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ABSTRACT

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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 models and analyzes such link: the role of commercialisation in raising efficiency wages as impersonal and anonymous 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 leads to higher capital-intensity in the production technology, resulting in 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. We finally calibrate the model to quantify the impact of a higher degree of anonymity on industrial production growth in England between 1300 and 1800.

JEL Classification: N13, O14, O43

Keywords: commercialisation, industrial revolution, anonymity, efficiency wages, learning by doing

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1 Introduction

Individuals are more or less anonymous in an economy to the extent that their past choices are known by other individuals. It has been argued that the level of anonymity can vary in the different economies. Greif (1994), for example, interprets different levels of anonymity as different "rules of the game" due to institutional or cultural differences, portrayed by the distinction between Genoese and Maghribi traders. Also the economic industrial structure has an important effect on the individual anonymity, in economies where the production is mainly implemented in the urban areas, the economic transactions are naturally more anonymous. In more general terms, one can say that development is characterized by a change in the informational structure among economic agents, as already emphasized in the theoretical literature by Banerjee and Newman (1998).

Lower availability of information regarding workers' past behavior, hence an increase in the anonymity in the labour market, can determine firms' choices of setting wages above market clearing level for efficiency purposes, as emphasized in the well known efficiency wages literature (Shapiro and Stiglitz, 1984). The high labour costs determined by the anonymity of the market lead firms to change their choices in terms of capital and labour and, given the technological esternalities generated by the use of more capital intensive technology, this may lead to technological progress through a more efficient use of capital, as the economic literature has largely emphasized (Hicks, 1932; Arrow, 1962).[1]

Therefore, we analyze a model of endogenous growth via learning by doing and a labor market characterized by incomplete information, where agents' incentives to supply effort are endogenously determined by the prevailing degree of anonymity and wages. We distinguish between the probability that shirking is detected (as in a model of efficiency wages) and the probability that a shirking worker who has been fired will be hired again in the future (as in Greif, 1994). Our model thus combines elements of efficiency wages, learning-by-doing and endogenous growth and the institutional enforcement of labour market discipline based. At the same time, our model is able to deliver a simple closed form solution under the assumption of perfect factor substitutability. Nevertheless, we show the key results to be robust to the relaxation of this assumption with the more realistic

[1]The perspective that technological 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).

assumption of imperfect substitutability.

In a recent paper, Legros et al. (2014, LNP henceforth) build a link between firm internal organization and technological progress. They argue that more labour specialization, generated by particular conditions in the labour market, can help the tinkering of *Nerds* by transforming the jobs in more elementary, and easier to mechanize, tasks; in our model the labour market plays a fundamental role as well, namely leads factories to became more capital intensive so that individuals learn how to use machines in a more efficient way, perhaps by attracting and inducing *Nerds* to tinker, to use LNP 's definitions.

Our paper represents a first attempt to determine how an increase in the market anonymity positively affects the economic growth through a more capital intensive way of producing. Our result finds some empirical support from Gorodnichenko and Roland (2010) showing a causal relationship from individualism to technological progress. As Grief (2004) pointed out, the collectivistic cultures are naturally endowed with a low level of anonymity and the opposite is true for the more individualistic ones.

The commercial and industrial revolutions provide the most natural backdrop for examining the issues. 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).

In particular, in this paper we are interested in the growing reliance on anonymous, impersonal relations, as against personalized customary relations in labor markets, following the commercial revolution which drives urbanization. With growing urbanization the degree of anonymity increases. Hence, the definition of commercialization implicit in this paper means more than simply an increase in the proportion of output passing through the market (Britnell and Campbell, 1995: 1).

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).[2] 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).

This "efficiency wage" argument 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 commercialized factor 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.

Whilst the basic model takes the increase in urbanization as exogenously given, the last

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

section of the paper includes a calibration exercise where the urbanization process is endogenized. This is achieved by simulating the effects of a shock to agricultural productivity in a two-sector model. We show how our mechanism can transform the increase in agricultural productivity into a later and much larger increase in productivity in the industrial sector. The extension of the model also explains how anonymity can naturally generate structural unemployment in the industrial sector in a dual economy model.

The paper proceeds as follows. In section 2, we present a literature review. Section 3 presents a theoretical one-sector model to derive the conditions under which commercialisation and technological progress are linked. Section 4 then provides a historical narrative using data on the historical transition to modern economic growth in northwest Europe, in which the Commercial Revolution of the early modern period is linked to the Industrial Revolution via its effects on factor prices. In section 5 we endogenize the urbanization shock by adding an agricultural sector, and we calibrate and simulate this two-sector model. Section 7 concludes. The appendix establishes that the main results of the theoretical model also go through when capital and labor are assumed to be gross substitutes in the production function of each individual firm.

2 Related literature

The current paper suggests a link between the two main strands of the macro-development literature: the institutional approach emphasizing the importance of trade and commercial development, which are supported by an appropriate institutional framework (e.g. North, 1990; Greif, 2004; 2006; Acemoglu and Robinson, 2006); and the endogenous growth approach (e.g., Romer, 1986, 1990, and Aghion-Howitt, 1992) with the perspective that invention should be understood as endogenous to economic forces. 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 endogenous growth models.[3]

Furthermore, within the institutional approach, our paper provides a link between com-

[3] Of course this leaves room for the operation of the Malthusian links between wages and population stressed in 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.)

mercial 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.

Finally, the last section of the paper, where our model is extended to explicitly introduce the effect of an increase in agricultural productivity, shows that our mechanism is complementary to contributions investigating the importance of the agricultural sector in the economic divergence, such as Galor, Moav and Vollrath (2009), Proto (2007) and Vollrath (2009 and 2011).

3 The benchmark model

In this section, building on a 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 in the labor market leads to an increase in wages and subsequently to a more capital intensive production and acceleration in technological progress eventually leading to an increase in labor efficiency.

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 not being detected by a new employer as having shirked in the past, accounting for the level of anonymity in the economy. We can think of σ as the probability that the news that a worker shirked in the past does not reach a new employer. The parameter σ can be reasonably considered close to 0 in a small village market and close to 1 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 working at $t + 1$. We define $V_t^E(e)$ as the intertemporal utility of an employed worker who exercises effort $e \in \{0, 1\}$ at time t.

We will now write down the conditions required to ensure that at each t, choosing high

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

effort $e = 1$ is optimal for each employed worker.

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

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 at t but does not shirk again in the future:

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

Here 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 mass n of identical firms, indexed by i. We will assume that each firm i has a production function with Harrod-neutral (or labor augmenting) technological progress $F(k_i, A_t l_i)$ where k_i is the capital used by firm i and l_i is the labor employed by firm i. We will assume that:

$$F(k_i, A_t l_i) = k_i^\alpha (A_t l_i)^{1-\alpha} \tag{5}$$

where $0 < \alpha < 1$ so that each firm has a Cobb-Douglas production function.

We assume that A_t evolves over time according to the standard rule:[5]

$$A_t = a(K_t). \tag{6}$$

The usual interpretation is that the prevailing technology in any period t is a function of the knowledge accumulated through learning by doing (e.g. Arrow,1962 and Romer, 1986), which is itself an increasing function of the aggregate investments in physical capital, K_t. A different, but equally consistent interpretation of (6) is provided by Voigtländer and Voth (2006) where the increase in technology is generated by the production of more specialized machines that a larger amount of investment generates. Specifically, the stock of knowledge increases with the amount of aggregate capital used i.e. $a(0) = 0$ and $a'(K_t) > 0$. The technological parameter A_t is therefore modelled as an aggregate capital externality.

Firms borrow capital from an external capital market at an exogenously given interest rate r.[6] 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 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.:

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

3.3 Market equilibria

We define a market equilibrium for a fixed σ as follows:
At any time t, a market equilibrium is a sequence of $(K_t^*, L_t^*, w_t^*, A_t^* : t \geq 1)$ such that:

1. *Given r, w_t^*, L_t^*, $K_t^*$and A_t^*, for each firm $l_{i,t} = \frac{L_t^*}{n}, k_{i,t} = \frac{K_t^*}{n}$ maximizes profits;*

2. *Given w_t^*, $t \geq 0$, no employed worker shirks i.e. w_t^* satisfies the no shirking constraint*

[5] This is a standard assumption in models of endogenous growth, see e.g. Barro and Sala-i-Martin (2004: 212-213).

[6] As will be shown later, this simplifying assumption is consistent with the historical experience. There were no capital controls at this time.

(4);

3. $A_t^* = a(K_t^*)$.

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 $A^* = a(K^*)$. Therefore, the steady state (long-run) values of the variables at a market equilibrium are denoted by $(K^*, L^*, w^*, A^* = a(K^*))$.

3.4 Characterizing market equilibrium

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

$$F_k(k_t, A_t l_t) = \alpha a(K_t)^{1-\alpha} k_t^{\alpha-1} l_t^{1-\alpha} = r \tag{8}$$

$$F_l(k_t, A_t l_t) = (1-\alpha)\, a(K_t)^{1-\alpha} k_t^{\alpha} l_t^{-\alpha} = w_t. \tag{9}$$

Assume, to begin with, that wages evolve according to the equation:

$$w_t = \omega_t A_t$$

where we interpret ω_t as wages measured in efficiency units of labor.

With $w_t = \omega_t A_t$, 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 at each $t \geq 0$:

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

Recalling that in equilibrium all firms are equal, so that $K_t = nk_{i,t}$ and $L_t = nl_{i,t}$, and given the standard assumption of constant return to scale on both factors, the aggregate production $nF(k_{i,t}, A_t l_{i,t}) = F(K_t, A_t L_t)$ for all firms i at each t.

Note that once the parameters of the model (including the degree of anonymity σ) are fixed, there are no dynamics: the system converges immediately to the steady state.

We can therefore determine the aggregate equations describing the steady state (where we have used (6)) as follows:

$$F_k(K^*, A(K^*) L^*) = \alpha a(K^*)^{1-\alpha} (K^*)^{\alpha-1} (L^*)^{1-\alpha} = r \tag{14}$$

and

$$\begin{aligned} F_l(K^*, A(K^*) L^*) &= (1-\alpha) a(K^*)^{1-\alpha} (K^*)^{\alpha} (L^*)^{-\alpha} && (15) \\ &= w^* && (16) \end{aligned}$$

For later reference, it is convenient to define the elasticity of the technological progress function, $\epsilon(K)$, with respect to aggregate capital as follows:

$$\epsilon(K) = \frac{a'(K)K}{a(K)}. \tag{17}$$

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, when the degree of anonymity in the market is not too high.

What is the impact of a change in the degree of anonymity σ on the steady state values of the capital stock, employment and wages? The following proposition examines the impact of a higher degree of anonymity on the steady state capital labor ratio and wages:

Proposition 1: *The relationship between anonymity, technology, capital and employment is given by the following:*

(i) For each $\sigma > 0$, there is a unique steady state with positive capital stock $K^* = K(\sigma)$ and employment level $L^* = L(\sigma)$ whenever the boundary condition $\frac{\mu(1-\beta p)}{\beta(1-p)} < (1-\alpha)\left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}}$ holds;

(ii) Suppose $\epsilon(K^*) > 1$. Then, the steady state capital stock K^*, technology $A^* = a(K^*)$ and real wages $w^* = \omega^* a(K^*)$ are all increasing in the degree of anonymity σ while steady state employment L^* is decreasing in the degree of anonymity σ.

Proof. (i) From the FOC characterizing the firm's optimum at the steady state we obtain:

$$K^* = a(K^*)L^* \left(\frac{\alpha}{r}\right)^{\frac{1}{1-\alpha}}. \tag{18}$$

Substituting K^* in (14) we have:

$$w = (1-\alpha)a(K^*) \left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}}$$

or recalling the definition of ω :

$$\omega^* = (1-\alpha) \left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}}. \tag{19}$$

Solving the system given by expressions (12), (11) and (10) recursively for the values of $v_t^E(1)$, $v_t^E(0)$ and v_t^{US}, and using the equilibrium condition (13), we have that the efficiency wage at time period t must satisfy the equation:

$$\omega_t = \frac{\mu(1-\beta p(1-q_t\sigma))}{\beta(1-(p+(1-p)q_t\sigma))}. \tag{20}$$

Now we can determine the equilibrium labor demand. In equilibrium nobody shirks, so the probability of finding a job for any unemployed worker is q, and dL is the 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. Let us then define:

$$q_t = q(L_t) = \frac{L_t}{N}. \tag{21}$$

Using (20) and (21), we can then rewrite the no shirking constraint as:

$$\omega(L_t, \sigma) = \frac{\mu\,(1-\beta p(1-q(L_t)\sigma))}{\beta\,(1-(p+(1-p)q(L_t)\sigma)} \tag{22}$$

where $q(L_t) = \frac{L_t}{N}$. From (22) it follows by computation that $\omega(L_t, \sigma)$ is increasing in both σ and L_t i.e. for a given level of aggregate employment, wages in efficiency units are higher the higher the level of anonymity.

Since both (22) and (19) must hold in equilibrium, we note that:

$$\lim_{L\to 0} \omega(L, \sigma) = \frac{\mu\,(1-\beta p)}{\beta\,(1-p)} \equiv \underline{\omega}$$

is independent of the value for σ. Therefore, as long as:

$$\frac{\mu\left(1-\beta p\right)}{\beta\left(1-p\right)}<\left(1-\alpha\right)\left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}} \tag{23}$$

there is a positive level of steady state employment L^* and capital K^* for each value of σ.

(ii) From (22) and (19) we obtain the equation:

$$\left(1-\alpha\right)\left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}}=\frac{\mu(1-\beta p(1-q(L^*)\sigma))}{\beta(1-(p+(1-p)q(L^*)\sigma))} \tag{24}$$

so that, by computation, it follows that $\frac{dL^*}{d\sigma}<0$.

Recalling expression (18), we write:

$$K^*=a(K^*)L^*\left(\frac{\alpha}{r}\right)^{\frac{1}{1-\alpha}} \tag{25}$$

so that, by computation it is verified that at the steady state, $\frac{dK^*}{dL^*}<0$ when $\epsilon\left(K^*\right)=\frac{a'(K^*)K^*}{a(K^*)}>1$. It follows that: $\frac{dK^*}{d\sigma}=\frac{dK^*}{dL^*}\frac{dL^*}{d\sigma}>0$ as required. ■

The above proposition shows that there is a unique positive steady state value of the capital stock K^* corresponding to each value of σ provided the boundary condition holds. An increase in σ, even when capital and labor are gross complements in the production function for each individual firm, in the presence of a capital externality, will generate greater capital intensity and technological progress via learning-by doing.

Given the Cobb-Douglas specification of the production function, wages in efficiency units, ω, have to be constant and therefore, the labor market clears, after an increase in σ, through a decrease in employment. If technology is sensitive to small changes in the capital stock (the elasticity condition on the capital externality), each firm anticipates that the aggregate stock of capital will go up and therefore, in the face of rising wages, ensures that a reduction in employment increases the demand for capital: such an expectation on the part of each firm is the only one consistent with equilibrium following an increase in the value of σ. Thus, an increase in the value of σ results in a larger capital stock, increased real wages and a higher level of technology. Therefore, at the steady state, capital and labor are substitutes even though the two factors of production are gross complements in the production function for each firm.

In the appendix (see below), we show that an increase in the degree of anonymity σ will result in a larger capital stock, lower employment, higher real wages and higher technology without any restriction on the elasticity of capital externality, provided capital and labor are gross substitutes in the production function for each firm; moreover, the labor market clears through both an increase of the wage in efficiency units and a reduction in employment.

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.

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.

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. 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 (22) are satisfied.

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. 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 practise 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. Before 1850, Boyer (2002) reports an increase in real per capita expenditure on poor relief from 24.9 in 1696 to 100 in 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.

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.

4.2 Changing factor prices

Table 2 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 2. 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 3. 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 4. 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 4 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%.

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 5. 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 price 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 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 5, 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 2, 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 6, 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 the whole 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 the whole 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 7 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 Indian 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.

As well as documenting the Little Divergence between northwest Europe and the rest of the continent, Tables 2, 6 and 7 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). 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 meant a smaller market providing less rewards for innovation (Broadberry and Gupta, 2009: 302). Britain's advantage in this regard was reinforced by a patent system which had grown increasingly effective during the eighteenth century (MacLeod, 1988).

5 A Two-Sector Model

In Figure 1, we can observe an increasing gap between urban manufacturing (outside London) and agricultural wages. The gap started to grow from 1600, in line with the increasing urbanization rate in England, as can be seen from Table 1. This gap became quite large, so that by 1800, the urban manufacturing wage was 70% higher than the agricultural wage. This gap was larger still if we include London: the wage of an unskilled urban worker in London was more that 300% higher than the agricultural wage in southern England in 1800 (Allen, 2001; 2009).

Pollard (1978) has noted this large gap, which can be explained in two ways: (i) it may reflect some market imperfection in the labor market, due in our model to the unobservability of effort; (ii) it may be the result of differences in the cost of living between the city and the countryside. The available empirical evidence and the economic history literature seems to suggest that while there is evidence of (ii), this cannot explain the entire gap. For example, Crafts (1982) constructs a spacial cost of living deflator for 1840, showing a differential of around 10% between rural regions and London.[7]

Consistent with this evidence, in the following extension of our model, we consider a two-sector economy with an agricultural sector where wages are fully flexible, and a manufacturing sector characterized by efficiency wage constraints, generating some equilibrium unemployment. These are normal assumptions in the dual-economy model of Harris and Todaro (1970). Pollard (1981: 903) applies this model to Britain during the first half of the nineteenth century, noting that, *"Indeed, many migrants did not even come for jobs, but for the expected opportunity of finding jobs, so that the weighed-up chances of wage levels and disamenity must have been an even more unreal calculation"*. Boyer and Hatton (1997) find strong empirical support for the dual-economy model, showing how migration reacted to the *expected* gap between rural and urban wages and that city unemployment positively affected rural wages even after controlling for prices. Similar conclusions can be inferred from Long (2005), who finds that, using a large dataset related to the period 1850-1881, unemployment rates among the stayers in the agricultural sector were lower than among the movers to the urban sector.

[7] The literature also considers the cost of urban disamenties, but they do not seem to be large enough to explain much of this gap. For example, Williamson (1981) estimates that the city disamenity premium accounts for around 9% of the wage of an unskilled urban laborer in 1905.

5.1 Calibration and Simulation of an Extended Two-Sector Model

In this section, in a two-sector extension of our basic model, we link anonymity to the degree of urbanization determined by migration from the rural sector following an increase in agricultural productivity that took place after 1500 (Broadberry et al., 2013) leading to an increase in urbanization and anonymity, higher wages and capital intensity in production in the industrial sector. This exercise has two purposes: (i) it allows the estimation of the extent to which anonymity in the urban sector is able to predict the wage differential between the manufacturing and agricultural sectors presented in Table 1; (ii) it allows the estimation of how much the exogenous shock to English agricultural productivity that took place after 1500 can explain the subsequent increase in industrial productivity.

We use the subscript "A" (respectively, "M") to denote the rural sector (respectively, manufacturing sector) output, prices, employment etc. Following Vollrath (2009), we assume that individuals must consume a fixed amount of the subsistence good produced in the rural sector, C_A, at a relative price p_A, (the price of the manufactured good is normalized to one and is treated as the numeraire) and individual preferences are represented by a utility function that is strictly increasing in the quantity of the manufactured good consumed; further, all manufactured goods are produced in the urban sector, and all subsistence goods are produced in the countryside.[8]

Agricultural Sector

Production in the agricultural sector requires land, R_A (resources), and labor, L_A and generates an output $p_A(A_A L_A)^{\phi} R_A^{1-\phi}$, expressed in units of the numeraire (the manufactured good), given the price p_A. Given our assumptions, the agricultural sector must produce a fixed quantity, C_A over time:

$$C_A = (A_A L_A)^{\phi} R_A^{1-\phi}. \tag{26}$$

We assume that in the agricultural sector individuals do not shirk.[9] Assuming that

[8]These assumptions determine a consumption pattern consistent with Engel's Law: as the economy gets richer, individuals devote a lower share of their income to agricultural goods.

[9]This can also be derived, at the cost of complicating the exposition, by using the above model of efficiency wages, under the assumption that shirking is detected for sure and individuals will not be rehired after shirking. We also note that this is consistent with the literature on agricultural contracts in backward economies, e.g. Eswaran and Kotwal (1985), who emphasize how family firms, typical of backward agricultural sectors, have an advantage in terms of monitoring.

firms are in perfect competition, they take wages and prices as given, and because of the constant returns to scale assumption, in equilibrium, there is no loss of generality if firms in the rural sector are required to produce an equal share of the quantity C_A and accordingly decide the amount of capital and labor to employ.

Therefore, in equilibrium, firms use labor so that its marginal product is equal to the wage rate, and all available land, R, is used, so that we have:

$$L_A = \frac{(C_A R^{\phi-1})^{\frac{1}{\phi}}}{A_A}, \tag{27}$$

From (27) we note that the individuals employed in the agricultural sector are a decreasing function of A_A, the labor productivity determined by the agricultural technology. Therefore, an increase of agricultural productivity results in a larger share of workers moving to the urban sector.

Using (27), we determine the marginal product of labor, which equals the agricultural wage:

$$w_A = p_A A_A \mu \left(\frac{R}{C_A}\right)^{\frac{1-\phi}{\phi}}. \tag{28}$$

Manufacturing Sector

We assume that production in the manufacturing sector takes place in the city, where there are u individuals supplying labor. Recalling that in the agricultural sector there is no unemployment, the level of urbanization $u = 1 - L_A$. For each firm, technology is determined by equation (5) (with the obvious change in notation). Firms are competitive and we assume that among the individuals living in this sector, there is a proportion ε of entrepreneurs. The number of firms is then proportional to u, so that the demand for labor in this sector is $\varepsilon u L_M$ and labor supply is u.[10] Therefore, the probability of finding a job for any individual who chooses this sector is:

$$q(L_M) = \varepsilon L_M.$$

Firms take wages as given. As in the one-sector model, in the manufacturing sector, the

[10] For notational simplicity, we are assuming that entrepreneurs also act as suppliers of labor.

non shirking constraint (4) must be binding so that:

$$w_M = \frac{A_M \mu \left(1 - \beta p(1 - q(L_M)\sigma)\right)}{\beta \left(1 - (p + (1-p)q(L_M)\sigma\right)} \tag{29}$$

must hold. Moreover, given that the labor market is competitive, wages in equilibrium must equal the marginal product of labor and given the perfect capital market, we have:

$$w_M = A_M(1-\alpha)\left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}}. \tag{30}$$

From (29) and (30) and noticing that $L_M \leq \frac{1}{\varepsilon}$, we obtain the following expression:

$$L_M(\sigma) = \begin{cases} \frac{\lambda(\mu,p,\alpha,r,\beta)}{\varepsilon\sigma} & \sigma \geq \lambda(\mu,p,\alpha,r,\beta) \\ \frac{1}{\varepsilon} & 0 \leq \sigma < \lambda(\mu,p,\alpha,r,\beta) \end{cases} \tag{31}$$

with

$$\lambda(\mu,p,\alpha,r,\beta) = \frac{(1-\alpha)\beta(1-p)\left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}} - \mu(1-\beta p)}{\beta\left(\mu p + (1-\alpha)(1-p)\left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}}\right)} \tag{32}$$

from which we note that $\lambda(\mu,p,\alpha,r,\beta) \leq 1$ for $\mu \geq 0$ (since it is maximal when $\mu = 0$) and it is $\lambda(\mu,p,\alpha,r,\beta) > 0$ given the conditions of proposition 1.

Migration, urbanization and anonymity

We assume that at the beginning, individuals face the choice of whether to live in the city and produce in the manufacturing sector in the next period, or stay in the countryside and produce in the rural sector. We assume that individuals take as given the two technology parameters A_M and A_A, the level of anonymity σ, the relative price of the rural sector, p_A, and the wages in the two sectors. We also assume that they do not expect them to change during their life span. Hence they consider a static environment when they make their choices. Individuals who die are replaced by their offspring who are born in the same sector, so the choice to locate in one sector or the other is made at the beginning by the first generation of individuals.

Individuals who choose the agricultural sector expect to be employed in a firm and perceive a wage w_A that is endogenous and derived below. As in the one-sector model, in the manufacturing sector there may be unemployment in equilibrium, hence individuals moving to the city to work in manufacturing may remain unemployed in each period with positive probability $(1-q)$. Individuals who do not find a job stay unemployed for a period and look for a job in the next period, so their expected utility when they make the choice to locate, is:

$$V^M = \beta(qV^E + (1-q)V^U).$$

In the agricultural sector, there is perfect monitoring and no unemployment. Workers start to work in the same period they make the choice to locate, so that their utility is:

$$V^E = \sum_t^{\infty} \beta w_M.$$

We assume that individuals are all initially born in the agricultural sector and if they decide to move they will start to look for a job in the next period. Hence, in equilibrium, individuals must be indifferent between the two sectors, and the following condition must hold:

$$\frac{w_A}{1-\beta} = \beta(q\frac{w_M}{1-\beta} + (1-q)\frac{\beta q w_M}{(1-\beta)(1-\beta(1-q))}), \tag{33}$$

from which we note that $w_M > w_A$. Equation (33) can be considered a dynamic version of the Harris-Todaro condition (Harris and Todaro, 1970). We are now in a position to calibrate this simple two-sector extension of the one-sector model studied above.

Calibration of the model

From Figure 1, we note that the trend of growing urbanization starts in 1500. Consistent with the wage data in this figure, Broadberry et al. (2013) find an increase in agricultural productivity of 0.15% per year in the period between 1500 and 1700, and almost no change between 1300 and 1500. Hence assuming that the agricultural technology evolves following the expression $A_A = A_A^0(1+\gamma)^t$, we consider the following exogenous pattern determining agricultural productivity:

$$\gamma = \begin{cases} 0 & t \leq 1500 \\ 0.0015 & t > 1500 \end{cases}.$$

In the following table, we show the wage differential between the manufacturing and agricultural sectors using the manufactured good as a numeraire. As for the first calibration, the wages are from Allen, as used in Figure 1, and are divided by the industrial price index from Broadberry et al. (2013). The share of manufacturing workers, defined as the share of workers in industry but excluding the individuals working in services, are from Broadberry et al. (2013):

t	$w_M^t - w_A^t$	u^t
1500	−0.3	0.28
1600	−0.3	0.375
1700	1.66	0.467
1750	2.51	0.481
1800	6.07	0.534

In the years before 1700, agrarian wages seem to have been about the same as unskilled wages in the manufacturing sector. From expression (33), this is not consistent with equilibrium unemployment in the manufacturing sector (i.e. $w^M \leq w^A$ only if $q = 1$). We can then argue that the level of anonymity starts to bind in wage determination only after 1700 (thus $\sigma^t < \lambda$, for $t \leq 1700$ in expression (31)).

Given that, following Broadberry et al.'s (2013) estimates, agricultural productivity begins to increase in a non-negligible way in 1500, we use this as the initial year to calibrate our model. Our assumptions imply that in 1500 there is no unemployment, so the expression (33) then becomes:

$$\frac{p_A A_A \mu \left(\frac{R}{C_A}\right)^{\frac{1-\mu}{\mu}}}{1-\beta} = \beta \frac{A_M (1-\alpha) \left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}}}{1-\beta}, \tag{34}$$

As we said, in the model we consider the industrial price as numeraire, hence we divide average daily manufacturing wages in the period 1500 by the price of industrial goods from Broadberry et al. (2013). Accordingly, we set the manufacturing daily wage in 1500 equal to 6.81, or

$$A_M^{1500}(1-\alpha)\left(\frac{\alpha}{r}\right)^{\frac{\alpha}{1-\alpha}} = 6.81. \tag{35}$$

We estimate the relative price p_A, as the ratio between industrial and agricultural prices. In 1500 this is:

$$p_A^{1500} = 0.89. \tag{36}$$

We initially set the return on the backyard activity in 1500:

$$\mu A_M^{1500} = 4. \tag{37}$$

We later show that our final results are insensitive to this assumption. Finally we assume that $\mu = 0.4$, as in Voigtlander and Voth (2006) (and we will later show that our calibration results are robust to reasonable changes in the values of this parameter).

We normalize the workers' population to unity, $N = 1$. We begin by working with a one sector model in which we do not consider land, but a 2-sector model will be considered in the next section. As suggested by Crafts (1985) we assume a capital share $\alpha = 0.5$ (we later show that assuming a lower α will not affect the results). We use 0.93 as the discount factor, although in our model this needs to be multiplied by the chance of surviving in adulthood. We use life tables to obtain estimates of $q(x)$, defined as the probability that someone aged x dies before reaching age x+1. The earliest available life tables, from the early 19th century, indicate that 1,000 $q(x)$ rose from 42.5 at age 20 to 51.5 at age 30 and 67.5 at age 40, giving a mean value of 53.8 (Wrigley and Schofield, 1989: 709) and an average probability of surviving during working age equal to 0.95. Therefore, given the definition above, $\beta = 0.95 * 0.93 \approxeq 0.88$.

We derive the interest rate from Table 4, by averaging all rates available within the period 1300-1800, so that the return on capital, $r = 1.058$. The technology parameter, measuring total factor productivity, A, and dependent on the capital available, K, as defined in function (6) must fulfil condition (17). Following Voigtländer and Voth (2006) we assume the following functional form:

$$A(K) = A_0 K^{\epsilon}. \tag{38}$$

Voigtländer and Voth (2006), estimate $\epsilon = 1.25$ by regressing TFP growth on capital growth derived from Crafts (1985) and Crafts and Harley (1992). Given our definition (38), $\epsilon = \frac{a'(K)K}{a(K)}$, hence this parameter, being larger than one, fulfils our condition (17) necessary to guarantee that labor is a substitute for capital in production.

Finally, we assume that there is full uncertainty in the possibility of being caught shirking, hence we set $p = 0.5$ (we later show that the results of the simulation are not sensitive to this number).

Using (33), (34), (35), (36) and (37), we determine the estimated values for C_A, A_M^0, A_A^0, γ, m that we report in Table 8.

We estimate the function linking σ^t and u^t by interpolating a line between u^t and wages for the years 1700, 1750 and 1800, which yields approximately a relation:

$$\sigma^t = 0.0015 + 0.167u^t.$$

This line interpolates the three points almost perfectly, providing some support to the assumption of the existence of a linear relationship between the two variables.

Given the parameters assumed, we have threshold $\lambda(\mu, p, \alpha, r, \beta) = 0.075$, and considering expression (31), we have that $\sigma^t > \lambda(\mu, p, \alpha, r, \beta)$, for $t > 1650$.[11] In figure 2 we report the estimated level and the respective data of: manufacturing workers; agricultural prices over industrial prices, manufacturing wages expressed in terms of industrial prices; the difference between manufacturing and agricultural wages in terms of agricultural prices; an index of industrial production, $eu^t k_t^\alpha (A_t l_t)^{1-\alpha}$ normalized to equalize the level of the Broadberry et al. (2013) index in 1500.

The last panel of the figure emphasizes that the model is able to explain remarkably well the increase in industrial productivity before 1750. In particular, it seems to correctly predict an acceleration in 1700, i.e. 200 years after the shock to the agricultural sector. At the same time, however, it explains less than half of the increase between 1750 and 1800. As noted before, this suggests the presence of other mechanisms of endogenous growth acting after the economy took off and becoming predominant in the years after 1750, when the English economy became predominantly industrial.

Furthermore, the model seems to explain well the wage differential in the years 1700 and 1750, but is only able to explain half of this difference in 1800. This is possibly due to other factors affecting the difference between the two sectors once the English economy became more industrialized, like a skill premium or congestion cost in the manufacturing sector.[12]

Finally Figure 3 shows how our mechanism magnifies the exogenous shock in agricultural productivity: the exogenous increase starting from 1500 in agricultural labor productivity

[11] Hence, consistently with our starting assumption, the calibrated model predicts that the efficiency wage level becomes binding only after 1650.

[12] The model rules out the possibility that agricultural wages are higher than industrial wages. We can observe that this occurs in the early years of our sample and it should be seen as the result of measurement error or due to some costs in the agricultural sector non considered in the model.

translates after 200 years into a much larger increase in industrial productivity.

5.2 Sensitivity Analysis

In Table 9, we present some sensitivity analysis for the growth of industrial productivity between 1500 and 1800 estimated by our calibrated model. We start from the baseline calibration and sequentially change key parameters (along the lines of Lagerlöf, 2006 and Voigtländer and Voth, 2006).

This shows how changing the key parameters does not significantly affect the results. We assumed the return from the backyard activity equal to 4, not far from the current wage in the manufacturing sector of 6.81. We show here that halving this value does not affect the final result. We assumed the labor share in the agricultural sector equal to 0.4, the value assumed in Voigtländer and Voth. Here, we set this equal to 0.7, the value assumed in Volrath (2009). Finally we assumed a much smaller value of ε, the proportion of entrepreneurs in the entire population. From the results reported in Table 12, we argue that all these changes do not affect the estimated industrial growth between 1500 and 1800.

6 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. (3) This led to a faster rate of technological progress through greater learning by doing on the capital intensive technology.

From the calibration of the model, we estimate that this mechanism can explain reasonably well the growth of GDP between before 1700, and about 40% of the growth between 1750 and 1800. Furthermore, we show that it can account for the entire growth of industrial production before 1750 and about one third of the increase between 1750 and 1800.

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A Appendix: The case of capital and labour as gross substitutes in the production function for each firm

For ease of exposition, as we do not calibrate the model when capital and labour are gross substitutes in the production function for each individual firm, we will assume that there is a fixed mass (normalized to one) of identical firms, indexed by i. 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[13] to scale in the two factors of production (k_i, l_i). 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 with 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 function must necessarily have the functional form:

$$\tilde{F}(f_i, k_i, A_t l_i) = (f_i)^{1-\alpha} \left(\theta k^\eta + (1-\theta)\left(A_t l\right)^\eta\right)^{\frac{\alpha}{\eta}} \tag{39}$$

where $0 < \alpha < 1$ and $\eta < 1$ where the elasticity of substitution between capital (respectively, labour) and entrepreneurship is one. Setting $f_i = 1$, we obtain

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

[13] 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.

We assume that A_t evolves over time according to (6). The specification of the firm's problem remains the same as before. In equilibrium, firms make non-zero profits due to 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. The definition of a market equilibrium remains the same as before. Manipulating FOC as before, we are in a position to state the following proposition that characterizes the impact of a change in the degree of anonymity σ on the steady state values of the capital stock, employment and wages when capital and labour are imperfect substitutes:

Proposition 2. *Suppose* $\frac{\alpha}{\eta} \leq 1$. *Then,* $F(k, A_t l)$ *is strictly concave in* k, l *and the relationship between anonymity, technological and the equilibrium capital dynamics when capital and labour are substitutes in production is given by the following:*

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

(ii) The steady state stock capital labour ratio $\frac{K^*}{L^*} = \frac{K(\sigma)}{L(\sigma)}$, *technology* $A^* = a(K(\sigma))$ *and real wages* $w^* = \omega(L(\sigma))\, a(K(\sigma))$ *are all increasing in the degree of anonymity* σ.

Proof: (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:

$$F_k(K, a(K)L) = r, \tag{40}$$

$$F_l(K, A(K)L) = \omega(L, \sigma). \tag{41}$$

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

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

where

$$F_{kl} = \alpha\theta\eta\left(\frac{\alpha-\eta}{\eta}\right)(a(K))^{\eta} K^{\eta-1}L^{\eta-1}(\theta K^{\eta} + (1-\theta)(a(K)L)^{\eta})^{\frac{\alpha-2\eta}{\eta}} \leq 0,$$

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

Consider, next, the equation $F_l(K, a(K)L) = \omega(L, \sigma)$. There exists an implicit function $g_2(L) = K$ with

$$g_2'(L) = -\frac{a(K)F_{ll} + \omega_l(L,\sigma)}{F_{kk} + F_{kl}a'(K)} < 0$$

where

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

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

$$\lim_{k\to 0} F_k = \lim_{k\to 0}\left[\alpha\theta K^{\eta-1}(\theta K^{\eta} + (1-\theta)(a(K)L)^{\eta})^{\frac{\alpha-\eta}{\eta}}\right] = \infty,$$

while

$$\lim_{l\to 0} F_l = \left[\alpha(1-\theta)a(K)^{\eta} L^{\eta-1}(\theta K^{\eta} + (1-\theta)(a(K)L)^{\eta})^{\frac{\alpha-\eta}{\eta}}\right] = \infty$$

$\lim_{L\to 0} g_3(L) = \infty$ while $\lim_{L\to\infty} g_3(L) = 0$ so that there exists $L^* = L(\sigma) > 0$ such that $g_3(L^*) = g_2(L^*) - g_1(L^*) = 0$. Finally, note that $K^* = K(\sigma) = g_2(L^*) = g_1(L^*) > 0$.

(ii) We examine how the steady state values of the key endogenously determined variables change due to changes in σ. After substituting for wages using the no shirking constraint (4), the total derivative of (40) and (41) at the steady state is given by the expression

$$\begin{bmatrix} F_{kk}^* + F_{kl}^* a'(K^*) & F_{kl}^* a(K^*) \\ F_{kl}^* + F_{ll}^* a'(K^*) & F_{ll}^* a(K^*) - \omega_l^* \end{bmatrix} \begin{bmatrix} dK^* \\ dL^* \end{bmatrix} = \begin{bmatrix} 0 \\ \omega_\sigma^* \end{bmatrix} d\sigma$$

where $\omega_\sigma^* = \omega_\sigma(L^*, \sigma)$ and

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

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

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

as $F(.)$ is strictly concave and $\omega_l^* > 0$. Therefore,

$$\begin{bmatrix} dK^* \\ dL^* \end{bmatrix} = \frac{1}{D'} \begin{bmatrix} F_{ll}^* a(K^*) - \omega_l^* & -F_{kl}^* a(K^*) \\ -F_{kl}^* + F_{ll}^* a'(K^*) & F_{kk}^* + F_{kl}^* a'(K^*) \end{bmatrix} \begin{bmatrix} 0 \\ \omega_\sigma^* \end{bmatrix} d\sigma$$

so that

$$\begin{bmatrix} dK^* \\ dL^* \end{bmatrix} = \frac{1}{D'} \begin{bmatrix} -F_{kl}^* a(K^*)\omega_\sigma^* \\ \left(F_{kk}^* + F_{kl}^* a'(K^*)\right)\omega_\sigma^* \end{bmatrix} d\sigma$$

and

$$\begin{aligned} \frac{dK^*}{d\sigma} &= -\frac{F_{kl}^* a(K^*)\omega_\sigma^*}{D'} \geq 0 \\ \frac{dL^*}{d\sigma} &= \frac{\left(F_{kk}^* + F_{kl}^* a'(K^*)\right)\omega_\sigma^*}{D'} < 0 \end{aligned}$$

as $\omega_\sigma^* > 0$. ■

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? Starting from the steady state capital stock and employment corresponding to σ, 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 $t+1$). The assumption that $\frac{\alpha}{\eta} \leq 1$ implies that capital and labour are gross substitutes in the production function of each individual firm. 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, there will be a partial substitution of labour by capital in the aggregate. Therefore, wages in efficiency units are no longer held constant and 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.

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: **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 3: **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 4: **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 5: **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

	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).

Table 6: **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 7: **GDP per capita levels (in 1990 international dollars)**

	1250	1300	1350	1400	1450	1500	1550	1600	1650	1700	1750	1800	1850
Northwestern Europe													
England	737	730	767	1095	1172	1164	1138	1144	1215	1649	1688	2085	3006
Holland			876	1195	1373	1454	1432	2662	2691	2105	2355	2408	1886
Belgium						929	1089	1073	1203	1264	1357	1497	
France						727		841		986		1230	
Southern Europe													
Spain	1249	1249	1388	1145	1160	1160	1294	1219	1175	1145	1190	1249	1487
Italy		1482	1376	1601	1668	1403	1337	1244	1271	1350	1403	1244	1350
Central-Eastern Europe													
Germany						1332		894	1130	1068	1162	1140	1428
Poland						462		516		566		636	
Austria						707		837		993		1218	
India								684	648	630	587	576	560

Source: Netherlands: van Zanden and van Leeuwen (2012); France, Austria, Poland: Maddison (2005), England: Broadberry et al. (2011).

Italy: Malanima (2011); Belgium: Buyst (2009), Blomme and van der Wee (1994); Germany: Pfister (2009); Spain: Álvarez-Nogal and Prados de la Escosura (2009); India: Broadberry and Gupta (2011).

Table 8 **: Baseline calibration for the two-sector model**

Symbol	Interpretation	Value
Values Assumed		
β	Discount rate*survival prob.	0.88
r	Average return on capital	1.058
α	Capital share in the maufacturing	0.35
φ	Labor share in the Rural	0.4
ϵ	Elasticity of TFP to capital	1.25
R	Land	8
$\overline{\gamma}$	Shock in the agricultural after 1500	0.0015
p	Probability of being detected	0.5
ε	Percentage of entrepreneurs	0.1
Values Estimated		
μ	Rentability of backyard Activity	0.21
C_A	Consusmption of the Rural Good	10.97
A_A^{1300}	Initial TFP in Rural Sector	24.6
A_{1500}^0	initial TFP in Manufacturing	0.06
C_A	Consumption of the Rural Good	6.31
$\lambda(\mu, p, \alpha, r, \beta)$	Threshold of Anonymity	0.074
$\underline{\sigma}$	Intercept of the anonymity function	0.0015
x_σ	Coefficient of the anonymity function	0.167

Table 9: **Sensitivity Analysis of the two sector model**

Changed Parameters	Growth in the Industrial Production 1500-1800
baseline model	4.32
$\mu A_{1500} = 2; \mu = 0.1; \underline{\sigma} = -0.009; x_\sigma = 0.97$	4.32
$\phi = 0.7; A_M^0 = 0.05; A_A^0 = 7.87; C_A = 6.27; \underline{\sigma} = -0.0015; x_\sigma = 0.17$	4.32
$e = 0.01; A_M^0 = 0.003$	4.32

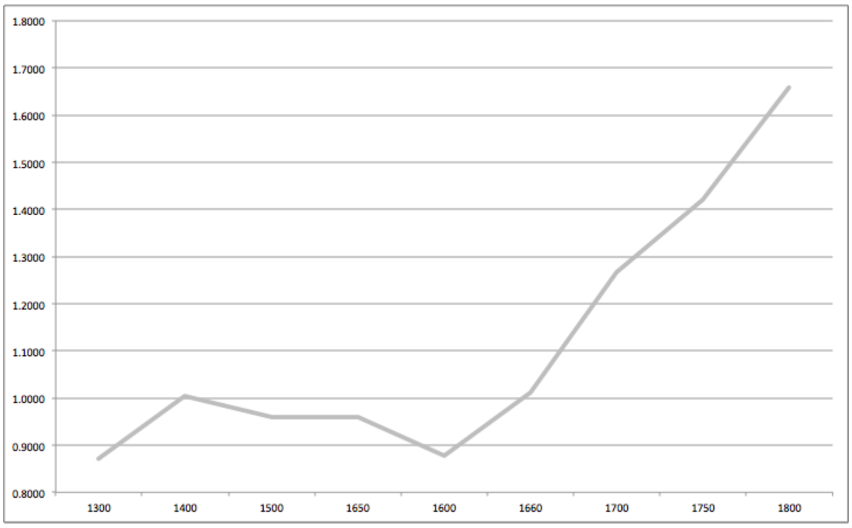

Figure 1: Urban over agricultural unskilled workers' wage ratio in Southern England (London is excluded).

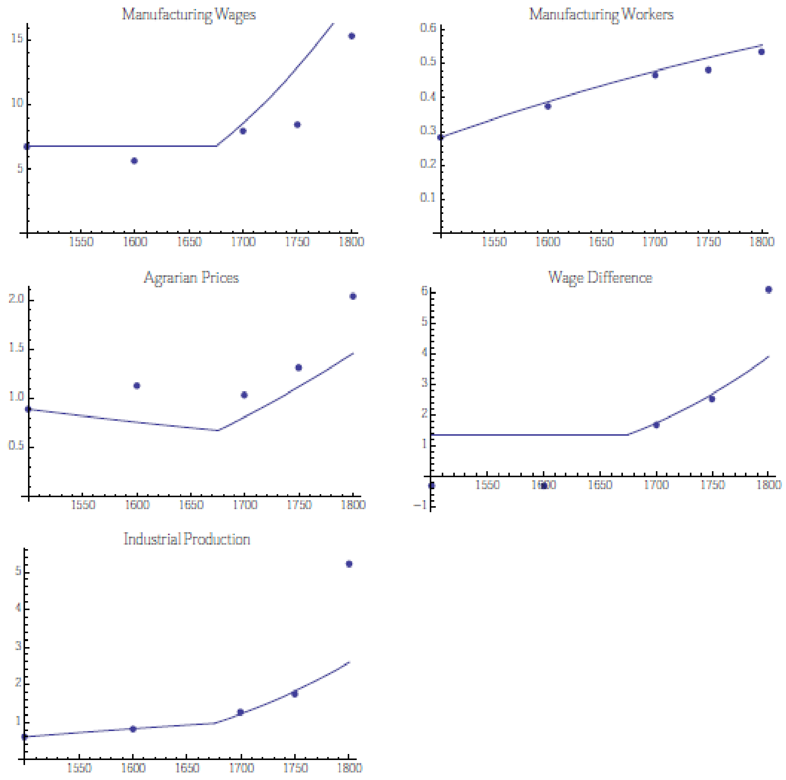

Figure 2: Estimated variables from the simulations of the two-sector model, and the actual data points.

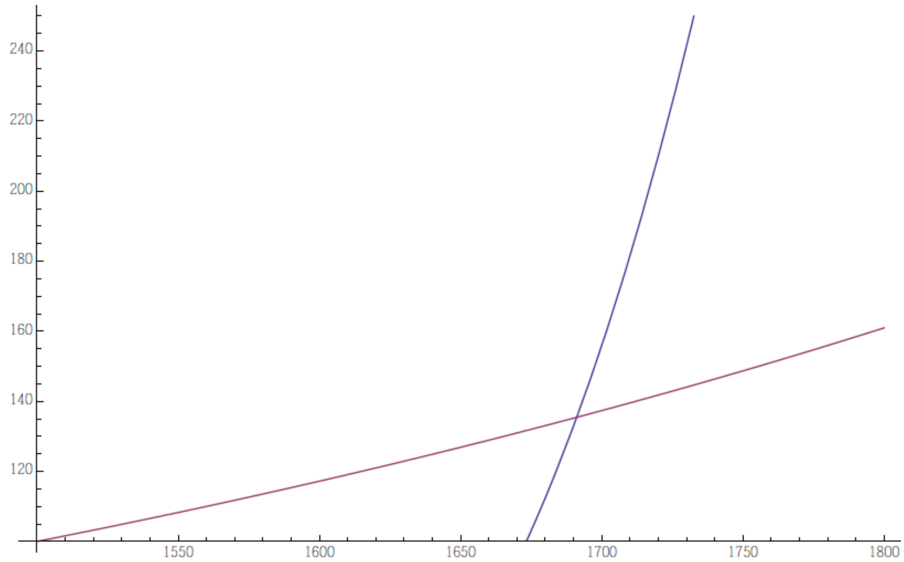

Figure 3: Evolution of agricultural and manufacturing labor productivity predicted by the model.