Anonymity, Efficiency Wages and Technological Progress

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CESIFO WORKING PAPER NO. 5926
CATEGORY 4: LABOUR MARKETS
MAY 2016

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ISSN 2364-1428

CESifo *Working Paper No. 5926*

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Abstract

Although the Industrial Revolution is often characterized as the culmination of a process of commercialisation, the precise nature of such a link remains unclear. This paper provides an analysis of one such link: the role of commercialisation in raising wages as impersonal labour market transactions replace personalized customary relations. In the presence of an aggregate capital externality, we show that the resulting shift in relative factor prices will, under certain conditions, lead to higher capital-intensity in the production technology and hence, a faster rate of technological progress. We provide historical evidence using European data to show that England was among the most urbanized and the highest wage countries at the onset of the Industrial Revolution. The model highlights the role of the informal sector and migration to urban areas, via their impact on the prevailing level of anonymity within an economy, as a driver of capital accumulation and technological progress in modern developing countries. Unemployment subsidies and cash transfer schemes that may have as a potential negative side effect the increase of employment in the informal sector can lead to increased efficiency wages, capital accumulation and technological progress in the formal sector, while restricting migration to the urban sector can have the opposite effect.

JEL-Codes: N130, O140, O430.

Keywords: commercialization, industrial revolution, anonymity, efficiency wages, learning by doing.

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May, 2016
We are grateful to Sascha Becker, Nick Crafts, Frank Lewis, Sharun Mukand, Jon Temple, Fabian Waldinger, Nico Voigtländer, Joachim Voth, Fabrizio Zilibotti and seminar/conference participants at Warwick; Queen's University, Canada; Krakow; Copenhagen and Sheffield for helpful comments and suggestions.

1 Introduction

In his seminal paper, Greif (1994) links the degree of anonymity in labour markets to the probability with which past choices of individual workers are revealed to a potential employer in current spot markets. Taking as his starting point the very different strategies deployed by Genoese and Maghribi traders, Greif (1994) makes the point that the degree of anonymity is linked to different "rules of the game" due to institutional or cultural practices. For Greif, a collectivist culture (as embodied in the hiring practices of Maghribi traders) is linked to a low degree of anonymity while an individualist culture (as embodied in the hiring practices of Genoese traders) is linked to a high degree of anonymity. In a related but different vein, Banerjee and Newman (1998), make the point that development is characterized by a change in the informational structure among economic agents leading to the bulk of GDP being produced in urban areas where markets are likely to have a greater degree of anonymity.

In this paper we wish to examine how the degree of anonymity impacts on the capital intensity of production and hence, on capital accumulation and technological change. The commercial and industrial revolutions provide the most natural backdrop for examining these issues. In particular, we focus on the growing reliance on anonymous, impersonal relations, as against personalized customary relations in labor markets following the commercial revolution which preceded the shift towards urbanization. With growing urbanization the degree of anonymity increased. Hence, for our purposes, commercialization means more than simply an increase in the proportion of output passing through the market (Britnell and Campbell, 1995: 1).

A number of recent studies have pointed to the emergence of northwest Europe as a high wage economy during the early modern period, between the sixteenth and eighteenth centuries, with Britain overtaking the Netherlands to become the highest wage economy in Europe (van Zanden, 1999; Allen, 2001; Broadberry and Gupta, 2006). At the same time Britain was among the most urbanized countries in the world in the first half of the eighteenth century, at the onset of the Industrial Revolution (de Vries, 1984; Malanima 2009). Since one of the key features of the Industrial Revolution was the development of labor saving technology in Britain, it is natural to link the Industrial Revolution to these prior developments in factor prices and the global commercial environment in which they emerged (Broadberry and Gupta, 2009; Allen, 2009).

Indeed, a long tradition in economic history links the transition to modern economic growth to the widespread commercialisation of Britain and other parts of northwest Europe between the late medieval period and the Industrial Revolution (Toynbee, 1890; Polanyi, 1944; Britnell and Campbell, 1995). However, the precise nature of the links between the Commercial Revolution and the Industrial Revolution has remained unclear. Furthermore, it must be emphasized that an older view that saw wages rising only in response to higher productivity resulting from technological progress, which was prevalent amongst a previous generation of economic historians, can no longer be sustained in the presence of the overwhelming evidence that Britain was already a high wage economy before the Industrial Revolution (Crafts, 2011; Allen, 2009; Mokyr, 2009).

The approach taken here draws on ideas which have been used in the literature on the importance of high wages in stimulating the innovations of the Second Industrial Revolution in late nineteenth century America (Rothbarth, 1946; Habakkuk, 1962; David, 1975; Broadberry, 1997).[1] Until recently, there has been a reluctance to cast Britain in the role of a high wage producer at the time of the Industrial Revolution, since the vast literature on the standard of living debate emphasized the slowness of real wages to rise. However, recent work has emphasized international comparisons of the level of real wages and other factor prices, pointing clearly to Britain's unusual combination of factor prices with expensive labor and cheap coal (Allen, 2001; 2009; Broadberry and Gupta, 2006; 2009). This is important not only in explaining the adoption of modern technology, but also its non-adoption in other countries with different factor prices, a point emphasized in the theoretical literature by Zeira (1998) and in the historical literature by Broadberry and Gupta (2009), Allen, (2009) and Fremdling (2000).

In this paper, we examine how an increase in the degree of anonymity impacts on capital

[1] See Acemoglu (2009) for a formal treatment of the link between labor scarcity and the rate of technological progress.

accumulation through a higher degree of capital intensity in production.[2] Our results are as follows. First, we deploy an efficiency wage argument (Shapiro and Stiglitz, 1984) to show that a greater degree of anonymity will lead to higher wages. Note that the efficiency wage argument developed here avoids the objection sometimes levelled at the literature on induced innovation that high wages do not necessarily reflect high labor costs because the labor is also highly productive. In our model, higher wages in anonymous labour markets are required to induce the same effort as achieved with lower wages in more personalized customary relationships backed up by greater information sharing between firms about shirking workers. Second, in the presence of an aggregate capital externality, we derive the conditions under which the resulting rise in the wage/cost of capital ratio leads to the adoption of a more capital-intensive technology for each individual firm: the key condition here is that when labour and capital are imperfect substitutes, the elasticity of substitution between labour and capital has to be greater than one. Third, the model shows how a higher degree of capital intensity in the production technology leads to a faster rate of technological progress via greater learning by doing (Hicks (1932) and Arrow (1962)), in a small open economy where interest rates are fixed by world markets.[3] Fourth, holding the degree of anonymity in the labour market fixed, the model shows an increase in the scale of the domestic economy also results in a shift to a more capital intensive production and higher wages and via technological progress, a higher stock of the steady state capital and real wages. Fifth, the model shows that the scale of the domestic economy and the degree of anonymity are mutual complements i.e. the impact of an increase in the degree of anonymity on the long run capital stock and technology is larger when the scale of the domestic economy is higher.

While it has already been emphasised that the changes in the information structure of a modernising economy have important consequences for access to credit (e.g. Banerjee and Newman (1998)) we are, to the best of our knowledge, the first to point out the effects of changes in information structure on efficiency wages and technological progress. Our paper highlights the role of the informal sector as a driver of capital accumulation and

[2]The literature on efficiency wages takes the capital stock and technolgy of a firm as fixed.

[3]The perspective that techological progress should be understood as endogenous to economic forces has been advanced by some of the scholars of the new growth theory, e.g., Romer (1986, 1990) and Aghion and Howitt (1992).

technological progress in modern developing countries and has implications for policies that impact on it. Our model shows that the efficiency wage and the level of anonymity are positively linked to the demand for capital and technological progress. A policy of unemployment subsidies, cash transfers or public job creation usually blamed for increasing employment in the informal sector can in fact increase efficiency wages and have a positive effect on capital accumulation and technological progress. Similarly, restricting migration to the urban areas may reduce the prevailing level of anonymity and hence, the efficiency wages and, ultimately, capital accumulation and technological progress.

The link we make between a greater degree of anonymity and technological progress finds empirical support in Gorodnichenko and Roland (2010), who find that less collectivistic societies are characterized by a higher degree of innovation.

The paper proceeds as follows. In section 2, we present a literature review. Section 3 present the theoretical model to derive the conditions under which anonymity and technological progress are linked. Section 4 then provides a historical narrative. Section 5 concludes. The proof of our main proposition is in the Appendix.

2 Related literature

The present paper is related to Legros, Newman and Proto (2013), who analyze how the incomplete information affects the level of labour division through the effect on wages. LNP consider a fully anonymous environment where wage levels change the level of labour division to improve the monitoring of workers' effort and the production of innovations. In our paper, the capacity of monitoring is given, but the level of anonymity, hence the capacity of punishment of shirking workers changes. Both paper emphasizes how the information on effort provision is crucial in shaping the firms' decisions and in determining externality that ultimately affects technological progress.

The current paper suggests a link between the two main strands of the macro-development literature: the institutional approach (e.g. North, 1990; Greif, 2004; 2006; Acemoglu and Robinson, 2006) and unified growth theory (e.g. Galor and Weil, 1999; 2000; Galor and Moav, 2000; Hansen and Prescott 2002; Doepke, 2004; Galor, 2005; Cervellati and Sunde, 2005, Madsen, Ang and Banerjee, 2010). The institutional approach emphasizes the importance of trade and commercial development, which are supported by an appropriate institutional framework, while unified growth theory links technological progress to wages via an emphasis on human capital, with families choosing to have fewer but more highly educated children as technology becomes more complex. Our approach sees the two theoretical frameworks as complementary. Establishing the right institutional framework to encourage the development of trade leads to a higher wage, which then has the effects on technology traced out in unified growth models.

Furthermore, within the institutional approach, our paper provides a link between commercial development and economic growth that is complementary to the links suggested by Acemoglu et al. (2005) and by Galor and Mountford (2006). Acemoglu et al. focus on the impact of Atlantic trade on institutions, with growing trade strengthening the position of merchants in northwest Europe and enabling them to impose effective constraints on the executive, hence contributing to the development of less extractive institutions. Galor and Mountford (2006) show that trade might have generated a demographic boom in non-industrial countries, specialized in the production of unskilled-labor-intensive goods, hence fostering the process of divergence. Our approach focuses on an alternative link between trade and growth, with increasing commercialisation affecting factor prices, choice of technology and the rate of technological progress.

Our setting is complementary to other model of endogenous growth, based on the idea that capital was an important engine of growth in the process of economic development (Galor and Moav 2004), since we emphasize the effect of high wages on the capital intensity of production and the subsequent rate of technological progress. Along similar lines Voigtländer and Voth (2006) emphasize the effects of growing capital inputs on TFP growth for the first phase of industrialization.

3 The model

In this section, building on Shapiro and Stiglitz's (1984) original model of efficiency wages, we introduce our concept of anonymity and endogenous technological progress via learning by doing. We show that a higher degree of anonymity, arguably generated by the commercial revolution, made more difficult monitoring workers and led to an increase in wages and subsequently to more capital intensive production. This process eventually led to a technological increase in labour efficiency that we characterize as the industrial revolution.

3.1 Workers

Time periods are indexed by t, $t = 0, 1, 2, ...$ There is a mass N of identical risk averse workers. There is a probability d that at each time t, the worker dies or permanently retires from working. Since the number of workers is fixed at each period, there are dN new workers in the economy so that the labor supply is always constant. Workers have an inter temporal discount factor which, for notational simplicity, we multiply by the probability of surviving next period, $(1 - d)$, and define the resulting product as $\beta < 1$.

At any period t, each worker can be either employed or unemployed and is endowed with a fixed amount of effort that can be costlessly provided. If she is unemployed she uses her effort in a backyard informal activity, which yields μA_t, where A_t is a technological parameter, linked to the general economic environment at any time t, which we will characterize later; if she is employed she earns a wage w_t.

Since effort cannot be observed, employed workers can either shirk or work (i.e. choose an effort level $e \in \{0, 1\}$). An employed shirking worker uses her effort for the backyard activity earning μA_t in addition to the wage offered by the employer. She can be detected with probability $1 - p$ and fired.[4] In this case, a shirking worker can look for a job in the next period by "hiding" among the pool of new workers dN and her probability of finding a new job is $q\sigma$, where q (which is endogenous and will be determined later) is the probability, common to all individuals in the unemployment pool, of being hired and $\sigma \in (0, 1)$ is a parameter, the probability of being detected by a new employer as having shirked in the last job, accounting for the level of anonymity in the economy. We can think of σ as the probability that the bad reputation of the shirking workers reached the new employer. The parameter σ can be reasonably considered close to 1 in a small village market and close to 0 in a large urban environment.

A non-shirking worker will work in the firm until termination (which happens with probability d at each t). We note that $p + (1 - p)\sigma q$ is the probability that a shirking worker at time t, will still be employed at time $t + 1$. We define $V_t^E(e)$ as the intertemporal utility of an employed worker that exercises effort $e \in \{0, 1\}$ at time t.

We will now write down the conditions required to ensure that at the prevailing wages

[4] As it has been already emphasized by Shapiro and Stiglitz (1980) firing a shirking worker is also the optimal strategy on the part of the employer.

at time period t, choosing high effort $e = 1$ is optimal for each employed worker. To this end, by the one-shot deviation principle (Blackwell (1965)), it is sufficient to show that no employed worker can gain by deviating and choosing low effort $e = 0$ for one period at any t.

Fix a sequence of market wages $\{w_t : t \geq 0\}$.

The intertemporal utility for an employed non shirking worker is

$$V_t^E(1) = w_t + \beta V_{t+1}^E(1), \tag{1}$$

and we have the following expected discounted utilities for an employed worker who shirks once but does not shirk again in the future:

$$V_t^E(0) = w_t + \mu A_t + \beta((p + (1-p)\sigma q)V_{t+1}^E(1) + (1 - (p + (1-p)\sigma q))V_{t+1}^{US}), \tag{2}$$

where V_t^{US} is the intertemporal utility of an unemployed worker who has shirked at least once in the past but does not shirk again if employed in the future i.e.

$$V_t^{US} = \mu A_t + \beta(q\sigma V_{t+1}^E(1) + (1 - q\sigma)V_{t+1}^{US}). \tag{3}$$

Therefore, given the sequence of market wages, the no shirking constraint is met whenever:

$$V_t^E(1) \geq V_t^E(0). \tag{4}$$

We assume that at each t, each worker correctly anticipates future levels of $V_t^E(e)$, $e \in \{0, 1\}$ and V_t^{US}.

3.2 Production and firms

There is a fixed mass $m > 0$ of identical firms, indexed by i, where m is a scale parameter in the model: a higher value of m will be associated with a larger domestic economy. We will assume that each firm i has a production function with Harrod-neutral (or labour augmenting) technological progress $\tilde{F}(f_i, k_i, A_t l_i)$ where f_i is a firm-specific input (which we interpret as entrepreneurship), k_i is the capital used by firm i and l_i is the labour employed by firm i. We will assume that f_i is in fixed supply for each firm i and we set $f_i = 1$ for each firm i. Let $F(k_i, A_t l_i) = \tilde{F}(1, k_i, A_t l_i)$. Although we assume that $\tilde{F}(f_i, k_i, A_t l_i)$ is a strictly increasing production function that satisfies constant returns to scale in the three factors of production (f_i, k_i, l_i), for a fixed quantity of f_i, we will assume that $F(k_i, A_t l_i)$ is a strictly increasing, strictly concave production function that satisfies decreasing returns to scale in the two factors of production (k_i, l_i).[5] Our theory hinges on the firms' choices in terms of the capital labor ratio; therefore, for sake of simplicity, we assume that the production function $\tilde{F}(f_i, k_i, A_t l_i)$ is a multi-factor constant elasticity of substitution production function. There are different partial elasticities of substitution between capital and labour on the one hand and capital and entrepreneurship (and labour and entrepreneurship) on the other (as a factor of production, we do not treat entrepreneurship symmetrically with capital and labour). Uzawa (1962) shows (Theorems 1 and 2) that such a production must necessarily have the functional form:

$$\tilde{F}(f_i, k_i, A_t l_i) = (f_i)^{1-\alpha} \left(\theta k^{\rho} + (1-\theta)\left(A_t l\right)^{\rho}\right)^{\frac{\alpha}{\rho}} \tag{5}$$

where $0 < \alpha < 1$ and $\rho < 1$ so that the elasticity of substitution between capital labour is $\frac{1}{1-\rho}$ and the elasticity of substitution between capital (respectively, labour) and entrepreneurship is one.[6] Setting $f_i = 1$, we obtain

$$F(k, A_t l) = \left(\theta k^{\rho} + (1-\theta)\left(A_t l\right)^{\rho}\right)^{\frac{\alpha}{\rho}}, 0 < \alpha < 1, \rho < 1.$$

We assume that A_t evolves over time according to

$$A_t = a(\frac{K_{t-1}}{m}). \tag{6}$$

where K_{t-1} is the aggregate stock of capital inherited from the preceding time period: the interpretation is that the prevailing technology in any period t is determined by an aggregate capital externality i.e. it is a function of the new knowledge created in the preceding period which is itself an increasing function of the per firm *aggregate* capital

[5] We need to assume that the production function displays decreasing returns to scale in capital and labour in order to ensure that the first order conditions characterizing profit-maximization can be inverted to yield a demand function for capital and labour as a function of relative factor prices.

[6] The CES production function is increasingly prominent in macroeconomics and growth economics, see e.g. Klump et al. (2011) for a survey.

stock in that period.[7] This assumption can be interpreted as productivity growth through learning by doing (e.g. Arrow (1962) and Romer (1986)), specifically the stock of knowledge increases with the amount of aggregate capital used i.e. $a(0) = 0$ and $a'(.) > 0$. We assume that each firm is negligible in the aggregate and does not take into account the impact of its own capital use on the aggregate capital stock (hence, on per firm aggregate capital stock) and on innovation. An increase in per firm aggregate capital impacts positively on innovation and productivity. The above specification can also be interpreted as a simple way of modelling, in a reduced form representation, the commecialisation in innovation (via a patenting system) on productivity (e.g. the patenting system is cheaper to run the larger the aggregate capital stock and flow of productivity enhancing innovation.

Firms borrow capital from an external capital market at an exogenously given interest rate r, the capital supply is perfectly elastic and, in equilibrium, make non-zero profits, given the assumption $\alpha < 1$, which implies decreasing return to scale on capital and labor factors. Therefore, profits of the firm can be interpreted as a return to a fixed factor of production, namely entrepreneurship.

All firms are price-takers. At each t, each firm i takes the sequence of future market wages w_t, the interest rate r and the technological parameter A_t as given. Although firms' choices at time $t-1$ influence the technology at time t, we make the standard assumption that the contribution of each firm is negligible and it is not internalized when the decision takes place: in effect, maximizing the sum of profits over time is equivalent to maximizing current period profits within each time period. Therefore, at each t, each firm maximizes current period profits only i.e.

$$\max_{k_{i,t}, l_{i,t}} F(k, A_t l) - w_{i,t} l_{i,t} - r k_{i,t} \tag{7}$$

3.3 Market equilibria and steady state

We define a market equilibrium for a fixed σ as follows:

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[7] An alternative specification would be to have $A_t = a(K_{t-1})$ i.e. the prevailing technology in any period t is a function of the new knowledge created in the preceding period which is itself an increasing function of the *aggregate* capital stock in that period. We point that out the results obtained below would continue to hold with this alternative specification as well. Although detailed calculations and expressions will differ, when technology is a function of the aggregate capital stock, the anonymity/scale complementarity result obatined below continues to hold.

A market equilibrium is a sequence of $(K_t^*, L_t^*, w_t^*, A_t^* : t \geq 1)$ *such that at each* $t = 0, 1 \ldots$:

1. *Given* r, w_t^* and A_t^*, *for each firms* $l_{i,t} = L_t^*, k_{i,t} = K_t^*$ *maximizes profits,*
2. *Given* w_t^*, *no employed worker shirks i.e.* w_t^* *satisfies the no shirking constraint (4),*
3. $A_t^* = a(\frac{K_{t-1}^*}{m})$.

At a steady state $K_t = K_{t+1} = K^*$, $L_t = L_{t+1} = L^*$ and $A_t = A_{t+1} = A^*$ for all t. From (6), it follows that $A^* = a\left(\frac{K^*}{m}\right)$. Therefore, the steady state (long-run) values of the variables at a market equilibrium are denoted by $\left(K^*, L^*, w^*, A^* = a(\frac{K^*}{m})\right)$.

Next, we characterize the market equilibrium in our model.

3.4 Characterization of Market equilibrium

At each t, the first order conditions characterizing profit maximizing input choices are:

$$F_k(k_t, A_t l_t) = r \tag{8}$$

$$A_t F_l(k_t, A_t l_t) = w_t. \tag{9}$$

Assume that at each t, $w_t = \omega_t A_t$ i.e. the market wage is linear in A_t. We interpret $\omega_t = \frac{w_t}{A_t}$ as wages measured in efficiency units of labour. In our model, as A_t will evolve over time, real wages w_t will change over time.

We can decompose the value functions (1), (2) and (3) for each worker as follows:

$$V_t^E(1) = A_t v_t^E(1) \tag{10}$$

$$V_t^E(0) = A_t v_t^E(0) \tag{11}$$

$$V_t^{US} = A_t v_t^{US}. \tag{12}$$

where $v_t^E(e)$ and v_t^{US} depend on ω_t. Furthermore, we note that in equilibrium the no shirking constraint (4) must bind, therefore

$$v_t^E(1) = v_t^E(0). \tag{13}$$

Recalling that in equilibrium all firms are equal, so that $K_t = mk_{i,t}$ and $L_t = ml_{i,t}$ for all firms i at each t, and solving recursively the system given by expressions (12), (11) and

(10) for the steady state values of $v_t^E(1)$, $v_t^E(0)$ and v_t^{US}, we can determine the aggregate equations describing the steady state (where we have used (6)) as follows:

$$F_k(\frac{K^*}{m}, a\left(\frac{K^*}{m}\right)\frac{L^*}{m}) \quad = \quad r \tag{14}$$

$$F_l(\frac{K^*}{m}, a\left(\frac{K^*}{m}\right)\frac{L^*}{m}) \quad = \quad \omega_t. \tag{15}$$

with the no shirking constraint (4)

$$\omega^* = \omega\left(L^*, \sigma\right) = \frac{\mu(1-\beta p(1-q(L^*)\sigma))}{\beta(1-(p+(1-p)q(L^*)\sigma))}. \tag{16}$$

where $q(L^*) = \frac{L^*}{N}$ is the probability of finding a job for any non employed worker in equilibrium.[8] We note that, differently from the classical model with "efficiency wages", our equilibria are compatible with no unemployment $N = L-$ i.e. it is possible that when $q(L) = 1$, $w < \infty$ for low values of σ i.e. when the degree of anonymity in the market isn't too high.[9]

What is the impact of a change in the degree of anonymity σ on the steady state values of capital stock, employment and wages?

The following proposition examines the impact of a higher degree of anonymity on the steady state capital labour ratio and wages:

Proposition 1 *Suppose $\frac{\alpha}{\rho} \leq 1$. Then, $F(k, A_t l)$ is strictly concave in k and l. The relationship between anonymity and scale of domestic labour and goods market, and the technological and capital dynamics when capital and labour are imperfect substitutes is given by the following:*

(i) For each $\sigma, m > 0$, there is a unique steady state with positive capital stock K^* and employment level L^*.

(ii) For each $m > 0$, the steady state capital stock K^*, capital labour ratio $\frac{K^*}{L^*}$, technology

[8]In equilibrium, nobody shirks, so is q, and dL is number of new jobs in the economy, at the same time dN is the flow of new employed workers, therefore the equation $qdN = dL$ must hold and $q = q(L) = \frac{L}{N}$.

[9]A standard critique of efficiency wage models is that non-employed workers would bid for the jobs by offering a bond up front. We refer the reader to Shapiro and Stiglitz (1984) for a discussion of the reasons why such an arrangment is unlikely to emrge in practice.

$A^* = a(\frac{K^*}{m})$ *and real wages* $w^* = \omega(L^*)\, a(\frac{K^*}{m})$ *are all increasing in the degree of anonymity* σ.

(iii) *For each* $\sigma > 0$, *the steady state stock capital stock* K^*, *capital labour ratio* $\frac{K^*}{L^*}$, *technology* $A^* = a(\frac{K^*}{m})$ *and real wages* $w^* = \omega(L^*)\, a(\frac{K^*}{m})$ *are all increasing in the scale of the domestic market* m.

(iv) The higher the scale of the domestic economy m, *the higher is the impact of an increase in the degree of anonymity* σ *on the steady state capital stock* K^*, *capital labour ratio* $\frac{K^*}{L^*}$, *technology* $A^* = a(\frac{K^*}{m})$ *and real wages* $w^* = \omega(L^*)\, a(\frac{K^*}{m})$ *i.e.* σ *and* m *are mutual complements.*

(v) Assume that in the vicinity of the steady state, at each t, *agents expect that future employment and wage levels will be the same as current employment levels. For each* $\sigma, m > 0$, *the steady state is locally a saddle. Further, there exists* $0 < \bar{\beta} < 1$ *such that whenever* $\bar{\beta} < \beta < 1$ *the steady state is locally stable.*

Proof: See the appendix.■

The above proposition shows that there is a unique positive steady state value of the capital stock K^* corresponding to each value of σ. If the degree of anonymity increases to $\sigma' > \sigma$, what are the short-run and long-run effects?

Given a fixed scale, starting from the steady state capital stock and employment corresponding to σ, with imperfect substitutes in the model, a change in σ results in a change in (real) wages in the short-term i.e. in a change in ω_t (as always A_t is fixed at t and will change from period $t+1$).

Given that the marginal productivity of capital will decrease, and the marginal productivity of labour will increase, as more capital is employed, in response to an increase in ω_t, as long as the degree of complementarity between labor with capital isn't too high, there will be a partial substitution of labour by capital in the aggregate. Therefore, when capital and labour are imperfect substitutes in production, both wages in efficiency units and employment will adjust to clear the labor market.

In the long-run, an increase in the anonymity of the labor market results in a shift to a more capital intensive production and higher wages in efficiency units and via technological progress (driven by learning by doing), the steady state capital and real wages associated with a higher level of anonymity (and hence, technology) is also an increasing function of σ.

An important condition is the assumption that $\rho \geq \alpha$, which restrict the degree of complementarity between capital and labour and implies that $\rho > 0$, so that labor and capital are substitutes and the elasticity of substitution between labour and capital in production is greater than one. Berthold et al. (2002) and Bertolila and Saint-Paul (2003) find empirical support for this condition when the technological progress is assumed Harrod-neutral like in our case.

The above proposition shows that in the long-run, for a fixed degree of anonymity in the labor market, an increase in the scale of the domestic economy also results in a shift to a more capital intensive production and higher wages in efficiency units and via technological progress (driven by learning by doing). Moreover, the scale of the domestic economy and the degree of anonymity are mutual complements and echoes results obtained elsewhere on the effect of scale in endogenous growth models (e.g.Kremer (1993) and Galor and Weil (2000)). For example, a large commercialised economy will have a higher long run capital stock, capital labour ratio, technology and real wages than a small commercialised economy. Another example is that productivity in urban areas depends on the scale of the domestic economy (Lobo et. al (2011) for suggestive evidence of such an effect). These results allow us to differentiate how commercialisation (via an invreasing degree of anonymity) impacts on two economies operating at very different scales (e.g. the case of England and Netherlands for which we provide evidence below).

In order to examine the local stability of the steady state, we assume that in the vicinity of the steady state, at each t, agents expect that future employment and wage levels will be the same as current employment levels. Under this assumption, when workers are patient enough, current wages in efficiency units aren't too sensitive to small changes in current labour market conditions. Therefore, small changes in current labour market conditions do not result in large changes in relative factor prices and therefore, capital stock and technology. Therefore, when workers are patient enough, the steady state is locally stable.

In the proof of the above proposition, for a fixed scale of the domestic economy, it is shown that once the level of anonymity is sufficiently high, we should observe equilibrium involuntary unemployment growing with the level of anonymity; hence an increase in the productivity should go hand in hand with an increase in the unemployment rate. This pattern is perfectly consistent with the models of industrialization based on the *dual economy* model (Lewis, 1954; for more recent contributions see e.g. Barenjee and Newman, 1998;

Proto, 2007; Vollrath, 2009a; Vollrath, 2009b). At the beginning of a process of development the *modern* section of the economy is characterized by a growing informal sector, generated by individuals who are not able to find a job in the formal sector. As Harris and Todaro (1970) point out, the reason of this involuntary unemployment is the downward rigidity of the wages in the modern sector. In our model this rigidity is due to the efficiency wages. In the next section, we will present some supportive empirical evidence based on the British industrialization.[10]

4 Historical evidence: the transition to modern economic growth in Northwest Europe, 1300-1850

We now examine the transition to modern economic growth, combining historical evidence with the theoretical model presented in the previous section. We argue that the Industrial Revolution was linked to the Commercial Revolution of the early modern period through the effects of growing commercialisation on factor prices. An increasing degree of anonymity due to growing commercialisation led to an increase in the price of labor relative to the price of capital, which induced a substitution into a more capital intensive technology and an acceleration of technological progress through learning by doing. We argue further that the fact that commercialisation went further in Britain than in the rest of Europe during the early modern period helps to explain why the Industrial Revolution occurred first in Britain. However, this does not mean that commercialisation should be seen as the sole cause of industrialization, which is a complex process. In particular, the institutional mechanisms proposed here should be seen as complementary to the factors proposed in unified growth theory, where higher wages are also linked to demographic factors. This is a point to which we will return later in this section, but we begin by setting out some historical evidence on the main steps in the argument linking growing commercialisation to real economic development.

[10] However, as is shown in the appendix, a potential mitigating factor is the scale of the domestic economy: as the size of the economy grows , total employment may go up.

4.1 Growing commercialisation and anonymity

The growing commercialisation of the European economy can be most easily captured quantitatively by the share of the population living in urban areas, since towns were the centres of commerce. Table 1 provides data on the share of the population living in towns of at least 10,000 inhabitants. For Europe as a whole, the trend is unmistakably upwards from 1400. Looking at regional trends, however, urbanization shows a pattern of divergence within Europe. In the late medieval period, there were two main urban centres of commerce in north Italy and in the Low Countries. While urbanization stalled in north Italy after 1500, there was a brief surge in Portugal and to a lesser extent Spain during the sixteenth century, following the opening up of the new trade routes to Asia and the New World, which undermined Venice's key role at the Mediterranean end of the Silk Road. However, the most dramatic growth of urbanization in the early modern period occurred in the Netherlands in the sixteenth and seventeenth centuries and in England during the seventeenth and eighteenth centuries as those countries displaced the Iberian powers in long distance trade and commercialized their domestic economies to an unprecedented extent. This strong positive correlation between urbanization and playing a leading role in international trade is worth emphasizing because some writers have played down the role of international trade in the process of British economic development, preferring to focus on developments in the home market (Deane and Cole, 1967; McCloskey, 1981; Oxley and Greasley, 1998). Partly as a result of taking an international comparative perspective over a long time span, recent writers such as Acemoglu et al. (2005) and Findlay and O'Rourke (2008) have tended to emphasize the importance of international trade in the Industrial Revolution.

The extent of commercialisation can also be captured quantitatively in the declining share of the labour force engaged in agriculture. The link between commercialisation and the share of the labour force in agriculture is at least implicit in the historical literature on proto-industrialisation following the work of Mendels (1972), who saw commercialisation leading to the development of industry in the countryside before the Industrial Revolution. It is also implicit in the work of Brenner (1982), who emphasized the contrast between England, where the peasantry was replaced by tenants and labourers who had to compete in the market, and the continent where peasants were able to cling to the land and preserve feudal property rights. Table 2 provides data on the share of the labour force in agriculture for a number of European countries. By 1600, the release of labour from agriculture had proceeded further in the Netherlands than in the rest of Europe, as the Dutch economy relied increasingly on imports of basic agricultural products such as grain and paid for them with exports of higher value added products (de Vries and van der Woude, 1997). By 1700, the share of the labour force engaged in agriculture was even smaller in England, where a highly commercialized agriculture produced enough grain to feed the population without recourse to substantial imports until well into the nineteenth century (Deane and Cole, 1962; Crafts, 1985). The share of the labour force in agriculture remained substantially higher in the rest of Europe.

This growth of commercialisation had implications for the degree of anonymity in economic relations, in factor markets as well as in product markets and this, in turn, had implications for wages. Whilst the association between commercialisation and anonymity is straightforward in product markets, the association requires more justification in factor markets, since it is possible in principle to envisage an industrial sector with highly personalized employment relations selling its output in highly impersonal product markets. However, in the development of early modern Europe, anonymity tended to increase in factor markets in parallel with product markets, as a result of economies of agglomeration. As the commercial sector became more concentrated in towns, it was natural for the industrial sector also to locate in towns, particularly in an era of high transport costs (Crafts and Venables, 2003). When workers were employed in small-scale enterprise in isolated rural locations where they formed part of a close-knit community, the problem of securing effort from workers could be solved through reliance on customary relations backed up by close supervision. As markets integrated and people moved to towns where they were unknown to their neighbors and potential employers, it became necessary for employers to find new ways to elicit effort. In the model above, this is captured by the result that an increase in the value of σ, the degree of anonymity in the economy, raises wages to ensure that the no-shirking constraint equations (4) and (16) are satisfied.

In the historical record, it shows up in the growing difference between urban and rural wages during the early modern period, shown here in Table 3 for the case of England. It is well known from the dual economy models that the existence of a wage gap between rural and urban sectors is justified by the existence of unemployment in the formal section of the urban sector, as we also explained at the end of section 3.4. This is due to the downward rigidity of the urban wages, in our case caused by informational asymmetries which prevent the wage from clearing the market. As the urban sector became more anonymous, information became less and less available. This should have caused the efficiency wage to increase, together with the wage gap between the urban sector and the rural/traditional sector, where informational asymmetries remained less severe. Therefore, what is interesting in Table 3 is the increase of this wage gap, consistent with our model, where growing urbanization leads to an increase in the level of anonymity and a higher efficiency wage.

Predating the changes of the classic Industrial Revolution period, the early modern period saw a number of changes which weakened the close monitoring of industrial production in medieval Europe, where a master directly oversaw the work of his apprentices. In light consumer goods industries such as textiles, the putting-out system emerged, with an entrepreneur taking responsibility for delivering materials to workers in their own homes, and taking responsibility for marketing the output. This allowed the gains of specialization and division of labor, but created opportunities for workers both to take leisure when the entrepreneur desperately needed production and to substitute poor materials for the good materials supplied by the entrepreneur or to cover up imperfections, if not to outright embezzle.[11] Indeed, Marglin (1974) sees the factory system as a solution to these problems, rather than as a more efficient method of production. This would be similar to the argument of Skott and Guy (2007) that information and communications technologies have recently made it easier to monitor the effort of low-skill workers. However, Marglin's interpretation is quite contrary to the mainstream view that the factory system was more efficient than putting-out, and created its own problems of disciplining and monitoring workers, which needed to be solved before it could be widely adopted.

It should be noted that although the degree of anonymity was clearly increasing, traditional ways of monitoring did not disappear overnight. Indeed, recent work by Humphries (2003) and Minns and Wallis (2012) suggests that industrial apprenticeship remained important during the Industrial Revolution period, even after the repeal of the Statute of Artificers in 1814, which meant that a legal apprenticeship was no longer required to prac-

[11] If the entrepreneur was under time pressure to fulfil an order and had provided materials to a shirking spinner or weaver, he may not have been able to fulfil an order without incurring substantial additional costs, such as borrowing to obtain additional materials and finding alternative suppliers at a time of shortage. If an individual spinner or weaver substituted inferior materials or covered up other imperfections affecting the durability of the yarn or cloth, this was hard to detect until much later, when it would be difficult to link back to the output of a particular individual.

tise a particular trade. However, apprenticeship did not apply to the bulk of the growing industrial labor force in the towns, which was relatively unskilled. One approach to dealing with this increase in the degree of anonymity in market based relationships, which was widely adopted in large urban enterprises during the early stages of the Industrial Revolution, was payment by results or piece rates (Pollard, 1965: 189-191). Of course, piece rates had also been used in a rural setting during the early modern period as part of the putting out system, but their "discovery" in the context of urban industry in the eighteenth century was often greeted as "an innovation of major significance" (Pollard, 1965: 190). However, as Huberman (1996: 17-32) points out, attempts to manage the wage-effort bargain through piece rate payments in early nineteenth century Lancashire often met with little success unless accompanied by the payment of an efficiency wage premium above the spot-market rate. Rather than risk the prospect of losing a job with a wage above the spot market rate, a worker employed at the efficiency wage was deterred from shirking (Shapiro and Stiglitz, 1984). Although the Lancashire market for labor in cotton spinning in the early nineteenth century has often been portrayed as the archetypal spot market, Huberman (1996) cautions against this interpretation, arguing that it was more myth than reality. It is, moreover, a myth which is difficult to square with the central finding that has emerged from the new focus on comparative levels of real wages in Europe: that Britain was a high wage economy at the time of the Industrial Revolution (Allen, 2001; Broadberry and Gupta, 2006).

Our theoretical model predicts that once the level of anonymity is sufficiently high, we should observe equilibrium involuntary unemployment, growing with the level of anonymity. The first reliable figures of urban unemployment, dating from the 1850s, indicate a level of around 5% (Mitchell, 1988: 122). However, the available data refer to the experience of relatively well paid and relatively skilled trade union workers. For a broader picture of unemployment, it is necessary to use data on poor relief. Boyer (2002) reports an increase in real per capita expenditure on poor relief by a factor of 4 between 1696 and 1800. This growing burden on ratepayers created pressure to reduce the generosity of the system, leading to the 1834 Poor Law Reform Act, which attempted to restrict Poor Law payments to indoor relief in workhouses where conditions were harsh (Rose, 1972). Boot (1990) and MacKinnon (1986) show an increasing trend in male able bodied paupers being offered indoor relief in London and in other urban areas from 1860 onward. Furthermore, Pollard (1981: 903) notes that, "Indeed, many migrants did not even come for jobs, but for the expected opportunity of finding jobs". Boyer and Hatton (1997) find strong empirical support for rigidity in manufacturing wages, showing how migration reacted to the expected gap between rural and urban wages. Similar conclusions can be inferred from Long (2005), who using a large dataset related to the period 1850-1881, finds that unemployment rates among the stayers in the agricultural sector were lower than among the movers to the urban sector.

In addition to the growing degree of anonymity associated with the rise of the putting out system and then the factory system, in the British context Nef (1934) emphasizes the growth of large-scale industry between 1540 and 1640. He points to the introduction of new industries into Britain with a high minimum efficient scale, such as paper and gunpowder mills, cannon foundries, alum and copper factories, sugar refineries and saltpeter works. However, of more importance quantitatively was the growing scale of production in older established industries such as coal and iron ore mining, where new technology was increasing minimum efficient scale.

To end this section, it is interesting to ask if industrial labour markets in early modern Britain were more akin to those described by Greif (1994) for Genoese traders or for Maghribi traders during the medieval period, i.e. individualistic or collectivist? We would see them as operating closer to the Genoese end of the spectrum, since there is no evidence of any widespread sharing of information about shirkers between employers. This is in striking contrast to the abundant evidence of groups of industrialists operating in ways more akin to the Maghribi traders to deter opportunistic behavior in their financial dealings, with Quaker networks being particularly singled out in this regard (Prior and Kirby, 1993).

4.2 Changing factor prices

Table 4 sets out the pattern of silver wages in Europe. The silver wage is the silver content of the money wage in the local currency, and is useful for comparing wages across countries on a silver standard. Note first that Northwestern Europe saw substantial silver wage growth in the century after the Black Death of the mid-fourteenth century and again during the early modern period after 1500, as well as during the Industrial Revolution period from the mid-eighteenth century, when Britain finally overtook the Netherlands decisively. Second, note that although southern Europe shared in the rise in the silver wage following the Black

Death, from the mid fifteenth century the region was characterized more by fluctuations than by trend growth in the silver wage. Third, central and eastern Europe were also characterized more by fluctuations than by trend growth in the silver wage from the mid-fourteenth century. This is the pattern that would be expected from the conventional economic history of Europe, with the Mediterranean region playing the leading economic role during the first half of the millennium, but with northwest Europe forging ahead after 1500.

It is worth noting that these changes in the ranking of silver wage levels within Europe are strongly associated with changes in commercial leadership. The decline of the north Italian city states as commercial centres with the opening up of the new trade routes to the East is one of the decisive turning points in European financial and commercial history and was accompanied by a relative decline in silver wages (Kindleberger, 1996). But equally, it is clear that after a short Iberian boom, commercial leadership shifted to northwest Europe rather than to Spain or Portugal, and this is again reflected in relative wage trends in Table 4. Furthermore, even within Europe, the link between relative wages and commercial leadership holds, with the emergence of Britain as the wage leader accompanied by London's eclipse of Amsterdam as the financial and commercial centre of the North Sea area (Neal, 1990).

We have focused so far on wage differences within Europe, but a complete picture of the transition to modern economic growth also requires a consideration of wage differences between Europe and Asia. Broadberry and Gupta (2006) provide some evidence of this Great Divergence in the form of silver wage differences, shown here in Table 5. Silver wages in India and the Yangzi delta region of China were already lower than those in England by the beginning of the seventeenth century, and then fell further behind. Contrary to the revisionist claims of Pomeranz (2000), Parthasarathi (1998) and Frank (1998) that the richest parts of Asia remained at the same level of development as the richest parts of Europe until as late as 1800, they appear closer to the poorer parts of Europe.

We are interested in the incentives to adopt capital intensive technology. Hence we need also to examine the cost of capital, an important element of which is the rate of interest. Nominal interest rates for a number of countries are presented in Table 6. Note that since interest rates changed together across Europe, it is reasonable to assume them exogenous with respect to each single European economy, so that intra-European differences in the factor price ratio were driven by wage rate changes, as highlighted in our model. Table 6 suggests a rate of interest in Europe around 10% in the late medieval period, falling to 5-6% in the aftermath of the Black Death, 1350-1400. There was a further reduction in European rates of interest during the first half of the eighteenth century, to around 3-4%. [12] By this point, interest rates were substantially lower in Europe than in other parts of the world such as India, where rates remained at medieval levels. Growing commercialisation was thus accompanied by declining interest rates. The downward trend of interest rates in Europe, combined with the increase in wages, translates into an increase in the wage/cost of capital ratio, raising the incentives to substitute capital for labor in production. The greater increase of wage rates in northwest Europe meant that the incentive to adopt capital intensive production methods was also greater in that region.

4.3 Factor prices and technology

Recent work by Broadberry and Gupta (2006; 2009) and by Allen (2009) emphasize the important role of factor prices in explaining the key technological choices of the Industrial Revolution period. Broadberry and Gupta (2009) analyze the shift of competitive advantage in cotton textiles between India and Britain. India was the world's major producer and exporter of cotton textiles during the early modern period, but was displaced from this position by Britain during the Industrial Revolution. Broadberry and Gupta (2009) point to the much higher wages in Britain than in India already in the late seventeenth century, when Indian cotton textiles were imported into Britain by the East India Company. This can be seen in the first column of Table 7. Combined with the smaller differences in the cost of raw cotton and the cost of capital, this presented British producers with a severe total factor input (TFI) price disadvantage. To get to a point where the free on board (FOB) price, (i.e. excluding transport costs), was cheaper in Britain, required a shift to more capital intensive technology and a sustained period of technological progress to increase total factor productivity (TFP). For much of the eighteenth century, the fledgling British

[12] Falling interest rates in the first half of the eighteenth century are usually associated with developments in the market for government debt, linked to the growth of state capacity in western Europe during the mercantilist era. The argument is perhaps best known through the work of North and Weingast (1989) on the aftermath of the Glorious Revolution in Britain, but it is easily generalised to western Europe as a whole, given the widespread increase in tax revenue per head and the growth of internationally traded stocks (Karaman and Pamuk, 200x; Neal, 1990: 141-165).

cotton industry required protection, although the point at which the shift in competitive advantage from India to Britain occurred varied by type of yarn or cloth (as a result of different input costs) and by market (as a result of transport costs).

Once the shift to capital-intensive technology had occurred, technological progress accelerated, as implied by equation (6) in the model. In Table 7, TFP growth shifted in Britain's favour at an annual rate of 0.3 per cent before 1770, rising to 1.5 per cent during the period 1770-1820. This would be quite consistent with the 1.9 per cent per annum TFP growth rate estimated by Harley (1993: 200) for the British cotton industry between 1780 and 1860, together with slowly rising or stagnating productivity in India. This acceleration of TFP growth following the shift to capital intensive technology can be explained in part by the greater potential for learning on capital intensive technology. A similar case of learning by doing on capital intensive technology is identified by David (1973) in the cotton industry at Lowell, Massachusetts, 1834-1856, drawing on the literature on the "Horndal" effect, named after the Swedish steel mill where the phenomenon was first documented.

However, learning by doing is not the only way in which switching to capital intensive technology could have stimulated TFP growth. Drawing in particular on the work of Sullivan (1989), Broadberry and Gupta (2009) also emphasize the role of the British patent system in helping to foster technological progress once high wages had stimulated the introduction of capital intensive technology. One way of thinking about this interaction between factor prices and the patent system is that they are both symptoms of a highly commercialized economy. Just as we have seen that high wages are associated with commercialisation, so it is possible to see the patent system as the commercialisation of invention. It should also be noted that patents protected intellectual property embodied in machinery, and so reinforced the shift to capital-intensive technology.

4.4 Real economic development

In Table 4, we examined the path of silver wages. However, an analysis of the transition to modern economic growth would not be complete without considering the path of real consumption wages and GDP per capita. The real consumption wage is obtained by dividing the silver wage with the silver price of basic consumption goods. Real consumption wages of European unskilled building laborers for the period 1300-1850 are shown in Table 8, taking London in the period 1500-49 as the numeraire. The first point to note is that real wages followed a similar pattern across the Black Death in much of Europe. Complete time series exist for comparatively few cities before 1500, but there is also scattered evidence for other cities. Taken together, the evidence supports the idea of a substantial rise in the real wage across most of the continent of Europe following the Black Death, which struck in the middle of the fourteenth century, wiping out between a third and a half of the population, when successive waves of the plague are cumulated (Herlihy, 1997). This episode of European economic history is thus broadly consistent with the Malthusian model, with a strong negative relationship between real wages and population (Postan, 1972: 27-40). It is worth emphasizing again that our approach is complementary to unified growth theory, rather than seeking to provide an alternative analytical framework.

In the first half of the fifteenth century, the real wage was quite uniform across the countries for which we have data, at about twice its pre-Black Death level. From the second half of the fifteenth century, however, Britain and Holland followed a very different path from the rest of Europe, maintaining real wages at the post-Black Death level and avoiding the collapse of real wages which occurred on the rest of the continent as population growth returned. Considering that in the same period Britain and Holland witnessed an increase in the level of urbanization, as noted above, we can argue that growing anonymity is a candidate to explain this emergence of high wages in northwest Europe.

Table 9 presents the results of the latest research on the reconstruction of national income during the late medieval and early modern periods in a number of countries. The GDP per capita data show northwest Europe pulling ahead of the previously more developed Mediterranean Europe from the late sixteenth century. The national income data thus reinforce the conclusion from the silver wage and real consumption wage data and from urbanization rates that Britain and Holland followed a different path from Italy and Spain. The Asian data confirm the conventional view that the Great Divergence was already underway during the early modern period, as Europe embarked upon a period of growing commercialisation which would ultimately end up with the Industrial Revolution and the transition to modern economic growth.

4.5 Why was the Industrial Revolution British?

As well as documenting the Little Divergence between northwest Europe and the rest of the continent, Tables 4, 8 and 9 also show the emergence of Britain as the leading economy within northwest Europe, consistent with the first Industrial Revolution and the transition to modern economic growth occurring there rather than in Holland. This does seem to have reflected trends in commercial development, with London replacing Amsterdam as the main commercial center in northwest Europe by the early nineteenth century (Neal, 1990). However, it must be recognized that during the sixteenth and seventeenth centuries, Holland was at least as commercialized as Britain, but did not go on to have the first industrial revolution.

To understand this, it is necessary to recognize a recent change in the understanding of patterns of economic growth in the past that has been permitted by work extending historical national accounting back to the medieval period on a high frequency basis (Broadberry, 2013; Fouquet and Broadberry, 2015). Graphs of GDP per capita based on conjectures for a very few years, such as Maddison (2001), paint a misleading picture of the world stagnating at bare-bones subsistence for thousands of years before a sudden burst of growth from the mid-eighteenth century. However, with high frequency data, we now know that before the eighteenth century, episodes of positive GDP per capita growth (growth booms) alternated with episodes of negative per capita GDP growth (growth reversals), so that there was no long run trend improvement of living standards. It turns out that there were a number of episodes where levels of GDP per capita in certain regions reached similar levels to those achieved in Britain on the eve of the Industrial Revolution. In these episodes, it is possible to see elements of the process we are describing in this paper. In Northern Song China, for example, coke smelting of iron was introduced 700 years before Abraham Darby perfected the process at Ironbridge (Hartwell, 1962). Indeed, the advanced nature of Chinese technology at this time and at the time of the famous "Voyages to the Western Oceans" during the early Ming dynasty has given rise to the famous "Needham Puzzle", concerning the failure of China to build on this technological precocity. However, this is no longer such a puzzle once it is recognized that growth booms have typically been followed by growth reversals across the whole of the second millennium, while archaeological evidence suggests that the pattern must also have held for millennia before that (Jongman, 2014). In the face of a stochastic, institutional and political, environment, the forces that we are modelling here should be seen as increasing the probability of an industrial revolution rather than mechanically guaranteeing it.

In the British case, commercialisation of the innovation process via the patent system can be seen as helping to break the pattern of growth reversals, by encouraging a continuous stream of inventions, so that Britain was the first nation to achieve sustained economic growth. Britain's patent system had its origins in the early seventeenth century, but only really became effective during the eighteenth century (MacLeod, 1988; Bottomley, 2014). It should also be borne in mind that although Holland had a similar factor price structure to Britain, it had a much smaller population, which acted as a constraining factor in the era of mercantilism.[13] A small population meant a small home market, which provided less rewards for innovation (Broadberry and Gupta, 2009: 302). Although in principle this problem could be overcome by accessing overseas markets, this was not straightforward in a world of mercantilist restrictions. An important limiting factor here was the need for an effective navy, which implied high per capita defence costs for a country with a small population because of a large fixed cost element. This had to be paid for with high taxes. The importance of the size of the economy is captured in the model by the scale parameter, m. Moreover, as we have shown, the scale of the domestic economy and the degree of anonymity are mutual complements i.e. the impact of an increase in the degree of anonymity on the long run capital stock and productivity is higher when the scale of the domestic economy is larger.

5 Concluding remarks

We have argued that commercialisation played an important role in the transition to modern economic growth. We see the growing commercialisation of the late medieval and early modern periods as leading to the acceleration of technological progress during the Industrial Revolution period via the effects of increasing anonymity on factor prices. The argument can be summarized as follows: (1) Commercialisation raised wages as a growing reliance on impersonal labor market relations in place of customary relations with a high degree of monitoring led to the adoption of efficiency wages. (2) The resulting rise in the wage/cost of capital ratio led to the adoption of a more capital-intensive production technology (which requires that the elasticity of substitution between capital and labour is greater than one).

[13] The Dutch also had an ineffective patent system during the seventeenth century, but it failed to improve significantly as the British system developed during the eighteenth century, and the Dutch patent system was abolished between 1869 and 1910 (Netherlands Enterprise Agency, 2016).

(3) This led to a faster rate of technological progress, via an aggregate capital externality and learning-by-doing. We present some empirical evidence supporting the pattern implied by the model. In particular, among other piece of historical evidence, we show that England and northwest Europe was the most urbanized region, and England in particular was the country with the lowest share of labour force in agriculture at the onset of the industrial revolution. We show evidence that wages in England were the highest in Europe in the same period. Furthermore, available data show an increasing wage gap between English rural and urban sectors that matches the increasing level of urbanization. Extending our analysis to a multi-sector model to model structural change is a topic of future research.

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Appendix

Proof of Proposition 1:

(i) We first show that there is a unique positive steady state capital stock K^* and that employment level L^* exists. Note that the steady state is a solution to the equations:

$$\begin{aligned} F_k(\frac{K}{m}, a\left(\frac{K}{m}\right)\frac{L}{m}) &= r, \\ F_l(\frac{K}{m}, a\left(\frac{K}{m}\right)\frac{L}{m}) &= \omega(L,\sigma). \end{aligned}$$

Consider the variables $\widetilde{K} = \frac{K}{m}$ and $\widetilde{L} = \frac{L}{m}$. Consider the equation $F_k(\widetilde{K}, a\left(\widetilde{K}\right)\widetilde{L}) = r$. Under the assumption that $\frac{\alpha}{\rho} \leq 1$ and $a'(.) > 0$ from the equation $F_k(\widetilde{K}, a\left(\widetilde{K}\right)\widetilde{L}) = r$ there exists an implicit function $g_1(\widetilde{L}) = \widetilde{K}$ with

$$g_1'(\widetilde{L}) = -\frac{a(\widetilde{K})F_{kl}}{F_{kk} + F_{kl}a'\left(\widetilde{K}\right)} < 0$$

where

$$\begin{aligned} F_{kl} &= \alpha\theta\rho\left(\frac{\alpha-\rho}{\rho}\right)\left(a\left(\widetilde{K}\right)\right)^{\rho}\widetilde{K}^{\rho-1}\widetilde{L}^{\rho-1}(\theta\widetilde{K}^{\rho} + (1-\theta)\left(a\left(\widetilde{K}\right)\widetilde{L}\right)^{\rho})^{\frac{\alpha-2\rho}{\rho}} \leq 0, \\ F_{kk} &= \left\{\begin{array}{c} \alpha\theta(\rho-1)\left(\widetilde{K}\right)^{\rho-2}(\theta\widetilde{K}^{\rho} + (1-\theta)\left(a\left(\widetilde{K}\right)\widetilde{L}\right)^{\rho})^{\frac{\alpha-\rho}{\rho}} \\ +\alpha\theta^2\rho\left(\frac{\alpha-\rho}{\rho}\right)\widetilde{K}^{2(\rho-1)}(\theta\widetilde{K}^{\rho} + (1-\theta)\left(a\left(\widetilde{K}\right)\widetilde{L}\right)^{\rho})^{\frac{\alpha-2\rho}{\rho}} \end{array}\right\} < 0. \end{aligned}$$

Consider the equation $q(L) = \frac{L}{N} = \frac{m\widetilde{L}}{N}$. Let $\widetilde{q}(m\widetilde{L}) = \frac{m\widetilde{L}}{N}$. Then, it is evident that $\widetilde{q}(m\widetilde{L}) = q(L)$. Define $\widetilde{\omega}\left(\widetilde{L},\sigma\right) = \frac{\mu(1-\beta p(1-\widetilde{q}(m\widetilde{L})\sigma))}{\beta(1-(p+(1-p)\widetilde{q}(m\widetilde{L})\sigma))}$. It follows that $\widetilde{\omega}\left(m\widetilde{L},\sigma\right) = \omega(L,\sigma)$. Two points are worth noting for later reference: (i) a change in m impacts on the function $\widetilde{\omega}\left(\widetilde{L},\sigma\right)$ only through its impact on $\widetilde{L}$; (2) the equation $F_l(\frac{K}{m}, A\left(\frac{K}{m}\right)\frac{L}{m}) = \omega(L,\sigma)$ can be replaced by the equation $F_l(\widetilde{K}, a\left(\widetilde{K}\right)\widetilde{L}) = \widetilde{\omega}\left(m\widetilde{L},\sigma\right)$. It follows that there exists an implicit function $g_2(\widetilde{L}) = \widetilde{K}$ with

$$g_2'(\widetilde{L}) = -\frac{a(\widetilde{K})F_{ll} - m\widetilde{\omega}_l\left(m\widetilde{L},\sigma\right)}{F_{kk} + F_{kl}a'(\widetilde{K})} < 0$$

where

$$F_{ll}=\left\{\begin{array}{c}\alpha\left(1-\theta\right)\left(\rho-1\right)\left(a\left(\widetilde{K}\right)\right)^{\rho}\widetilde{L}^{\rho-2}(\theta\widetilde{K}^{\rho}+\left(1-\theta\right)\left(a\left(\widetilde{K}\right)\widetilde{L}\right)^{\rho})^{\frac{\alpha-\rho}{\rho}}\\+\alpha\left(1-\theta\right)^{2}\rho\left(a\left(\widetilde{K}\right)\right)^{2\rho}\widetilde{L}^{2(\rho-1)}(\theta\widetilde{K}^{\rho}+\left(1-\theta\right)\left(a\left(\widetilde{K}\right)\widetilde{L}\right)^{\rho})^{\frac{\alpha-2\rho}{\rho}}\end{array}\right\}<0.$$

Steady state employment $\widetilde{L}^{*}$ is the solution to $g_3(\widetilde{L})=g_2(\widetilde{L})-g_1(\widetilde{L})=0$. As

$$\lim_{k\to0}F_k=\lim_{k\to0}\left[\alpha\theta\widetilde{K}^{\rho-1}(\theta\widetilde{K}^{\rho}+\left(1-\theta\right)\left(a\left(\widetilde{K}\right)\widetilde{L}\right)^{\rho})^{\frac{\alpha-\rho}{\rho}}\right]=\infty,$$

while

$$\lim_{l\to0}F_l=\left[\alpha\left(1-\theta\right)a\left(\widetilde{K}\right)^{\rho}\widetilde{L}^{\rho-1}(\theta\widetilde{K}^{\rho}+\left(1-\theta\right)\left(a\left(\widetilde{K}\right)\widetilde{L}\right)^{\rho})^{\frac{\alpha-\rho}{\rho}}\right]=\infty$$

$\lim_{L\to0}g_3(\widetilde{L})=\infty$ while $\lim_{L\to\infty}g_3(\widetilde{L})=0$ so that there exists $\widetilde{L}^{*}=\widetilde{L}\left(\sigma\right)>0$ such that $g_3(\widetilde{L}^{*})=g_2(\widetilde{L}^{*})-g_1(\widetilde{L}^{*})=0$. Note that $\widetilde{K}^{*}=\widetilde{K}\left(\sigma\right)=g_2(\widetilde{L}^{*})=g_1(\widetilde{L}^{*})>0$. As $m\widetilde{K}^{*}=K^{*}$ and $m\widetilde{L}^{*}=L^{*}$ and $m>0$, it follows that both $K^{*}>0$ and $L^{*}>0$.

(ii)-(iii)-(iv) We examine how the steady state values of the key endogenously determined variables change due to changes in σ and m. We begin by examining comparative statics of $\widetilde{K}^{*}=\widetilde{K}\left(\sigma,m\right)$ and $\widetilde{L}^{*}=\widetilde{L}\left(\sigma,m\right)$ and then extend the analysis to K^{*} and L^{*}. After appropriately relabelling variables and substituting for wages using the no shirking constraint (4), the total derivative of (14) and (15) at the steady state is given by the expression

$$\left[\begin{array}{cc}F_{kk}^{*}+F_{kl}^{*}a'(\widetilde{K}^{*}) & F_{kl}^{*}a(\widetilde{K}^{*})\\ F_{kl}^{*}+F_{ll}^{*}a'(\widetilde{K}^{*}) & F_{ll}^{*}a(\widetilde{K}^{*})-m\widetilde{\omega}_{l}^{*}\end{array}\right]\left[\begin{array}{c}d\widetilde{K}^{*}\\ d\widetilde{L}^{*}\end{array}\right]=\left[\begin{array}{cc}0 & 0\\ \widetilde{L}\widetilde{\omega}_{l}^{*} & \widetilde{\omega}_{\sigma}^{*}\end{array}\right]\left[\begin{array}{c}dm\\ d\sigma\end{array}\right]$$

where $\widetilde{\omega}_{\sigma}^{*}=\omega_{\sigma}\left(m\widetilde{L}^{*},\sigma\right)$, $\widetilde{\omega}_{l}^{*}=\omega_{l}\left(m\widetilde{L}^{*},\sigma\right)$ and

$$F_{kl}^{*}=\alpha\theta\rho\left(\frac{\alpha-\rho}{\rho}\right)\left(a\left(\widetilde{K}^{*}\right)\right)^{\rho}\left(\widetilde{K}^{*}\right)^{\rho-1}\left(\widetilde{L}^{*}\right)^{\rho-1}\{\theta\left(\widetilde{K}^{*}\right)^{\rho}+\left(1-\theta\right)\left(a\left(\widetilde{K}^{*}\right)\widetilde{L}^{*}\right)^{\rho}\}^{\frac{\alpha-2\rho}{\rho}}\leq0,$$

$$F_{kk}^{*}=\left\{\begin{array}{c}\alpha\theta\left(\rho-1\right)\left(\widetilde{K}^{*}\right)^{\rho-2}(\theta\left(\widetilde{K}^{*}\right)^{\rho}+\left(1-\theta\right)\left(a\left(\widetilde{K}^{*}\right)\widetilde{L}^{*}\right)^{\rho})^{\frac{\alpha-\rho}{\rho}}\\+\alpha\theta^{2}\rho\left(\frac{\alpha-\rho}{\rho}\right)\left(\widetilde{K}^{*}\right)^{2(\rho-1)}(\theta\left(\widetilde{K}^{*}\right)^{\rho}+\left(1-\theta\right)\left(a\left(\widetilde{K}^{*}\right)\widetilde{L}^{*}\right)^{\rho})^{\frac{\alpha-2\rho}{\rho}}\end{array}\right\}<0,$$

$$F_{ll}^{*}=\left\{\begin{array}{c}\alpha\left(1-\theta\right)\left(\rho-1\right)\left(a\left(\widetilde{K}^{*}\right)\right)^{\rho}\left(\widetilde{L}^{*}\right)^{\rho-2}(\theta\left(\widetilde{K}^{*}\right)^{\rho}+\left(1-\theta\right)\left(a\left(\widetilde{K}^{*}\right)\widetilde{L}^{*}\right)^{\rho})^{\frac{\alpha-\rho}{\rho}}\\+\alpha\left(1-\theta\right)^{2}\rho\left(a\left(\widetilde{K}^{*}\right)\right)^{2\rho}\left(\widetilde{L}^{*}\right)^{2(\rho-1)}(\theta\left(\widetilde{K}^{*}\right)^{\rho}+\left(1-\theta\right)\left(a\left(\widetilde{K}^{*}\right)\widetilde{L}^{*}\right)^{\rho})^{\frac{\alpha-2\rho}{\rho}}\end{array}\right\}<0.$$

The determinant, D', of the preceding matrix can be written as

$$D' = -\left(F_{kk}^* + mF_{kl}^* a'(\widetilde{K}^*)\right)\omega_l^* + a(\widetilde{K}^*)\left(F_{kk}^* F_{ll}^* - (F_{kl}^*)^2\right) > 0$$

as $F(.)$ is strictly concave (so that $\left(F_{kk}^* F_{ll}^* - (F_{kl}^*)^2\right) > 0$)and $\omega_l^* > 0$. Therefore,

$$\begin{bmatrix} d\widetilde{K}^* \\ d\widetilde{L}^* \end{bmatrix} = \frac{1}{D'} \begin{bmatrix} F_{ll}^* a(\widetilde{K}^*) - m\widetilde{\omega}_l^* & -F_{kl}^* a(\widetilde{K}^*) \\ -F_{kl}^* - F_{ll}^* a'(\widetilde{K}^*) & F_{kk}^* + F_{kl}^* a'(\widetilde{K}^*) \end{bmatrix} \begin{bmatrix} 0 & 0 \\ \widetilde{L}\widetilde{\omega}_l^* & \widetilde{\omega}_\sigma^* \end{bmatrix} \begin{bmatrix} dm \\ d\sigma \end{bmatrix}$$

so that

$$\begin{bmatrix} d\widetilde{K}^* \\ d\widetilde{L}^* \end{bmatrix} = \frac{1}{D'} \left\{ \begin{bmatrix} -F_{kl}^* a(\widetilde{K}^*)\widetilde{L}\widetilde{\omega}_l^* \\ \left(F_{kk}^* + F_{kl}^* a'(\widetilde{K}^*)\right)\widetilde{L}\widetilde{\omega}_l^* \end{bmatrix} dm + \begin{bmatrix} -F_{kl}^* a(\widetilde{K}^*)\widetilde{\omega}_\sigma^* \\ \left(F_{kk}^* + F_{kl}^* a'(\widetilde{K}^*)\right)\widetilde{\omega}_\sigma^* \end{bmatrix} d\sigma \right\}.$$

Therefore,

$$\begin{aligned} \frac{\partial \widetilde{K}^*}{\partial \sigma} &= -\frac{F_{kl}^* a(\widetilde{K}^*)\widetilde{\omega}_\sigma^*}{D'} \geq 0 \\ \frac{\partial \widetilde{L}^*}{\partial \sigma} &= \frac{\left(F_{kk}^* + F_{kl}^* a'(\widetilde{K}^*)\right)\widetilde{\omega}_\sigma^*}{D'} < 0 \end{aligned}$$

as, from (16), $\widetilde{\omega}_\sigma^* > 0$, so that $\frac{\widetilde{K}^*}{\widetilde{L}^*}$ is increasing in σ. Further,

$$\begin{aligned} \frac{\partial \widetilde{K}^*}{\partial m} &= -\frac{F_{kl}^* a(\widetilde{K}^*)\widetilde{L}\widetilde{\omega}_l^*}{D'} \geq 0 \\ \frac{\partial \widetilde{L}^*}{\partial m} &= \frac{\left(F_{kk}^* + F_{kl}^* a'(\widetilde{K}^*)\right)\widetilde{L}\widetilde{\omega}_l^*}{D'} \leq 0 \end{aligned}$$

as $\widetilde{\omega}_l^* > 0$, so that $\frac{\widetilde{K}^*}{\widetilde{L}^*}$ is increasing in m. As $\widetilde{\omega}_{\sigma,l}^* > 0$ it follows that $\frac{\partial^2 \widetilde{K}^*}{\partial\sigma\partial m} \geq 0$ while $\frac{\partial^2 \widetilde{L}^*}{\partial\sigma\partial m} < 0$ so that $\frac{\partial^2\left(\frac{\widetilde{K}^*}{\widetilde{L}^*}\right)}{\partial\sigma\partial m} > 0$. As $K^* = m\widetilde{K}^* = m\widetilde{K}(\sigma, m)$ and $L^* = m\widetilde{L}^* = m\widetilde{L}(\sigma, m)$ and $m > 0$, it follows that $\frac{\partial K^*}{\partial\sigma} = m\frac{\partial\widetilde{K}^*}{\partial\sigma} \geq 0$, $\frac{\partial L^*}{\partial\sigma} = m\frac{\partial\widetilde{L}^*}{\partial\sigma} < 0$, $\frac{\partial K^*}{\partial m} = m\frac{\partial\widetilde{K}^*}{\partial m} + \widetilde{K}(\sigma, m) > 0$ while the sign of the partial derivative $\frac{\partial L^*}{\partial m} = m\frac{\partial\widetilde{L}^*}{\partial m} + \widetilde{L}(\sigma, m)$ is ambiguous (so that total employment could either go up or go down with a change in the scale of the domestic economy). It follows that as $\frac{K^*}{L^*} = \frac{m\widetilde{K}^*}{m\widetilde{L}^*} = \frac{\widetilde{K}(\sigma,m)}{\widetilde{L}(\sigma,m)}$ is increasing in σ, m and $\frac{\partial^2\left(\frac{K^*}{L^*}\right)}{\partial\sigma\partial m} > 0$. Furthermore, $A^* = a(\widetilde{K}^*) = a\left(\widetilde{K}(\sigma, m)\right)$ is increasing in both σ and m and $\frac{\partial^2 A^*}{\partial\sigma\partial m} > 0$.

(v) We examine the local stability of $\widetilde{K}^*$ and $\widetilde{L}^*$; the local stability of K^* and L^* is an immediate consequence. In order to characterize the local stability of the steady state, we need to characterize how real wages change in the vicinity of the steady state as equilibrium employment changes.

Consider the scenario described by (1), (2), (3) and the no shirking constraint (4). As the no shirking constraint (4) holds as an equality in equilibrium, setting $v_t^E(1) = v_t^E(0)$ and equating the RHS of (1) and (2) we obtain that at each t,

$$v_{t+1}^E(0) = \frac{\mu}{\beta\left(1-(p+(1-p)\widetilde{q}_t\sigma)\right)} + v_{t+1}^{US}.$$

Substituting for $v_{t+1}^E(0)$ in (2) we obtain that at each t

$$v_t^{US} = \frac{\mu\left(1-p\left(1-\widetilde{q}_t\sigma\right)\right)}{\left(1-(p+(1-p)\widetilde{q}_t\sigma)\right)} + \beta v_{t+1}^{US}$$

which yields that at each t,

$$v_t^{US} = \sum_{t'\geq t}\beta^{t'-t}\left(\frac{\mu\left(1-p\left(1-\widetilde{q}_t\sigma\right)\right)}{\left(1-(p+(1-p)\widetilde{q}_t\sigma)\right)}\right)$$

and therefore,

$$v_t^E(0) = \frac{\mu}{\beta\left(1-(p+(1-p)\widetilde{q}_{t-1}\sigma)\right)} + \sum_{t'\geq t}\beta^{t'-t}\left(\frac{\mu\left(1-p\left(1-\widetilde{q}_t\sigma\right)\right)}{\left(1-(p+(1-p)\widetilde{q}_t\sigma)\right)}\right).$$

Further, by computation, from (1) we obtain that at each t,

$$v_t^E(1) = \sum_{t'\geq t}^{\infty}\beta^{t'-t}\widetilde{\omega}_t.$$

Equating $v_t^E(0)$ and $v_t^E(1)$ in the vicinity of the steady state as required by the no shirking constraint (4) we obtain that at each t,

$$\sum_{t'\geq t}^{\infty}\beta^{t'-t}\widetilde{\omega}_t = \frac{\mu}{\beta\left(1-(p+(1-p)\widetilde{q}_{t-1}\sigma)\right)} + \sum_{t'\geq t}\beta^{t'-t}\left(\frac{\mu\left(1-p\left(1-\widetilde{q}_{t'}\sigma\right)\right)}{\left(1-(p+(1-p)\widetilde{q}_{t'}\sigma)\right)}\right).$$

At this point, we will assume that in the vicinity of the steady state, at each t, agents expect that future employment and efficiency wage levels will be the same as current employment levels so that $\widetilde{L}^e_{t'} = \widetilde{L}_t$ and $\widetilde{\omega}^e_{t'} = \widetilde{\omega}_t$for all $t' \geq t$ where the superscript e denotes the expected level of future employment and future wages. In other words, in order to characterize the dynamics in the vicinity of the steady state,we do not assume that agents have rational expectations.

Under this assumption, it follows that we can write at each t,

$$\widetilde{\omega}_t = \frac{\mu (1-\beta)}{\beta (1-(p+(1-p)\widetilde{q}_{t-1}\sigma))} + \left(\frac{\mu (1-p(1-\widetilde{q}_t\sigma))}{(1-(p+(1-p)\widetilde{q}_t\sigma))} \right).$$

so that at each t in the vicinity of the steady state $d\widetilde{\omega}_t = \widetilde{g}^*_l d\widetilde{L}_{t-1} + \widetilde{f}^*_l dL_t$ where $\widetilde{f}^* = \frac{\mu\left(1-p\left(1-\widetilde{q}\left(\frac{m\widetilde{L}^*}{N}\right)\sigma\right)\right)}{\left(1-(p+(1-p)\widetilde{q}\left(\frac{m\widetilde{L}^*}{N}\right)\sigma\right)\right)}$ and $\widetilde{g}^* = \frac{\mu(1-\beta)}{\beta\left(1-(p+(1-p)\widetilde{q}\left(\frac{m\widetilde{L}^*}{N}\right)\sigma\right)\right)}$.

Taking the above computation into account and noting that at the steady state $A^* = a\left(\widetilde{K}^*\right)$, examining the local stability of the steady state requires us to linearize the equations (6), (14) and (15) at the steady state to obtain

$$\begin{bmatrix} F^*_{kk} & a(\widetilde{K}^*)F^*_{kl} & 0 \\ F^*_{kl} & a(\widetilde{K}^*)F^*_{ll} - \widetilde{f}^*_l & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} d\widetilde{K}_t \\ d\widetilde{L}_t \\ dA_t \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & \widetilde{g}^*_l & 0 \\ a'(\widetilde{K}^*) & 0 & 0 \end{bmatrix} \begin{bmatrix} d\widetilde{K}_{t-1} \\ d\widetilde{L}_{t-1} \\ dA_{t-1} \end{bmatrix}$$

where $F^*_{ij} = F_{ij}(\widetilde{K}^*, a\left(\widetilde{K}^*\right)\widetilde{L}^*)$, $i,j = k,l$.

The matrix on the LHS of the preceding equation is invertible. Its determinant, D, is

$$D = -F^*_{kk}\widetilde{f}^*_l + a(\widetilde{K}^*)\left[F^*_{kk}F^*_{ll} - (F^*_{kl})^2\right] > 0$$

by strict concavity of the production function, $F^*_{kk} < 0$ and $\left[F^*_{kk}F^*_{ll} - (F^*_{kl})^2\right] > 0$ and as $\widetilde{f}^*_l > 0$.

It follows that

$$\begin{bmatrix} d\widetilde{K}_t \\ d\widetilde{L}_t \\ dA_t \end{bmatrix} = \frac{1}{D} \begin{bmatrix} a(\widetilde{K}^*)F^*_{ll} - f^*_l & -a(\widetilde{K}^*)F^*_{kl} & 0 \\ -F^*_{kl} & F^*_{kk} & 0 \\ 0 & 0 & D \end{bmatrix}$$
$$\begin{bmatrix} 0 & 0 & 0 \\ 0 & g^*_l & 0 \\ a'(\widetilde{K}^*) & 0 & 0 \end{bmatrix} \begin{bmatrix} d\widetilde{K}_{t-1} \\ d\widetilde{L}_{t-1} \\ dA_{t-1} \end{bmatrix}$$

so that

$$\begin{bmatrix} d\widetilde{K}_t \\ d\widetilde{L}_t \\ dA_t \end{bmatrix} = \begin{bmatrix} 0 & -a(\widetilde{K}^*)F^*_{kl}g^*_l & 0 \\ 0 & F^*_{kk}g^*_l & 0 \\ Da'(\widetilde{K}^*) & 0 & 0 \end{bmatrix} \begin{bmatrix} dK_{t-1} \\ dL_{t-1} \\ dA_{t-1} \end{bmatrix}$$

By computation, the eigenvalues of the matrix on the RHS of the preceding equation must satisfy the equation $\lambda_1 \left(\lambda_2 - F^*_{kk}g^*_l\right) \lambda_3 = 0$ so that it immediately follows that two eigenvalues always have a modulus strictly less than one so that the steady state is locally a saddle and whenever $|F^*_{kk}g^*_l| < 1$, the steady state is a sink. By computation, $g^*_l = \frac{\mu m \widetilde{q}'\left(\frac{m\widetilde{L}^*}{N}\right)(1-\beta)}{N\beta(1-(p+(1-p)\widetilde{q}\sigma))}$. Clearly, if β is close enough to one, $|F^*_{kk}g^*_l| < 1$.■

Table 1: **European urbanization rates (%)**

	1300	1400	1500	1600	1700	1750	1800	1870
Northwestern Europe								
Scandinavia	–	–	0.7	2.1	4.3	4.6	4.6	5.5
England (Wales)	4.0	2.5	2.3	6.0	13.2	16.4	22.1	43.0
Scotland	–	–	2.3	1.5	5.3	11.5	23.9	36.3
Ireland	0.8	2.1	–	1.0	5.1	5.1	7.3	14.2
Netherlands	–	–	17.1	29.5	32.5	29.6	28.6	29.1
Belgium	18.2	21.9	17.6	15.1	20.2	16.5	16.6	25.0
France	5.2	4.7	5.0	6.3	8.7	8.7	8.9	18.1
Southern Europe								
Italy CN	18.0	12.4	16.4	14.4	13.0	13.6	14.2	13.4
Italy SI	9.4	3.3	12.7	18.6	16.1	19.4	21.0	26.4
Spain	12.1	10.2	11.4	14.5	9.6	9.1	14.7	16.4
Portugal	3.6	4.1	4.8	11.4	9.5	7.5	7.8	10.9
Central-Eastern Europe								
Switzerland	3.0	2.0	2.8	2.7	3.3	4.6	3.7	8.2
Austria (Czech, Hung)	0.6	0.5	0.8	1.6	1.7	2.6	3.1	7.7
Germany	3.4	3.9	5.0	4.4	5.4	5.7	6.1	17.0
Poland	1.0	1.3	5.4	6.6	3.8	3.4	4.1	7.8
Balkans	5.2	4.6	7.7	13.3	14	12.3	9.8	10.6
Russia (European)	2.1	2.3	2.0	2.2	2.1	2.5	3.6	6.7
EUROPE	5.4	4.3	5.6	7.3	8.2	8.0	8.8	15.0

Source: Malanima (2009).

The urbanization rate is defined as the proportion of the population living in settlements of at least 10,000.

Table 2: **Share of agriculture in the European labour force, 1300-1800 (%)**

	England	Netherlands	Italy	France	Poland
1300			63.4		
1400	57.2		60.9	71.4	76.4
1500	58.1	56.8	62.3	73.0	75.3
1600		48.7	60.4	67.8	67.4
1700	39.9	41.6	58.8	63.2	63.2
1750	36.8	42.1	58.9	61.1	59.3
1800	31.7	40.7	57.8	59.2	56.2

Sources: Derived from Broadberry et al. (2015a); Allen (2000: 8-9).

Table 3: **English urban and rural unskilled wage rates, 1290-1803**

	Urban building labourer's daily wage (d)	Rural farm labourer's daily wage (d)	Urban to rural wage ratio (rural wage = 1.00)
1290	1.75	1.59	1.10
1381	3.00	3.30	0.91
1522	4.00	4.14	0.97
1620	8.00	10.00	0.80
1688	12.00	12.00	1.00
1759	16.00	12.00	1.33
1801/03	24.00	18.30	1.31

Sources: Broadberry et al., 2015: 311; derived from Allen (2001)

Table 4: **Daily silver wages of European unskilled building laborers**
(grams of silver per day)

	1300	1350	1400	1450	1500	1550	1600	1650	1700	1750	1800
Northwestern Europe											
London	2.9	3.4	4.5	3.8	3.2	4.6	7.1	9.7	10.5	11.5	17.7
Amsterdam					3.1	4.7	7.2	8.5	8.9	9.2	9.2
Antwerp			3.5	3.1	3.0	5.9	7.6	7.1	6.9	6.9	7.7
Paris					2.8	5.5	6.6	6.9	5.1	5.2	9.9
Southern Europe											
Valencia			5.6	5.2	4.2	6.6	8.8	6.9	5.7	5.1	–
Madrid					–	6.3	8.0	–	5.1	5.3	8.0
Florence/Milan	2.2	4.5	3.8	3.5	2.9	3.8	4.7	4.1	3.2	2.9	3.1
Naples					3.3	3.5	5.3	4.8	4.8	3.8	3.8
Central-Eastern Europe											
Gdansk					2.1	2.1	3.8	4.3	3.8	3.7	4.8
Warsaw					–	2.5	3.2	2.7	1.9	3.4	4.9
Krakow			2.7	2.1	1.9	2.9	3.4	2.9	2.2	2.9	2.4
Vienna			4.0	3.2	2.7	2.6	4.4	3.5	3.2	3	2.1
Leipzig					–	1.9	3.5	3.9	3.7	3.1	4.4
Augsburg					2.1	3.1	4.0	4.7	4.2	4.3	–

Source: Broadberry and Gupta (2006: 7).

Derived from the database underlying Allen (2001: 429).

Table 5: **Silver wages of unskilled labourers (grams of silver per day)**

A. Silver wages in England and India

Date	England	India	India/England
1550-99	3.4	0.7	0.21
1600-49	4.1	1.1	0.27
1650-99	5.6	1.4	0.25
1700-49	7.0	1.5	0.21
1750-99	8.3	1.2	0.14
1800-49	14.6	1.8	0.12

B. Silver wages in England and China

Date	England	China	China/England
1550-1649	3.8	1.5	0.39
1750-1849	11.5	1.7	0.15

Source : Broadberry and Gupta (2006)

Table 6: **Interest rates (% per annum)**

	England	Flanders	France	Italy	Germany	India
1201-1250	10.3		10.8	8.6		
1251-1300	10.2	10	11.1	10.6	10.8	
1301-1350	11.2			12.9	10.1	
1351-1400	4.5			8.1	9.7	
1401-1450				9.6	8.5	
1451-1500	4.0	6.4	9.2	7.6	6.5	
1501-1550	4.6		8.2		5.3	
1551-1600	6.0	4.3	8.3			
1601-1650	6.0	3.9	6.6			
1651-1700	5.3	4.4				8
1701-1750	4.3	3.8	4.2			10
1751-1800	4.0	2.7	4.8	4.7		12

Source: Clark (1988: 273-274); Moosvi (2001: 337-9, 342, 351-2).

Table 7: **Comparative GB/India costs and prices (India =100)**

A. Cost

	Wage W/W*	Raw Cotton P C/C*	Cost of Capital R/R*	TFI Price
c.1680	400	182	137	206
c.1770	460	320	113	270
c.1790	663	480	106	357
c.1820	517	127	61	150

B. Prices and TFP[14]

	TFI price	FOB Price P/P*	TFP A/A*
c.1680	206	200	103
c.1770	270	200	135
c.1790	357	147	243
c.1820	150	53	283

Source: Broadberry and Gupta (2009).

[14]TFP is calculated using the cost dual approach. Instead of calculating TFP growth as the excess of the growth of output over a weighted average of the growth of factor inputs, it is derived as the decrease (or lower increase) of the output price compared with the increase in the weighted average growth of input prices. For cotton textiles, there are three important factor inputs, labour capital and raw cotton. Detailed sources for the prices of outputs and inputs and also the input weights are provided in Broadberry and Gupta (2009: 288-293).

Table 8: **Daily real consumption wages of European unskilled building labourers (London 1500-49 = 100)**

	1300	1350	1400	1450	1500	1550	1600	1650	1700	1750	1800
Northwestern Europe											
London	57	75	107	113	100	85	80	96	110	99	98
Amsterdam					97	74	92	98	107	98	79
Antwerp			101	109	98	88	93	88	92	88	82
Paris					62	60	59	60	56	51	65
Southern Europe											
Valencia			108	103	79	63	62	53	51	41	
Madrid						56	51		58	42	
Florence/Milan	44	87	107	77	62	53	57	51	47	35	26
Naples					73	54	69		88	50	33
Central-Eastern Europe											
Gdansk					78	50	69	72	73	61	40
Warsaw						75	66	72	45	64	82
Krakow			92	73	67	74	65	67	58	63	40
Vienna			115	101	88	60	61	63	61	50	27
Leipzig						34	35	57	53	44	53
Augsburg					62	50	39	63	55	50	

Source: Broadberry and Gupta (2006: 7);
derived from the database underlying Allen (2001: 429).

Table 9: **GDP per capita levels (in 1990 international dollars)**

	1300	1400	1500	1600	1650	1700	1750	1800	1850
Northwestern Europe									
Great Britain	711	1,053	1,041	1,037	887	1,513	1,695	2,097	2,718
Netherlands		920	1,119	2,049	2,071	1.620	1,812	2,008	2,371
Belgium			1,487	1,589	1,445	1,375	1,361	1,479	1,847
Sweden				768	974	1,352	981	864	1,086
Southern Europe									
Italy		1,596	1,398	1,243	1,275	1,346	1,398	1,243	1,350
Spain	960	892	919	1,005	860	905	893	965	1,144
Central-Eastern Europe									
Germany			1,146	807	948	939	1,050	986	1140
Poland		562	702	810		569		634	
Asia									
China		1,025	851	857		1.096	723	613	600
Japan			552	605	619	597	622	703	777
India				682	638	622	573	569	556

Sources: Great Britain: Broadberry et al. (2015a). Netherlands: 1400-1805: van Zanden and van Leeuwen (2012) 1807-1850: Smits, Horlings and van Zanden (2000);.Belgium: Buyst (2011). Sweden: Schön and Krantz (2012; 201 Italy: Malanima (2011). Spain: Álvarez-Nogal and Prados de la Escosura (2013). Germany Pfister (2011). Poland: : Malinowski and van Zanden (2015). China: Broadberry et al. (2015c). Japan: Bassino et al. (2015).

India: Broadberry et al. (2015b). Benchmarks for 1850 derived from Maddison (2010).