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Structural Transformation and Cross-Country Income Differences

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ABSTRACT

This paper examines the effect of agricultural policy on a country's development and growth. We find that low agricultural productivity can delay the start of industrialization in a country for a long period of time, causing a country's per capita income to fall far behind the industrial leader. Once industrialization begins, this trend is reversed. However, the extent to which a country catches up to the leader depends primarily on factors that affect productivity in non-agricultural activities. Agricultural policy, therefore, is largely irrelevant in the long run. But in the short run, a country that experiences large improvements in agricultural productivity, due to say a Green Revolution, will experience an increase in its income relative to the leaders.

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1. Introduction

One of the longstanding questions in economics is why some countries are so much richer than others. Today, for example, income per capita in the world's richest countries is roughly thirty-five times greater than it is in the world's poorest countries. Recent efforts aimed at understanding current international income differences (e.g., Lucas 2001, and Ngai 1999) argues that the proximate cause of the disparity is that today's poor countries began the process of industrialization much later than today's rich countries, and that this process is rather slow.

A basic development fact is that countries experience a structural transformation as they develop. The rich countries of the world currently have less than 10 percent of their workforce in agriculture, while for many of the world's poorest countries this figure exceeds 60 percent. However, this is roughly the employment share that existed two centuries ago in today's rich countries. In this paper we argue that a simple model of this process of structural transformation provides a useful theory both of why industrialization occurs at different dates, and why once underway the process occurs slowly. A key implication of our analysis is that a greater understanding of the determinants of agricultural productivity is key to building models that can better confront the issues facing many of today's developing nations.

Our model is an extension of the standard neoclassical growth model that includes an agriculture sector and in which individuals face subsistence food requirements. The key feature of our model is that resources cannot move out of agriculture unless the subsistence needs of the population are met. It follows that the pace of industrialization depends on developments in the agricultural sector.[1] Factors that lead to low agricultural productivity can, therefore, delay a country's development. Consequently, technological innovations (e.g., the Green Revolution), institutional changes (e.g., land reforms), or even policy changes (e.g., tax or regulatory changes) that lead to increases in agricultural productivity will affect the pace of industrialization and hence the time series of the cross-country income distribution. This is the case even though the productivity of the agricultural sector is irrelevant for the asymptotic distribution of international incomes. Asymptotically, this distribution is determined entirely by the distribution of policies and institutions in each country that affect productivity in the nonagricultural sector.

Our simulations suggest that our model provides a natural and useful framework in which to interpret past, current and future differences in international incomes. For example, in our baseline model, a country that does not industrialize until 1950 will be only 1/40th as rich as the industrial leader at that date. If, for example, this country's institutions imply an asymptotic income equal to 1/4th the leader, it will not approach this level until the year 2050. As of 2000, this country will only have a relative income equal to roughly 15 percent of the leader. We also show that a Green Revolution, for example, that substantially raises agricultural productivity in this country, will greatly hasten the rate at which it reaches its asymptotic level of relative income. We also present evidence to suggest the importance of the economic effects highlighted by our model.

Our model shares several features with that of Hansen and Prescott (forthcoming). They model the development process as the transition of an economy from one steady state in which everyone uses a "Malthusian" technology and in which output per capita is

[1] This observation is emphasized in an older strand of the development literature. See, for example, Schultz (1964), and Johnston and Mellor (1961), who argued that productivity improvements in agriculture are a

stagnant, to another steady state in which everyone uses a “Solow” technology and output per capita grows at a positive rate. Asymptotically their model is identical to the neoclassical growth model, but the transition between the two steady states is much slower than the transition in a standard growth model. A key difference between the Hansen-Prescott model and ours is that their model does not explicitly contain an agricultural sector—both the Malthusian technology and the Solow technology produce the same good. As we show later, this has substantively different predictions for several key experiments. Whereas in our model an improvement in agricultural productivity in a poor country will free up labor to move into the nonagricultural sector and hasten the transition to the steady state, in their model an increase in productivity in the Malthusian sector will increase the share of labor devoted to that sector and retard the transition to the steady state.

Development economists have long emphasized the role of agriculture in the development process.[2] Macroeconomists have only recently begun to emphasize its role. Caselli and Coleman (2001) argued that explicit modeling of the structural transformation is central to understanding the evolution of relative incomes across regions in the United States. Several others have also analyzed models of the structural transformation that explicitly incorporate an agricultural sector. These include Echevarria (1995, 1997), Kongsamut, Rebelo and Xie (1998), Laitner (1998), Glomm (1992), Matsuyama (1992), and Goodfriend and McDermott (1995). While our model shares several features with

precondition for an economy to industrialize.

[2] The contributions are far too numerous to include an exhaustive list, but important references include Johnston and Mellor (1961), Fei and Ranis (1964), Schultz (1964), Lewis (1965), Kuznets (1966), Chenery and Syrquin (1975), Johnston and Kilby (1975), Hayami and Ruttan (1985), Mellor (1986), Timmer (1988), and Syrquin (1988).

these other papers, none of them use their models to explore the evolution of cross-country income differences over time.

2. A Model of Structural Transformation

2.1 The Economy

Our model is an adaptation of those of Laitner (1998) and Hansen and Prescott (forthcoming). We purposely work with a very simple version of our model to better highlight those mechanics that we wish to emphasize. Where possible we try to indicate the role of the simplifying assumptions and how their relaxation would affect the analysis. The basic structure of our model is that of the one-sector neoclassical growth model extended to allow for an explicit agricultural sector in addition to the usual non-agricultural sector. The extension is done in such a way that the process of development is associated with a structural transformation of economic activity, characterized by a declining share of economic activity accounted for by the agriculture. Asymptotically, agriculture's share of the labor force shrinks to zero, and the model becomes identical to the standard one-sector neoclassical growth model.[3]

Economies are treated as being closed. Hence, each economy is required to produce its own food. This assumption precludes a poor country that is relatively unproductive at producing food from simply importing it, a restriction that can be significant for some specifications of our model. However, this assumption is not particularly at odds with the data--the evidence is that imports of basic foodstuffs tend to be quite small in developing countries.[4]

Preferences

The economy is populated by an infinitely-lived representative family endowed with a unit of time in each period. Instantaneous utility is defined over two consumption goods: a non-agricultural good denoted by c_t, and an agricultural good denoted by a_t. To account for the secular decline in agriculture's share of economic activity we follow the convention of assuming a utility function of the Stone-Geary variety. To keep the analysis simple, we adopt a rather extreme functional form, namely[5],

$$U(c_t, a_t) = \begin{cases} \log(c_t) + \bar{a} & if \quad a_t > \bar{a} \\ a_t & if \quad a_t \leq \bar{a} \end{cases}. \tag{1}$$

Lifetime utility is given by:

$$\sum_{t=0}^{\infty} \beta^t U(c_t, a_t), \tag{2}$$

where β is the subjective time discount factor.

These preferences imply that a family will never consume the agricultural good beyond $\bar{a}$ no matter how cheap agricultural goods may be relative to nonagricultural goods. In equilibrium this will imply that once output in the agricultural sector reaches $\bar{a}$, all remaining labor will flow out of agriculture regardless of the state of the non-

[3] In reality it may be that although agriculture's share of economic activity becomes small, it remains bounded away from zero. This would not matter at all for our analysis.

[4] We do not model why a country that would benefit from food imports chooses not to do so. While this may reflect trade barriers, it may also reflect the lack of sufficient infrastructure to feasibly deliver food to rural areas.

agricultural sector. More generally, one might expect that a very low level of relative productivity in the non-agriculture sector might cause more labor to be allocated to agricultural production as consumers shift their consumptions bundles toward agricultural goods. This is potentially an important effect and one that we focused on in Gollin, Parente and Rogerson (2000). We abstract from it here, not because we believe it is insignificant, but rather because we want to focus attention on feedback effects going in the other direction, i.e., how the state of the agricultural sector affects the labor available for the manufacturing sector.

Technologies

Non-Agriculture

Following the tradition in the literature, we refer to the nonagricultural sector as the manufacturing sector, though in fact it is meant to capture the full range of activities in the nonagricultural sector. For this reason we use the subscript, *m*, to refer to non-agricultural variables. The nonagricultural sector produces output (Y_{mt}) using capital (K_{mt}) and labor (N_{mt}) as inputs according to the following constant returns to scale technology:

$$Y_{mt} = A_m [K_{mt}^{\theta} ((1+\gamma_m)^t N_{mt})^{1-\theta} + \alpha N_{mt}]. \tag{3}$$

In equation (3), A_m is a total factor productivity parameter, and γ_m is the constant exogenous rate of technological change.[6] This technology is standard except for the term αN_{mt}. This term is added to the production function so that an economy with no physical

[5] Technically we should assume that a family has a very small endowment of the nonagricultural good that is always consumed to avoid the issue that instantaneous utility is lowered when c increases from zero to a small positive amount. We ignore this for simplicity.

capital to begin accumulating capital. In the numerical work that follows we will pick α to be a small number.[7]

The TFP parameter, A_m, is assumed to be country-specific, being determined by policies and institutions that impact on activity in the non-agriculture sector.[8] It can be interpreted as the fraction of the exogenous stock of knowledge in the world that a country would use, given its institutions, were it to produce the non-agricultural good. In contrast, the parameters γ_m and α are identical across countries. To be sure, the growth rate of productive knowledge has not been constant through history. The assumption of a constant rate of technological change, however, is not critical to the results we establish in this paper. Additionally, much of the stock of useful knowledge owes its creation to research and development in the rich countries. Poor countries, however, are generally not in the business of creating ideas, and so from their perspective, the assumption of exogenous technological change is reasonable.

Output from the manufacturing sector can be used for consumption or to augment the capital stock. The non-agriculture resource constraint is thus,

$$C_t + X_{mt} \leq Y_{m,,} \tag{4}$$

and the law of motion for the stock of capital in the economy is

$$K_{mt+1} = (1-\delta)K_{mt} + X_{mt}\,. \tag{5}$$

[6] We abstract from issues such as embodiment of technology and appropriate technology.
[7] Alternatively, we could have assumed that all countries are naturally endowed with a very small amount of capital that is always available. This would not affect our results at all.
[8] See Parente and Prescott (2000) for an explicit discussion of a mapping from policies into the level of TFP at the aggregate level. Certainly, an important issue in this literature is to identify those policies and institutions that are most responsible for generating cross-country differences in TFP. While we believe this remains an important issue in this literature, it is not central to our purpose, and hence we feel the reduced form approach makes our analysis more transparent.

Agriculture

We distinguish between a traditional and a modern agricultural technology. Both technologies produce output (Y_{at}) using only labor (N_{at}). The difference is that the modern agriculture technology is subject to exogenous technological change, and that its level of TFP is potentially affected by policies and institutions that impact on agricultural activity. While admittedly somewhat extreme, these assumptions are all made to simplify the presentation. Adding land to the production function would have no impact on our results. There are, of course, other inputs to agricultural production, including capital and intermediate inputs produced in the manufacturing sector. However, the nature of capital inputs is likely to differ between the two technologies. In particular, capital used in the modern technology is likely to be produced in the non-agricultural sector, whereas capital used in the traditional technology is likely to be produced in the agriculture sector. A richer structure would model these inputs. This would again introduce some interesting feedback effects from the non-agriculture sector to the agricultural sector. In particular as will be seen in more detail below, in our model distortions to the non-agricultural sector have no impact on outcomes in the agricultural sector. However, if capital or some other output from the manufacturing sector were used in the agricultural sector, this would no longer be true. As mentioned earlier, we believe these feedback effects are significant, but we want to highlight other interactions in this analysis.

We assume that with the traditional technology, one unit of time produces $\bar{a}$ units of the agricultural good. There is nothing particularly special about this value, and our results would not be much affected by assuming that it were either somewhat higher or lower than $\bar{a}$.[9]

The modern technology, in contrast, is given as follows:

$$Y_{at} = A_a (1+\gamma_a)^t N_{at} . \qquad (6)$$

In equation (6), A_a is a total factor productivity parameter in the modern agricultural production function. The value of A_a is assumed to be country-specific. As was the case with the manufacturing technology, one source of cross-country differences in this parameter is policies and or institutional features that impact on agricultural activity. However, another very important source of variation is differences in the amount or quality of land per person, and climate. In particular, technological innovations that are useful for a specific crop in a given climate may not be particularly relevant for other crops in other parts of the world, thus generating large differences in cross-country productivity levels that are independent of policy.

The parameter, γ_a, denotes the rate of exogenous technological change in the modern agricultural technology. Though it is easy to imagine circumstances in which because technological innovations are not applicable in all countries, growth rates of technology may differ across countries, for the purposes of our analysis here, we assume that this value is common to all countries. Output from the agriculture sector can only be used for consumption so the agriculture resource constraint is simply $a_t \leq Y_{at}$.

[9] We note that there are reasons to believe that a value close to $\bar{a}$ is appropriate. Models in which fertility is endogenous suggest that output per capita will be close to subsistence levels for economies that have not

2.2 Solving for Equilibrium

We focus on the competitive equilibrium for this economy. Our primary interest is in how different values of the technology parameters A_a and A_m affect the resulting dynamic allocations generated by the competitive equilibrium. Solving for the competitive equilibrium is fairly straightforward, and involves two steps. The first step determines the labor allocation across sectors in each period t. Preferences imply that labor will be allocated entirely to the agricultural sector until $A_a(1+\gamma_a)^t \geq \bar{a}$. At the date this equality is satisfied, agricultural production switches from the traditional technology to the modern technology, and labor flows out of agricultural production at a rate of γ_a. Hence, we have $N_{at} = \min\left\{\frac{\bar{a}}{A_a(1+\gamma_a)^t}, 1\right\}$ and $N_{mt}=1-N_{at}$.

Once the time path of labor allocations is determined, the optimal path for investment can be solved. Solving this part of the model is equivalent to solving the neoclassical growth model given an exogenous time profile of labor inputs given by N_{mt}. As technology in the agriculture sector increases at rate γ_a, N_{at} will eventually approach zero, and hence N_{mt} will approach one. Asymptotically, therefore, the model is identical to the standard one sector neoclassical growth model.

3. Numerical Experiments

3.1 Benchmark Parameterization

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begun the process of industrialization.

In this section we report some numerical results that serve to illustrate our main findings. We begin by providing a benchmark specification that loosely captures the development of the United Kingdom over the last 250 years. We choose the length of a time period to be one year. Without loss of generality the values of A_m and A_a are normalized to one for the UK. Asymptotically, the growth rate of (per capita) output in this economy will be equal to γ_m. Since, Maddison (1995) reports that the growth rate of per capita output in the United Kingdom has been around 1.3 percent per year over the last 100 years, we choose γ_m=.013. The capital share parameter, θ, is set to 0.50. This is a somewhat higher value than those typically used in the real business cycle research. This reflects two factors. First, recent revisions to capital stock series for the US suggest substantially higher capital stocks. Second, the higher value reflects the realization that intangible capital is also an important input in the production of non-agricultural goods, but is unmeasured in the national accounts.[10] The depreciation rate is set to 0.065. The final parameter in the non-agriculture technology is α, which we set to 0.0001. The motivation for this choice is that the parameter must be non-zero so that the economy can accumulate capital starting with no capital, but it should be close to zero so that it does not affect the model's predictions once the economy has a positive capital stock.

The parameters $\bar{a}$ and γ_a are set so that the model matches UK agriculture employment shares in 1800 and 1950, which are reported by Kuznets (1966) to be 35 percent and 5 percent respectively. Finally, the subjective time discount factor, β, is set so that the asymptotic annual interest rate is 5 percent. According to this calibration, the

[10] See Parente and Prescott (1994, 2000) for a formal discussion of the size of the intangible capital stock and its implications for total capital's share.

first year in which resources are moved out of agriculture in the United Kingdom is 1720. In the experiments that follow this is the year that is associated with t = 0 in the model.

Despite the model's simplicity, it matches the UK development and growth experience closely over the last 250 years. Figures 1-3 compare the time series generated by the model to UK data taken from Kuznets (1966). Figure 1 displays agriculture's employment share. By the process of the calibration, the model trivially matches agriculture's share of employment in 1800 and 1950. As can be seen, the model's predictions for the period between 1820 and 1950, and the period after 1950 are also very close to the actual data. Figure 2 displays the path of per capita output over the 1820-1990 relative to the 1820 value. As can be seen the model matches the path of UK output fairly closely except for the period comprising the two World Wars. It is well known that the British economy grew well below trend values during the interwar period, a phenomenon that is still subject to some debate and one that our calibration does not attempt to capture. Finally, Figure 3 displays agriculture's share of output at each date measured in date t prices. Here, the model's ability to match the data is not as good, but it is not too bad in light of the very simple form of the model.

3.2 Implications for Cross-Country Income Differences

In this section we explore the implications of cross-country productivity differences for the evolution of cross-country income differences and economic structure over time. As already mentioned, we use these productivity differences as a reduced form catchall to reflect cross-country differences along a number of dimensions, including taxation, regulation, assignment and enforcement of property rights, institutions such as collective bargaining, and soil and climate conditions. Recall that the values of A_a and A_m were normalized to one for the benchmark economy. In what follows we will refer to an economy as being distorted if either A_a or A_m, or possibly both, is less than one, even though the difference may not result from policy.[11]

Given our simplifying assumptions, a property of our model is that the date at which an economy industrializes is determined solely by the agriculture TFP parameter. The non-agricultural TFP parameter does not affect the date of initial industrialization, and hence, is irrelevant for determining a country's income relative to the industrial leader prior to the time at which the country begins to industrialize. Thus, for the purpose of determining the model's predictions for a country's relative income up to the date at which it starts to industrialize, we need not take a stand on the value of A_m. Moreover, the non-agricultural TFP parameter also has no effect on the agricultural employment share after industrialization. Prior to the start of industrialization, the share of employment in agriculture is one, and thereafter, it is determined solely by the rate of exogenous technological change in the modern agriculture technology.

Figure 4 depicts the path of the agricultural employment share for economies that start to industrialize in 1800, 1850, 1900, 1950, and 2000, and Table 1 reports the value of A_a for which the model implies these industrialization dates and the per capita output of the distorted economy relative to the benchmark economy at these dates. Relative income for each distorted economy is computed using year 2000 prices from the benchmark economy. A country that begins to industrialize in the year 1800 has an agricultural TFP equal to 35 percent of the industrial leader, and an 1800 per capita

[11] More precisely, these economies are only distorted relative to the benchmark. While we normalized the TFP values for the benchmark to equal one, this does not imply that this economy is not itself distorted in

income equal to 18.2 percent of the leader. Between 1800 and 2000, agriculture's share of employment declines from 100 percent to 7 percent. In contrast, a country that begins to industrialize in 1950 has an agricultural TFP equal to 5 percent of the leader and a 1950 per capita income equal to 2.5 percent of the leader. Between 1950 and 2000, agriculture's share of employment declines from 100 percent to 50 percent. These values are typical of the employment shares and relative incomes observed among the poorest countries in the world over the second half of the twentieth century.[12] From a quantitative perspective, the longstanding idea in the development literature that distortions that impact on the agricultural sector are a major reason that some countries are so poor is entirely plausible.

Table 1: Agricultural TFP and Industrialization

Date	A_a	Relative Income
1800	.35	18.2%
1850	.19	9.4%
1900	.10	5.0%
1950	.05	2.5%
2000	.03	1.3%

Although in our model productivity differentials in agriculture have important consequences for a country's development, they have no consequences for its asymptotic income level. To make this point clearer, we plot the path of per capita output over the period 1725-2050 for economies with distortions to agricultural activity that correspond

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the sense that its policies result in TFP levels below what is technically achievable.

[12] The required differences in agricultural TFP in the model are most surely larger than actual differences in the data. In light of the model's simplicity, this is not surprising. The implied differences in agricultural TFP needed to give rise to a given industrialization date would be substantially smaller if capital were introduced as an input to the modern agricultural production technology.

to initial industrialization dates of 1750, 1850 and 1950. These are shown in Figure 5. Each country's per capita output at each date is calculated relative to the benchmark economy using its prices in year 2000 as the base year. For transparency here, we assume no distortions to non-agricultural activity so that $A_m = 1.0$ and all distorted economies, asymptotically, have an income equal to the benchmark economy.

There are a number of interesting implications that follow from Figure 5. One implication is that it is potentially quite misleading to interpret current cross-country differences in income as steady state differences. Such an approach is taken by Parente, Rogerson, and Wright (2001), Parente and Prescott (1994, 2000), Chari, Kehoe, and McGrattan (1996), Schmitz (2001), Restuccia and Urrutia (1999) and Mankiw, Romer and Weil (1992) to name a few.

Another implication of Figure 5 is that countries that start the development process later will tend to grow faster than earlier entrants as they industrialize. This prediction is broadly consistent with the finding of Parente and Prescott 1994, which shows that countries that achieved a certain level of income (say, e.g. $2,000) later in history were able to double their income (to $4,000) in a far shorter period than countries that achieved this level of income earlier in history.

Thus far we have only considered differences in TFP in the agricultural sector. In fact, a laggard country in the model may actually grow slower over some initial period of its industrialization compared to earlier entrants if A_m is sufficiently small. Table 2 establishes this point. It reports per capita output for various years over the 1950-2050 as well as the asymptotic level for a number economies that start the industrialization process in 1950, but differ in their value of A_m. Output is expressed relative to the benchmark economy for various years over the 1950-2050 period, as well as its asymptotic value. As can be seen, the gap in income between the distorted economies and the undistorted economy decreases subsequent to industrialization for all values of A_m except for A_m equal to .10. Indeed, it is easy to show that for all values of A_m greater than 0.107, relative income differences fall. For such an economy, the gap in relative income would widen while the laggard country industrializes.

Table 2: 1950-2050 Per Capita Output
(Differences in Non-Agricultural Policy)

A_m	1950	1975	2000	2025	2050	∞
1.00	.026	0.24	0.59	0.79	0.85	1.00
0.50	.026	0.08	0.16	0.20	0.22	0.25
0.25	.026	0.032	0.050	0.058	0.06	.0625
0.10	.026	0.02	.0198	.0177	0.015	0.010

Such values for non-agricultural TFP, however, seem implausibly small. Cross country studies at the industrial level by Bailey (1993), Bailey and Gerbach (1995), and Bailey and Solow (2001) suggest that TFP in manufacturing and service industries differs by less than a factor of five between the most and least productive nations. According to the model, therefore, the most likely scenario for future international income differences is that they fall, holding the cross-country pattern of distortions constant.

Another significant point to be taken from the plots in Figure 5 concerns its implications for the speed of development once industrialization begins. As already noted, a country that begins to industrialize in 1950 would not be near its steady state output level until roughly one hundred years later. It is important to emphasize that this transition is much slower than one would observe if one simply started out with a small capital stock in the one-sector neoclassical growth model. The reason is that in our model labor is only moved slowly into the non-agricultural sector, whereas in the standard one-sector neoclassical growth model the entire labor endowment is always in that sector. This matters a lot for the speed of convergence to the steady state.

One final important point to note in these simulations is how a productivity differential or "distortion" in only one sector can have such a large aggregate impact on an economy. In general, if only one activity is distorted, economic agents will devote fewer resources to that activity and more to the other activities, thereby lessening the impact of the distortion. However, in our model output from agriculture is necessary and hence the economy cannot substitute away from it. Moreover, if productivity in agriculture goes down, then there will actually be an increase in the number of resources devoted to that activity.

3.2 Empirical Support

Underlying all of the above results is the implication that improvements in agricultural productivity allow resources to be released to other activities. Before going further with our analysis it is instructive to ask what the empirical support is for this proposition. In this section we document three facts about the agricultural transformation. First, in most poor countries, large amounts of labor and land are devoted to the production of basic foods for domestic consumption – in other words, to meeting subsistence needs. Second, increases in the productivity of the agricultural sector are associated with a structural transformation: the shifting of resources away from agriculture and into non-agriculture. Third, this structural transformation appears to play a critical role in economic growth: productivity gains in agriculture and the movement of resources into non-agriculture together account for the majority of growth in aggregate incomes. We consider these three facts in turn.

Subsistence needs

In most poor countries, agriculture accounts for very large fractions of employment and value added. Some agriculture is devoted to producing non-food export crops are important in some places. But in general, most of the land and labor in poor countries are devoted to food production – and specifically, to meeting the subsistence needs of the population.

Table 3 at the end of the paper shows the extent to which resources in the developing world are allocated to meeting subsistence needs. For the 97 countries in the data, in 1999, about 65 percent of arable land was devoted to grains, roots, and tubers.[13] Of the resulting production, almost all was devoted to domestic consumption: only a handful of developing countries were net exporters of grain or root crops (Argentina, Guyana, India, Paraguay, Thailand, Uruguay, and Vietnam).[14] Of these, only Argentina exported more than a quarter of its grain production (FAOSTAT 2001).

Thus, in today's poor countries, most of the resources in agriculture are used for meeting domestic food needs. The resources required are large, relative to the aggregate economy.

Productivity growth and the agricultural transformation

Early development economists were uncertain about the forces driving the agricultural transformation. One view, articulated by Lewis 1965, among others, was that

[13] The data include all countries classified by the United Nations Food and Agriculture Organization (FAO) as developing countries for which arable land in 1999 was greater than 100,000 ha. The major countries missing from the data are the countries of the former Soviet Union, along with some small island countries and some small oil producers.

Note that it is possible for some arable land to be cropped more than once per year. This is why some countries show more than 100 percent of the arable land planted to grain, roots, and tubers.

[14] A number of countries from the former Soviet Union are major exporters of grain, including Ukraine and Kazakhstan.

the agricultural labor force was essentially a residual pool of effectively unemployed labor. In this view, the agricultural transformation was assumed to result from the emergence of a dynamic non-agricultural sector that would accumulate capital and perhaps bring improved technology.

An alternative view, identifiable in Schultz (1964) as well as in Johnston and Mellor (1961), was that productivity improvements within the agriculture sector were critical to the agricultural transformation and would eventually – almost paradoxically – lead to the diminishing importance of the agricultural sector.

Forty years later, it seems fairly clear that the second view is more consistent with the data.[15] On average, countries that have succeeded in increasing productivity in agriculture have experienced relatively sharp declines in agriculture's share of GDP. In other words, growth in agricultural productivity has been associated with a diminishing role for agriculture. This result is fairly robust to the ways in which we measure agricultural productivity, and it mirrors results reported by Timmer (1988), among others.

Using data on a set of 62 countries defined as developing by the Food and Agriculture Organization (FAO) of the United Nations, and for which all relevant data were available, we can examine the relationship between agricultural productivity growth and structural change. Table 4 reports the results of an OLS regression on the data, for the 1960-90 period. The results show a negative and significant relationship between the change in agriculture's share of employment and the change in agricultural output per person.[16] A similar (stronger) result obtains if we use agricultural output per worker on

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[15] See the survey of Rosenszweig (1988) for persuasive defense of this.

[16] Agriculture's share of employment is a useful measure of agriculture's importance in economic activity. The other commonly reported measure – agriculture's share of GDP – is directly related to increases in productivity and thus is a less attractive measure of agriculture's importance in the economy.

the right-hand side, although this variable by construction is linked with agriculture's share of employment.[17]

The implication is that countries experiencing increases in agricultural productivity are able to release labor and other resources from agriculture into other sectors of the economy. This finding is particularly important because the data suggest that in most poor countries, output per worker in non-agriculture is far higher than in agriculture. This means that a shift of workers from agriculture to non-agriculture increases average productivity in the economy. For example, shifting a worker from agriculture to non-agriculture in 1960 would have tripled his or her output in Korea or Malaysia; it would have increased it by a factor of nine in Thailand.

Agricultural productivity growth and economic growth

Productivity growth in agriculture thus has two major effects on economic growth. First, since agriculture is the largest sector in most poor countries, increases in agricultural productivity have a big direct impact on aggregate output. Second, by stimulating the movement of resources into non-agriculture, productivity growth in agriculture can help to raise the average productivity of the economy.

The first effect is visible in the data of Table 4, included at the end of the paper, which reports growth rates in agriculture, non-agriculture, and per capita GDP for the 1960-90 period. For most of the countries that grew the fastest in terms of real per capita GDP, agricultural productivity growth over this period was more rapid than non-agricultural productivity growth. This reflects, in part, the large initial size of the

[17] This also supports the notion that the increase in agricultural productivity is not occurring simply because unproductive labor is being removed from the sector.

agricultural sector and the difficulty of achieving high growth in GDP per capita without gains in agriculture.

The second important effect of productivity growth in agriculture is to release workers to the non-agriculture sector. As noted above, the movement of labor from agriculture into non-agriculture is a critical part of the growth story.

Thus, the data support the idea – somewhat unconventional, in terms of the current growth literature – that improvements in agricultural productivity play an important role in stimulating economic growth. To formalize this idea, consider a decomposition of economic growth into three components: growth within agriculture, growth within non-agriculture, and growth attributable to sectoral shifts. Growth within agriculture is simply the growth in output per worker within agriculture, weighted by agriculture's share of GDP in the initial period. Similarly, growth within non-agriculture is the growth in output per worker in non-agriculture, weighted by the initial share of non-agriculture in GDP. Together, these two measures show how much growth could have been expected if the sizes of the two sectors had remained constant, and the only source of growth had been improvements in productivity within each sector. In actuality, however, there is a third source of growth – from sectoral shifts that reallocated workers from low productivity sectors to high productivity ones.

This decomposition is presented in Table 5. For 50 of the countries in the data, agricultural productivity growth and sectoral shifts were together more important contributors to the growth of real per capita GDP than is non-agricultural growth. These countries include Malaysia, Indonesia, Thailand, and China (though not Korea or Singapore). In slightly more than half of the countries – 36 out of 62 – agricultural productivity growth was higher than non-agricultural productivity growth. If one averages over the sample, one finds that the contribution of agricultural growth, non-agricultural growth, and sectoral shifts are 30 percent, 20 percent and 50 percent respectively. From this decomposition, we conclude that agricultural productivity growth, along with the ensuing sectoral shifts in employment, is an important source of economic growth.

3.4 Productivity Increases in Agriculture

As noted above, in this model the asymptotic differences across economies are determined entirely by relative TFP of the non-agricultural sector. Reaching this asymptotic difference can take a long period of time. In the numerical experiment of the last subsection, it is not until the year 2050 that the economy seems to be approximately described by its asymptotic behavior. In view of this, an interesting question to ask is: What would be the impact over the 1950-2000 period of a one time increase in productivity in agriculture equal to 100 percent in 1950?

We emphasize that there is a real world basis for this question. A substantial literature describes the Green Revolution of the period 1960-2000 in developing countries. (See, for example, Evenson and Gollin 2002.) The Green Revolution is the term used to describe the application of modern (conventional) plant breeding techniques to the problems of developing countries. Although the biggest gains of the Green Revolution occurred in wheat and rice, advances have been made in almost all crops. Since 1960, more than 8,000 modern crop varieties have been released by breeding programs in the developing world.

Crop-level estimates of yield gain from the Green Revolution range from 20 percent to 100 percent. According to Evenson (1999), the Green Revolution has contributed significantly to growth in agricultural TFP, which has increased at an annual rate of more than 1 percent over long time periods. Hence, this type of experiment is relevant for assessing the consequences of this type of change on the cross-country income distribution.

In addition to technology changes, a number of counties have improved agricultural productivity through major changes in institutions – such as land reform designed to let individual farmers gain title to the land that they work. By improving the incentives of farmers, land reform can lead to dramatic increases in productivity. Taiwan offers a useful example of this. A major land reform in 1952 altered the incentives for smalholders to farm and to invest in land improvements. This land reform reinforced changes in technology and encouraged the rapid diffusion of modern rice varieties.

Figure 6 shows the relative income of the distorted economy, both with and without the productivity innovation. Without the innovation, A_a = .05 and with the innovation A_a = .10. In both cases A_m = .50. The results are striking. With the innovation, income relative to the benchmark economy in 1975 is equal to 18 percent. Without the innovation, income is equal to 8 percent of the benchmark economy's income. These differences decrease over time; in the year 2000, relative incomes of the distorted and the reform economies are 16 percent and 23 percent respectively. And by 2050, the relative income of both economies is roughly equal. This leads to our second main finding—improvements in agricultural productivity can have large impacts on cross-country income differences.[18] Equivalently, though we have not reported the growth rates of the two economies over time, it is clear that the economy with the innovation grows a lot faster over the period 1950-2000, implying that a productivity innovation can have substantial effects on growth rates over the short and medium run.

There are large differences in the size of agricultures share of employment between the two economies subsequent to 1950. In 1975, the economy with the innovation has 38 percent of its labor force in agriculture, and in 2000 this value is down 26 percent. In comparison, the economy without the innovation has an agriculture share of employment of 72 percent in 1975 and 50 percent in 2000. Larger increases in agricultural productivity result in larger decreases in agricultural employment.

3.5 Productivity Increases in Manufacturing

In order to increase an economy's asymptotic value of relative income it is necessary to raise the level of A_m. In this section we calculate the effect that a one-time increase in A_m will have on the development of the economy. To facilitate comparison with the example of the previous subsection we consider an increase in 1950 of A_m from .50 to .70. For A_m=0.70, the asymptotic level of output for such an economy is two times larger compared to the A_m=0.50 economy. Figure 7 shows the results.

It is of particular interest to compare the results of this experiment with those of the previous subsection. Specifically, although the asymptotic effects of a change in A_m will

[18] The experiment just considered might well understate the true effects of technological innovation in the agricultural sector for the reason that the assumed innovation is associated with a one-time change in the level of productivity. As a matter of fact, introductions of new seed varieties were accompanied by changes in TFP agricultural growth.

necessarily exceed those associated with any change in A_a, it is of interest to contrast the transitional effects of the two. For this reason, Figure 7 also shows the relative output for the economy that undergoes an agricultural reform. Over the first 36 years the economy with the increase in A_a has a higher per capita income, being twice as rich in 1968. After 1986, the economy that experiences an increase in non-agriculture TFP becomes richer relative to the economy that experiences an increase in agricultural TFP. This shows that, although an increase in agricultural TFP can increase a country's living standards relative to the industrial leaders, its effect is transitory. Ultimately, the extent to which a country catches up to the industrial leader depends exclusively on non-agricultural policy relative to the industrial leader.

4. Conclusion

We have shown in a rather simple model that low agricultural productivity can delay industrialization process for a long period of time. By delaying the industrialization process, such policies result in a country's per capita income falling far behind the leader. Improvements in agricultural productivity can hasten the start of industrialization, and by doing so can have large effects on a country's relative income. Such changes will, in the short-run have a larger impact than a comparable change in non-agriculture. Ultimately, however, the nature of non-agricultural policy determines a country's position to the leader. While we have painted a picture of development that uses fairly broad brush strokes, we believe the important message that emerges is that greater attention to the determinants of productivity in agriculture will greatly enhance our understanding of cross- country differences in income.

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Table 3: Regression results: Changes in agricultural productivity and their relationship to changes in agriculture's share of employment, 1960-1990, for 62 developing countries.

Dependent Variable: Change in Log of Agriculture's Share of Employment

Regression Statistics	
Multiple R	0.423
R Square	0.179
Adjusted R Square	0.137
Standard Error	0.093
Observations	62
Significance – F	0.009

ANOVA

	Df	*SS*	*MS*	*F*
Regression	3	0.109	0.036	4.218
Residual	58	0.501	0.009	
Total	61	0.610		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-0.052	0.035	-1.479	0.145
Change in log ag output per person	-0.150	0.072	-2.076	0.042
Ag Output per Person 1970	-1.6E-4	8E-05	-1.984	0.052
Dummy: 1960 data	-0.075	0.024	-3.018	0.004

Table 4: Variables relating to the structural transformation of agriculture, 62 developing countries, 1960-90.

Country	Non-Ag Productivity Growth	Ag Productivity Growth	Fraction of Workforce in Agriculture, 1960	Fraction of Workforce Moving to Non-Agriculture	Initial Ratio of Non-Ag Prod to Ag Prod	Average Growth in GDP Per Capita (PWT), 1960-90	Notes on GDP Growth Rates
Singapore	1.068	1.081	0.074	0.070	2.035	1.074	
Korea Rep	1.055	1.059	0.613	0.432	2.938	1.071	
Malaysia	1.030	1.046	0.633	0.359	3.295	1.046	
Indonesia	1.039	1.015	0.748	0.196	2.800	1.045	
Lesotho	1.077	1.010	0.473	0.073	0.295	1.045	
Thailand	1.026	1.020	0.837	0.196	8.954	1.042	
Jordan	1.026	1.059	0.498	0.347	3.767	1.041	
Syria	1.000	1.073	0.607	0.275	5.087	1.037	
China	1.011	1.039	0.830	0.110	16.945	1.037	
Brazil	1.017	1.030	0.552	0.319	4.747	1.035	
Congo, Dem R	0.991	1.057	0.793	0.115	17.755	1.033	
Egypt	1.010	1.025	0.658	0.255	3.779	1.032	
Cameroon	0.991	1.019	0.892	0.195	12.317	1.031	
Nigeria	1.018	1.015	0.732	0.301	1.543	1.029	
Ecuador	1.015	1.015	0.594	0.262	3.560	1.029	1970-87
Algeria	0.994	1.073	0.710	0.449	10.344	1.028	
Morocco	1.002	1.037	0.731	0.284	7.487	1.028	
Colombia	1.013	1.027	0.521	0.255	2.380	1.025	
Paraguay	1.019	1.026	0.542	0.153	2.066	1.025	
Dominican Rp	1.005	1.022	0.636	0.388	2.992	1.024	
Gabon	0.996	0.989	0.852	0.337	12.127	1.023	
Pakistan	1.025	1.012	0.658	0.140	2.236	1.023	
Sri Lanka	1.015	1.018	0.566	0.081	2.811	1.023	
Mauritius	1.036	1.068	0.396	0.229	2.695	1.022	1960-89
Fiji Islands	1.023	1.008	0.596	0.142	2.638	1.022	
Rwanda	1.029	0.975	0.947	0.030	7.483	1.022	1960-89
Togo	1.012	1.009	0.801	0.145	3.312	1.019	1960-88
Trinidad Tob	1.013	0.986	0.217	0.106	2.058	1.017	
India	1.012	1.009	0.754	0.114	3.706	1.017	1970-90
Costa Rica	1.009	1.023	0.512	0.251	2.520	1.016	
Philippines	1.005	1.021	0.636	0.178	5.074	1.015	
Kenya	1.000	1.009	0.879	0.083	11.719	1.015	
Honduras	0.993	1.011	0.725	0.311	4.406	1.012	
Gambia	0.993	1.000	0.892	0.072	12.838	1.012	
Burkina Faso	1.014	0.995	0.918	-0.006	13.780	1.010	1960-89
Malawi	0.988	1.011	0.936	0.070	14.671	1.010	
Guatemala	0.993	1.007	0.661	0.137	4.174	1.010	
Zimbabwe	0.989	1.009	0.808	0.126	16.015	1.010	1960-89
Bangladesh	0.982	1.006	0.876	0.224	8.370	1.008	

Country	Non-Ag Productivity Growth	Ag Productivity Growth	Fraction of Workforce in Agriculture, 1960	Fraction of Workforce Moving to Non-Agriculture	Initial Ratio of Non-Ag Prod to Ag Prod	Average Growth in GDP Per Capita (PWT), 1960-90	Notes on GDP Growth Rates
Chile	1.008	1.027	0.303	0.115	4.177	1.007	
Uruguay	1.009	0.989	0.213	0.071	0.891	1.007	1960-89
Jamaica	1.003	1.014	0.415	0.169	6.104	1.007	
Mali	1.002	0.997	0.938	0.080	6.518	1.006	
Argentina	0.990	0.996	0.206	0.085	1.787	1.006	
El Salvador	1.003	0.997	0.618	0.254	1.978	1.005	
Peru	0.998	0.978	0.523	0.167	4.061	1.005	
Burundi	1.032	1.013	0.947	0.030	6.046	1.004	
GuineaBissau	0.971	1.012	0.912	0.060	8.492	1.004	
Senegal	0.992	0.998	0.839	0.071	17.071	1.002	
Papua N Guin	0.972	0.978	0.896	0.104	10.600	1.001	
Mauritania	0.953	1.003	0.921	0.369	12.435	1.001	
Uganda	0.963	1.004	0.927	0.082	11.850	0.999	
Venezuela	0.988	1.036	0.334	0.214	9.947	0.996	
Ghana	0.992	1.006	0.633	0.040	2.499	0.995	
Benin	0.968	0.998	0.850	0.215	6.629	0.995	
Sierra Leone	0.950	1.006	0.813	0.139	7.334	0.995	
Cent Afr Rep	0.948	1.007	0.934	0.132	14.921	0.995	
Guyana	0.976	1.021	0.377	0.158	1.700	0.993	
Nicaragua	0.948	1.010	0.630	0.344	3.161	0.990	
Zambia	0.962	1.007	0.846	0.099	28.722	0.990	
Madagascar	0.953	0.991	0.862	0.080	16.639	0.980	1960-86
Chad	0.941	0.975	0.955	0.123	30.765	0.971	

Table 5: Growth decomposition, 62 countries, 1960-90.

Country	Contribution from non-agriculture only	Contribution from agriculture only	Contribution from sectoral shifts
Singapore	0.068	0.000	0.006
Korea Rep	0.045	0.011	0.015
Malaysia	0.022	0.013	0.011
Indonesia	0.018	0.008	0.020
Lesotho	0.046	0.004	-0.005
Thailand	0.010	0.013	0.020
Jordan	0.022	0.009	0.010
Syria	0.000	0.024	0.014
China	0.003	0.028	0.006
Brazil	0.013	0.007	0.015
Congo, Dem R	-0.003	0.038	-0.003
Egypt	0.006	0.010	0.016
Cameroon	-0.003	0.013	0.020
Nigeria	0.010	0.006	0.012
Ecuador	0.010	0.005	0.013
Algeria	-0.004	0.019	0.013
Morocco	0.001	0.017	0.010
Colombia	0.009	0.007	0.008
Paraguay	0.011	0.010	0.003
Dominican Rp	0.004	0.006	0.014
Gabon	-0.002	-0.006	0.031
Pakistan	0.012	0.006	0.005
Sri Lanka	0.008	0.009	0.007
Mauritius	0.030	0.011	-0.019
Fiji Islands	0.012	0.004	0.006
Rwanda	0.002	-0.023	0.043
Togo	0.004	0.006	0.009
Trinidad Tob	0.012	-0.002	0.007
India	0.004	0.006	0.007
Costa Rica	0.007	0.006	0.003
Philippines	0.003	0.010	0.003
Kenya	0.000	0.007	0.008
Honduras	-0.004	0.004	0.012
Gambia	-0.001	0.000	0.013
Burkina Faso	0.001	-0.005	0.014
Malawi	-0.002	0.010	0.002
Guatemala	-0.003	0.004	0.009
Zimbabwe	-0.003	0.006	0.007
Bangladesh	-0.006	0.004	0.010

Chile	0.007	0.005	-0.004
Uruguay	0.008	-0.002	0.001
Jamaica	0.002	0.003	0.002
Mali	0.000	-0.002	0.009
Argentina	-0.009	0.000	0.015
El Salvador	0.002	-0.001	0.004
Peru	-0.001	-0.008	0.013
Burundi	0.003	0.012	-0.011
GuineaBissau	-0.004	0.010	-0.002
Senegal	-0.002	-0.001	0.005
Papua N Guin	-0.006	-0.018	0.025
Mauritania	-0.021	0.002	0.020
Uganda	-0.006	0.004	0.001
Venezuela	-0.010	0.004	0.002
Ghana	-0.003	0.004	-0.005
Benin	-0.012	-0.002	0.008
Sierra Leone	-0.016	0.004	0.008
Cent Afr Rep	-0.010	0.006	-0.001
Guyana	-0.019	0.005	0.007
Nicaragua	-0.037	0.003	0.025
Zambia	-0.010	0.005	-0.006
Madagascar	-0.010	-0.007	-0.003
Chad	-0.010	-0.021	0.002

Figures

Figure 1: Agriculture's Share of Employment

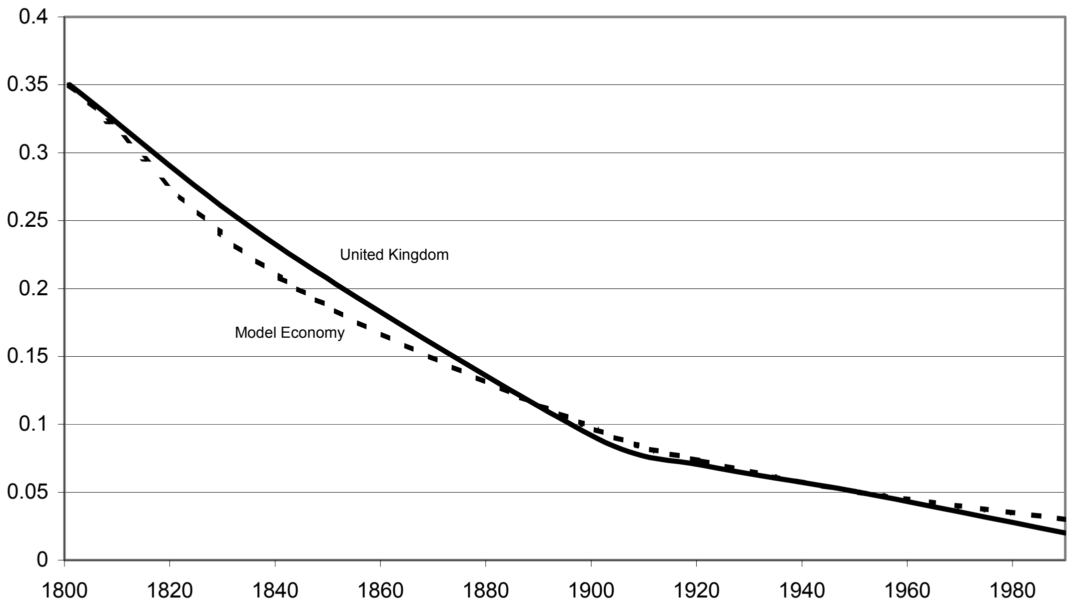

Figure 2: Per Capita Output Comparisons
(Relative to 1820)

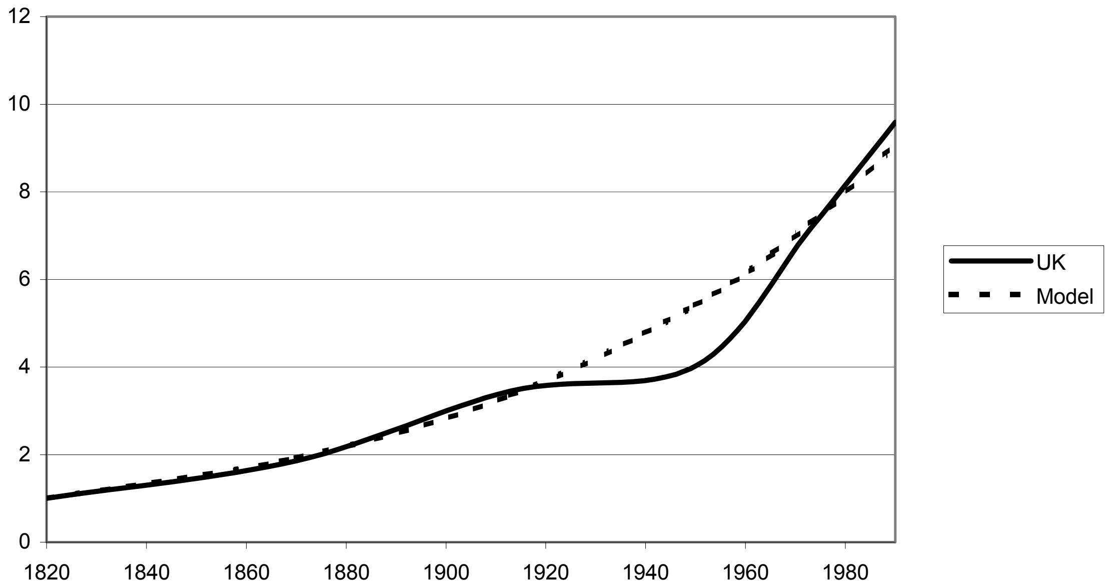

Figure 3: Agriculture's Share of Output

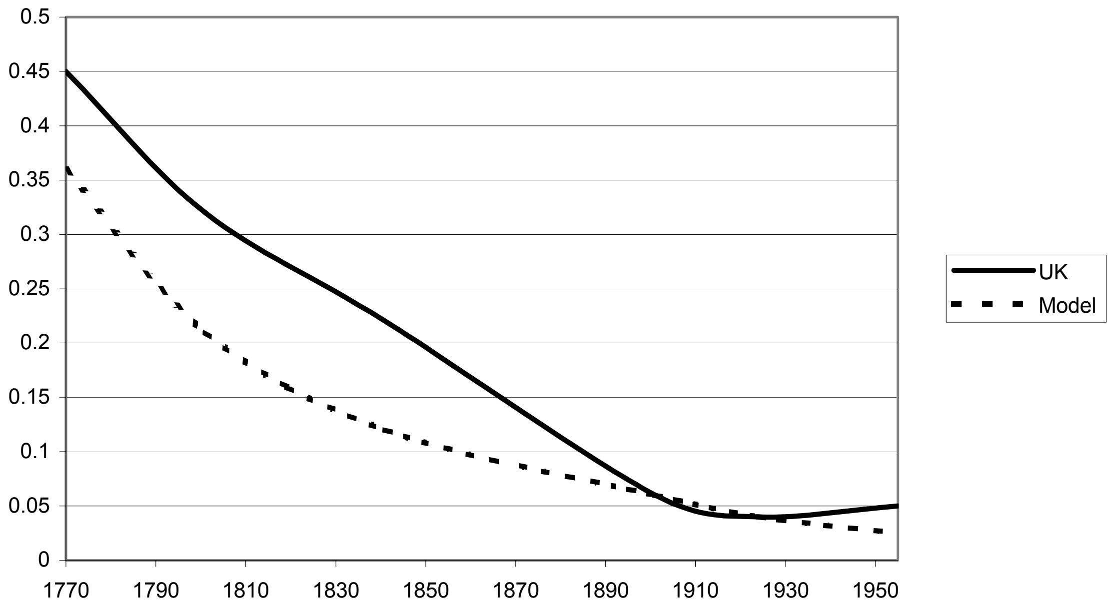

Figure 4: Agriculture's Share of Employment for Different Industrialization Dates

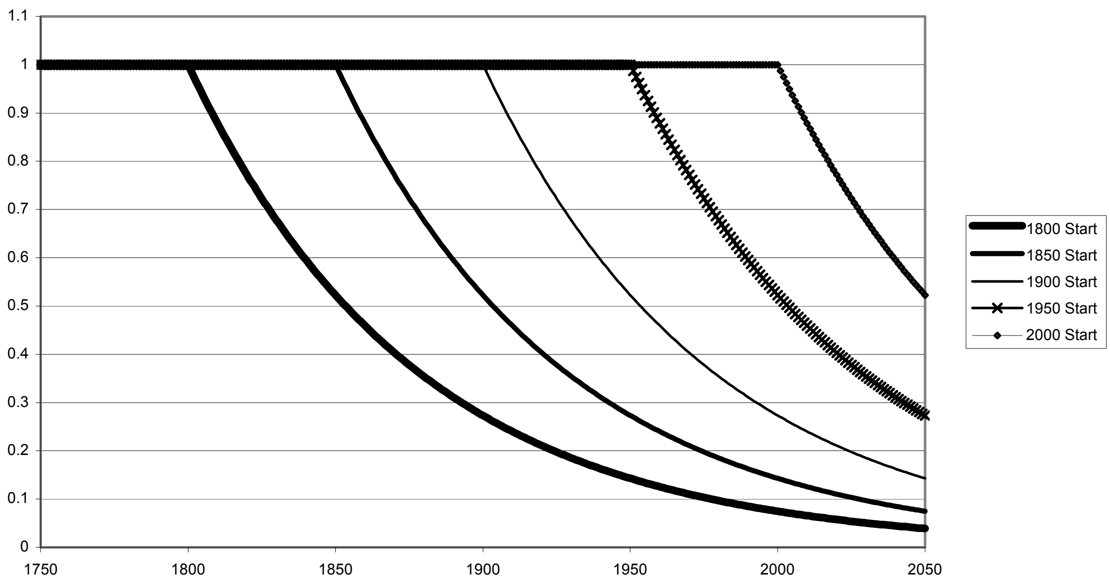

Figure 5: Relative Outputs for Different Industrialization Dates

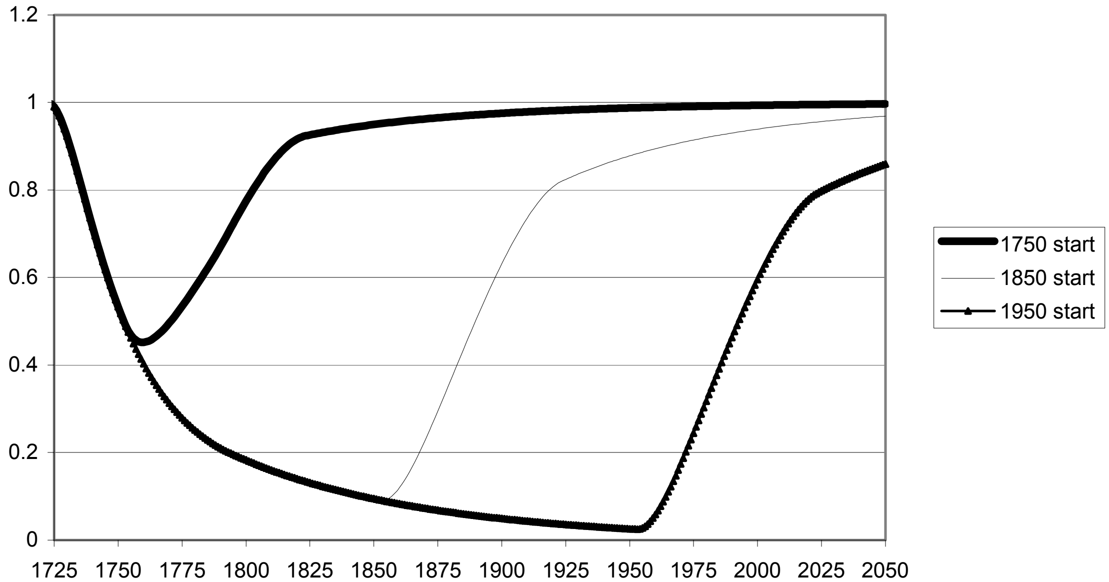

Figure 6: 1950 Green Revolution

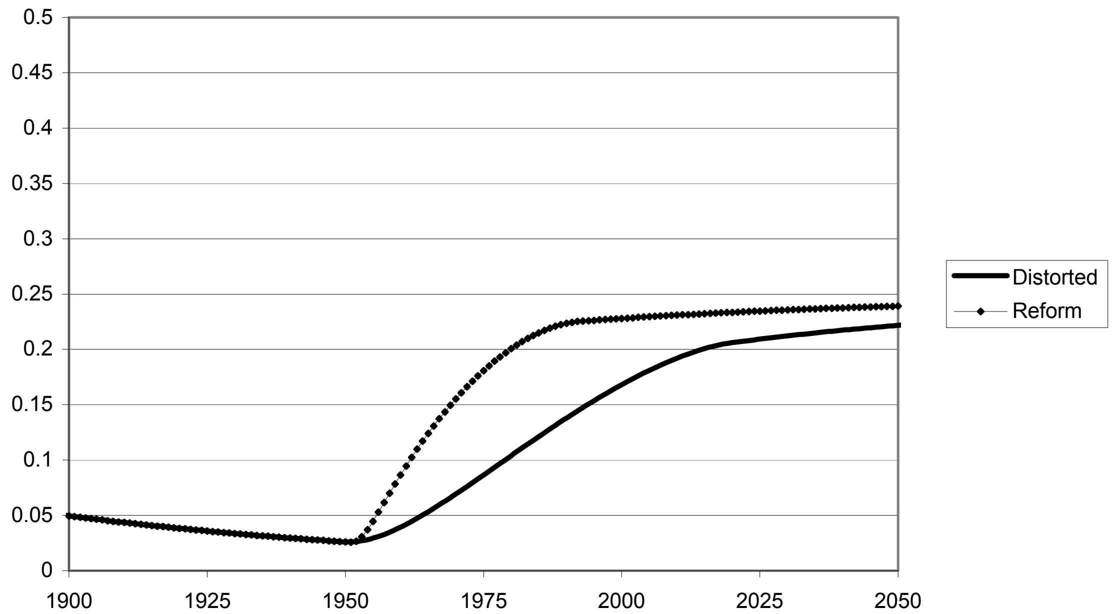

Figure 7: 1950 Non-Agriculture Reform
(Income Relative to the Leader)