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A Malthusian Model for all Seasons:
A Theoretical Approach to Labour Input and Labour Surplus in Traditional Agriculture [*]

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Abstract: It has become popular to argue (e.g. Clark 2007) that all societies were Malthusian until about 1800. At the same time, the phenomenon of surplus labour is well-documented for historical (as well as modern) pre-industrial societies. This study discusses the paradox of surplus labour in a Malthusian economy. Inspired by the work of Boserup (1965) and others, and in contrast to the Lewis (1954) approach, we suggest that the phenomenon of surplus labour is best understood through an acceptance of the importance of seasonality in agriculture. Boserup observed that the harvest season was invariably associated with labour shortages (the high-season bottleneck on production), although there might be labour surplus during the low season. We introduce the concept of seasonality into a stylized Malthusian model, and endogenize the extent of agricultural labour input, which is then used to calculate labour surplus and the rate of labour productivity. We observe the effects of season-specific technological progress, and find that technological progress in the low-season increases labour surplus and labour productivity whilst, perhaps surprisingly, technological progress in the high-season, by relaxing the high-season bottleneck, leads to work intensification and a drop in labour surplus and labour productivity.

JEL classification codes: J22, N13, O10

Keywords: Boserup, Labour Productivity, Labour Surplus, Land Productivity, Malthus, Seasonality

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The discussion of low or zero marginal productivity in agriculture suffers from a neglect of the seasonal differences in employment and wages. Many off-season operations are in fact required in order to obtain higher crop frequency through labor intensive methods alone, and so may well appear to be of very low productivity if viewed in isolation from their real function.

- Ester Boserup, in 'Agricultural Growth and Population Change,' *The New Palgrave* 1987

1. Introduction

The so-called 'Malthusian' model is frequently used by development economists, growth economists and economic historians to model a traditional agricultural society.[1] The stylized Malthusian model fails, however, to capture two important and well-known features of pre-industrial societies, namely the existence of surplus labour and the process of work intensification, both of which have been observed among pre-industrial farmers (the latter mainly in the run up to the Industrial Revolution). In fact, in the presence of these features, it is not apparent that it is even possible to argue that pre-industrial societies truly were Malthusian. We show, however, that the phenomenon of surplus labour and work intensification within a Malthusian context can be easily understood through an acceptance of the importance of seasonality in agriculture.

A defining characteristic of a Malthusian society is that there is no long-run trend growth in real wages. The stylized model captures this through the Law of Diminishing Returns to Labour, which, in the presence of a fixed factor such as land, implies that improvement in productive potential is ultimately swallowed up by a larger population. As population growth is being regulated by checks on fertility or mortality, the economy, over the long run, is kept in a homeostatic 'Malthusian' equilibrium where wages are maintained at subsistence level.[2] The absence of a trend growth in real wages, though, by no means implies that living conditions remain constant over time. For example, an essential component of the Malthusian model is that new technology that increases land productivity will serve to permit a larger population density. Ultimately, therefore, technological progress in a Malthusian economy, at least according to the stylized version of the Malthusian model, makes living conditions more crowded without affecting real wages.

It is here, then, that the paradox of surplus labour becomes evident. A society which, as soon as income exceeds its equilibrium subsistence level, is being forced back to this level through increasing

[1] Recently, it has even become popular to argue (e.g. Clark 2007) that *all* societies were Malthusian until about 1800.
[2] See Clark (2007) for a detailed exposition of the modern Malthusian model and the Malthusian law of population.

population and food scarcity, hardly seems to be one in which there is room for idle labour. And if pre-industrial farmers were able to work harder in the run up to the Industrial Revolution, then why didn't they do so before?

In this paper, we make a distinction between two seasons in agriculture: a *slack* or *low* season with little agricultural activity and thus little labour demand, and a *peak* or *high* season where the demand for labour spikes sharply. We argue that the two phenomena, labour surplus and work intensification, make perfect sense within the context of a Malthusian model if we take into account the role of seasonality in traditional agricultural societies. Indeed, labour surplus in the current framework can exist even in a Malthusian equilibrium, and work intensification (as well as the opposite) can take place even while wages are kept at subsistence level. The important point for these conclusions to prevail, as was emphasised by Boserup (1965) and others, is that land productivity in traditional agricultural societies is limited, not by how much food can be grown, but by how much labour is available in the harvest season. Inspired by this observation, we will argue that it makes a crucial difference to changes in living conditions (broadly defined) whether technological change in a Malthusian economy takes place in relation to harvest activities or non-harvest activities (such as seeding, weeding, hoeing, harrowing, threshing etc).

More specifically, as we will clarify below, technological progress that occurs in relation to non-harvest season activities (such as a more efficient plough) will increase labour surplus and rates of labour productivity, but remarkably will have no effect on land productivity and neither, therefore, on population density. By contrast, technological progress that occurs in relation to harvest season activities (such as a more efficient sickle) will increase land productivity, and will thus permit a larger population, but surprisingly will end up *reducing* labour surplus and labour productivity, thereby increasing the number of hours that farmers will need to spend on their fields. According to the current theory, therefore, work intensification, as observed in the early phases of England's Industrial Revolution, would have come from progress made in harvest technology.

This conclusion ties into a theoretical debate about the impact on labour productivity of increasing land productivity. Boserup (1965) made a strong case that agricultural intensification raised labour costs per unit of food produced, so that there was a negative correlation between labour productivity and land productivity. This has become known as the 'decline thesis'. Other scholars have pointed to the nearly fourfold increase of England's population level between 1500 and 1800 and compared it to the halving of the share of England's population employed in agriculture over the same period as convincing evidence for the opposite: the 'rise thesis' (Hunt 2000). We will demonstrate below that both these theses can in fact be captured within the context of a single framework.

The paper continues as follows. Section 2 reviews the main evidence on agrarian labour surplus and work-intensification in traditional agricultural societies and discusses the related literature. Section 3 constructs a Malthusian model with seasonality suitable for analysing the season-specific long-run effects of technological progress on real wages, population levels, labour surplus and rates of land and labour productivity in an agricultural economy. Section 4 first discusses the model's stability features and then provides a comparative static analysis. Finally, Section 5 concludes.

2. Evidence for agrarian labour surplus and work-intensification

The purpose of this section is to illustrate some of the previous work which has investigated the phenomena of surplus labour in traditional agricultural societies. Some empirical evidence is discussed, and the theoretical explanations provided by other scholars are criticized.

The theoretical understanding of the phenomenon of surplus labour has its roots in W.A. Lewis' seminal paper on *Economic Development with Unlimited Supplies of Labour* from 1954, which has become a staple of the development economics literature. Lewis assumed that as modern industry accumulated capital, it could draw on an 'unlimited' supply of labour in agriculture, without this resulting in a cost in terms of agricultural output.[3] Our approach is somewhat different. Whereas Lewis' and subsequent labour surplus theories analyse the effects of developments in modern industry on agricultural labour surplus, the current study analyses the effects of development within the agricultural sector itself. More specifically, by endogenizing the extent of agricultural labour input, and thus labour surplus, we examine the impact of season-specific technological progress in agriculture.

Lewis posited that the removal of labourers would have no effect on output, because the remaining workers would simply work harder, and this is supported to some extent by the work of economic historians. For example, Allen (1988) found for England that enclosure and the shift to large, capitalist farms in the eighteenth century reduced agricultural employment per acre and thereby raised labour productivity. The resultant release of labour from agriculture contributed to England's economic development. Along similar lines, Clark (1991) found that the reduction in the agricultural labour force due

[3] Due to the vast overabundance of agricultural labour, the marginal product of labour, Lewis held, was practically zero. Although this might seem to imply that wages also should be zero, Lewis argued that institutions such as family income sharing, the prestige attached to having a large number of servants or charity would allow workers to earn a subsistence wage. The model was later extended by Fei and Ranis (1961).

to the Black Death had little effect on yields in England. Indirect evidence for surplus labour is even available for periods usually considered to mark a high point for pre-industrial population levels. Since Lewis' model implies that the productivity of labour is low when population is high, it might be considered surprising that for example Karakacili (2004), using evidence based on English manorial account roles, found that even for the period immediately prior to the Black Death the productivity of agricultural workers was relatively high. This might suggest that labour surplus was a permanent feature of pre-industrial agriculture.

Similarly, although we should be careful in drawing parallels between modern developing countries and pre-industrial Europe, the development economics literature provides a wealth of examples of agricultural societies in which there is surplus labour (see for example Kao et al 1964, Gill 1991).

In Lewis' model, labour surplus is a *technological* phenomenon: there is simply too much labour compared to other factors of production (so some workers have a zero marginal productivity), and this is why it is possible to remove workers from agriculture without an impact on agricultural production. This stands in sharp contrast to the usual understanding of a Malthusian society in which farmers are struggling to provide a subsistence level of food. A crucial point, however, forwarded by Boserup (1965) and Jones (1964), is that although pre-industrial agricultural production involved surplus labour this was emphatically not the case during harvest time when labour was a crucial limiting factor to agricultural production. Indeed, the origin of the long school vacations in many countries, for example, can be traced to the need to work children in the peak season. In fact, Jones (1964) notes that labour was normally insufficient during the arable harvest in England,[4] and that itinerant labourers were therefore brought in from Scotland, Wales and especially Ireland. This constraint was apparent as late as the mid-nineteenth century, as witnessed by the fact that even the famously active Anti-Corn Law League ceased campaigning in rural areas during the harvest (*Economist* 1843). In other words, the phenomenon of surplus agricultural labour can only be properly understood as a *seasonal* phenomenon.

The presence of surplus labour is inherently related to the possibility of work intensification. This has particularly been suggested for the period up to the Industrial Revolution, initially by De Vries (1994), who suggested the concept of an 'industrious revolution', and later by Voth (2003), who for early phases of the Industrial Revolution observed that 'Europeans began to work longer—much longer'. Voth's estimates for agriculture suggest that the hours worked per year by the average English farmer increased from about

[4] Jones also notes that seasonality was to be detected in other types of farming, for example haymaking and dairy farming, although to a lesser extent.

2,500 in 1750 to over 3,000 by the turn of the century, whilst the percentage of the labour force in agriculture declined from 49.6 to 39.9 (Voth 2000, p. 129). Although this might be a product of the reaction of farmers to high prices during the French and Napoleonic Wars, Voth shows that this high level of hours worked remained in 1830. In any case, the obvious point to draw from this is that farmers were able to choose to work harder, something which the stylized Malthusian model simply does not provide for. However, the current work provides an alternative explanation for the intensification of agricultural labour, namely that technological progress was occurring in relation to harvest activities, allowing farmers to harvest more units of food, but at the same time forcing them to work harder during the low season in order to permit this increase in production.

To be empirically relevant, therefore, the Malthusian model must provide an explanation for the phenomenon of labour surplus within a seasonal context.

3. The model

We now provide a formal yet simple theoretical framework—a Malthusian model with seasonality—suitable for analysing the long-run season-specific effects of technological progress on real wages, population levels, labour surplus and rates of land and labour productivity in a Malthusian economy.

Consider, therefore, a one-sector agricultural economy that produces a single type of good: food. Food production is a two-step procedure: first, the goods are grown (an 'intermediate' goods activity), then harvested (a 'final' goods activity). Economic activities extend over infinite (discrete) time, and, unless explicitly stated, all variables are considered in period t.

There are two types of season in the economy: a *high* or *peak* season and a *low* or *slack* season. Low seasons are synonymous with intermediate goods production (i.e. non-cropping agricultural activities such as seeding, weeding, harrowing, hoeing, threshing etc). High seasons are synonymous with final goods production (i.e. harvest activities).

The fraction $\gamma \in (0,1)$ measures the fraction of high seasons to all seasons. The size of γ may be affected by geography, climate, crop types etc, but throughout the analysis is taken to be exogenous (or already optimally chosen).

Demography

As for the demographic aspects, consider a two-period overlapping-generations economy with children and adults. Productive and reproductive activities take place only during adulthood. For simplicity, reproduction is asexual, so that each child is born to a single parent.

In period t, the economy's adult population (synonymous to its labour force) consists of N_t individuals, who are identical in every way. At the beginning of each period, a new generation replaces the old one. Then change in the size of the adult population from one period to the next is thus given by

$$N_{t+1} = n_t N_t, \qquad (1)$$

where n_t is the number of surviving offspring of any given adult individual in generation t. Since all individuals are identical, n_t is also the gross rate of growth of population.

To include the Malthusian law of population, a positive correlation between real wages and population growth is required. Suppose, therefore, that surviving offspring are checked (in a Malthusian sense) by the resources of their parents. More specifically, the number of surviving offspring per adult is an increasing function of an adult's real wage, measured by w, such that $n_t=n(w_t)$, where $n(\cdot)$ is assumed to be continuous and monotonic, with $n(0)=0$ and $n(\infty)>1$. It follows that there exists a unique level of income per capita, denoted w^s, at which the population level is constant (i.e. where $n(w^s)=1$). When $n=1$, the economy is said to be in a 'Malthusian' equilibrium. Throughout, the level of income in the Malthusian equilibrium (i.e. w^s) is referred to as the 'subsistence level'.

Preferences

Adults have preferences over surviving offspring, measured by n, and time spent in leisurely (or, more generally, non-agricultural) activities, measured by l. More specifically, the preferences of a representative adult are represented by the following utility function:

$$u(n,l) = \lambda \ln(n) + (1-\lambda)\ln(l),$$

with $\lambda \in (0,1)$ being the weight put by the adult on children.

Each adult is endowed with one unit of time. They divide this time-endowment between agricultural activities (in order to feed their offspring) and other activities (such as leisure time). It follows that, in optimum, the fraction $\lambda \in (0,1)$ is allocated to agricultural activities to bring up children, whereas the fraction $1-\lambda$ is spend in the pursuit of other activities.

Output

The results of the model, which will be presented below, rest on two well-established postulates about traditional agriculture. The first is that traditional agricultural societies are normally subject to the Malthusian law of population described above (see also Clark 2007). The second, which relates to the role of seasonality, is that harvest seasons in traditional agriculture are often characterized by severe labour shortage (Boserup 1965; Jones 1964).

To construct a framework in which the Malthusian law of population applies, two elements are required. The first element, which was introduced above, is a positive correlation between real wages and population growth. The second element is diminishing returns to labour in production. To capture the latter, suppose that the production of output is subject to constant returns to land and labour, and that land is in fixed supply.[5] For simplicity, there are no property rights over land, so that per capita income is equal to the average product.

As explained above, the production of output is a two-step procedure, involving first the production of intermediate goods, then the production of final goods.

Intermediate goods production technology

Suppose that the intermediate goods production function (superscript L for low-season agricultural activities) is given by

$$Y^L = A^L \left((1-\gamma) e^L \lambda N \right)^{\alpha} X^{1-\alpha}, \ \alpha \in (0,1), \tag{2}$$

where $1-\gamma$ is the fraction of low seasons to all seasons; $e^L \in [0,1]$ is the share of total low-season labour resources employed during the low season; λ is the fraction of time allocated by each individual to

[5] To keep the model tractable, and without loss of generality, the use of capital goods in production is suppressed throughout the analysis.

agricultural activities; N is the total labour force; X are units of land put under cultivation (which are in fixed supply); and A^L measures total factor productivity in intermediate goods production. To be used later on, the net rate of growth of low-season total factor productivity between any two periods is denoted by $g_{A^L} \geq 0$.

Final goods production technology

The final goods production function (superscript H for high- or harvest-season agricultural activities) is

$$Y^H = A^H \left(\gamma e^H \lambda N\right)^\beta X^{1-\beta}, \ \alpha \geq\leq \beta \in (0,1), \tag{3}$$

where $e^H \in [0,1]$ is the share of total high-season labour resources employed, and A^H is total factor productivity in final goods production, which has a net growth rate between any two periods of $g_{A^H} \geq 0$.

High-season effort and per capita income

As was discussed above, Boserup (1965) and Jones (1964) made a strong case that harvest seasons in traditional agriculture are often characterised by severe labour shortage. The harvest season labour supply will therefore set the upper limit to agricultural output (hence the term *peak* season). As will become apparent below, this will imply that final output is limited, not by how much food can be grown, but by how much food can be harvested.

Since utility is derived from surviving children, and since children subsist on the agricultural income provided by the parents, the total high-season labour resources, in accordance with parents' preferences, are employed in final goods production, implying that e^H=1. Rewriting (3), the economy's total output is thus

$$Y^H = A^H \left(\gamma \lambda N\right)^\beta X^{1-\beta}, \tag{4}$$

meaning that income per capita, measure by w, can be written as

$$w \equiv \frac{Y^H}{N} = A^H (\gamma\lambda)^\beta \left(\frac{X}{N}\right)^{1-\beta}. \tag{5}$$

Low-season effort and 'underemployed' labour

By construction, goods that are not harvested in the harvest season will decay. In the absence of uncertainty, which, for simplicity, is suppressed, no more goods are to be grown than can be harvested. Hence, no more labour resources are employed during the low season than it takes to grow the total amount of final goods that there is time to harvest in the high season.

Equating (2) and (4), therefore, it follows that the share of low-season labour resources employed during the low season is

$$e^L = \left(\frac{A^H}{A^L}\frac{\gamma^\beta}{(1-\gamma)^\alpha}\left(\frac{N}{X}\right)^{\beta-\alpha}\right)^{\frac{1}{\alpha}} < 1. \tag{6}$$

If high-season (rather than low-season) labour is in short supply, then this means that the inequality in (6) is not violated, an assumption that will apply throughout the analysis below.

Land and labour productivity

One purpose of this study is to analyse the long-run effects on agrarian land and labour productivity of season-specific technological progress. To this end, land productivity, denoted D, is calculated as output per unit of land, i.e.

$$D = \frac{Y}{X} = \frac{wN}{X}. \tag{7}$$

Agrarian labour productivity is calculated as output per unit of land divided by labour input per unit of land. Using (4)-(6), labour productivity, denoted E, can thus be written as

$$E = \frac{Y/X}{\left(\gamma + (1-\gamma)e^L\right)N/X} = \frac{w}{\gamma + (1-\gamma)e^L}. \tag{8}$$

An important point must be made here. Namely that the effects on labour productivity of technological progress in a Malthusian equilibrium (where income per capita is at subsistence level) depend entirely on whether new techniques are labour-saving (i.e. reduce the size of the denominator in (8)) or labour-demanding (i.e. increase the size of the denominator). Since γ (i.e. the fraction of high-seasons to all seasons) is taken to be exogenous, changes in labour productivity arise exclusively from changes in the share of low-season labour resources employed during the low season (i.e. e^L).

However, before the effects on technological progress on land and labour productivity can be further explored, the stability conditions of the dynamic system need to be analysed.

4. Stability and comparative statics

In the following, the goal is to study the long-run effects of season-specific technological progress on land and labour productivity in steady state. In a steady state, all variables grow at a constant rate, which is possibly zero. First, we identify income per capita, population density and land and labour productivity in steady state. Then, we explore the effects on these variables of technological progress.

To simplify matters, and without loss of generality, we can use the parameterization $n(w)=w$ to analyse steady state and stability conditions. Using (5), the gross rate of growth in income per capita from one period to the next is

$$\frac{w_{t+1}}{w_t}=\frac{A^H\gamma^\beta\left(\frac{X}{N_{t+1}}\right)^{1-\beta}}{A^H\gamma^\beta\left(\frac{X}{N_t}\right)^{1-\beta}}=\left(\frac{1}{w_t}\right)^{1-\beta}.$$

In a steady state, the rate of growth of population is zero. Using the parameterization $n(w)=w$, income per capita is, therefore, constant. Setting $w_{t+1}=w_t$, we obtain a unique, non-trivial steady state level of income per capita at $w^*=1$. Since in a steady state (marked with asterisks) the population level is constant ($n=w=1$, so that $N_{t+1}=N_t$), income per capita in steady state is at subsistence level. In symbolic terms, that is, $w^*=w^s$.

Note that stability of the steady state requires that $\partial w_{t+1} / \partial w_t |w_t = w^* < |1|$. This condition is fulfilled when β<1, i.e. when there is diminishing returns to labour in the production of final output, which we have assumed above.

Using (5), it follows that the steady state population level (or density, when keeping the land mass fixed) is

$$N^* = \left(\gamma^\beta A^H\right)^{\frac{1}{1-\beta}} \equiv N^*\left(\underset{+}{\gamma}, \underset{+}{A^H}\right), \; X \equiv 1. \tag{11}$$

Note that technological progress in the harvest season, in accordance with the Malthusian model, makes living-conditions more crowded, i.e. increases population density while keeping real wages fixed at subsistence level. Technological progress in the non-harvest season, on the other hand, has no effect on the density of population.

Furthermore, inserting (11) into (6), the share of labour resources employed during the non-harvest season in steady state is

$$e^L * = \left(\frac{\left(\gamma^\beta A^H\right)^{\frac{1-\alpha}{1-\beta}}}{(1-\gamma)^\alpha A^L} \right)^{\frac{1}{\alpha}} \equiv e^L * \left(\underset{+}{\gamma}, \underset{+}{A^H}, \underset{-}{A^L}\right). \tag{12}$$

It follows that technological progress that occurs in relation to harvest-season activities over the long-run is labour-*demanding*, i.e. requires a more extensive use of non-harvest-season labour resources. Technological progress that occurs in relation to non-harvest-season activities, by contrast, is labour-*saving*.

Finally, inserting (10) and (11) into (7), land productivity in steady state can be written as

$$D^* = \left(\gamma^\beta A^H\right)^{\frac{1}{1-\beta}} \equiv D^*\left(\underset{+}{\gamma}, \underset{+}{A^H}\right),$$

while, combining (8) and (12), it follows that labour productivity in steady state given by

$$E^* = \left(\gamma + \left(\frac{\left(\gamma^{\beta} A^{H}\right)^{\frac{1-\alpha}{1-\beta}}}{A^{L}} \right)^{\frac{1}{\alpha}} \right)^{-1} \equiv E^*\left(\underset{-}{\gamma}, \underset{-}{A^{H}}, \underset{+}{A^{L}} \right). \tag{13}$$

Two important notes should be made here. Firstly, only technological progress that occurs in relation to harvest activities affects (i.e. increases) land productivity. Secondly, the effects of technological progress on the labour productivity are ambiguous: Technological progress that occurs in relation to non-harvest season activities (such as a more efficient plough) increases labour productivity. By contrast, technological progress that occurs in relation to harvest activities (such as a more efficient sickle), surprisingly, reduces labour productivity.

The latter result can be understood as follows. In a society where the Malthusian law of population applies, any improvements in real wages over the long run are swallowed up by a larger population. In the Malthusian equilibrium, therefore, income per capita is at the level of subsistence, and the effects on labour productivity of technological progress, as was explained above, therefore depend entirely on whether new technology is labour-saving or labour-demanding. By increasing land productivity, the introduction of, say, a more efficient sickle requires more food to be grown in the non-harvest season. This necessitates more labour resources employed in the non-harvest season, and is why harvest-season technological progress is labour-demanding. Putting more hours into their fields, a more efficient sickle, therefore, leads to work intensification.

The following proposition summarises the main conclusions.

Proposition 1

Over the long run, technological progress in harvest-season activities:

- increases land productivity

- increases the population level

- does not affect real wages, which are at the level of subsistence

- increases non-harvest-season labour input, and thus

- reduces labour productivity.

Over the long run, technological progress in non-harvest season activities:

- does not affect land productivity

- *does not affect the population level*
- *does not affect real wages, which are at the level of subsistence*
- *reduces non-harvest-season labour input, and thus*
- *increases labour productivity.*

The model presented above can be used to shed light on a dispute (see Hunt 2000) about the correlation between land and labour productivity in traditional agricultural societies. The introduction noted the competing 'decline' and 'rise' theses for this relationship. As follows from (13), however, both theses may be valid. More specifically, using the net rate of growth of season-specific total factor productivity defined above, it follows that:

Proposition 2

If $\frac{1-\alpha}{1-\beta} g_{A^H} > g_{A^L} \geq 0$*, then the 'decline thesis' applies. By contrast, if* $g_{A^L} > \frac{1-\alpha}{1-\beta} g_{A^H} > 0$*, then the 'rise thesis' applies.*

In words, the labour-demanding effect of new technology introduced in harvest-season activities can be compensated for by the labour-saving effect of new technologies being introduced into non-harvest-season activities. Whether the aggregate effect on labour input of technological progress is to increase or decrease demand depends on the relative speed of technological progress in the two seasons, as specified in Proposition 2.

5. Conclusion

The model outlined above incorporates the importance of seasonality as motivated by the discussion in Section 2. As is consistent with the historical evidence, we allow for the existence of surplus labour while keeping the basic Malthusian assumptions. Although some of the conclusions might seem surprising or even counter-intuitive, there is some evidence the postulated relationship between season-dependent technological progress and land- and labour productivity changes existed in England, where agriculture was particularly seasonal due to the heavy dependence on wheat (see Sokoloff & Dollar 1997).

For instance, Collins (1969) showed that the harvesting technique used in Britain was the same in 1790 as it was in the 1500s. If Collins' position is true, all technological progress, according to our framework, therefore came from non-harvest-season discoveries such as the Rotherham plough in 1730 (Overton 1996). The implication, that labour productivity should have been increasing, is in fact consistent with the empirical findings of Allen (2000). What is more, there is at least one famous and well-documented example of the impact of non-harvest-season technological progress on labour surplus. As Jones (1964) notes, threshing was the only winter task of any importance for the arable farmer. However, with the introduction of the threshing machine in England in the early nineteenth century, the result was 'chronic winter unemployment and distress' (ibid., p. 60).

In summary, we have demonstrated that seasonality is vital for understanding the conflicting effects of technological progress on land and labour productivity in a Malthusian environment. The analysis shows that labour productivity in agriculture can go up or down with higher land productivity, depending on the relative rate of growth of technological progress in cropping and non-cropping activities, respectively. The results of the model seem broadly consistent with the historical evidence presented above, but the conclusions should otherwise be fairly easy to test empirically, if not with historical European data, then through the more recent experience of developing countries.

If nothing else, our model will serve as a reminder to the economic history profession of the historical importance of the seasons and serve as a warning that the simple Malthusian model, although perhaps useful for understanding some important demographic dynamics, fails to capture crucial features of pre-industrial agriculture.

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