From Domestic Manufacture to Industrial Revolution: Long-Run Growth from a Boserupian Perspective*

Jacob L. Weisdorf†

September 24, 2003

Abstract

This paper explores the changes in the behaviour of the pre-industrial farm household that paved the way for the Industrial Revolution. Using a theory proposed by Boserup (1965) in which the intensification of farmland comes at a cost to labour, it is shown that improvements in industrial productivity, such as the introduction of the spinning wheel in the English textile industry, induce the farm household to increase its food surplus at the expense of its domestic goods production of non-agrarian goods, and that the increase in the food surplus is used to purchase manufactued goods produced in the industrial sector.

Keywords: agricultural development, household production, industrial revolution, structural change, time-allocation

JEL codes: O14, O31, J21, J22

*This work has benefitted from comments and discussions with Eona Karakacili, Karl Gunnar Persson, and Christian Schultz. I am also indebted to Joel Mokyr and Robert C. Allen for their help with literature recommendations and historical data.

†Institute of Economics, University of Copenhagen, 6, Studiestraede, 1455 Copenhagen K, Denmark (Fax: +45 35 32 30 00; e-mail: jacob.weisdorf@econ.ku.dk.)

"Some family members had produced textiles and other non-agrarian products for home consumption, but when prices of such products declined steeply, home production was replaced by the purchase of industrial products. Home workers either gave more help in agriculture, or they began to work in or for the new factories."

Boserup, *The Conditions of Agricultural Growth*, 1990

1 Introduction

One of the most important pre-conditions for economic growth and the wealth of nations is the release of labour from food generating activities. By 1500, the share of the English's labour force in agriculture was nearly 75 percent (Allen, 2000). Today, that share is less then three percent (World Bank, 2002). This change in the occupational structure reflects the astonishing performance of the agricultural sector over the past five centuries. But why then are technological breakthroughs in the industrial sector, such as the introduction of the spinning wheel in the English textile industry, said to be responsible for the Industrial Revolution industrial when it would seem that it is productivity improvements in the agricultural sector that enabled the transfer labour from agriculture to industry?

This paper explores a possible link between improvements in the industrial sector's productivity and the performance of the agricultural sector. We construct a model which is founded on ideas presented in Ester Boserup's *Conditions of Agricultural Growth* from 1965. In this book, Boserup argues that agricultural productivity is limited, not by the state of knowledge of how to increase output per unit of land, but by the fact that an increase in farmland productivity comes at a cost to labour. We use this theory to show that an increase in the industrial manufacturers' productivity automatically leads to an intensification in the use of farmland.

The model presented below is inspired by the historical development pattern of the western world. So is a large series of theoretical studies that also examine the long transition from economic stagnation to sustained growth; these include Goodfriend and McDermott (1995), Galor and Weil (2000), Galor and Moav (2002), Galor *et al.* (2002), Hansen and Prescott (2002), Jones (2001), Lagerlöf (2003), Lucas (2002), Tamura (2002), and Weisdorf (2003). Common to most of these papers is a Malthusian building block in which a fixed amount of land generates decreasing returns to labour industrial technology is held constant. Economic growth then reflects the interaction between new technology, diminishing returns to labour, and demographic growth.

The introduction of Boserup's thinking is the primary way in which this paper differs from the literature. For whereas the Malthusian model implies that productive opportunities are always fully exploited, the Boserupian model suggests that farmers are in fact able to increase their farmland productivity by transferring labour from other activities such as domestic non-agrarian production and leisure time.

The inclusion of Boserup's theory in long-run growth models is not entirely new. Lagerlöf (2002), who investigates the institution of serfdom in history, includes a Boserupian feature in which agricultural productivity progresses as a result of population pressure. Similarly, Strulik (1997) employs a learning-by-doing mechanism that acts as a positive externality, which increases with the size of the population and helps it overcoming diminishing returns to labour. A working paper by Klausen and Nestmann (2000) also uses Boserup's insight of demand-driven technological change in an extension of the famous growth model presented in Kremer (1993). All of these presentations, however, lack significant aspects of Boserup's theory concerning the labour costs associated with an increase in farmland productivity.

An important issue, which is strongly related to the work of Boserup, concerns the role of agricultural in the process of development. Whereas the new growth theory almost always abstract from sectorial issues, development economists stress that due to the income-inelastic demand for agricultural products, improvements in the agricultural sector's productivity are a significant source of economic growth since it re-allocates labour from agrarian into non-agrarian activities. This issue is considered in a body of papers that examine the structural transformation of a dual economy (e.g., Chanda and Dalgaard, 2003; Echevarria, 1997; Galor and Mountford, 2003; Gollin *et al.*, 2002; Kongasmut *et al.*, 2002; Kögel and Prskawetz, 2001; Laitner, 2000; Matsuyama, 1992). The main inside received from these papers, most of which address the cause of the disparity in income per capita in contemporary countries, is that non-homotetic preferences with an income elasticity of demand for agricultural goods below unity creates a positive link between improvements in agriculture productivity and economic growth.

The work presented in this paper is most closely related to the studies by Kögel and Prskawetz (2001) and in Galor and Mountford (2003). Kögel and Prskawetz show that an increase in the growth of agricultural productivity transfers labour from agriculture to industry, which, due to increasing returns to labour in the industrial sector, increases both income per capita and fertility. However, in contrast to this paper, the level of agricultural productivity in Kögel and Prskawetz's model progresses exogenously, and changes in the level of the industrial sector's productivity does not influence the farmers' behaviour.

Galor and Mountford's paper shows that the current distribution of world population can be attributed to the contrasting effects that international trade played in the timing of the demographic transition in agricultural and industrialised countries. An important feature, which draws parallels to our work, is that the level of the agrarian productivity in Galor and Mountford's model is determined endogenously. In their model, the level of farmland productivity increases with the economy's overall level of technology, which in turn is positively correlated with the population's level of human capital.

The model in this paper differs from the existent literature in three important ways. First, we query the idea that the productive opportunities in pre-industrial farming were fully used. Inspired by the thinking of Boserup, we show that when the intensification of farmland comes at a cost to labour, and when utility is derived from spare-time activities, then farmers lack the incentive to use the highest level of farmland productivity possible, and is why productive opportunities in the agrarian sector need not be fully exploited.

Second, we propose an new way in which to endogenise farmland productivity. With the exception of Galor and Mountford's model discussed above, improvements in farmland productivity in the existent literature occur in an exogenous manner. In this paper, in contrast to the set-up presented by Galor and Mountford, the number of hours that the farmer chooses to spend in his fields, which implicitly determines the productivity of his farmland, is based upon the farmer's optimization behaviour.

Third, we introduce domestic non-agrarian activities. Models that deal with long-run growth from a historical perspective tend to neglect the fact that in societies whose occupational structure is dominated by agriculture, a significant part of the non-agrarian goods that farmers consume are produced by themselves. This subject is discussed in a number of papers that explore the labour allocation of an agrarian household (e.g., Devereux and Locay, 1992; Gronau, 1977; Hymer and Resnick, 1969; Locay, 1990), most of which are rooted in Becker's (1965) theory of time-allocation. Here, we build upon the work by Hymer and Resnick, who, in a partial equilibrium analyses, investigates the role of non-agrarian activities in an agrarian economy. Comparable to their study, we take the analysis further by implanting the agrarian sector's activities in a general equilibrium framework. We then use this framework to show that the process of industrialisation, not only in a historical perspective but also in contemporary developing countries, actually consists of a shift in the consumption of non-agrarian goods from goods produced domestically into similar goods produced in an industrial sector.

The theoretical argument rests upon two empirically well-supported assumptions, namely, that the demand for food is income-inelastic and that farmers are able to increase the productivity of their farmland by putting more hours of work into agriculture at the expense of other activities. Under these assumptions, the model shows that an increase in the industrial sector's productivity relative to the productivity in domestic production, induces the farmer to increase his work hours in agriculture in order to increase his food surplus. The increase in the farmer's work reduces his consumption of non-agrarian good that are produced domestically. However, this decline in consumption of domestic goods is compensated for by an increase the consumption of manufactured goods that the farmer obtains from selling his additional food surplus.

The analysis also shows that the increase in the farmer's food surplus releases labour from agrarian activities and thus increases the share of labour engaged in industrial manufacturing. All together, this explains why technological breakthroughs in the industrial sector, such as the introduction of the spinning wheel, would lead to an intensification of farmland and stimulate the process on industrialisation at a cost to the farmer's production and consumption of domestic goods.

In an extension of the model, we discuss the effect that an increase in the size of the population has on the structural composition of the labour force. It has been argued that prior to the Industrial Revolution, there is a scale-effect from the size of the population on output per capita (e.g., Kremer, 1993). By creating a positive link between the level of non-agrarian technology and the size of the population, we show that if the industrial sector uses the available technology more efficiently than does the domestic sector, then more a denser populated economy may be more industrialised. The reason is not, as is normally argued, that the agricultural sector's total factor productivity is higher. Rather, it appears that that the farm household in more densely populated economies work for more hours.

The paper proceeds as follows. Section 2 presents the historical evidence upon which the model builds. Section 3 presents the model, section 4 performs a comparative static analysis, while section 5 concludes.

2 Evidence

Contrary to the common belief, the process of industrialisation is not confined to the past two centuries. In the words of Hicks (1969, p. 141), "[t]he Industrial Revolution is the rise of modern industry, not the rise of industry as such". In today's terms, Hicks is referring to the concept of 'proto-industrialisation'. Mendels, the initiator of this modern version of this concept, writes (Mendels, 1972, p. 241) that "[w]ell before the beginning of machine industry, many regions of Europe became increasingly industrialized in the sense that a growing proportion of their labor potential was allocated to industry". Mendels' statement encapsulates well the way in which this paper wants to define an economy's degree of industrialisation, namely, as its share of labour devoted to industrial production.

Due to Engel's law, which captures the fact that the demand for agricultural goods is income-inelastic (e.g., Craft, 1985), the transfer of labour from agrarian into non-agrarian activities is inseparably linked to improvements in the agricultural sector's productivity. Intuitively, one would therefore expect that the historical movement of labour into industrial manufacture awaited advances in the knowledge of how to intensify the use of farmland.

Opposite to the classical economists such as Malthus and Ricardo who took it for granted that the productive opportunities are always fully exploited, one of the most striking aspects of Boserup's (1965) theory is that the intensity with which farmland is cultivated is not limited by the state of knowledge of how to increase output per unit of land. Instead, she convincingly argues that pre-industrial peasants were virtually always capable of increasing farmland productivity by increasing the number of hours that they spend in the fields.

More contemporary studies are in support of Boserup's theory. Grantham (1999, p. 212), for example, argues that intensive cultivation during the Middle Ages, "demanded more labour and capital per acre of land than traditional farming, and therefore cost more per hectare, but they did not require advances in knowledge".[1] In order to increase the output per acre of land, Grantham asserts (*loc.cit.*) that fields were seeded more thickly and that farmers weeded, ploughed, harrowed and hoed their fields more frequently and more intensively. Hatcher and Bailey (2001, p. 54) argue that the high levels of Medieval farmland productivity recorded in eastern Norfolk England, "were achieved largely by the use of labour-intensive methods of farming such as weeding, marling, and manuring, rather than through any revolutionary innovations in agricultural technology". Clark (1987), who provides evidence that output per farm-worker in northern United States and Britain in the early nineteenth century was many times that in Eastern Europe, asserts (*ibid.,* p. 419) that "[t]echnical progress explains little of the high American and British productivity [...], nor, in the American case, does abundant land per worker. Instead, most of the differences derived from more intense labor." So if an increase in farmland productivity came at a cost to labour, then something along the way must have induced the farmers to accept the inherent decline in their spare-time activities.

It has been argued that the systems of land use and cultivation can be understood only if considered as a part the pattern of social organisation as a hole. The pre-industrial economy is commonly considered as being dominated by agriculture, when in fact, as pointed out by, for example, Reynolds (2000), it is actually dominated by *household* production. Reynolds postulates that up till 1700, 80-90 percent of the European population lived in rural areas, on isolated farms or in small villages close to the farmland. In these rural households, he notes (*ibid.,* p. 80), "[e]ach family produces not only most of its own food, but most of its housing and clothing, plus a wide range of services". Out of the time available to the rural household, Reynolds asserts (*loc.cit.*), "agricultural activities take perhaps 50 to 60 percent of the total, the remainder going to 'industrial' and service activities" (Reynolds' quotation marks).

Industrial manufacture gains a foothold to the extent that farmers find it to their advantage to substitute domestic goods for similar goods produced by commercial producers. During the process of development, many services of the rural household, Reynolds notes, "tends to move outside the family which becomes more strictly a producer of agricultural goods rather than a multi-purpose producer of everything" (*ibid.,* p. 89). But to what extent did pre-industrial farmers increase the productivity of their farmland in order to shift their consumption-pattern in favour of industrial rather than domestic goods, thereby stimulating the process of industrialisation?

The transfer of labour into industrial activities is reflected in the occupation structure of the economy. However, historical records containing information about pre-industrial occupational structures are hard to come by. Instead, the rate of urbanisation, i.e., the share of people living in urban areas, is taking as a rough measurement of the economy's share of industrial labour. Allan (2000), reporting such data for pre-industrial Europe, estimates that the rate of urbanisation in England moved from four percent in 1300 to 23 percent in

[1] In fact, Grantham claims that the techniques that were used to increase output per acre of land during the Middle Ages had been around since the Iron Age.

1750. This clearly indicates that in the English case, a significant transfer of labour into industrial activities took place in the centuries prior to the Industrial Revolution. But what exactly was it that induced the increase in the production and consumption of industrial goods?

In the early modern era, there was an upward movement in agricultural terms of trade, i.e., in the number of non-agrarian goods that a farmer receives for a unit of food. This shift in terms of trade between the two sectors is believed to have encouraged farmers to improve the productivity of their farmland with the aim of increasing the number of agrarian goods that could then be exchanged for industrial produce. Craig and Fisher (2000, p. 46), for example, note that "[t]he effort to expand acreage and production during the fifteen and sixteenth centuries was prompted by favorable trends in the demand for agricultural products, which was reflected in the upward movement in farm prices relative to all other prices". Allen (2000), reporting English agricultural terms of trade between 1500 and 1800, shows (*ibid.*, Figure 1) that aside from a slight decrease between 1650 and 1750, the overall trend is an increase in the price that farmers receive for their products in terms of other goods.[2]

In support of this view, Reynolds (2000, p. 89) mentions that "[a]s agricultural production becomes more labour-absorbing and more profitable, and as manufacturers can be purchased from outside on more favorable terms, the rural family sheds some of its goods-producing functions and passes them over to the specialized producers". Along similar lines, Boserup (1990, p. 35) argues that around the time of the Industrial Revolution, "[s]ome family members had produced textiles and other non-agrarian products for home consumption, but when prices of such products declined steeply, home production was replaced by the purchase of industrial products. Home workers either gave more help in agriculture, or they began to work in or for the new factories".

Since the transfer of household activities into industrial manufacture is reflected in the occupational structure, and since industrial activities are more readily detected and measured than are those performed by the household,[3] one would expect to see a positive relationship between the share of labour in industrial activities and GDP per capita. Acemoglu *et al.* (2002), for example, provides evidence of a positive relationship between rates of urbanisation and log GDP per capita in contemporary countries. Taking urbanisation ratios as a proxy for the share of labour in industrial activities, their illustration (*ibid.,* Figure 3) indicates that countries that employ a relatively large proportion of their labour force in the industrial sector (or at least in non-agrarian activities),

[2] This is in accordance with work by Echevarria (1997), who, based on contempary data, observes a positive relationship between the degree of industrialisation and the price of foodstuff in relation to manufactured goods.

[3] See Devereux and Locay (1992) for a discussion. The shift from household production to market production is also examined by Locay (1990), who presents a model where scale economics give market production a cost advantage over household production. In his model, as with our's, it scale economics that gives market production an advantage hover household production. However, Locay does not consider with the role of agriculture in the process of economic development.

also enjoy relatively higher standards of living.[4] This seems to indicate that economic growth is strongly linked to the transfer of labour from agriculture into industrial activities.

The discussion in this section suggests that the historical process of industrialisation actually consisted of a shift in the farm household's consumption of manufactured goods, from produced domestically into similar goods produced the an industrial sector, and that this shift was accompanied by an increase in farmland productivity, stemming from an increase in the number of hours that the farmer spends in the fields.

In the following, a framework that is capable of replicating this process of development is presented. The framework is then used to trace the underlying factors that prompt the process of industrialisation.

3 The Model

Consider a three-sector, one-period, non-overlapping generations model with agrarian as well as non-agrarian production and consumption. The economy consists of N identical individuals, out of which the fraction $s \in (0,1]$, which is determined endogenously below, is engaged in the agrarian sector. Non-agrarian goods are produced domestically as well as in an industrial sector, in which the fraction $1-s$ of the labour force is employed.

Each individual is endowed with $\bar{l}$ units of time. As will become apparent below, this time-endowment is divided between domestic production on the one hand, and agrarian or industrial production—depending on the individual's sectorial choice—on the other.

3.1 Agrarian Production

We assume that agrarian production has constant returns to land and labour.[5] The output per farmer (superscript A for *agrarian* goods) is

$$y^A = l^\alpha x^{1-\alpha}, \quad \alpha \in (0,1), \tag{1}$$

where l is the number of hours that the farmer spends producing food and x the units of land that each farmer has to his disposal.

We assume that a fixed amount of farmland, X, is available to the economy. For convenience, this farmland is divided equally among the individuals who choose to become farmers. We further assume that the land is owned by those that are engaged in farming, meaning that y^A is the farmer's income, expressed in terms of food. With s being the share of labour in agriculture and N being

[4] Likewise, Echevarria (1997, Figure 2) shows that among 67 present-day countries, there is a perceptible negative relationship between the share of agricultural goods in GNP and GNP per capita.

[5] In the entire paper, we suppress the use of capital; this is a common simplification in models that investigate pre-industrial economic growth and development.

the size of the total population, each farmer thus receives

$$x = X/sN$$

units of farmland.

With a fixed amount of land at the farmers' disposal, the assumption that $\alpha \in (0,1)$ implies that there is diminishing returns to labour in agrarian production. However, in accordance with the theory of Boserup (1965), farmers are able to increase the productivity of their farmland by increasing the number of hours that they spend in the fields, that is, by increasing l.

Note that the total agrarian output is

$$Y^A = y^A \cdot sN = (lsN)^{\alpha} X^{1-\alpha} \equiv (lsN)^{\alpha}, \quad X \equiv 1. \tag{2}$$

Both the share of labour in agriculture, s, and the number of hours that each farmer spends producing food, l, will be determined below.

3.1.1 Food Demand and Agrarian Market Equilibrium

In accordance with Craft (1985), we assume that the demand for food, unlike other goods that we consider, is income-inelastic.[6] More specifically, suppose that $\overline{a}$ units of agrarian goods are required per individual in order to ensure the individual's survival.

With N individuals who each demands $\overline{a}$ units of food, equilibrium in the market for food implies that the total demand, $\overline{a}N$, equals the total supply, Y^A. The share of labour in agriculture that is required to satisfy the economy's food needs is thus determined endogenously from the agrarian market equilibrium. Using equation (2), it follows that the share of labour in agriculture, in equilibrium, is

$$s = (\overline{a}N^{1-\alpha})^{1/\alpha}/l. \tag{3}$$

All other things being equal if follows from equation (3) that the share of the population that is engaged in agriculture increases with the size (or, in effect, the density) of the economy's population, N, but that it decreases to the extent that farmer decide to increase their work hours spend producing food, l.

3.2 Preferences

Suppose that having consumed the $\overline{a}$ units of food that is required for survival, the individual derives utility from the consumption of non-agrarian goods. Non-agrarian goods can be of an industrial type, denoted m (for *manufactured* goods), and of domestic type, denoted d (for *domestic* goods). Domestic goods are produced by the individual in his or her spare-time. Manufactured goods

[6] Adam Smith (1776, p. 164) perhaps said it most precisely, noting that "[t]he desire for food is limited in every man by the narrow capacities of the human stomach but the desire of the conveniences and ornaments of buildings, dress, equipage, and household furniture, seems to have no limit or certain boundary".

are produced by the share of the labour force, $1 - s$, that is engaged in the industrial sector, henceforth denoted the manufacturers.

Domestic goods and manufactured goods are considered to be perfect substitutes. The representative utility function is thus

$$u(m, d) = m + \gamma d \equiv m + d, \quad \gamma \equiv 1, \tag{4}$$

with γ being the subjective value of domestic goods relative to manufactured goods. For convenience, γ is assumed to be the same for all individuals, and in the following is set to one. Note that the consumption of the $\overline{a}$ units of food that the individual needs in order to subsist, does not provide any utility but is necessary for survival.[7]

3.3 Non-Agrarian Production

There are two types of technologies available for producing non-agrarian goods: domestic technology (denoted D) and industrial technology (denoted M). Both are assumed to exhibit constant returns to labour, which implicitly means that land for the purpose of non-agrarian production is not constrained. The total non-agrarian output thus is

$$Y^i = \Omega^i \cdot L, \tag{5}$$

where L is labour and Ω^i the level of productivity in sector $i = \{D, M\}$. We define the level of productivity in the industrial sector to be

$$\Omega^M = (1 + \Phi)\,\Omega^D, \quad \Phi > 0.$$

Note that the assumption that Φ is positive implies that the level of productivity in the industrial sector is higher than that in the domestic sector.

3.4 Occupation, Income, and Consumption

Each individual decides whether to be a farmer or a manufacturer. We assume that once the occupational decision is made, then manufacturers do not have access to farmland and farmers do not have access industrial technology.

3.4.1 The Manufacturer's Income and Consumption

The manufacturer's income consists of the wage that he earns in the industrial sector, which is Ω^M times the number of hours that he decides to work. Since the manufacturer is more productive at work than at home, he chooses not to produce domestic goods at all and instead spends his entire time-endowment, $\overline{l}$, at work.

[7] A similar construction is found in Kögel and Prskawetz (2001). It is possible, but severely complicates matters, to have food consumption entering the utility function such that, once a given amount of food has been consumed, individuals care for food along with manufactured goods.

A share of the income that the manufacturer generates at work is spent on the $\overline{a}$ unit of food that he needs in order to subsist. Since utility is derived from the consumption of non-agrarian goods once his food needs are fulfilled, the remaining income is spent on manufactured goods. The number of manufactured goods that the manufacturer consumes is thus

$$m^M = \Omega^M \overline{l} - p\overline{a},$$

where the variable p is the price of food in terms of manufactured goods, i.e., agricultural terms of trade. Since the manufacturer is not engaged in domestic production, his consumption of domestic goods is

$$d^M = 0.$$

3.4.2 The Farmer's Income and Consumption

The farmer's income consists of the value of his food surplus. The food surplus is the difference between the farmer's food output, y^A, and the number of food units that is needed for subsistence, $\overline{a}$. The price that the farmer receives, measured in terms of manufactured goods, is p per unit of food. It thus follows that the number of manufactured goods that the farmer consumes is

$$m^A = p\left(y^A - \overline{a}\right). \tag{6}$$

Since farmers do not have access to the industrial technology, the farmer spends his spare time, i.e., the time left from agrarian activities, $\overline{l} - l$, producing domestic goods. His consumption of domestic goods is therefore

$$d^A = \Omega^D\left(\overline{l} - l\right). \tag{7}$$

Note that as long as $l < \overline{l}$, the farmer is able to increase the productivity of his farmland and thus his food surplus. However, as this increase in farmland productivity means that he needs to reduce this consumption of domestic goods, the farmer is reluctant towards using the highest farmland productivity possible, which is obtained by setting $l = \overline{l}$. In other words, an increase in farmland productivity is obtained at the expense of the farmer's spare-time activities.

4 Analysis

Using the set-up presented above, we are now ready to find the number of hours, l, that a farmer chooses to spend in the fields. We then use this to find the agricultural terms of trade, p, and the economy's degree of industrialisation, $1 - s$, and to see how these variables respond to changes in productivity and demography.

4.1 Optimization

A farmer chooses the number of agrarian work hours, l, that maximises his utility. Inserting the farmer's consumption of manufactured as well as domestic goods, equations (6) and (7), and the farmer's production function, equation (1), into the utility function, equation (4), the optimization problem thus becomes

$$\max_{l} u^A = p\left(l^\alpha (sN)^{\alpha-1} - \overline{a}\right) + \Omega^D\left(\overline{l} - l\right), \tag{8}$$

subject to the time-budget constraint that requires that $l \leqslant \overline{l}$.

An interior solution implies that

$$p\alpha (lsN)^{\alpha-1} = \Omega^D, \tag{9}$$

meaning that the marginal utility gained from increasing his agrarian work hours (the left-hand term), stemming from an increase in his food surplus and thus an increase in his consumption of manufactured goods, in optimum equals the marginal utility forgone from increasing his agrarian work hours (the right-hand term), which is due to a decline in his consumption of domestic goods. Note in particular, that an increase in the price that the farmer receives for his food surplus, p, increases the marginal utility obtained from increasing his agrarian work hours.

4.2 Labour Market Clearing

We assume that there is free labour mobility. Occupational indifference, i.e., having $u^A = u^M$, thus implies that the labour market clears when the price of food in terms of manufactured good is

$$p = \eta\left(\Phi\overline{l}sN\right)^{1-\alpha}\Omega^D. \tag{10}$$

Note specifically, that p increases with the degree to which the industrial sector's productivity exceeds that of the domestic sector, Φ.

Note also that despite the fact that a farmer and a manufacturer receive the same level of utility, the model indicates that if domestic production is not taken into consideration, an income-study will show that the wage of the manufacturer exceeds that of the farmer.

Inserting equation (10) into the solution to the farmer's optimization problem, equation (9), it follows that the optimal number of hours that a farmer spends producing food in equilibrium is

$$l = \mu\Phi\overline{l}. \tag{11}$$

Note that the farmer work hours in agriculture, l, increases with the degree to which the industrial sector's productivity exceeds that of the domestic sector, Φ. Note also that l increases with the individual's longevity, for which the size of $\overline{l}$ is a proxy, and that l is unaffected by the size of the economy's population, N.

Finally, the share of labour that is employed in the agricultural sector in equilibrium is found from inserting equation (11) into equation (3). It thus follows that the share of labour in agrarian activities is

$$s = \frac{(\overline{a}N^{1-\alpha})^{1/\alpha}}{\mu\Phi\bar{l}}, \tag{12}$$

which increases with the size of the population, N, but decreases with the degree to which the industrial sector's productivity exceeds that in domestic production, Φ. The proposition below summarises the results.

Proposition 1 *The model predicts that an increase in the industrial sector's productivity relative to that in the domestic sector increases the farmer's work hours in agriculture, which increases farmland productivity and thus transfers labour from agriculture to industry.*

Proposition 1 follows trivially from the solution to the optimization problem and thus from the derivatives of equations (11) and (12) discussed above.

4.3 Extension: Increasing Returns to Labour

[Incomplete!]

5 Conclusion

This paper investigates the process of industrialisation from a point of view inspired by Boserup's (1965) theory about agricultural development. The model shows that productivity improvements in the industrial sector makes farmers increase farmland productivity and substitute non-agrarian goods produced at home for similar goods produced in the industrial sector. This explains why technological breakthroughs in the industrial sector, such as the introduction of the spinning wheel in the English textile industry, intensified the use of farmland and transferred labour from agriculture to industry.

References

[1] Acemoglu, D., S. Johnson, and J.A. Robinson (2002), "Reversal of Fortune: Geography and Institutions in the Making of the Modern World Income Distribution", *Quarterly Journal of Economics* 117, pp. 1231-1294.

[2] Allen, R.C. (2000), "Economic Structure and Agricultural Productivity in Europe, 1300-1800", *European Review of Economic History* 3, pp. 1-25.

[3] Becker, G.S. (1965), "A Theory of the Allocation of Time", *Economic Journal* 75, pp. 493-517.

[4] Boserup, E. (1965), *The Conditions of Agricultural Growth*, Earthscan, London.

[5] Boserup, E. (1990), *Economic and Demographic Relationships in Development*, John Hopkins Press, London.

[6] Chanda, A. and C.-J. Dalgaard (2003), "Dual Economics and International Total Factor Productivity Differences", University of Copenhagen, mimeo.

[7] Craft, N.F.R. (1985), "Income Elasticities of Demand and the Release of Labor by Agriculture During the British Industrial Revolution", in *The Economics of the Industrial Revolution*, edited by Mokyr, Rowman and Allanheld, Totowa.

[8] Craig, L.A. and D. Fisher (2000), *The European Macroeconomy: Growth Integration and Cycles 1500-1913*, Edward Elgar, Cheltenham.

[9] Devereux, J. and L. Locay (1992), "Specialization, Household Production, and Measurement of Economic Growth", *American Economic Review, Papers and Proceedings* 82, pp. 399-403.

[10] Echevarria, C. (1997), "Changing Sectorial Composition associated with Economic Growth", *International Economic Review* 38, pp. 431-452.

[11] Galor, O. and Weil D.N. (2000), "Population, Technology, and Growth: From Malthusian Regime to the Demographic Transition", *American Economic Review* 90, pp. 806-828.

[12] Galor, O., and O. Moav (2002), "Natural Selection and the Origin of Economic Growth", *Quarterly Journal of Economics* 117, pp. 1133-1191.

[13] Galor, O., and A. Mountford (2003), "Trade, Demographic Patterns and the Great Divergence. Why Are a Third of People Indian and Chinese?", Brown University, mimeo.

[14] Galor, O., O. Moav, and D. Vollrath (2002), "Divergence and Overtaking: Land Abundance as a Hurdle for Education Reforms", Brown University, mimeo.

[15] GOLLIN D., S. PARENTE AND R. ROGERSON (2002), "The Role of Agriculture in Development", *American Economic Review, P&P* 92, pp. 160-164.

[16] GOODFRIEND, M. AND J. MCDERMOTT (1995), "Early Development", *American Economic Review* 85, pp. 116-133.

[17] GRANTHAM, G. (1999), "Contra Ricardo: On the Macroeconomics of Pre-Industrial Economics", *European Review of Economic History* 2, pp. 199-232.

[18] HANSEN, G.D., AND E. PRESCOTT (2002), "Malthus to Solow", *American Economic Review* 92, pp. 1205-1217.

[19] HATCHER, J. AND M. BAILEY (2001), *Modelling the Middle Ages: The History and Theory of England's Economic Development*, Oxford University Press, Oxford.

[20] HICKS, J. (1969), *A Theory of Economic History*, Oxford University Press, Oxford. Reprinted in 2001.

[21] JONES, C.I. (2001), "Was an Industrial Revolution Inevitable? Economic Growth over the Very Long Run", *Advances in Macroeconomics* 1, pp. 1-43.

[22] KALEMLI-OZCAN, S. (2002), "Does the Mortality Decline Promote Economic Growth", *Journal of Economic Growth* 7, pp. 411-439.

[23] KARAKACILI, E. (2001), "Peasants, Productivity, and Profit: A Study of Economic and Social Development", Ph.D. thesis, University of Toronto.

[24] KARAKACILI, E. (2002), "Peasants, Productivity, and Profit: A Study of Economic and Social Development", Journal of Economic History 62, pp. 538-543.

[25] KLAUSEN, S. AND T. NESTMANN (2000), "Population, Population Density, and Technological Change", London School of Economics, mimeo.

[26] KREMER, M. (1993), "Population Growth and Technological Change: One Million B.C. to 1990", *Quarterly Journal of Economics* 108, pp. 681-716.

[27] KONGSAMUT, P., S. REBELO, AND D. XIE (2000), "Beyond Balanced Growth", *Review of Economic Studies* (forthcoming).

[28] KÖGEL, T., AND A. PRSKAWETZ (2001), "Agricultural Productivity Growth and Escape from the Malthusian Trap", *Journal of Economic Growth* 6, pp. 337-357.

[29] LAGERLÖF, N.-P. (2002), "The Roads to and from Serfdom", Concordia University, mimeo.

[30] LAGERLÖF, N.-P. (2003), "From Malthus to Modern Growth: Can Epidemics Explain the Three Regimes", *International Economic Review* (forthcoming).

[31] LAITNER, J. (2000), "Structural Changes and Economic Growth", *Review of Economic Studies* 67, pp. 545-561.

[32] LOCAY, L. (1990), "Economic Development and the Division of Labour Between Households and Markets", *Journal of Political Economy* 98, pp. 965-982.

[33] LUCAS, R.E. (2002), *Lectures on Economic Growth*, Harvard University Press, Cambridge.

[34] MATSUYAMA, K. (1992), "Agricultural Productivity, Comparative Advantage, and Economic Growth", *Journal of Economic Theory* 58, pp. 241-261.

[35] MENDELS, F.F. (1972), "Proto-Industrialization: The First Phase of the Industrialization Process", *Journal of Economic History* 32:1, pp. 241-261.

[36] REYNOLDS, L.G. (2000), "The Spread of Economic Growth to the Third World: 1850-1980", in *Leading Issues in Economic Development*, edited by G.M. Meier and J.E. Rauch, Oxford University Press, Oxford, pp. 80-95.

[37] SLICHER VAN BATH, B.H. (1963), *The Agrarian History of Western Europe*, London.

[38] SMITH, A. (1776), *An Inquiry Into the Nature and Causes of the Wealth of Nations*, The Modern Library, New York. Reprinted in 1957.

[39] STRULIK, H. (1997), "Learning-by-Doing, Population Pressure, and the Theory of Demographic Transition", *Journal of Population Economics* 10, pp. 285-298.

[40] TAMURA, R. (2002), "Human Capital and the Switch from Agriculture to Industry", *Journal of Economic Dynamics and Control* 27, pp. 207-242.

[41] VOTH, H.-J. (2000), *Time and Work in England 1750-1830*, Clarendon Press, Oxford.

[42] WEISDORF, J.L. (2003), "From Stagnation to Growth: Revisiting Three Historical Regimes", *Journal of Population Economics* (forthcoming).