The Role of Agriculture in Development

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A longstanding question 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 work (e.g., Robert E. Lucas 2001, and Rachel Ngai 1999) argues that the proximate cause of this disparity is that today's poor countries began the process of industrialization much later and that this process is slow.

In this paper we argue that a model of structural transformation provides a useful theory of both why industrialization occurs at different dates, and why it proceeds slowly. A key implication of this model is that growth in agricultural productivity is central to development, a message that also appears prominently in the traditional development literature. (See, e.g., Peter Timmer (1986)).

I. A Model of Structural Transformation

Our model builds on the works of John Laitner (1998) and Gary Hansen and Edward C. Prescott (forthcoming).[1] Its basic structure is that of the one-sector neoclassical growth model extended to include an explicit agricultural sector. In our model, development is associated with a structural transformation (i.e., a declining role for agriculture). Asymptotically, agriculture's employment share shrinks to zero, and the model becomes identical to the standard one-sector neoclassical growth model.

Preferences—There is an infinitely-lived representative family endowed with a unit of time in each period. Period utility is defined over a non-agricultural good (c_t) and an agricultural good (a_t). To generate a structural transformation we assume a utility function of the Stone-Geary variety. For simplicity we adopt the following extreme functional form:[2]

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

Lifetime utility is given by:

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

It follows that once (per capita) output in the agricultural sector reaches $\bar{a}$, all remaining labor will flow out of agriculture regardless of the state of the non-agricultural sector. A more general treatment would allow for the state of the non-agricultural sector to impact the labor allocated to agriculture. This potentially important effect is explored in Douglas Gollin, Stephen Parente, and Richard Rogerson (2000). We abstract from it here so as to focus attention on how the state of the agricultural sector affects the labor available for the non-agricultural sector.

Technologies--The nonagricultural sector produces output (Y_{mt}) using capital (K_{mt}) and labor (N_{mt}) as inputs:

$$Y_{mt} = A_m [K_{mt}^q ((1+g_m)^t N_{mt})^{1-q} + aN_{mt}]. \tag{3}$$

In equation (3), A_m is a TFP parameter, and γ_m is the constant exogenous rate of technological change. This production function is standard except for the term aN_{mt}. It is added to allow an economy with no physical capital to accumulate capital. In the numerical work that follows we will pick α to be a small number.

The parameter A_m is assumed to be country-specific, being determined by policies and institutions that impact on activity in the non-agriculture sector. In contrast, the parameters γ_m and α are assumed to be identical across countries. Much of the stock of useful knowledge owes its creation to research and development in the rich countries. Since poor countries are generally not in the business of creating ideas, the assumption of exogenous technological change is reasonable from their perspective.

Output from the manufacturing sector can be used for consumption or investment (X_{mt}), and the law of motion for the economy's stock of capital is

$$K_{mt+1} = (1-d)K_{mt} + X_{mt}. \tag{4}$$

The agricultural sector produces output (Y_{at}) using only labor (N_{at}). Though we abstract from land as an input, adding land to the production function would have no impact on our results.

There are two available technologies for producing the agricultural good: a traditional technology and a modern technology. The key difference is that the modern agriculture technology is subject to exogenous technological change. Using 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 if it were either somewhat higher or lower than $\bar{a}$.[3]

The modern technology is given by:

$$Y_{at} = A_a (1+g_a)^t N_{at}. \tag{5}$$

In equation (5), A_a is a TFP parameter that is assumed to be country-specific, and γ_a is the rate of exogenous technological change in the modern agricultural technology, that is common across countries. Like the non-agricultural TFP parameter, the agricultural TFP parameter is affected by country policy and institutions. It is also affected by both climate and the quantity and quality of land per person. 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.

Output from the agriculture sector can only be used for consumption so the agriculture resource constraint is simply $a_t \leq Y_{at}$.

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

Given the time path of labor allocations, the second step solves for the optimal path for investment. This is equivalent to solving the transitional dynamics of the neoclassical growth model with an exogenous time profile of labor input given by N_{mt}. As technology in the agriculture sector increases at rate γ_a, N_{at} eventually approaches zero, and N_{mt} approaches one. Asymptotically, therefore, the model is identical to the standard one sector neoclassical growth model.

II. Numerical Experiments

We begin by providing a benchmark specification that broadly captures the development of the United Kingdom over the last 250 years. The length of a time period is set to one year. Without loss of generality the values of A_m and A_a are normalized to one. Asymptotically, the growth rate of (per capita) output in this economy is γ_m. Since Angus 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. Following Parente and Prescott (1994, 2000) the capital share parameter θ is set to 0.50. We set δ to 0.065 and α to 0.0001. The parameters $\bar{a}$ and γ_a are set so that the model matches UK agricultural employment shares in 1800 and 1950 of 35 percent and 5 percent respectively (see Simon Kuznets (1966)). We choose β so that the asymptotic annual interest rate is 5 percent. Given this calibration, the first year in which resources are moved out of agriculture in the United Kingdom is 1720.

Despite the model's simplicity, it matches the UK development and growth experience over the last 250 years quite closely. Figures 1 and 2 compare the time series generated by the model to UK data taken from Kuznets (1966) for agriculture's employment share and output per capita relative to its 1820 level.

We now explore the implications of cross-country productivity differences for the evolution of cross-country income differences and economic structure. 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 A_a and A_m were normalized to one for the benchmark economy.

Figure 3 depicts the path of output relative to the benchmark for economies that start to industrialize in 1750, 1850, and 1950, assuming A_m =1 for all economies. Relative income for each economy is computed using year 2000 prices from the benchmark economy. A country that begins to industrialize in 1850 has $A_a = .19$, and an 1850 per capita income equal to 9.4 percent of the leader. By 2000, agriculture's share of employment declines from 100 percent to 15 percent. In contrast, a country that begins to industrialize in 1950 has $A_a = .05$, a 1950 per capita income equal to 2.5 percent of the leader, and by 2000 agriculture's share of employment declines 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.[4] From a quantitative perspective, this model supports the longstanding idea in the development literature that low agricultural productivity is a major reason that some countries are so poor.

Several interesting implications follow from Figure 3. First, it is misleading to interpret all cross-country differences in income in 2000 as steady-state differences. This interpretation is taken by Parente, Rogerson, and Randall Wright (2000), Parente and Prescott (1994, 2000), and V.V. Chari, Patrick Kehoe, and Ellen McGrattan (1996), to name a few.

Second, countries that start the development process later will exhibit faster growth than earlier developers. This is consistent with the finding of Parente and Prescott (1994), that countries that first 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.

Third, the development process is a slow process. A country that begins to industrialize in 1950 will not be near its steady state relative output level until roughly one hundred years later. This transition is much slower than what occurs in the one-sector neoclassical growth model starting with a small capital stock. The reason for this difference is that, in our model, labor moves only slowly into the non-agricultural sector. This matters a lot for the speed of convergence to the steady state.

Fourth, a distortion to agricultural activity actually leads to more resources being devoted to this activity. This is in contrast to many models whereby if only one sector is distorted, agents substitute out of it. In our model agricultural output is necessary and hence the economy cannot substitute away from producing it.

The results described above assumed A_m =1, implying that all income differences vanish asymptotically. As stressed earlier, many factors may contribute to cross-country variation in the value of A_m as well. Though we do not provide details the basic results just described continue to hold if the industrializing countries also have lower values of A_m. For instance, consider a country with A_m =.5, implying an asymptotic relative income of .25. If this country begins industrialization in 1950, then in 2000 its relative income is only about .15 and it is not until almost 2050 that it approaches its steady-state value.

III Evidence

Since the notion that improvements in agricultural productivity allow resources to be released to other activities is central to our results, it is important to assess the empirical support for this proposition. In reality there is a large dispersion in both the levels and growth rates of agricultural productivities across countries. Here we ask whether these differences are consistent with the predictions of our model.

We examined data for the 1960-1990 period for 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. Two main findings support the mechanics of our model. First, in the cross section, there is a negative relationship between agricultural productivity and both GDP per capita and the share of employment in agriculture. This same relationship holds for the productivity of agriculture relative to non-agriculture. Second, in the panel data there is a positive relationship between the growth in a country's agricultural productivity and the movement of labor out of agriculture. This relationship also holds if we consider the growth in food output per capita instead of agricultural productivity.

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

We also find that growth in agricultural productivity is quantitatively important in understanding the growth of GDP per worker for developing countries. To establish this result, we decomposed growth in per worker GDP over the 1960-1990 period into three components: growth within agriculture, growth within non-agriculture, and growth due to sectoral shifts. Growth within agriculture (non-agriculture) is simply the growth in output per worker within agriculture (non-agriculture), weighted by agriculture's (non-agriculture's) employment share in the initial period. The sectoral shift component is the residual. On average, the contribution of agricultural growth, non-agricultural growth, and sectoral shifts are 54 percent, 17 percent and 29 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 for these countries.[5]

IV. Conclusions

We have shown in a simple model that low agricultural productivity can substantially delay industrialization. By delaying the onset of industrialization, poor agricultural technologies or policies result in a country's per capita income falling far behind that of the leader. Improvements in agricultural productivity can hasten the start of industrialization, and hence have large effects on a country's relative income. Such changes will, in the short-run, have a larger impact than comparable increases in non-agricultural productivity, even though in the long run it is productivity in the non-agricultural sector that determines a country's position relative to the leader. The key message that emerges from our analysis is that a greater understanding of the determinants of agricultural productivity will enhance our understanding of the development process for those nations that are currently poor.

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Figure 1: Agriculture's Share of Employment

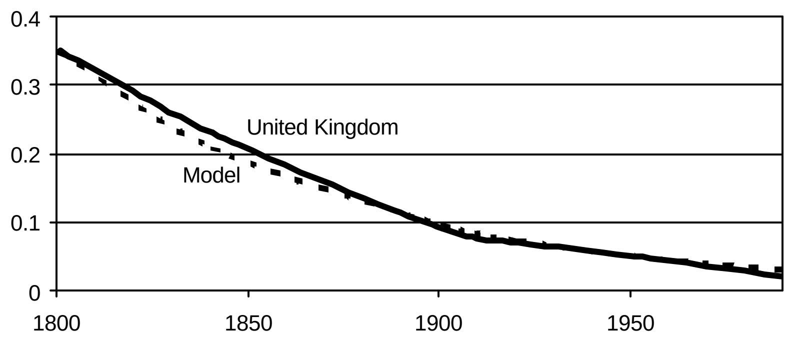


Figure 2: Per Capita Output Comparisons
(Relative to 1820)

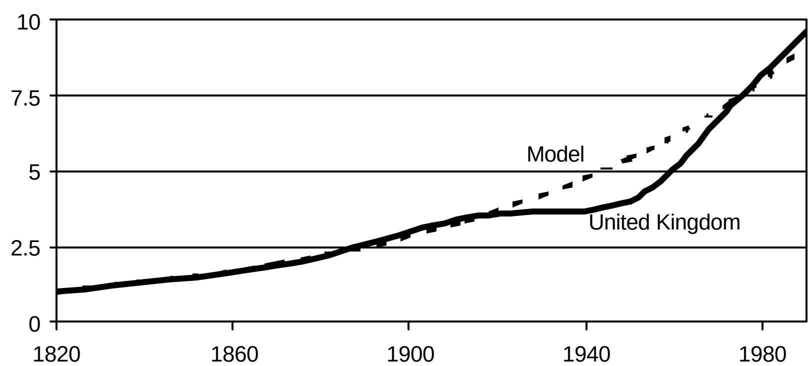
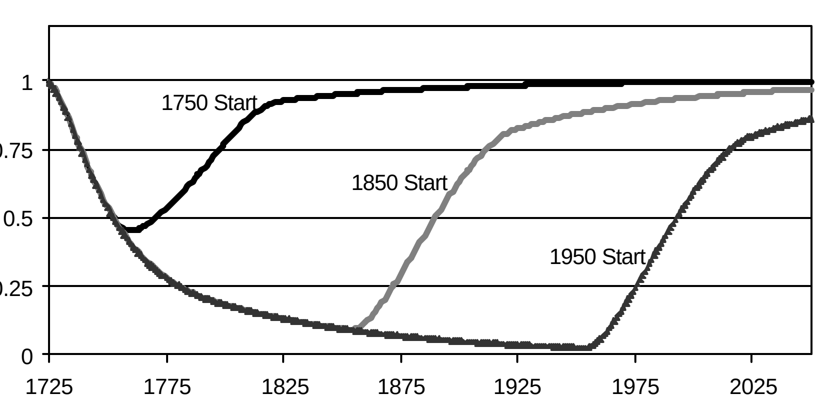


Figure 3: Relative Outputs
for Different Industrialization Dates



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[1] Other related works include Cristina Echevarria (1997), Kiminori Matsuyama (1992), Piyabha Kongsamut, Sergio Rebelo, and Danyang Xie (forthcoming), Marvin Goodfriend and John McDermott (1995), and Francesco Caselli and John Coleman (2001).

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

[3] There are theoretical reasons to believe that a value close to $\bar{a}$ is appropriate. Models with endogenous fertility suggest that output per capita will be close to subsistence levels for economies that have not begun the process of industrialization. See Hansen and Prescott (forthcoming) and Oded Galor and David Weil (2000).

[4] The 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 technology.

[5] In a similar vein, Caselli and Coleman (2000) argue that the delayed structural transformation of the American South accounts for a substantial fraction of the convergence of regional incomes in the US.