. In the main text, we discuss the simplest dynamic general equilibrium model that illustrates the inequality mechanism. In the Appendix, we discuss an extended model that also includes international trade and capital accumulation, and we show that all major results are preserved. In Section 4, we introduce the estimation method and the data. The empirical results are presented in Section 5, and Section 6 concludes the paper.

2. The Model

2.1. **Households and Society.** Consider an economy populated by two classes, workers (of size L_t at time t) and landowners (of size L_t^X). Landowners supply land (of total size X) and each worker supplies one unit of labor. Members of both classes share the same utility function:

$$u_t = m_t + \beta \log c_t + \gamma \log n_t, \tag{1}$$

in which m_t is consumption of manufactured goods, c_t is consumption of agricultural goods, and n_t is the number of children. The utility function introduces a hierarchy of needs (Maslow, 1943). Since m_t enters linearly in u_t while c_t and n_t enter logarithmically, consumption of agricultural goods is a necessity while consumption of manufactured goods is a luxury. The quasi-linear form of u_t greatly simplifies the analysis but it is not necessary for the results. Essential for a hierarchy of needs is that the elasticity of intertemporal substitution is higher for manufactured goods than for agricultural goods.

Rearing a child requires a certain input of agricultural goods. We take this input as exogenously given and normalize it to one unit per child. The budget constraint of households is thus given by

$$y_t = m_t + p_t c_t + p_t n_t, \tag{2}$$

in which p_t is the relative price of agricultural goods and y_t is income. Income is generated according to class assignment from either work, such that $y_t = W_t$, or from land supply, such that $y_t = R_t X / L_t^X$, in which W_t and R_t are the wage rate and the rent on land.

Maximizing (1) subject to (2) provides the interior solution:

$$c_t = \frac{\beta}{p_t}, \qquad n_t = \frac{\gamma}{p_t}, \qquad m_t = y_t - \gamma - \beta, \qquad \text{for } y_t > \gamma + \beta. \tag{3}$$

If income is sufficiently low, a corner solution for demand for manufactured goods applies:

$$c_t = \frac{\beta}{\beta+\gamma}\frac{y_t}{p_t}, \qquad n_t = \frac{\gamma}{\beta+\gamma}\frac{y_t}{p_t}, \qquad m_t = 0, \qquad \text{for } y_t \leq \gamma + \beta. \tag{4}$$

At the corner solution, individuals spend all income on food and income exerts a positive impact on fertility. We then say that the subsistence constraint is binding. The model can be extended by assuming that individuals must consume a minimum (subsistence) level of non-food items. Such a constraint would add more realism but provides no additional insights and is therefore omitted for simplicity.

2.2. **Production.** Production is constant returns to scale in both sectors. Production in agriculture needs labor and land as inputs while production in manufacturing needs only labor. In the Appendix we discuss an extended model with essential physical capital in manufacturing and show that all main results are preserved. For simplicity, we assume a Cobb-Douglas technology, which implies that technological progress is unbiased. Let Y_t^j denote output of sector j at time t, with $j = A$ for agriculture and $j = M$ for manufacturing. Let L_t^j denote sectoral inputs of labor. Production is then given by:

$$Y_t^A = A_t \left(L_t^A\right)^{\alpha} X^{1-\alpha}, \tag{5}$$

$$Y_t^M = M_t L_t^M, \tag{6}$$

in which α is the labor share in agriculture, and A_t and M_t are the total factor productivities (TFP) in agriculture and manufacturing, respectively. We omit human capital in production. Adding human capital and education would introduce the child-quantity-quality mechanism and therewith the standard mechanism for the take-off to growth (e.g., Galor and Weil, 2000). Here, we want to establish a new mechanism based on the interaction between technological progress, income of the elite, and population growth. The new channel can be established most efficiently as a stand-alone mechanism. Introducing education as another driver of the takeoff to growth would blur the new mechanism. As discussed in the Introduction, education played an inferior role in the first Industrial Revolution. In the econometric analysis we control for education as a potential confounder.

From (5) and (6) we obtain land rents and wages as

$$R_t = p_t(1-\alpha)A_t \left(L_t^A\right)^{\alpha} X^{-\alpha} \tag{7}$$

$$W_t = p_t \alpha A_t \left(L_t^A\right)^{\alpha-1} X^{1-\alpha} = M_t, \tag{8}$$

where the last equality holds in labor market equilibrium.

2.3. **Dynamics.** For the model of the main text, we assume that the classes do not mix such that there is no upward or downward mobility. In the Appendix, we alternatively consider a setup where only one child of any landlord inherits the land and the remaining children enter the workforce (strong primogeniture). Since landowners are a small fraction of the total population, the alternative assumption changes the quantitative solution only marginally and preserves all qualitative conclusions. We furthermore assume that only an exogenously given fraction, π_t, of children reach adulthood. The inclusion of child mortality does not affect the theoretical results, but makes it easier to calibrate the model to the data. Next period's number of landowners is thus obtained as $L_{t+1}^X = (\pi_t \gamma / p_t) L_t^X$ and next period's workforce is obtained as

$$L_{t+1} = \begin{cases} \frac{\pi_t \gamma}{\beta+\gamma} \frac{M_t}{p_t} L_t & \text{for } M_t \leq \beta + \gamma \\ \frac{\pi_t \gamma}{p_t} L_t & \text{otherwise.} \end{cases} \tag{9}$$

Finally, we assume that sectoral TFP grows via learning-by-doing such that

$$A_{t+1} = A_t + \mu \left(Y_t^A\right)^{\epsilon} \quad \Rightarrow \quad g_t^A = \mu \left(Y_t^A\right)^{\epsilon} / A_t \tag{10}$$

$$M_{t+1} = M_t + \delta \left(Y_t^M\right)^{\phi} \quad \Rightarrow \quad g_t^M = \delta \left(Y_t^M\right)^{\phi} / M_t, \tag{11}$$

where here, and henceforth, g_t^z denotes the growth rate of any variable z in period t, $g_t^z \equiv (z_{t+1} - z_t)/z_t$.

2.4. **Static Equilibrium.** In labor market equilibrium workers are fully employed:

$$L_t = L_t^A + L_t^M. \tag{12}$$

We first solve for the goods market equilibrium when the subsistence constraint binds for workers. The goods market equilibrium is described by (13) and (14):

$$A_t \left(L_t^A\right)^{\alpha} X^{1-\alpha} = \frac{M_t L_t}{p_t} + \frac{(\beta+\gamma) L_t^X}{p_t} \tag{13}$$

$$M_t L_t^M = p_t (1-\alpha) A_t \left(L_t^A\right)^{\alpha} X^{1-\alpha} - (\beta+\gamma) L_t^X. \tag{14}$$

It is explained as follows. When the subsistence constraint binds, workers spend all their income, $y_t = W_t = M_t$, on agricultural goods such that food demand from all workers is given by $M_t L_t / p_t$. Landowners are not bound by subsistence such that any landowner family spends

$(\beta+\gamma)/p_t$ on food, see (3). Since there are L_t^X landowners, their food demand is given by $(\beta+\gamma)L_t^X/p_t$. Equilibrium condition (13) states that food supply on the left-hand side equals aggregate demand on the right hand side. Aggregate demand for manufactured goods is given by aggregate income of landowners minus landowners' spending on agricultural goods. Aggregate income of landowners is given by $R_tX = p_t(1-\alpha)A_t\left(L_t^A\right)^\alpha X^{1-\alpha}$ and food expenditure of landowners is given by $p_t(c_t+n_t)L_t^X = (\beta+\gamma)L_t^X$. Demand for manufactured goods is given by aggregate income of landowners' minus aggregate food demand of landowners. The equilibrium condition (14) states that supply of manufactured goods on the left-hand side equals aggregate demand on the right-hand side.

As long as workers are tied to subsistence, aggregate demand and production of manufactured goods can only increase as landowners become richer, as shown in equation (14). When workers become richer, aggregate demand for agricultural goods increases, as shown in equation (13). These observations provide a first indication that increasing inequality in terms of higher rent-wage ratios could promote industrialization, understood as increasing employment in the manufacturing sector.

Solving (13) and (14) for the equilibrium price and allocation of employment, we obtain:

$$L_t^M = (1-\alpha)L_t - \frac{\alpha(\beta+\gamma)L_t^X}{M_t}, \tag{15}$$

$$p_t = \frac{M_tL_t + (\beta+\gamma)L_t^X}{A_t\left(L_t - L_t^M\right)^\alpha X^{1-\alpha}}. \tag{16}$$

Notice that an increase of TFP in agriculture (A_t), ceteris paribus, reduces the relative price of agricultural goods while an increase of TFP in manufacturing (M_t) increases the relative price of agricultural goods as well as the number of workers in manufacturing. Equations (15) and (16) are the solution of the model because all variables on the right hand side are predetermined in period t, i.e., given by the fertility and production decisions of period $t-1$.

We next consider the equilibrium when workers are not bound by subsistence. In this case, food spending of workers equals that of landowners and food demand per family is given by $c_t + n_t = (\beta+\gamma)/p_t$ (see (3)) such that aggregate food demand is given by $(\beta+\gamma)(L_t+L_t^X)/p_t$. Food market equilibrium is thus established by equation (17). Demand for manufactured goods is obtained by subtracting aggregate food spending from aggregate income. Aggregate income consists of income of all workers, M_tL_t, plus income of all landowners, $p_t(1-\alpha)A_t\left(L_t^A\right)^\alpha X^{1-\alpha}$. The resulting manufactured goods equilibrium is stated in (18).

$$A_t\left(L_t^A\right)^\alpha X^{1-\alpha} = \frac{(\beta+\gamma)\left(L_t+L_t^X\right)}{p_t} \tag{17}$$

$$M_tL_t^M = M_tL_t + p_t(1-\alpha)A_t\left(L_t^A\right)^\alpha X^{1-\alpha} - (\beta+\gamma)(L_t+L_t^X). \tag{18}$$

The equilibrium conditions (17) and (18) are solved for the equilibrium price and factor allocation:

$$L_t^M = L_t - \alpha(\beta+\gamma)\frac{\left(L_t+L_t^X\right)}{M_t}, \tag{19}$$

$$p_t = \frac{(\beta+\gamma)\left(L_t + L_t^X\right)}{A_t\left(L_t - L_t^M\right)^{\alpha} X^{1-\alpha}}. \tag{20}$$

2.5. **Results: Inequality and Industrialization.** Following O'Rourke and Williamson (2005), we measure inequality by the rent-wage ratio. From (7) and (8),

$$\frac{R_t}{W_t} = \frac{p_t(1-\alpha)A_t(L_t^A)^{\alpha}X^{-\alpha}}{M_t}. \tag{21}$$

Equation (21) shows that, ceteris paribus, inequality rises with technological progress in agriculture (rising A_t) and growth of the agricultural workforce (L_t^A) whereas it declines with technological progress in manufacturing (rising M_t) and with structural change (the move of employment from agriculture to manufacturing).

Proposition 1 (Inequality and Industrialization)**.** *The size of the manufacturing sector is positively associated with inequality, i.e.,*

$$L_t^M = \left(\frac{R_t}{W_t}\right)X - \frac{\beta+\gamma}{M_t}L_t^x \qquad \textit{for } M_t < \beta+\gamma \tag{22}$$

$$L_t^M = \left(\frac{R_t}{W_t}\right)X + L_t - \frac{\beta+\gamma}{M_t}(L_t + L_t^x) \qquad \textit{otherwise.} \tag{23}$$

For the proof of (22), we insert (21) into (14) and solve for L_t^M. For the proof of (23), we insert (21) into (18) and solve for L_t^M. Notice that, aside from R_t/W_t, all variables on the right-hand side of equation (23) are pre-determined in period t. Since inequality is endogenous, however, causality is less straightforward to infer. What can be said is that, ceteris paribus (i.e. controlling for population size and the level of technology), the economy in which inequality is greater has the larger manufacturing sector. A stronger statement can be made for the early phase of industrialization.

Corollary 1. *As long as workers are bound by subsistence needs, there exists a positive one-to-one association between industrialization and rising inequality.*

This claim is verified by inspection of (22). Industrial technology M_t and the number of landlords L_t^X are state variables. They are predetermined and thus invariant in period t. Therefore, L_t^M can only rise when inequality increases. Intuitively, since manufactured goods are only demanded by the landed elite, demand for manufactured goods increases when landowners become relatively richer. With increasing expansion of employment in manufacturing, learning-by-doing leads to improvements in technology M_t, which in turn dampens the expansion of the manufacturing sector because fewer workers are needed to produce the demanded goods. So it is rising inequality that keeps industrialization going in its early stages. Rising inequality is fueled by growth of the agricultural workforce since workers are still in the Malthusian regime where increasing labor productivity leads to higher fertility.

Industrialization is still positively associated with inequality after workers have left subsistence, see (23). However, it is now also fueled by the growing working population, L_t. This population push mechanism eventually becomes the dominating force and explains why industrialization continues in its later stages although inequality declines. The next proposition eliminates the scale effect from population growth and provides an alternative view on industrialization.

Proposition 2 (Functional Income Distribution and the Manufacturing Employment Share)**.** *The manufacturing employment share is positively associated with the land-labor-income ratio, $(R_tX)/(W_tL_t)$, i.e.,*

$$\frac{L_t^M}{L_t} = \left(\frac{R_tX}{W_tL_t}\right) - \frac{(\beta+\gamma)L_t^X}{L_tM_t} \qquad \textit{for } M_t < \beta+\gamma \tag{24}$$

$$\frac{L_t^M}{L_t} = \left(\frac{R_tX}{W_tL_t}\right) + 1 - \frac{(\beta+\gamma)(L_t+L_t^x)}{L_tM_t} \qquad \textit{otherwise.} \tag{25}$$

Proposition 2 is simply obtained by dividing (22) and (23) by L_t. While the manufacturing employment share may be considered an intuitively more appealing measure of industrialization than the level of employment, these equations are less useful for scrutinizing the role of inequality in the early stages of industrialization. To see why, notice that rising inequality, R_t/W_t, is consistent with a constant land-labor-income ratio, $(R_tX)/(W_tL_t)$, when R_t/W_t grows at the same rate as the work force, L_t. As shown below, early industrialization, measured as increasing L_t^M, can be propelled by rising inequality (considered in Proposition 1) with little change in the land-labor-income ratio and the manufacturing employment share (considered in Proposition 2).

2.6. **Results: Transition after Early Industrialization.** We next characterize the transition to the steady-state that happens after early industrialization, i.e., after productivity in manufacturing has grown to a level that allows workers to leave subsistence. After workers have left subsistence, the fertility rates of workers and landowners coincide (see (3)) such that the ratio between landowners and workers remains constant at a certain level, denoted by $\lambda \equiv L_t^X/L_t$.

Proposition 3 (Structural Change)**.** *After workers have left subsistence, the share of workers employed in agriculture declines at the rate of TFP in manufacturing.*

Proof. Inserting (19) into (12) and replacing $L_t^X = \lambda L_t$, we obtain the employment share in agriculture:

$$\frac{L_t^A}{L_t} = \frac{\alpha(\beta+\gamma)(1+\lambda)}{M_t}. \tag{26}$$

The agricultural share of employment converges to zero with growing productivity in manufacturing. This result can also be interpreted as an expression of Engel's law. As people get richer (as $W_t = M_t$ rises), they spend a declining share of their income on agricultural goods.

Proposition 4 (Fertility Transition)**.** *The fertility transition is initiated when productivity in manufacturing grows at a sufficiently high rate, i.e., fertility declines iff $(1-g_t^M)^\alpha > (1+g_t^A)/(1+g_t^L)^{1-\alpha}$.*

Proof. Inserting $L_t^X = \lambda L_t$ into (20) and substituting $L_t - L_t^M = L_t^A$ in (20) by (26), we obtain the relative price of agricultural goods as:

$$p_t = \frac{[(\beta+\gamma)(1+\lambda)]^{1-\alpha}}{\alpha^\alpha}\frac{M_t^\alpha L_t^{1-\alpha}}{A_t} \qquad \Rightarrow \qquad 1+g_t^P = \frac{(1+g_t^M)^\alpha(1+g_t^L)^{1-\alpha}}{(1+g_t^A)}. \tag{27}$$

As shown in (3), fertility declines when the relative price of agricultural goods increases, i.e., for $g_t^P > 0$. From (27) we see that this requires the condition stated in Proposition 4.

Proposition 5 (Timing)**.** *Inequality starts declining after the onset of the fertility transition.*

Proof. Inserting $L_t^X = \lambda L_t$ into (20) and then the result into (21), we see that inequality starts declining when (for the first time) $g_t^M > g_t^L$ and thus $1 + g_t^M > 1 + g_t^L > (1 + g_t^L)^{(\alpha-1)/\alpha}$ since $g_t^L > 0$. It therefore holds that $(1 + g_t^M)^\alpha > 1/(1 + g_L)^{1-\alpha} > (1 + g_A)/(1 + g_L)^{1-\alpha}$ since $g_t^A > 0$. From Proposition 4, it then follows that inequality starts declining after the onset of the fertility transition.

A steady state is defined as a situation where prices, factor shares, population size, and sectoral TFP are constant or grow at a constant rate. The long-run behavior of the economy is characterized by the following features.

Proposition 6. *(i) There always exists a steady state with zero population growth. (ii) A steady state with positive population growth exists only for the knife-edge case where $\alpha = 1 - \epsilon$.*

Proposition 7. *(i) There exists no long-run growth with negative population growth. (ii) A sufficient condition that rules out explosive growth is $\alpha < 1 - \epsilon$.*

The steady state results are similar to those for the one-class economy in Strulik and Weisdorf (2008) and the proof of the propositions is thus relegated to the Appendix. The results imply that for $\alpha < 1 - \epsilon$, long-run dynamics are characterized by convergence towards a steady state with stationary population and no economic growth. This is the most plausible path, since the alternatives are explosive growth (population size becomes infinite in finite time) and growth on-the-knife-edge in the case of a specific parameter constellation (that occurs with zero probability). Proposition 6 fully characterizes economic development after the fertility transition. For a correct assessment, recall that the model does not include human capital accumulation or market R&D activities, i.e., the most important factors that could make long-run growth infinitely sustainable are missing.

The knife-edge case from Proposition 6 characterizes a degenerate scenario of economic growth without industrialization and without fertility transition. An exploding population generates sufficient technological progress in agriculture such that the relative price of agricultural goods converges to zero and fertility converges to infinity (or a biological defined maximum fecundity rate). This unobserved development can be ruled out for quickly decreasing returns of labor in agriculture (low α) and quickly decreasing returns of learning-by-doing (low ϵ). Moreover, there are parameter constellations that support a stable Malthusian steady state, in which the economy and the population are stationary and there is (asymptotically) no technological progress. This is obvious when considering the case $\epsilon \to 0$ or $\mu \to 0$.

To examine the extent to which our model can explain the Industrial Revolution, we conduct a calibration study in Section 3 and a regression analysis in Sections 4 and 5. The calibration study demonstrates the model's ability to explain the course and timing of British industrialization. The regression analysis shows that inequality is a significant and robust determinant of the industrial production and employment.

3. Early Industrialization and Long-Run Development: A Calibration Study

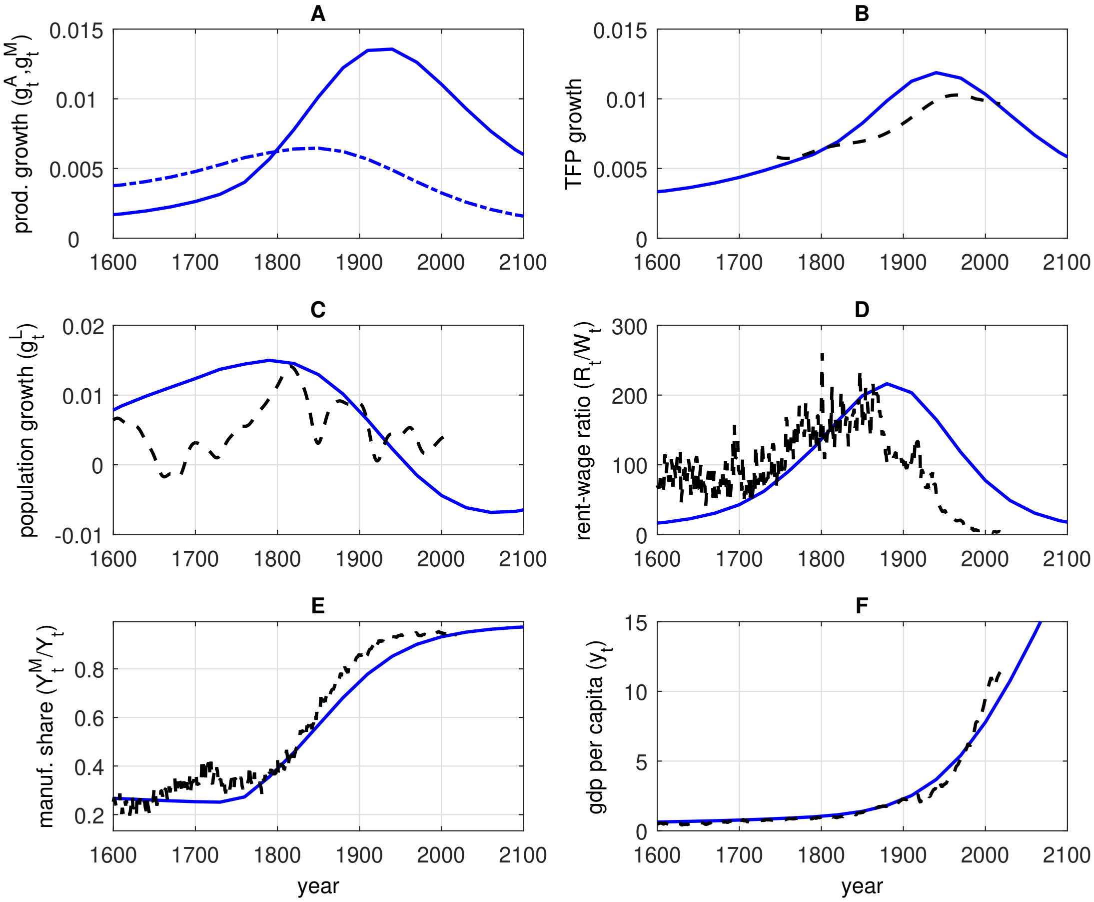
3.1. **Benchmark Economy.** In this section we illustrate the path of convergence towards the steady state and the impact of inequality on early industrialization. We calibrate a benchmark economy with data for Great Britain from the year 1600 to the year 2100. The model period is 30 years and the growth rates are annualized to allow for a better quantitative assessment. Given our simple model, which emphasizes one channel of industrialization and neglects a plethora of other potential influences, it is clear that the model's predictions will not provide a perfect picture of the British economy. Specifically, we target the following time series: (i) average growth of total factor productivity (TFP), (ii) population growth, (iii) the rent-wage ratio, the employment share in manufacturing, and the wage (of unskilled labor) in manufacturing.

For the model's prediction of TFP growth we compute the weighted growth rate of sectoral TFP, A_t and M_t, where the weights are the predicted sectoral shares in aggregate output. The TFP data are from Madsen (2017). Predicted population growth is computed as the annualized rate of growth of the working population, $\pi_t n_t - 1$. The fertility rate predicted by the model is multiplied by the child survival rate, which is assumed to be constant at 0.6 until the year 1720 and then increases at a constant rate to 0.99 in the year 2000 (this trend approximates the calibrated time series in Bar and Leukhina, 2010). The data series for population are from Madsen (2017). In order to smooth out the large fluctuations in the annual growth rates, we compute 30-year-moving averages for TFP growth and 5-year-moving averages for population growth. The data for the computation of the rent-wage ratio and the GDP share of manufacturing production are at the center of our empirical analysis and their construction is explained in detail in Section 4.2. In order to compare the structural change predicted by the two-sector model with the data, we take the data series for Y_t^A and Y_t^M and compute $Y_t^M/(Y_t^A + Y_t^M)$ as the model-equivalent GDP share of manufacturing. Finally, we target the evolution of GDP per capita with data taken from Bolt and van Zanden (2020). For the comparison, we normalize both the model prediction and the data series such that GDP in 1800 is 1. The targeted time series are shown by the black (dashed) lines in Figure 1.

The blue (solid) lines in Figure 1 show the model's prediction from 1600 to 2100 for the parameter set $X = 1$, $\alpha = 0.72$, $\beta = 1.14$, $\gamma = 1.90$, $\delta = 0.055$, $\epsilon = 0.6$, $\phi = 0.6$, $\mu = 0.14$, and the initial values $A_0 = 7$, $M_0 = 2$, $L_0 = 6$ and $L_0^X = L_0/100$. In the calibrated economy, workers leave the subsistence constraint in the year 1760; population growth reaches a maximum in 1800, the rent-wage ratio reaches a maximum in 1880, and TFP growth reaches a maximum in 1950. Compared with the data, population and TFP peak a bit too early while the rent-wage ratio peaks too late and declines too slowly. The slow decline of the rent-wage ratio is likely an artefact of the omission of human capital and the takeoff of mass education in the model. Overall, however, the model is reasonably good at predicting the level and turning points of the targeted time series.

The simulated economy starts in a backward position where workers' demand is constrained by subsistence needs and the growth rate of technology is low in both sectors and in the aggregate (Panels A and B). In panel A, the dashed line shows TFP growth in agriculture and the solid line shows TFP growth in manufacturing. Since labor is initially mostly allocated to food

Figure 1: Long-Run Development: Calibration

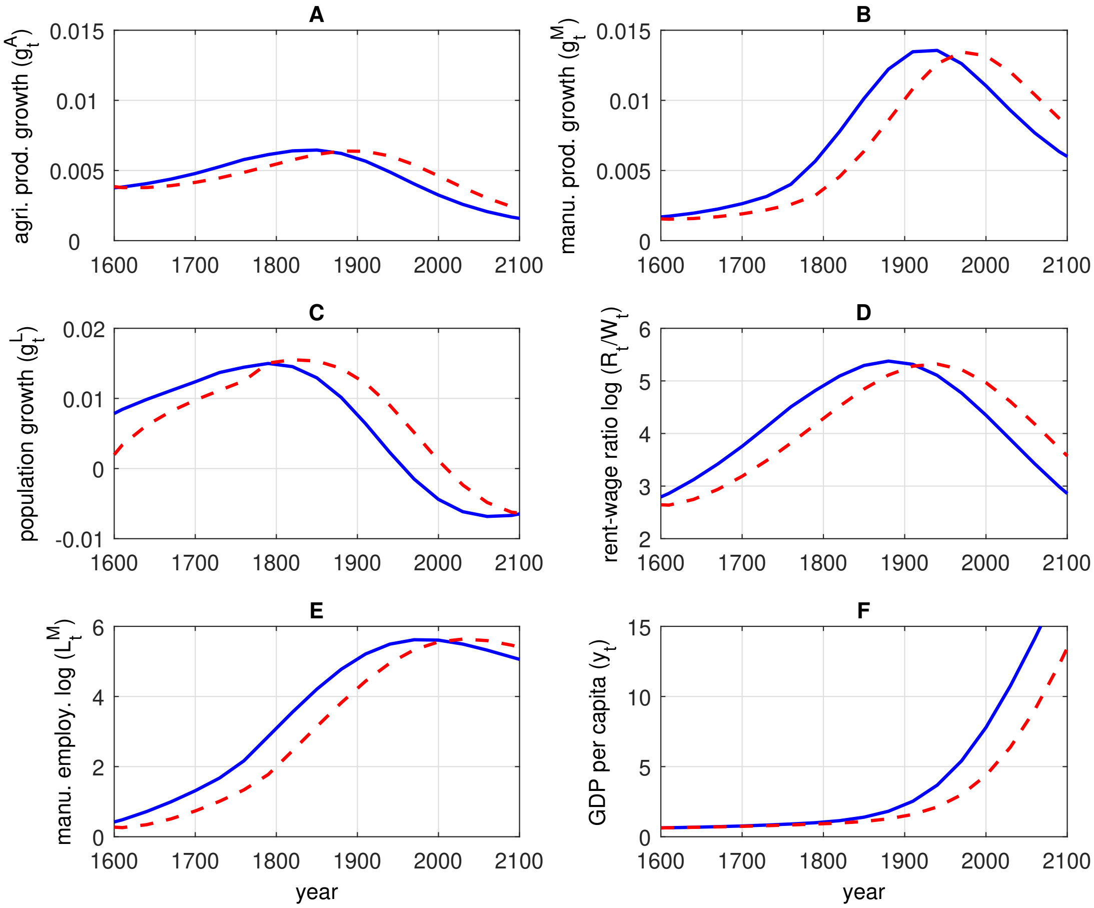


Blue (solid) lines: benchmark economy; Black (dashed) lines: data for Britain. See text for details. Panel A: solid line: TFP growth in manufacturing; dashed line: TFP growth in agriculture.

production, technological progress is higher in agriculture than in manufacturing. Gradually improving productivity in agriculture leads to increasing inequality (Panel D). Workers are in the Malthusian regime where improvements in productivity are mainly used to expand fertility. The rising workforce in agriculture dampens the growth of wages but amplifies the growth of land rents. Landowners thus benefit directly from technological progress in agriculture and indirectly via the expansion of the agricultural workforce that is caused by technological progress in agriculture.

The higher income of the landed elite fuels demand for manufactured goods and the manufacturing sector (which could be a cottage industry in the beginning) gradually expands. The early industrialization effect is most visible by the slowly improving TFP in manufacturing (solid line in panel A). It is not visible in the GDP share of manufacturing because agricultural production also expands due to the growing workforce. After workers are no longer bound by subsistence and start demanding manufactured goods, manufacturing output (panel E) and productivity (panel A) take off. Around the year 1800, productivity growth in manufacturing exceeds productivity growth in agriculture, the relative price of agricultural goods increases, and population growth declines. Eventually a point is reached at which productivity growth in manufacturing exceeds population growth and inequality starts declining (Panel D). The economy is now in the phase of its highest productivity growth. With further growth, decreasing returns to learning-by-doing reduce the growth rate of TFP and the economy gradually adjusts from above towards its steady state (Proposition 6 and Panel B in Figure 1).

Figure 2: Inequality and Industrialization



Blue (solid) lines: benchmark economy; red (dashed) lines: economy with lower inequality due to initially 20% lower level of agricultural technology, other parameters and initial values as for the benchmark case).

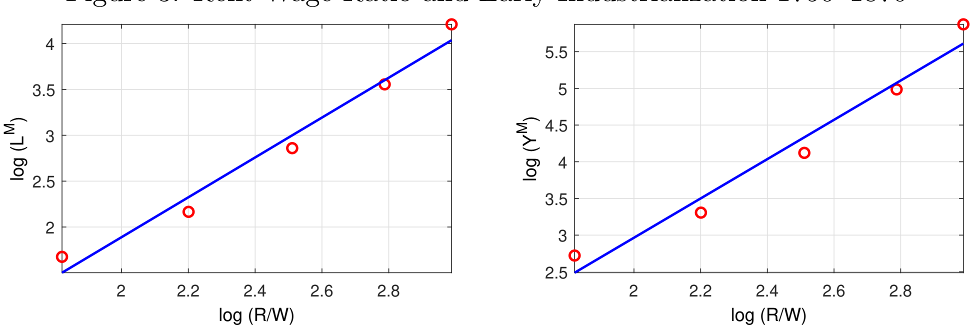
3.2. **Inequality and Early Industrialization.** There are different ways to show a causal effect of income inequality on industrialization in terms of comparative dynamics analysis. Here, we focus on inequality driven by technology and consider a hypothetical economy where everything is like in the calibrated British economy but the initial endowment with agricultural technology A_0 is lower than in Britain (perhaps because there were fewer learning opportunities associated with domestication of plants and animals, Diamond, 1997). As explained above, lower agricultural productivity reduces land rents directly as well as indirectly via lower growth of the workforce. Lower land rents reduce the income of land owners who are the sole driver of demand for manufactured goods as long as workers are tied by subsistence needs. Since lower demand means lower levels of production and therewith lower productivity growth in manufacturing, we expect that the hypothetical economy will industrialize later and more slowly than the benchmark economy.

The results are shown in Figure 2. The blue (solid) lines replicate the benchmark run from Figure 1 albeit in a slightly modified diagram in order to improve the visualization of the inequality and industrialization paths. Panel D shows the log of the rent-wage ratio and panel E shows the log level of employment in manufacturing. We have also separated the diagrams for TFP growth in agriculture (panel A) and manufacturing (panel B). The development for the economy with 20% lower A_0 is shown by the red (dashed) lines. Because landowners are relatively poorer, demand for manufacturing goods is lower, the manufacturing sector expands at a slower pace, workers leave the subsistence constraint at a later stage, and the takeoff of the manufacturing sector occurs later. As a consequence, the decline in inequality also eventuates later.

3.3. **Inequality and Development within Countries.** Finally, we inspect more thoroughly the predicted within-country association between the rent-wage ratio and the level of employment and output of the manufacturing sector. We focus on the early period of industrialization, 1750–1870. The results are shown in Figure 3. The association between the log of the rent-wage ratio and the log of employment in manufacturing predicted by the benchmark model is shown by circles in the panel on the left-hand. The association between inequality and industrialization appears to be about linear in logs.

The panel on the right-hand side of Figure 3 shows the predicted association between the log of the rent-wage ratio and the log of manufacturing output, which is our preferred dependent variable in the empirical analysis due to data availability. Again, the association is almost linear in logs.

Figure 3: Rent-Wage Ratio and Early Industrialization 1750–1870



Red circles: model prediction; blue line: regression line.

In the Appendix we show the robustness of the inequality-industrialization nexus for a model extended by international trade and capital accumulation. The main effect of international trade is that it delays the fertility transition because the import of cheap food reduces the cost of children. In the Appendix we also show the robustness of the results when introducing strong primogeniture, such that one child per landowner inherits all the land and the other children enter the labor market.

4. Empirics

In this section, we take the calibration exercise of the last section a step further by testing whether income inequality is a significant determinant of industrialization in Britain and whether the significance of inequality is robust to the inclusion of confounders that have been highlighted in the literature as key determinants of the British Industrial Revolution. We allow for the association between inequality and industrialization to weaken and eventually turning negative after the fertility transition. We estimate these predictions using annual data for Britain over the period 1270-1940, where the estimation period ends in 1940 after the conclusion of the fertility transition. The main focus will be on the period 1750-1912 because it is the essential period of the British Industrial Revolution (Mokyr, 1977, 2011; Clark, 2008).

4.1. Model Specifications.

4.1.1. *Basic Regression Equations.* We estimate two sets of models: One set in which employment and the employment share are dependent variables and a another set in which manufacturing production and the manufacturing production share are the dependent variables. Although employment is the target variable in the theoretical model, manufacturing GDP and the GDP share data are of significantly better quality than the employment data and are available back to 1270, as detailed in Section 5 below.

Based on employment, the key equations (22)-(25) are stochastically specified as follows:

$$\log L_t^M = \sum_{j\in J} \alpha_j D^F \log\left(\frac{R}{W}\right)_{t-j} + \sum_{j\in J} \delta_j (1-D^F)\log\left(\frac{R}{W}\right)_{t-j} + \sum_{j\in J} \log Z'_{t-j}\varphi_j + \sum_{j\in J} \gamma_j t \log Pop_{t-j} + \epsilon_{it}, \tag{28}$$

$$\log\left(\frac{L^M}{L}\right)_t = \sum_{j\in J} \alpha_j D^F \left(\frac{RX}{WL}\right)_{t-j} + \sum_{j\in J} \delta_j (1-D^F)\left(\frac{RX}{WL}\right)_{t-j} + \sum_{j\in J} \log Z'_{t-j}\varphi_j + \epsilon_{2,t}, \tag{29}$$

with $J = \{5, 6, ..., 15\}$ and where L^M is manufacturing employment; L is total employment; R is nominal land rent per hectare; W is nominal annual wages; Pop is population size; t is a time trend; Z is a vector of control variables; X is agricultural land area; ϵ is an error term; and D^F is a dummy taking the value of one before the onset of the fertility transition and zero thereafter, where the fertility transition year is from Reher (2004). The confounders, Z, and the R-W and RX-WL ratios, are lagged 5-15 years to allow for a gradual adjustment of the dependent variables to changes in their determinants, to allow for gestation lags in the industrialization process, and to deal with potential feedback effects from the dependent variable to the stochastic variables. The exact timing of the lags has no bearing on the results.

Using manufacturing production data, we arrive at regression equations (30) and (31), where Y^M is real manufacturing GDP and Y is economy-wide real GDP:

$$\log(Y^M)_t = \sum_{j\in J} \alpha_j D^F \log\left(\frac{R}{W}\right)_{t-j} + \sum_{j\in J} \delta_j (1-D^F)\log\left(\frac{R}{W}\right)_{t-j} + \sum_{j\in J} \log Z'_{t-j}\varphi_j$$

$$+\sum_{j\in J}\gamma_j t\log Pop_{t-j}+\epsilon_{3,t}, \tag{30}$$

$$\log\left(\frac{Y^M}{Y}\right)_t=\sum_{j\in J}\alpha_j D^F\log\left(\frac{RX}{WL}\right)_{t-j}+\sum_{j\in J}\delta_j(1-D^F)\log\left(\frac{RX}{WL}\right)_{t-j}+\sum_{j\in J}\log Z'_{t-j}\varphi_j+\epsilon_{4,t}. \tag{31}$$

Our maintained hypothesis is that the increasing R-W and RX-WL ratios promoted the British Industrial Revolution because the increasing income of the landed class was increasingly spent on manufactured goods. As shown in Section 2, this mechanism is particularly strong when workers' demand is constrained by physiological needs and ceases to prevail after the onset of the fertility transition. After the onset of the fertility transition, the positive association between industrialization and inequality eventually turns negative or insignificant because workers reduce their demand for agricultural goods and their consumption is increasingly oriented towards manufacturing where wages are not bound by diminishing returns. Furthermore, innovation-driven productivity growth is higher in the manufacturing than agriculture.

While RX is an adequate indicator of the income of the landed class in the latter part of the British Industrial Revolution, it underestimates the income of the landed class by leaving out income that are either directly or indirectly associated with land ownership. The most important sources of income of the landed class left out of RX are the returns to livestock and agricultural buildings that house livestock and store fodder, hay, non-fodder grain and vegetables, and agricultural implements. The asset values of agricultural buildings and livestock assets amounted to 33% (66%) and 18% (40%) of total (non-land) wealth, on average, over the periods 1300-1600 and 1601-1850, respectively (Madsen, 2017). More indirect sources of income of the landed class are returns to gold, silver, and non-monetary durable personal possessions, and rental income from housing property. When the earnings from these assets (livestock, agricultural buildings, gold and silver, and personal durable possessions) are included as income of the landed class, only a small income residual is left to the capitalist class that emerged during the 19th century. Including returns to all assets as income of the landed class, we compute the OS-WL ratio, where OS is operating surplus, the sum of income from all assets including earnings on agricultural land, private fixed capital, agricultural buildings, durable consumables, private urban houses, government land, and net foreign assets. We present estimates using the RX-WL and OS-WL ratios as proxies for inequality in the estimates of (29) and (31).

4.1.2. *Endogeneity.* While theory and calibration study suggest that a causal impact from inequality to industrialization, we cannot rule out potential endogeneity due to feedback effects from the dependent to the independent variables in the estimates. Furthermore, endogeneity may arise because of omitted variables that are correlated with the regressors, particularly the influence of technology as implied by our model. To reduce endogeneity to a minimum, we take the following approach. First, we lag the explanatory variables from 5-15 years to overcome contemporaneous correlation between the dependent and independent variables. Second, to further reduce the correlation between the error term and the regressors, we include as confounders the variables that were considered key determinants of the British Industrial Revolution.

4.1.3. *Confounders.* As the primary confounder, we allow for trade in the baseline regressions following the predictions of our model extended with trade in the Appendix. Population growth during industrialization increased the demand for food imports which were financed by exports of manufactured goods. Thus, in exchange for Britain's exports of textiles and machinery, the imports of inexpensive grain implicitly benefited the British industrialization. Trade has often been stressed as an important lever of the British Industrial Revolution in the literature (Harley and Crafts, 2000; O'Rourke and Williamson, 2005). Intuitively, in the absence of an international market for British manufactures, industrialization would not have gained the same momentum as it did during the first globalization wave in the second half of the 19th century. By 1910, for example, the lion's share of textile machinery in operation in the world was manufactured in Britain (Clark, 1987).

Although foreign trade potentially played an important role in British industrialization, it was first from the mid-19th century that trade openness started its accent and, from this perspective, it could not have promoted the First Industrial Revolution and the initial phase of the Second British Industrial Revolution. Britain's net imports of grain fluctuated around zero before taking off in the mid-19th century. This suggests that the increasing food demand of the increasing population over the period 1788-1833 and its continued high growth thereafter was met with an increasing domestic grain production at high prices. The Corn Laws enacted in 1772 and implemented in 1815, obstructed the import of inexpensive grain, initially by forbidding importation below a set price, and later by imposing steep import duties (Williamson, 1990). The Corn Laws resulted in increasing food prices that may have hampered the growth of manufacturing because of higher real product wages induced by the higher cost of living. The repeal of the Corn Laws in 1846 and reduced transport costs resulted in a surge of imports of inexpensive food from the New World in the second half of the 19th century (Williamson, 1990; O'Rourke and Williamson, 2005).

Of other key confounders that are often used as approximate determinants of economic growth and some of which are consistent with our model, we include education, innovations, and institutions. A large literature emphasizes human capital and technology as key drivers of industrialization (e.g. Mokyr, 1977; Crafts, 1995; Rosenberg, 1994; Madsen et al., 2010; Kelly et al., 2014; Madsen and Murtin, 2017; Fernihough and O'Rourke, 2021). To account for these confounders, we measure technology by patent stock and human capital by the average years of education of the population of working age. The patent stock is estimated using the perpetual inventory method with a 15% depreciation rate.

An influential explanation for the British Industrial Revolution is the quality of institutions and their evolution over time (North and Thomas, 1973; North and Weingast, 1989; Acemoglu et al., 2005). North and Thomas (1973), for example, argue that the development of systems that created and enforced intellectual property rights were fundamental for knowledge-based growth. De Long and Schleifer (1993) show that industrialization was stunted by absolute monarchs who cared more about maximizing tax revenue from the landed class than industrialization and, therefore, that the democratic reforms in the 17th century resulted in policies that cared more about the merits of industrialization. Furthermore, Acemoglu et al. (2005) suggest that the expansion of Atlantic trade strengthened merchant groups vis-á-vis the monarch, helped merchants to obtain improvements in institutions to protect property rights, and paved the way for the industrialization of Western Europe.

The final confounder is the real price of coal. Several economic historians have argued that easy access to coal was an impetus for industrialization for various reasons (see, for critical assessments, Clark and Jacks, 2007; Clark, 2012; Kelly et al., 2023). Allen (2009), for example, argues that low prices of energy and high costs of labor induced British entrepreneurs to adopt labor saving innovations that would not be profitable elsewhere. If easy access to coal were an underlying cause of industrialization, then we should expect a negative relationship between the real price of coal and industrialization.

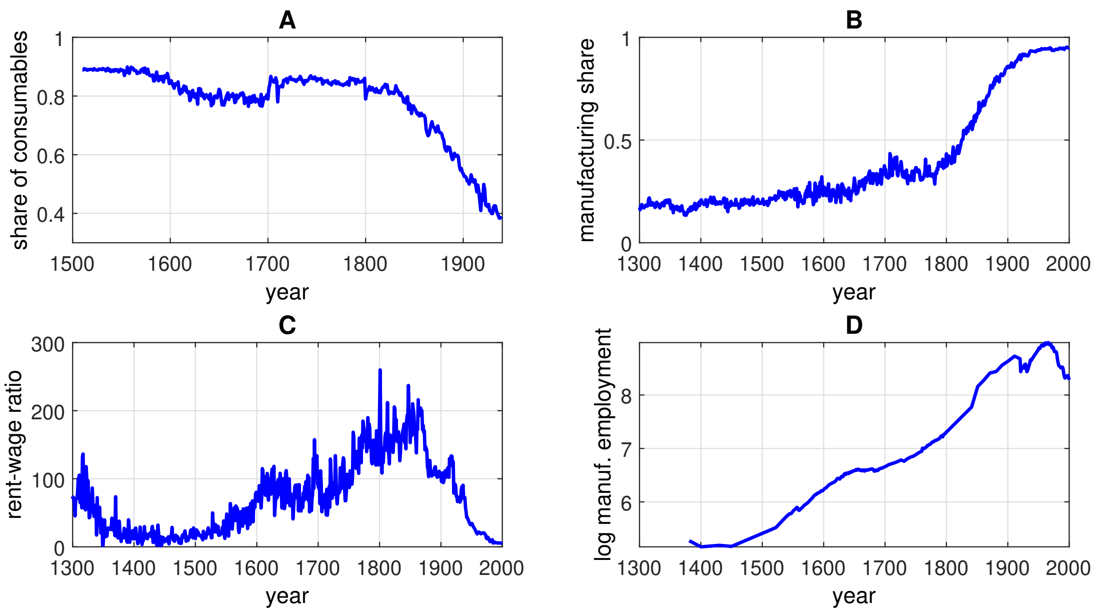
4.2. **Data.** The data come from various sources, particularly Mitchell (1988), Clark (2010), Broadberry et al. (2015), Madsen (2017), and Madsen and Murtin (2017), as described in the Data Appendix. Most of the employment data are based on census data that are interpolated between the census years by multiplying the labor force by the interpolated manufacturing employment share. Total employment is from population censuses and retropolated using population of working age before the first census. Wages are measured as the weighted average of daily wages of agricultural and urban labor, where the urban wages are measured as the unweighted average of the daily wages of unskilled and skilled labor in the building industry.

Agricultural land rent is measured as the annual land rent per hectare. Since land rent is measured annually and wages are measured daily, the rent-wage data are measured with an error over the periods in which the annual working days changed. However, research suggests that the greatest change in annual working days occurred in the 16th century, when the Reformation was introduced in England, i.e., before the Industrial Revolution (Allen and Weisdorf, 2011). The earnings on all tangible assets, OS, as stated above, include earnings on agricultural land, private fixed capital, agricultural buildings, durable consumables, private urban houses, government land, and net foreign assets. Returns to land are directly available, whereas the returns to the other non-land assets are based on bond/lending rates, and stock returns. The data sources for asset returns are detailed in Madsen (2017).

Educational attainment is the years of education of the population of working age and is based on school enrollment at primary, secondary and tertiary levels divided by the population in the respective school ages. The transformation of gross enrollment rates to education attainment is shown formally by Madsen and Murtin (2017). The patent stock is measured by aggregating the number of patents granted per year using the perpetual inventory method with a 15% depreciation rate. The patent data are available from 1552. Imports of grain and exports of manufactured goods, which are first available after 1700, are measured in volume terms. Manufacturing exports are retropolated to 1270 using total nominal exports deflated by the GDP deflator. Annual data for constraints on the executive are from Polity IV after 1832. Before 1832, the measurement of constraints on the executive follows the method used in Polity IV and is detailed in the Data Appendix.

4.3. **Graphical Analysis.** A condition for industrialization to be promoted by consumer demand is that consumables are a large share of manufacturing production before and during the initial stages of industrialization in Britain. Figure 4 Panel A displays the share of consumables in total manufacturing production for Britain over the period 1500-1940. The share of consumption goods in total manufacturing production fluctuated around 80% up until 1830 and subsequently steadily declined along with increasing industrialization. While domestic demand for manufactured consumer goods increased the potential for industrialization in the 18th century, Britain would not have industrialized had it not had the incentives, technological knowledge and skilled labor force to mass-produce, improve and increase the variety of the manufacturing products (Berg, 2004). This line of reasoning is consistent with the reasoning of Mokyr (2011), Madsen et al. (2010), and Kelly et al. (2023) that innovations were pivotal for industrialization.

Figure 4: Industrialization and Inequality



Notes: Panel A: Consumption is the share of textiles and industrially processed food, drink, and tobacco in total manufacturing production in fixed prices (the non-consumption part of the manufacturing sector is 'metals, chemicals, paper, and other'). Panel B: Share of manufacturing in agricultural and manufacturing real output. Panel C: The rent-wage ratio is indexed to an average of 100. Panel D: Employment in manufacturing measured in 1000 persons.

To gain insight into the industrialization process, Figure 4 Panel B shows the evolution of manufacturing as the share of manufacturing and agricultural real output for Britain, 1270-1830. The British manufacturing share progressed at a slow pace up until its takeoff around 1810, accelerated over the period 1810-1875, and then grew steadily along a positive but eventually declining trend. The start of the British Industrial Revolution is usually dated to around 1760-1770 but it took a while for major innovations, usually referred to as general-purpose technology, to take hold on production, as demonstrated by Mokyr (2011) and Kelly et al. (2014). The manufacturing share increased by approximately 50% over the period 1270-1800, corresponding to an annual geometric growth rate of 0.0006%.

Figure 4 Panel C shows the time-profile of inequality measured by the rent-wage ratio. As real wages and the agricultural land area were relatively constant during the Malthusian epoch, the rent-wage ratio approximates the purchasing power of the landed class before the fertility transition. The marked increase in the population during the 13th century pushed the R-W ratio up to a local peak in 1322. During the black death pandemic, the R-W ratio declined by 78% between 1322 and 1369, with the strongest decline concentrated over the period 1322-1348, during which the R-W ratio decreased by 63%. The decrease in the R-W ratio over the period 1348-1369, however, was not accompanied by a decrease in the manufacturing share. To understand this outcome, we note that the decline of the R-W ratio was counterbalanced by the decline of the population such that the land-labor-income ratio $RX/(WL)$ stayed almost constant over the period 1340-1600, as shown in Figure A.4 in the Appendix. This means that per capita demand for manufactured goods stayed almost constant during the period 1340-1600. As shown in equation (24) in the theory section, the employment share in manufacturing remains constant when the land-labor income ratio remains constant and the proportion of landlords to workers L^X/L remains constant, i.e. when the black death pandemic killed people of both social groups in equal proportions.[3]

The R-W ratio increased markedly in the century leading up to the start of the industrial revolution and further accelerated during the industrialization period. After the 1870s, the R-W ratio begins to fall due to lower population pressure, increasing wages, vanishing stimulus from advances in agricultural productivity, and increasing imports of inexpensive food from the New World. The significant increase in the R-W ratio after the 1730s gave Britain an opportunity to industrialize. As predicted in our model, the expansion of manufacturing led to technological advances in the 18th century. Sparked by increasing market demand, several new technologies were invented, consisting of a stream of micro inventions that gradually increased the production possibility frontier of the manufacturing sector (Mokyr, 2011).

Manufacturing employment, which is displayed in Figure 4 Panel D, shows a secular increase over the period 1450-1640 and an uninterrupted increase from 1730 up until WWI. The increase during the of period 1450-1640 and the stagnation over the period 1640-1730 are consistent with the path of the R-W ratio over the same periods. Similarly, the increasing manufacturing employment over the period 1730-1880 coincides with the path of the R-W ratio.

5. Empirical Results

5.1. **Baseline Regressions: Manufacturing Employment and Employment Share.** The results of estimating (28) are presented in columns (1)-(5) in Table 1, where the reported coefficients are the sum of the 5-15 year lags of the explanatory variables and the associated t-values are tests of their joint significance. The model is estimated over periods that vary between 1715 and 1940. Notice that DF first goes to zero after 1910 (Britain's onset of the fertility transition, according to Reher, 2004). Thus, in the regressions ending in 1912, the $\log(R/W) \times DF$ coef-

[3]A number of possible mechanisms explain why the rise in the R-W ratio during the period 1260-1322 did not lead to early industrialization: 1) insufficient technological knowledge to support a manufacturing production process (Mokyr, 2011); 2) the volatility in the R-W ratio being too high to nail down the trend and the persistence of the upturn; 3) the absence of imported luxuries from the East, which rendered the existence of these goods unknown to the landed class; and 4) spending on household services and investment in impressive buildings possibly being higher than manufactured consumer goods in the needs hierarchy of the landed class. At lower levels of the R-W ratio, the landed class used their earnings to pay for home services and buildings. Only when their income increased sufficiently, did they begin to demand manufactured products.

ficient covers the whole estimation period. As stated above, the results with the employment data should be treated with a great deal of caution due to measurement errors and their long time-lapses.

The coefficients of the R-W ratio are significantly positive before the fertility transition regardless of whether trade is included in the model. When the trade variables are included in the model, the size of the coefficients of R-W are reduced noting that the coefficient of R-W is likely to be downward biased because the R-W ratio captures some of the increasing manufacturing exports that were enabled by the British industrialization, as shown below. Finally, consistent with the model predictions, the coefficients of the interaction between time and population are significantly positive, suggesting that industrialization was aided by technological progress generated from population pressure.

The estimates of (29), in which the share of manufacturing employment in total employment is regressed on the RX-WL ratio and the OS-WL ratio, are presented in columns (6)-(9) in Table 1. The coefficients of the RX-WL and the OS-WL ratios are again all significantly positive.

Considering trade openness, the coefficients of manufacturing exports are consistently highly significantly positive and the size of the coefficients is largely independent of estimation period and whether the level or the share of manufacturing employment is the dependent variable. The coefficients of grain imports, by contrast, are very small and significantly positive only when the estimation period is limited to 1765-1912. The insignificance of the grain imports over the periods 1815-1912 and 1815-1940, is partly driven by a marked decline in the grain imports after 1895 despite continuing industrialization. According to the model extended by international trade (Appendix B), imports should play no role in the regression when exports are included because trade is balanced and rising food imports only have an effect on industrialization through the associated increase of manufacturing exports. The finding of a small and sometimes insignificant coefficient for imports is consistent with this implication of the trade-extended model.

5.2. **Baseline Regressions: Manufacturing GDP and GDP share.** We now turn to estimates with manufacturing GDP and the manufacturing share of total GDP as dependent variables (equations (30) and (31)). The data for manufacturing GDP are not only of substantially better quality than the employment data but are also available at annual frequencies dating back to 1270. Our main focus is on the periods 1745-1835 and 1745-1880, where the first period covers the First Industrial Revolution and a few decades leading up to it and the second period covers the First Industrial Revolution and the initial stage of the Second Industrial revolution.

Consider first the estimates of equation (30) in columns (1)-(7) of Table 2. The coefficients of the R-W ratio and the interaction between population and time are significantly positive in all the estimates, even in the estimates covering the period 1285-1835 in columns (5) and (6). In columns (8)-(11) in Table 2, in which the manufacturing GDP share is the dependent variable, all the coefficients of the RX-WL and OS-WL ratio are significantly positive.

Turning to trade, the coefficients of manufacturing export openness are significantly positive in all the estimates except for those in columns (3) and (8), covering the period 1745-1835, while the coefficient of grain imports is small and sometimes insignificant. The importance of manufacturing exports for the Second Industrial Revolution further supports the consumption

Table 1. Inequality and Industrialization: Employment Baseline Estimates

Dep Var	(1) $\log(L^M)$	(2) $\log(L^M)$	(3) $\log(L^M)$	(4) $\log(L^M)$	(5) $\log(L^M)$
$\log(R/W) \times DF$	0.18(3.03)***	0.15(1.91)*	0.09(2.02)**	0.04(3.61)***	0.09(6.57)***
$\log(R/W) \times (1 - DF)$		-0.24(0.98)			-0.38(3.92)
$\log(Im/Y)$			-0.01(0.81)	0.02(3.61)***	0.03(7.64)***
$\log(Ex/Y)$			0.24(5.06)***	0.20(10.1)***	0.23(9.25)***
$\log(Pop) \times t \times DF$	0.54(22.7)***	1.62(16.4)***	0.36(17.5)***	0.34(25.1)***	0.89(18.8)***
$\log(Pop) \times t \times (1 - DF)$		1.90(8.60)***			1.28(14.2)***
N	98	126	98	201	226
Period	1815-1912	1815-1940	1815-1912	1715-1912	1715-1940

Dep Var	(6) $\log(L^M/L)$	(7) $\log(L^M/L)$	(8) $\log(L^M/L)$	(9) $\log(L^M/L)$
$\log(OS/WL) \times DF$	0.05(1.71)*	0.06(2.39)**		
$\log(OS/WL) \times (1 - DF)$		0.11(7.77)***		
$\log(RX/WL) \times DF$			0.07(1.74)*	0.21(3.64)***
$\log(RX/WL) \times (1 - DF)$				-0.12(6.09)***
$\log(Im/Y)$	0.03(5.18)***	0.03(0.98)	0.03(5.26)***	0.00(0.10)
$\log(Ex/Y)$	0.20(10.5)***	0.20(5.18)***	0.16(18.0)***	0.21(5.92)***
N	148	126	148	126
Period	1765-1912	1815-1940	1765-1912	1815-1940

Notes: Absolute t-values are in parentheses and based on heteroscedasticity and serial correlation robust standard errors. All variables are lagged 5-15 years. The coefficients and their associated t-values are the sum of the coefficients and their joint significance. L^M is manufacturing employment; L is economy-wide employment; Pop is population; OS is operating surplus, $(rX + rK)$; Im/Y is food imports-GDP ratio; Ex/Y is the manufacturing exports-GDP ratio; and D^F is a dummy taking the value of one before the onset of the fertility transition and zero thereafter. The coefficient of $\log(Pop_t) \times t$ is multiplied by 10^3. *, **, ***: significant at 10%, 5%, and 1% level.

hypothesis. The high demand for sophisticated clothes by the landed class resulted in a technically advanced textile industry that gave Britain a comparative advantage in textile production. The manufacturing export boom in the second half of the 19th century was not primarily driven by exports of highly sophisticated products, such as machinery and instruments. Instead, the boom was primarily driven by exports of manufactured textile products. Over the period 1814-1880, for example, exports of textiles increased from 26.4 to 96.2 million pounds or by 62% of total exports (Mitchell, 1988, p. 482). The export share of machinery increased from being negligible in 1814 to 6% in 1880, outperformed by coal exports, suggesting that high-tech exports were not the key to the industrialization and its interaction with trade.

These results have two implications. First, the large domestic market for manufactured consumables created by the high-income class during the first part of the British Industrial Revolution is likely to have been a main impetus to the international success of the textile industry. Second, technological progress and knowledge-spillovers promoted by exports of high-tech products were too small to have been a major driver of British industrialization. This may have been one of the reasons why Britain's industrialization lost momentum during the 20th century.

Returning to the estimates in columns (1), (3), (5), (6), (8), and (10) in which the estimation period ends in 1835, shortly before industrialization gains momentum, the significance of inequality in these regressions is useful for eliminating concerns about reverse causality; that

Table 2. Inequality and Industrialization: Output Baseline Estimates

Dep Var	(1) $\log(Y^M)$	(2) $\log(Y^M)$	(3) $\log(Y^M)$	(4) $\log(Y^M)$	(5) $\log(Y^M)$	(6) $\log(Y^M)$	(7) $\log(Y^M)$
$\log(R/W) \times DF$	0.18(2.50)**	0.29(4.09)***	0.11(1.84)*	0.33(4.86)***	0.23(18.9)***	0.18(13.4)***	0.14(2.14)**
$\log(R/W) \times (1-DF)$							-0.78(3.95)***
$\log(Im/Y)$			-0.01((4.06)***	0.01(0.95)		0.05(8.81)***	0.19(4.84)***
$\log(Ex/Y)$			0.01(0.48)	0.42(7.74)***		0.13(2.06)**	0.15(2.48)**
$\log(Pop) \times t \times DF$	0.67(12.1)***	0.82(32.4)***	0.77(16.3)***	0.56(10.6)***	0.34(51.1)***	0.31(35.0)***	2.23(25.4)***
$\log(Pop) \times t \times (1-DF)$							3.09(19.9)***
N	91	136	91	136	551	551	126
Period	1745-1835	1745-1880	1745-1835	1745-1880	1285-1835	1285-1835	1815-1940

Dep Var	(8) $\log(Y^M/Y)$	(9) $\log(Y^M/Y)$	(10) $\log(Y^M/Y)$	(11) $\log(Y^M/Y)$
$\log(OS/WL) \times DF$	0.74(3.66)***	0.36(3.93)***		
$\log(RX/WL) \times DF$			1.05(8.41)***	0.43(6.42)***
$\log(Im/Y)$	0.01(4.93)***	0.01(4.14)***	0.02(5.96)***	0.02(3.99)***
$\log(Ex/Y)$	0.10(1.36)	0.42(13.0)***	0.29(9.26)***	0.58(19.8)***
N	91	136	91	136
Period	1745-1835	1745-1880	1745-1835	1745-1880

Absolute t-values are in parentheses and based on heteroscedasticity and serial correlation robust standard errors. All variables are lagged 5-15 years. The coefficients and their associated t-values are the sum of the coefficients and their joint significance. Y^M is manufacturing GDP; Y is economy-wide GDP; Pop is population; OS is operating surplus, $(rX + rK)/WL$; Im/Y is food imports-GDP ratio; Ex/Y is the manufacturing exports-GDP ratio; and D^F is a dummy taking the value of one before the onset of the fertility transition and zero thereafter. A dummy variable taking a value of one before 1700 and zero elsewhere is included in the estimates in columns (5) and (6) to cater for the unavailability of food imports before 1700. The coefficient of $\log(Pop) \times t$ is multiplied by 10^3. *, **, ***: significant at 10%, 5%, and 1% level.

is, causality running from industrialization to agricultural productivity and income inequality in the agricultural sector. Potential feedback from industrialization to inequality before 1835 is minimal since almost none of the productivity improvements in pre-industrial agriculture were derived from manufactured tools and fertilizers (Brunt, 2003; Allen, 2004). Instead, the pre-industrial productivity advances in agriculture were derived from improvements in methods and practices, such as land enclosure, draining, marling, fencing, simple implements made by the local blacksmith, crop rotation, isolating high-yielding and disease resistant strains of crops, introduction of atmospheric nitrogen fixing crops, diffusion of seed drills and improvements of the plough (Brunt, 2003; Allen, 1994). None of these improvements were derived from the industrial sector. Synthetic fertilizer, for example, was first invented in the mid-19th century and manufacturing of it first started in the 20th century. While some agricultural machinery and tools started to become manufactured during the Second Industrial Revolution, the mechanization of agriculture with manufactured machinery gained momentum only after the mid 20th century (Allen, 1994; Brunt, 2003). In the pre-1830 estimates, the coefficient of the R-W ratio is significantly positive and as large as for the extended period, a result that corroborates the hypothesis that inequality promoted industrialization and not vice versa.

5.3. **Inclusion of Confounders.** Table 3 shows the result of extending the baseline regressions (30) and (31) with confounders that are often considered to have contributed to the British industrialization, viz education, innovations, institutions, and real coal prices. We focus on the entire British Industrial Revolution, 1765-1912, as well as on the period 1285-1912 to get a longer perspective on the evolution of manufacturing. All explanatory variables are lagged 5-15 years.

As dependent variables, we use alternatively manufacturing GDP, the share of manufacturing in total GDP, and manufacturing GDP per capita.

The non-coal confounders are all highly significantly positive if they are included one at a time, suggesting that they have all contributed to the industrialization (the results are not shown). Here we show results when all confounders (except coal prices) are included in the regressions at the same time. We are therefore conducting horse races to see how far we can push the results.

5.3.1. *The 1765-1912 Period.* The estimation results for this period are presented in columns (1)-(6) of Table 3. We first consider the price of coal. As discussed above, the price of coal has often been considered to be an important factor in the British industrialization. To obtain the real price of coal, we deflate nominal coal prices by the manufacturing price deflator, noting that the estimation period ends in 1865 because coal prices are not available after 1865. The coefficient of the real price of coal is weakly negative in the first regression but significantly positive in the other two regressions, which is the opposite of the prediction of the coal hypothesis, according to which easy access to coal made it a cheap source of energy. Thus overall, there is little evidence to support the coal access hypothesis. This, of course, does not rule out the possibility that coal aided industrialization but it is just difficult to trace a significant effect in our sample. Using a difference-in-difference estimation strategy, Fernihough and O'Rourke (2021), for example, show that cities closer to coalfields grew substantially faster after 1750 than those further away.

Turning to the regressions in columns (4)-(6), the coefficients of educational attainment, EA, and export openness, Ex/Y, are consistently significantly positive, while the coefficients on executive constraints, $Exec$, and patent stock, S^{Pat}, are only sometimes significantly positive and the coefficient of food imports, Im/Y, is very small and only sometimes significant.

Finally, the coefficients on our inequality measures are estimated to be significantly positive regardless and their size is relatively robust to the inclusion of the confounders in both the R-W and the OS-WL regressions.

5.3.2. *The 1285-1912 Period.* The regression results for this period are presented in columns (7)-(9). Shift dummy variables take the value of one before import (patent) data become available in 1700 (1552), and zero thereafter, are included in the models to ensure that the parameter estimates are not biased due to missing data during these periods. The coefficients of Ex/Y, EA, and S^{Pat} are all significantly positive suggesting that all these factors played a role for the manufacturing share in the pre-industrial period as well as during the British Industrial Revolution. The coefficients of institutions are either insignificant, negative, or positive. Coupled with the finding that institutions have positive effects on industrialization in the estimates over the period 1765-1912, this result may indicate that the quality of institutions was an outcome of industrialization and education rather than the other way around.

Finally, and most importantly, the coefficients on our inequality measures are all significantly positive regardless of whether inequality is measured as (OS/WL) or (R/W) and the magnitudes of the coefficients of R-W and OS-WL regressions are only slightly lower than they are in the baseline regressions.

Table 3. Confounders Included in the Baseline Regressions

Dep Var	(1) $\log(Y^M)$	(2) $\log(Y^M/Y)$	(3) $\log(Y^M/Pop)$	(4) $\log(Y^M)$	(5) $\log(Y^M/Y)$	(6) $\log(Y^M/Pop)$
$\log(R/W) \times DF$	0.24(2.79)***			0.41(4.77)***		
$\log(OS/WL)$		0.47(2.37)**	0.72(2.59)**		0.38(7.59)***	0.52(2.55)**
$\log(Im/Y)$	-0.02(2.13)*	0.02(1.35)	0.05(2.93)***	-0.03(3.42)***	-0.01(1.06)	-0.003(0.20)***
$\log(Ex/Y)$	0.13(1.78)*	0.09(1.69)*	0.28(4.15)***	0.24(5.59)***	0.34(11.7)***	0.38(10.9)***
$\log(EA)$				1.10(7.54)***	0.34(2.19)**	1.73(4.33)***
$\log(S^{Pat})$				0.09(0.96)	0.09(3.76)***	-0.04(0.51)
$\log(Exec)$				0.42(2.36)**	0.01(0.26)	0.49(2.02)**
$\log(P^{Coal}/P^{Man})$	-0.28(2.04)*	0.57(4.53)***	0.55(3.26)***			
$\log(Pop) \times t$	0.82(16.2)***			0.04(2.35)**		
N	100	100	100	148	148	148
Period	1765-1865	1765-1865	1765-1865	1765-1912	1765-1912	1765-1912

Dep Var	(7) $\log(Y^M)$	(8) $\log(Y^M/Y)$	(9) $\log(Y^M/Pop)$
$\log(R/W) \times DF$	0.11(4.66)***		
$\log(OS/WL)$		0.29(5.94)***	0.52(4.62)***
$\log(Im/Y)$	0.02(2.69)***	-0.004(0.76)	0.02(1.46)
$\log(Ex/Y)$	0.57(15.8)***	0.23(10.1)***	0.47(12.9)***
$\log(EA)$	0.01(1.78)*	0.01(1.25)	0.79(5.90)***
$\log(S^{Pat})$	0.04(3.07)***	0.09(8.97)***	0.06(1.99)**
$\log(Exec)$	0.09(3.22)***	-0.08(5.99)***	0.00(0.01)
$\log(Pop) \times t$	0.43(20.4)***		
N	628	628	498
Period	1285-1912	1285-1912	1400-1912

Absolute t-values are in parentheses and based on heteroscedasticity and serial correlation robust standard errors. All variables are lagged 5-15 years. The coefficients and their associated t-values are the sum of the coefficients and their joint significance. Y^M is manufacturing GDP; Y is economy-wide GDP; Pop is population; OS is operating surplus, $(rX + rK)/WL$; Im/Y is food imports-GDP ratio; Ex/Y is the manufacturing exports-GDP ratio; EA is the educational attainment of the population of working age; $Exec$ is constraints on executive; S^{Pat} is patent stock; and D^F is a dummy taking the value of one before the onset of the fertility transition and zero thereafter. The coefficient of $\log(Pop) \times t$ is multiplied by 10^3. A dummy taking a value of one before 1700 (1552) and zero elsewhere is included in the estimates in columns (7) and (9) to cater for the unavailability of food imports (patents) before 1700 (1552). *, **, ***: significant at 10%, 5%, and 1% level.

5.4. **Causality.** Even if the inequality variables are lagged 5-15 years, the estimates above do not guarantee causality when the residuals are serially correlated. In this section, we therefore check for endogeneity caused by feedback effects from the dependent variable (industrialization) to land productivity. We undertake two types of tests to check for feedback effects from manufacturing to agriculture. First, we regress land productivity on lagged values of industrialization to check the extent to which industrialization improved agricultural productivity by supplying quality-improved implements to agriculture. Second, we regress the prices of agricultural products deflated by the manufacturing price deflator on lagged manufacturing employment/output and the manufacturing employment/output share over the periods 1765-1870 (employment) and 1665-1870 (output) while controlling for population and a time trend. The estimation period ends in 1870 due to data availability and because our focus is on the early phase of industrialization. The reasoning behind these causality tests is as follows. If industrialization Granger-causes the R-W, OS-WL or RX-WL ratios, then the real agricultural prices should be positively affected by industrialization because urban demand for agricultural goods drives up agricultural prices and because the relative manufacturing prices are driven down due to technological progress in manufacturing.

The regression results, which are presented in Table 4, give little evidence of spillover effects from manufacturing to agriculture. The coefficients of the 5-15 year lags of the manufacturing employment/output levels or shares are insignificant at conventional levels in columns (1) and (5)-(8), significantly positive in column (2), and significantly negative in columns (3)-(4), where the latter result is the opposite of what we should expect if agricultural productivity is driven by the progress in manufacturing. On balance it can be concluded that the feedback effects from manufacturing to agriculture are too small to bias the coefficients of inequality up in the regressions of Tables 1-3. This conclusion is consistent with the discussion above that technological advances in the industrial production of agricultural machinery had no impact on land productivity; at least not during the First Industrial Revolution.

Table 4. Tests for Feedback Effects

Dep Var	(1) $\log(P^A/P^M)$	(2) $\log(P^A/P^M)$	(3) $\log(Y^A/X)$	(4) $\log(Y^A/X)$	(5) $\log(P^A/P^M)$	(6) $\log(P^A/P^M)$	(7) $\log(Y^A/X)$	(8) $\log(Y^A/X)$
$\log(L^M)$	0.36(1.55)		-0.05(1.72)*					
$\log(L^M/L)$		0.81(2.21)**		-0.10(2.09)**				
$\log(Y^M)$					-0.03(0.21)		-0.02(1.20)	
$\log(Y^M/Y)$						-0.009(0.38)		-0.01(0.38)
$\log(Pop)$	0.69(2.21)**	1.43(2.97)***	0.10(2.80)***	0.03(0.61)	0.07(3.08)	0.07(3.08)***	0.09(3.64)***	0.07(3.08)***
R^2	0.9	0.89	0.9	0.9	0.92	0.92	0.92	0.92
N	106	106	106	106	206	206	206	206
Period	1765-1870	1765-1870	1765-1870	1765-1870	1665-1870	1665-1870	1665-1870	1665-1870

Absolute t-values are in parentheses and based on heteroscedasticity and serial correlation robust standard errors. All variables are lagged 5-15 years. The coefficients and their associated t-values are the sum of the coefficients and their joint significance. Y^M is manufacturing GDP; Y^A is agricultural GDP; P^M is manufacturing prices; P^A is agricultural prices; Y is economy-wide GDP; L^M is manufacturing employment; L is economy-wide employment; Pop is population; and X is the agricultural land area. *, **, ***: significant at 10%, 5%, and 1% level.

5.5. **Simulations.** Thus far we have concentrated on statistical significance. To address economic significance, counterfactual simulations are presented in Table 5. The simulation is based on the coefficient estimates of column (4) in Table 3 in which manufacturing production is regressed against the *R-W* ratio, education, trade, knowledge stock, constraints on the executive, and population size. To find the contribution of each factor to industrialization, we multiply each coefficient by the percentage change in the variables over the periods 1700-1850, 1735-1885 and 1800-1900. The results are presented in Table 5.

Overall, the sum of the contribution of each variable shown in the last column is reasonably close to the actual increase shown in the first column. The *R-W* ratio contributed to industrialization to about the same extent as manufacturing exports, education levels, and knowledge base. The magnitudes of these effects are intuitive in the sense that these factors, except for the *R-W* ratio, have often been stressed as the approximate determinants of industrialization in the literature. The significance of manufacturing exports in the simulations may, however, be exaggerated because it is heavily endogenous and because it first started to increase significantly in the mid 19th century - well into the British industrialization. Furthermore, industrialization

Table 5. Contributors to the British Industrialization

Period	(1) Y^M	(2) R/W	(3) Ex/Y	(4) Im/Y	(5) S^{Pat}	(6) EA	(7) $Exec$	(8) Pop	(9) Sum of col. 2-8
1700-1850	230.6	63.0	41.5	-17.8	36.5	50.9	14.1	116.3	241.6
1735-1885	301.2	32.1	47.6	-33.9	46.3	80.7	14.1	132.5	287.3
1800-1900	268.9	34.8	22.2	-23.7	34.9	63.8	6.5	98.2	201.9

Notes: The numbers in columns (2)-(7) indicate the percentage change in Y^M explained by each of the variable over the specified period indicated. This is done by multiplying the change in each variable over the indicated period and their estimated coefficients in column (4) in Table 3. Y^M is manufacturing GDP; R/W is the rent-wage ratio Ex/Y is manufacturing exports as a share of GDP; Im/Y is food imports as a share of GDP; S^{Pat} is the patent stock; EA is educational attainment; $Exec$ is constraints on executive; and Pop is population interacted with a time trend.

Granger causes manufacturing exports and not vice versa.[4] However, the contribution of manufacturing exports to the industrialization during the second half of the 19th century should not be downplayed. Furthermore, scale effects from exporting to the world market may have added to the advances during the late 19th century. The trade-induced specialization in textile production, learning by doing, and investment in R&D may well have increased the level and the rate in growth of real output (see, for discussion of scale effects and trade, Backus et al., 1992).

The positive effect of population growth on industrialization captures the impact of factor growth (growth at the extensive margin) as well as scale effects from learning-by-doing. Employment in manufacturing increased because a greater share of the population worked in manufacturing and because the population was growing. More employment in manufacturing means more innovations through learning-by-doing and more industrial output due to productivity growth (this effect is captured in equation (11)). The industrialization effect of food imports is more difficult to conceptualize. However, since we found that the import coefficients were insignificant in most estimates and sometimes showed conflicting evidence, the negative industrialization effects from imports are likely to be exaggerated in the simulation. The industrialization-effects of constraints on executive are relatively small, which likely reflects that institutions impact on industrialization through the other confounders in the estimates.

6. Conclusion

Establishing a two-class–two-sector model of unified growth, we show that the productivity-induced wealth expansion of the landed elite increased the demand for manufactured goods, which in turn fueled early industrialization. To substantiate the hypothesis that inequality promotes industrialization, we compiled new data for Britain and show that the British industrialization prior to the fertility transition was preceded by increasing income inequality measured by the agricultural land rent-wage ratio, the land-labor-income ratio, and the ratio between operating surplus and the labor income. We conduct several tests to show that the results are

[4]Regressing the log of Ex on 1-20 years lags of Ex and Y^M/Y over the period 1775-1912, yields a $t = 5.24$ for the joint significance of the lagged coefficients of Y^M/Y, while the reverse regression yields a $t = 0.72$ for the joint significance of the lagged coefficients of Y^M/Y.

plausibly not driven by endogeneity and that the agricultural productivity advances were transmitted to industrialization through the income-gap between the landed class and agricultural workers.

Taking into account the more well-known drivers of modern growth, we find that inequality is a major contributor to the British Industrial Revolution, alongside foreign trade, education, technological knowledge and, to some extent, institutions. While the R-W ratio was the driving force behind the early British industrialization, education and innovations took on the role of the important drivers of the second part of industrialization. As argued by many economic historians and growth theorists, several factors contributed to Britain's gradual ability to bring about the Industrial Revolution.

Appendix A

Proof of Proposition 6. From (10) and (5) we obtain

$$\frac{g_{t+1}^A}{g_t^A} = \frac{\left(A_{t+1}(L_t^A)^\alpha\right)^\epsilon}{A_{t+1}} \frac{A_t}{\left(A_t(L_t^A)^\alpha\right)^\epsilon} = \frac{\left(1+g_t^A\right)^\epsilon \left(1+g_t^L\right)^{\alpha\epsilon}}{1+g_t^A}, \tag{A.1}$$

where the last equality follows from the feature that factor shares stay constant in the long-run. For constant g^A (potentially zero) we thus have

$$1 = \frac{g_{t+1}^A}{g_t^A} \qquad \Rightarrow \qquad (1+g_t^L) = (1+g_t^A)^{\frac{1-\epsilon}{\alpha\gamma}}. \tag{A.2}$$

From (11) and (6) we obtain

$$\frac{g_{t+1}^M}{g_t^M} = \frac{\left(M_{t+1}L_t^M\right)^\phi}{M_{t+1}} \frac{M_t}{\left(M_t L_t^M\right)^\phi} = \frac{\left(1+g_t^M\right)^\phi \left(1+g_t^L\right)^\phi}{1+g_t^M}, \tag{A.3}$$

and for constant g^M,

$$1 = \frac{g_{t+1}^M}{g_t^M} \qquad \Rightarrow \qquad (1+g_t^L) = (1+g_t^M)^{\frac{1-\phi}{\phi}}. \tag{A.4}$$

From (9) and (17) we obtain:

$$\frac{n_{t+1}}{n_t} = \frac{p_t}{p_{t+1}} = \frac{\left(L_{t+1}+L_{t+1}^X\right) A_t(L_t^A)^\alpha}{A_{t+1}(L_{t+1}^A)^\alpha \left(L_t + L_t^X\right)} = \frac{\left(1+g_t^L\right)}{\left(1+g_t^L\right)^\alpha \left(1+g_t^A\right)}, \tag{A.5}$$

where the last equality follows from $L_t^X = \lambda L_t$ and the feature that L_t^A/L_t stays constant at a steady state. Furthermore, at a steady state, π_t and n_t stay constant such that

$$1 = \frac{n_{t+1}}{n_t} \qquad \Rightarrow \qquad (1+g_t^L) = (1+g_t^A)^{\frac{1}{1-\alpha}}. \tag{A.6}$$

For $g_t^L \neq 0$, (A.2) and (A.6) are simultaneously true only for the knife edge case of $(1-\epsilon)/(\alpha\epsilon) = 1/(1-\alpha)$ that is for $\alpha = 1-\epsilon$. This proves part (ii) of Proposition 2. For $gL = 0 = g_M = g_A = 0$, (A.2), (A.4), and (A.6) are fulfilled for all feasible parameters. This proves part (i) of Proposition 2.

Proof or Proposition 7. Part (i). Suppose there is long-run development with negative population growth, i.e., $n_t < 1$ for all t. Thus, $\lim_{t\to\infty} L_t = 0$ and $\lim_{t\to\infty} L_t^A = 0$. This implies $\lim_{t\to\infty}(L_t^A)^{\alpha-1} = \infty$. Since knowledge cannot decline, A_t and M_t converge to positive constants. Thus, labor market equilibrium requires $\lim_{t\to\infty} p_t = 0$. But then, from (3) $\lim_{t\to\infty} n_t = \infty$, which contradicts the initial assumption that $n_t < 1$.

Part (ii). For exploding growth, the growth rate of the population increases over time. From (27), an increasing population growth rate requires

$$\frac{n_{t+1}}{n} = \frac{p_t}{p_{t+1}} = \frac{(1+g_t^A)}{(1+g_t^L)^{1-\alpha}(1+g_t^M)^\alpha} > 1. \qquad \Rightarrow \qquad (1+g_t^A) > (1+g_t^L)^{1-\alpha}(1+g_t^M)^\alpha. \tag{A.7}$$

From (5), (10), and (26) we obtain:

$$g_t^A = \mu A_t^{\epsilon-1}\left(L_t^A\right)^{\alpha\epsilon} = c_3 A_t^{\epsilon-1} \frac{L_t^{\alpha\epsilon}}{M_t^{\alpha\epsilon}}, \tag{A.8}$$

in which c_3 is a compound of constants. Explosive growth of agricultural technology requires an increasing growth rate, i.e.,

$$\frac{g_{t+1}^A}{g_t^A} = \frac{(1+g_t^L)^{\alpha\epsilon}}{(1+g_t^M)^{\alpha\epsilon}(1+g_t^A)^{1-\epsilon}} > 1 \qquad \Rightarrow \qquad (1+g_t^L)^{\alpha\epsilon} > (1+g_t^M)^{\alpha\epsilon}(1+g_t^A)^{1-\epsilon}.$$

Thus, explosive growth does not occur if

$$(1+g_t^L)^{\alpha\epsilon} < (1+g_t^M)^{\alpha\epsilon}(1+g_t^A)^{1-\epsilon}. \tag{A.9}$$

Using (A.7), a sufficient condition for this to be true is

$$(1+g_t^L)^{\alpha\epsilon} < (1+g_t^M)^{\alpha\epsilon}(1+g_t^L)^{(1-\alpha)(1-\epsilon)}(1+g_t^M)^{\alpha(1-\epsilon)}.$$

Since $g_t^M \geq 0$, a sufficient condition for this to be true is

$$(1+g_t^L)^{\alpha\epsilon} < (1+g_t^L)^{(1-\alpha)(1-\epsilon)} \qquad \Rightarrow \qquad (1+g_t^L)^{\alpha\epsilon-(1-\alpha)(1-\epsilon)} < 1.$$

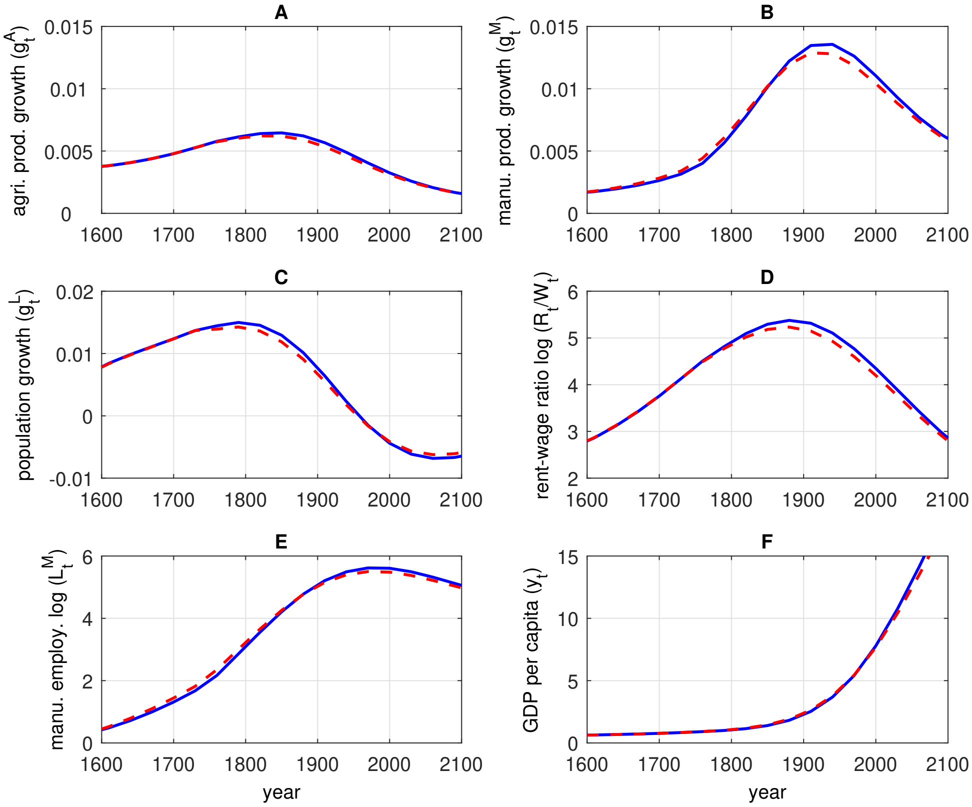
Since $g_L > 0$, this is fulfilled for $\alpha\epsilon < (1-\alpha)(1-\epsilon)$ that is for $\alpha < 1-\epsilon$.

Primogeniture. Suppose that only the first-born child of landowners inherits the land and that the remaining children enter the workforce such that the landed class evolves as $L_{t+1}^X = \min\{1, \gamma/p_t\} L_t^X$ and (9) is replaced by

$$L_{t+1} = \begin{cases} \frac{\gamma}{\beta+\gamma}\frac{M_t}{p_t} L_t + \max\left\{0, \frac{\gamma}{p_t} - 1\right\} L_t^X & \text{for } M_t \leq \beta+\gamma \\ \frac{\gamma}{p_t} L_t + \max\left\{0, \frac{\gamma}{p_t} - 1\right\} L_t^X & \text{otherwise.} \end{cases} \tag{A.10}$$

Figure A.1 shows the solution of the model. Parameters and initial values are taken from the basic model (Figure 1 and in the text). Blue (solid) lines reiterate the solution from Figure 1 and 2. Red (dashed) lines show results under the primogeniture assumption when the initial population of landowners is 1/100 of the initial population of workers. Green (dash-dotted) lines show results when the initial value increases to 1/10. The deviations from the basic model are minimal. The reason is that the population of landowners is too small for a substantial scale effect.

Figure A.1: Inequality and Industrialization: Primogeniture



Blue (solid) lines: benchmark model from the text. Red (dashed) lines: primogeniture with initial $L_t^X/L_t = 1/100$. In the primogeniture simulation, one child of a landowner inherits the land while the other children enter the workforce. Parameters as for the benchmark model (Figure 1 and 2).

Appendix B: Extended Model

In this section we extend the model to account for physical capital accumulation and international trade. The extension is subject to some simplifying assumptions that are necessary in order to keep the model analytically tractable. We show that the results from the basic model are preserved for the extended model.

B.1. Production and Factor Prices. We assume that physical capital enters as an essential input in manufacturing, while the agricultural production function is kept from the basic model. The sectoral production functions are given by:

$$Y_t^A = A_t \left(L_t^A\right)^{\alpha} X^{1-\alpha}, \qquad Y_t^M = \left(M_t L_t^M\right)^{\theta} K_t^{1-\theta}, \tag{A.11}$$

in which θ is the labor share and $(1-\theta)$ is the capital share in manufacturing. The assignment of the productivity parameter θ to the compound $M_t L_t^M$ (and not only to L_t^M) is irrelevant for the results since, due to the Cobb-Douglas form, all technological progress is quasi-labor augmenting but it has the analytically convenient side effect that the extended model, in its reduced-form, will be isomorphic to the benchmark model (see below). The land rent and the wage rate are obtained as in (A.12) and (A.13):

$$R_t^X = p_t(1-\alpha)A_t \left(L_t^A\right)^{\alpha} X^{-\alpha} \tag{A.12}$$

$$W_t = p_t \alpha A_t \left(L_t^A\right)^{\alpha-1} X^{1-\alpha} = \theta M_t^{\theta} \left(L_t^M\right)^{\theta-1} K_t^{\theta}. \tag{A.13}$$

We assume that physical capital depreciates fully within one generation. The net return to physical capital investments equals the real interest rate, i.e., $(1-\theta)M_t^{\theta}\left(L_t^M\right)^{\theta} K_t^{-\theta} - 1 = R_t^K$. We assume that interest rates are determined on the world market and are given for Britain. The assumption of exogenous interest rates is plausible since Britain was on the gold standard since 1717, which ensured basically perfect capital mobility (Eichengreen, 1996; Obstfeld et al., 2005). Physical capital is thus obtained as

$$K_t = \left(\frac{1-\theta}{1+r_t^K}\right) M_t^{\theta} \left(L_t^M\right)^{\theta}. \tag{A.14}$$

Insertion of (A.14) into (A.11) and (A.13) provides:

$$Y_t^M = \nu_t M_t L_t^M \tag{A.15}$$

$$W_t = \theta \nu_t M_t \tag{A.16}$$

with $\nu_t \equiv \left[(1-\theta)/(1+r_t^K)\right]^{(1-\theta)/\theta}$. The parameter ν_t is exogenously given for households and firms but may vary over time. Capital income $r_t^K K_t$ accrues to capital owners who may or may not be the same as the landowners. The crucial (and plausible) assumption here is that capital owners are not bound by subsistence consumption. We denote the total population of landowners and capitalists by L_t^X.

B.2. International Trade. In order to establish international trade as an additional driver of industrialization it is sufficient to consider a simple model extension. For this purpose, suppose that a share ψ_t of domestic food demand can be imported at price $\tau_t p_t$, in which $\tau_t \geq 1$

captures trade costs and tariffs. The notation by time-indexed Greek symbols indicates that the parameters ψ_t and τ_t are taken as given by households and firms but may vary over time. Food imports are traded for industrial goods and we assume that trade is balanced such that

$$\tau_t p_t Im_t = Ex_t, \tag{A.17}$$

in which Im_t are imports and Ex_t are exports. To see how international trade has the potential to confound our main results, consider the period in which workers are bound by subsistence such that workers respond to productivity increases solely with greater food demand and population growth. According to the basic model, industrialization can, therefore, only be driven by increasing income of the landed elite. However, due to balanced international trade (A.17), industrialization is also being driven by labor force growth, as increasing demand for food leads to higher food imports and thus more exports and higher demand for manufactured goods.

B.3. Goods Market Equilibrium with Binding Subsistence Constraint. When workers are bound by subsistence, they spend all income on food while food consumption of the non-working elite is given by $(\beta+\gamma)L_t^X$, as for the benchmark model. The difference is that now only a share $(1-\psi_t)$ of food demand is met by domestic production such that the food market equilibrium is given by (A.18). In equilibrium for manufactured goods, aggregate supply equals aggregate demand, which is made up of exports and the income of land and capital owners that has not been spent on food, as described in (A.19). Additionally, trade equilibrium requires that imports equal exports, as in (A.20).

$$p_t A_t \left(L_t^A\right)^\alpha X^{1-\alpha} = (1-\psi_t)\left[\theta\nu_t M_t L_t + (\beta+\gamma)L_t^X\right] \tag{A.18}$$

$$\nu_t M_t L_t^M = Ex_t + p_t(1-\alpha)A_t\left(L_t^A\right)^\alpha X^{1-\alpha} + R_t^K K_t - (\beta+\gamma)L_t^X \tag{A.19}$$

$$Ex_t = \tau_t p_t Im_t = \tau_t\psi_t\left[\theta\nu_t M_t L_t + (\beta+\gamma)L_t^X\right]. \tag{A.20}$$

Inserting (A.14), (A.18), and (A.20) into (A.19) and solving for employment in manufacturing provides the solution:

$$L_t^M = \frac{\theta\nu_t}{\omega_t}\left[\tau_t\psi_t + (1-\alpha)(1-\psi_t)\right]L_t - \left[\alpha + \psi_t(1-\alpha) - \tau_t\psi_t\right]\frac{(\beta+\gamma)L_t^X}{\omega_t M_t}, \tag{A.21}$$

with $\omega_t \equiv \left\{\left[(1-\theta)/(1+r_t^K)\right]^{(1-\theta)/\theta} - r^K\left[(1-\theta)/(1+r^K)\right]^{1/\theta}\right\}$. For $\psi_t = 0$ and $\theta = 1$ (and thus $\omega_t = \nu_t = 1$), the solution collapses to the simple model from the main text. Agricultural prices are obtained by inserting the solution $L_t^A = L_t - L_t^M$ into (A.18) and from there follows the solution of the rest of the model.

B.3. Goods Market Equilibrium without Binding Subsistence Constraint. Beyond subsistence, aggregate food demand of the population is given by $(\beta+\gamma)\left(L_t + L_t^X\right)$ of which a share of $1-\psi_t$ is met by domestic supply, as in (A.22). Demand for manufactured goods is given by exports plus all income generated in the economy minus demand for food, which equals supply in equilibrium, as in (A.23). Finally, exports equal imports in trade equilibrium (A.24).

$$p_t A_t\left(L_t^A\right)^\alpha X^{1-\alpha} = (1-\psi_t)(\beta+\gamma)\left(L_t + L_t^X\right) \tag{A.22}$$

$$\nu_t M_t L_t^M = Ex_t + p_t(1-\alpha)A_t\left(L_t^A\right)^\alpha X^{1-\alpha} + r_t^K K_t + W_t L_t - (\beta+\gamma)\left(L_t + L_t^X\right) \tag{A.23}$$

$$Ex_t = \tau_t p_t Im_t = \tau_t \psi_t(\beta+\gamma)\left(L_t + L_t^X\right). \tag{A.24}$$

The term $r_t^K K_t + W_t L_t$ comprises all income generated in manufacturing plus wage income in agriculture and can be replaced by $\nu_t M_t L_t^M + \theta \nu_t M_t (L_t - L_t^M)$ using income and wages from (A.15) and (A.16). Then, inserting (A.22) and (A.24) into (A.23) and solving for employment in manufacturing provides the solution:

$$L_t^M = L_t - \left[\alpha + \psi_t(1-\alpha) - \tau_t\psi_t\right] \frac{L_t + L_t^X}{\theta \nu_t M_t}, \tag{A.25}$$

The solution collapses to that of the basic model for $\psi_t = 0$ and $\theta = 1$. The rest of the model is solved as before.

Inequality and Industrialization. The rent wage ratio is obtained from (A.12) and (A.16) as

$$\frac{R_t^X}{W_t} = \frac{p_t(1-\alpha)A_t(L_t)^\alpha X^{-\alpha}}{\theta \nu_t M_t}. \tag{A.26}$$

Inserting (A.26) into (A.19) and solving for employment in manufacturing provides (A.27) for the case of a binding subsistence constraint. Inserting (A.26) into (A.23) and solving for employment in manufacturing provides (A.28) when the subsistence constraint is not binding.

$$L_t^M = \tau_t\psi_t\theta L_t + \theta\frac{R_t^X}{W_t}X + \theta\frac{R_t^K}{W_t}K_t - \frac{(1-\tau_t\psi_t)(\beta+\gamma)L_t^X}{\nu_t M_t} \qquad \text{for } M_t < \beta+\gamma \tag{A.27}$$

$$L_t^M = \theta L_t + \theta\frac{R_t^X}{W_t}X + \theta\frac{R_t^K}{W_t}K_t - \frac{(1-\tau_t\psi_t)(\beta+\gamma)\left(L_t + L_t^X\right)}{\nu_t M_t} \qquad \text{otherwise.} \tag{A.28}$$

Inspection of (A.27) and (A.28) verifies the claim that our main result of Proposition 1 holds also in the extended model: inequality, as measured by the rent-wage ratio is positively associated with industrialization, i.e., the level of employment in the industrial sector (when controlling for population size and trade).

Dividing by L_t we obtain the association between employment shares and the functional income distribution:

$$\frac{L_t^M}{L_t} = \tau_t\psi_t\theta + \frac{\theta\left(R_t^X X + r_t^K K_t\right)}{W_t L_t} - \frac{(1-\tau_t\psi_t)(\beta+\gamma)L_t^X}{\nu_t M_t L_t} \qquad \text{for } M_t < \beta+\gamma \tag{A.29}$$

$$\frac{L_t^M}{L_t} = \theta + \frac{\theta\left(R_t^X X + r_t^K K_t\right)}{W_t L_t} - \frac{(1-\tau_t\psi_t)(\beta+\gamma)\left(L_t + L_t^X\right)}{\nu_t M_t L_t} \qquad \text{otherwise.} \tag{A.30}$$

The employment share in manufacturing is positively associated with the ratio between operating surplus and labor-income, $(R_t^X X + r_t^K K_t)/(W_t L_t)$.

Finally, we compute the derivatives

$$\frac{\partial(L_t^M/L_t)}{\partial\psi_t} = \theta\tau_t + (\beta+\gamma)\tau_t\frac{L_t^X}{\nu_t M_t L} > 0 \qquad \text{for } M_t < \beta+\gamma \tag{A.31}$$

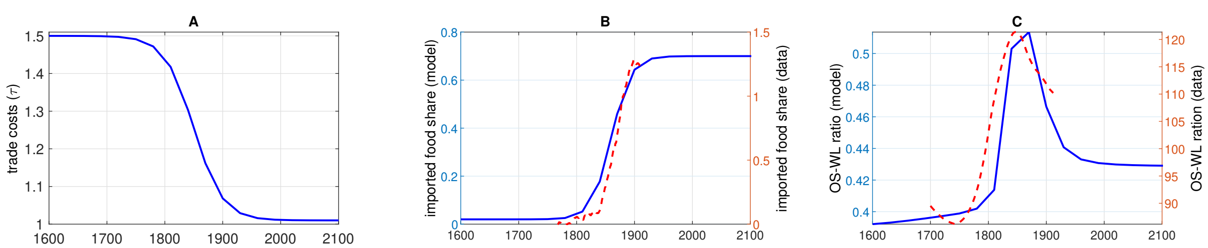
$$\frac{\partial(L_t^M/L_t)}{\partial\psi_t} = \theta\tau_t + (\beta+\gamma)\tau_t\frac{L_t^X}{\nu_t M_t L} > 0 \qquad \text{otherwise.} \tag{A.32}$$

Increasing international trade (increasing ψ_t) is positively associated with industrialization and the partial effect of trade is, ceteris paribus, larger when workers are bound by subsistence. Notice, however, that the predicted positive association between inequality and industrialization is independent of international trade, i.e., independent of the size of ψ_t and τ_t

Calibration. For the calibration, we feed into the model two time series for the share of imports in food consumption ψ_t and trade costs τ_t. Before the mid 19th century, landowners in Britain were largely protected against food imports. In particular, a series of 'Corn Laws' enacted since 1772 prevented the import of the workers' most important staple. Nye (1991, Figure 1) provides a time series of average tariffs which were around 50% in 1820 and then declined to around 10 % by 1900. We approximate this trend with a logistic function of τ_t that starts at 1.50 in 1600 and declines to 1.01 in 2100 with the greatest momentum around the year 1860 and arriving at 1.1 in 1900. The imputed time series for τ_t is shown in panel A of Figure A.2.

To obtain an approximation of the time path of ψ_t, we computed the ratio of grain imports divided by grain consumption of the total population. Grain consumption per capita is assumed to be constant over the entire period and set equal to 0.46 kg per day per person according to Broadberry eta al. (2015, p 289). The import ratio is normalized to be equal to 0.32 in 1855 following the estimates of Broadberry et al. (2015, p 289). The data sources for population and net import of grain are relegated to the Data Appendix. The implied trajectory is shown by the red dashed line in the Figure A.2 Panel B. The grain import/consumption ratio approaches a value larger than one because grain is also used as animal fodder. Because it is unknown how much of the grain was not consumed by households, we assume a logistic function for ψ_t that increases from 2% in 1600 to 70% in 2100 with the greatest momentum around 1870. This series greatly overestimates the share of food imports in the UK today (which is around 45%). However, errors in the 21st century when industrialization is over and the importance of food in households' budget is small are irrelevant for our exercise that focusses on the drivers of industrialization. For the late industrialization period from 1890 to 1920, the logistic function assigns a food import share of 50% to 60%, which is a high but not implausibly high value. The main purpose of the calibration is to determine the right timing for the sharp increase in food imports during industrialization. This leads to the estimate of the time series for ψ_t as shown by the solid blue line in panel in Figure A.2 Panel B.

Figure A.2: Extended Model: Trade Costs, Food Import Share, and OS-WL Ratio

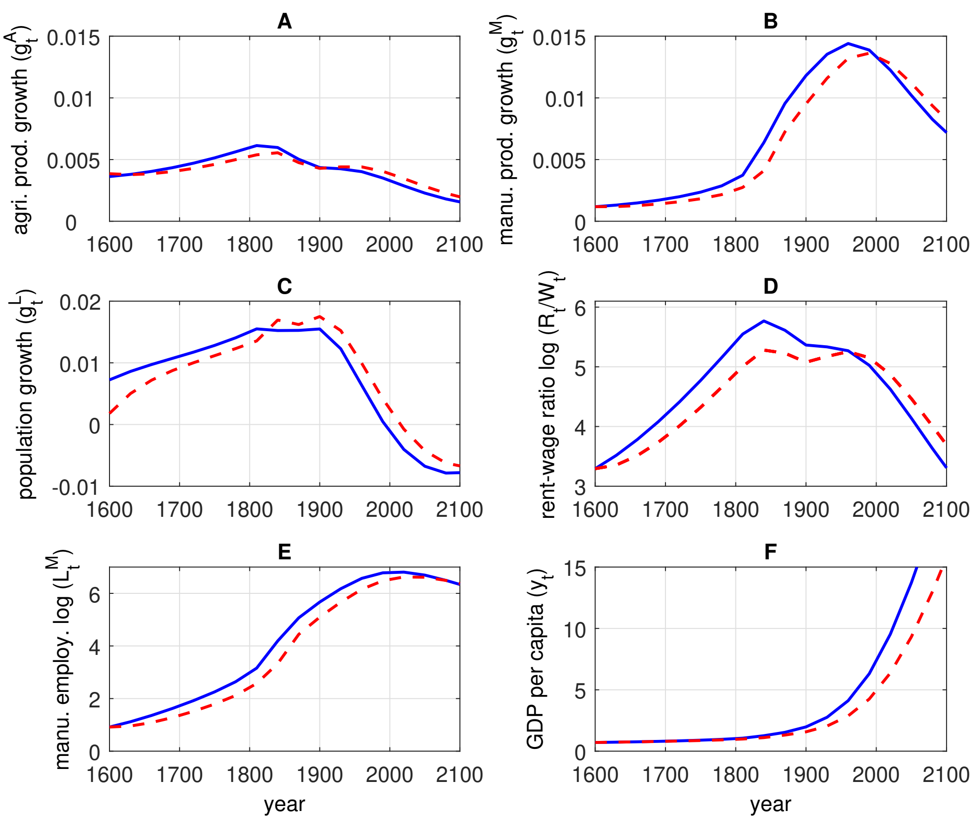


Blue (solid) lines: model; red (dashed) lines: data; see text for details. The OS-WL ratio is the ratio between aggregate operating surplus $R_t X + r^K K_t$ and labor income $W_t L_t$.

We set the capital share θ to 0.3 and impose an annual net interest of 0.05, which translates into a gross 30-year interest rate of 2.3. We recalibrate the parameters $\alpha = 0.70$ (instead of 0.72), $\delta = 0.092$ (instead of 0.055), and $\mu = 0.12$ (instead of 0.014). All other parameters are kept from the benchmark model. Figure A.3 shows the predicted trajectories by blue (solid) lines and replicates the main computational experiment (from Figure 2) for the extended model. The main difference to the basic model is the delayed decline in population growth. Increasing imports of food and declining trade costs delay the increase of the relative price of food that initiates the fertility decline and the demographic transition. Otherwise, the picture looks very similar to that of the basic economy.

Panel C of Figure A.2 shows the implied ratio between operating profits and labor income, $OS_t/(W_tL_t) \equiv (R_tX + r_t^K K_t)/(W_tL_t)$. The blue solid line shows the prediction of the calibrated model and the red dashed line shows the data series used in the empirical section. We see that the OS-WL ratio preserves the hump-shape of the rent-wage ratio but with much steeper upward and downward branching path. The downward trend is again initiated around the time when population growth declines. As the importance of the agricultural sector vanishes asymptotically, the OS-WL ratio approaches the functional income distribution of labor and capital implied by the production elasticities in the manufacturing sector, $\theta/(1-\theta) = 0.43$. The model provides a good approximation of the timing of the rise and fall of the OS-WL ratio.

Figure A.3: Inequality and Industrialization: Extended Model



Blue (solid) lines: benchmark economy; red (dashed) lines: economy with lower inequality due to initially 20% lower level of agricultural technology, other parameters and initial values as for benchmark).

Red (dashed) lines in Figure A.3 show the trajectories of an otherwise identical economy starting with 20% lower productivity in agriculture, implying that landowners benefit less from increasing growth of agricultural productivity, both directly (panel A) and indirectly via the more slowly growing workforce (panel C). As a result, inequality increases less steeply (panel D) and the country industrializes more slowly (panel E). Summarizing, also quantitatively, the extended model preserves the main results obtained from the simple model of the main text. The main reason for the quantitative robustness of the results is that food imports are low during the early industrialization period when workers are bound by subsistence and rising inequality has the strongest impact on the demand for manufactured goods.

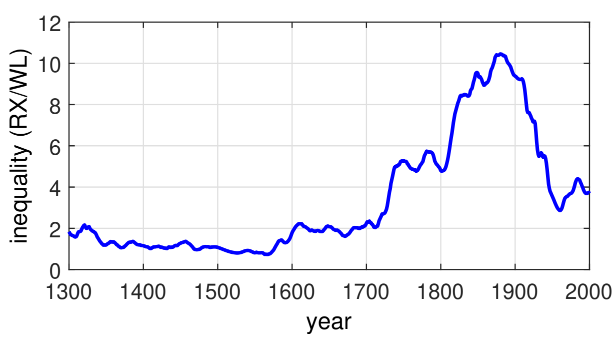
Appendix C

Table A.1 Summary Statistics

	Mean	Std. Dev.	Period	Mean	Std. Dev.	Period
$\log(Y^M/Y)$	-2.36	0.38	1750-1913	-2.84	0.38	1270-1912
$\log(Y^M/Pop)$	-1.65	0.68	1750-1913	-2.79	0.87	1270-1912
$\log(Y^M)$	8.31	1.08	1750-1913	6.30	1.48	1270-1912
$\log(R/W)$	0.21	0.22	1750-1913	-1.05	0.37	1270-1912
$\log(OS/WL)$	0.26	0.21	1750-1913	0.26	0.16	1270-1912
$\log(RX/WL)$	-0.74	0.33	1750-1913	-1.04	0.37	1270-1912
$\log(Pop)$	9.96	0.41	1750-1900	9.08	0.67	1270-1912
$\log(Exec)$	1.82	0.13	1750-1900	1.17	0.31	1270-1912
$\log(EA)$	1.39	0.23	1750-1900	0.07	2.01	1270-1912
$\log(L^M/L)$	-1.293	0.16	1750-1900			
$\log(L^M)$	-1.293	0.16	1750-1900			
$\log(Pat^S)$	7.49	1.62	1750-1900			
$\log(EX^M/Y)$	0.26	0.75	1750-1900			
$\log(IM^F/Y)$	0.17	1.91	1750-1900			
$\log(P^{Coal}/P^M)$	0.19	0.01	1750-1865			

Notes. Y^M is manufacturing GDP; Y is economy-wide real GDP; R is agricultural rent; W is the agricultural wage rate; Pop is population; L^M is manufacturing employment; L is total employment; X is agricultural land area; Pat^S is patent stock; P^{Coal} is the price of coal; P^M is the manufacturing price deflator; $Exec$ is constraints on the executive; Ex^M is export of manufacturing products; Im^F is imports of grain; $Exec$ is constraints on executive; EA is educational attainment measured by years of education of the working age population; OS is operating surplus.

Figure A.4: Inequality measured by the RX/WL-ratio



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