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ABSTRACT

The role of agricultural productivity in economic development is addressed in a two-sector model of endogenous growth in which a) preferences are non-homothetic and the income elasticity of demand for the agricultural good is less than unitary, and b) the engine of growth is learning-by-doing in the manufacturing sector. For the closed economy case, the model predicts a positive link between agricultural productivity and economic growth and thus provides a formalization of the conventional wisdom, which asserts that agricultural revolution is a precondition for industrial revolution. For the open economy case, however, the model predicts a negative link; that is, an economy with a relatively unproductive agricultural sector experiences faster and accelerating growth. The result suggests that the openness of an economy should be an important factor when planning development strategy and predicting growth performance.

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1. Introduction

For many years, economists have discussed the role of agricultural productivity in economic development. Generations of development economists have stressed improving agricultural productivity as an essential part of successful development strategy. For example, Nurkse (1953, p.52) argued that "[e]veryone knows that the spectacular industrial revolution would not have been possible without the agricultural revolution that preceded it," and Rostow (1960, p.8) stated that "revolutionary changes in agricultural productivity are an essential condition for successful take-off." A casual reading of recent development textbooks suggests that this view seems to have achieved almost the status of an axiom in development economics.[1]

According to this conventional view, which is based in part on the experiences of the Industrial Revolution in Britain, there are positive links between agricultural productivity and industrialization. First, rising productivity in food production makes it possible to feed the growing population in the industrial sector. With more food being produced with less labor, it releases labor for manufacturing employment. Second, high incomes generated in agriculture provide domestic demand for industrial products. Third, it increases the supply of domestic savings required to finance industrialization.

However, a comparative look at some regional experiences of industrialization tells a different story. For example, why were Belgium and Switzerland the first to become leading industrial countries in continental Europe, while the Netherlands lagged behind and did not take off until the last decades of the nineteenth century? Or why did industrialization of the United States during the antebellum period, mainly in the cotton textile industry, occur in New England, not in the South? Economic historians who studied these experiences found their answer in the Law of Comparative Advantage, which implies a negative link between agricultural productivity and industrialization; see Mokyr's (1976) comparative study of industrialization in Belgium and the Netherlands, and Field (1978) and Wright (1979) for industrialization in New England and the South. According to this view, the manufacturing sector has to compete with the agriculture sector for labor. Low productivity in agriculture implies the abundant supply of "cheap labor" which the manufacturing sector can rely on.

The key to understanding these two conflicting views can be found in the difference in their assumptions concerning the openness of economies. Note that the logic behind the conventional wisdom crucially rests on the implicit assumption that the economy is an effectively closed system. This assumption, which may be appropriate for Britain during the half-century of the Seven Year War, the War of American Independence, the French Revolution and the Napoleonic Wars, should not be taken for granted for many developing countries.[2] In an open trading system, where prices are mainly determined by the conditions in the world markets, a rich endowment of arable land (and natural resources) could be a mixed blessing. High productivity and output in the agricultural sector may, without offsetting changes in relative prices, squeeze out the manufacturing sector. Economies which lack arable land and thus have the initial comparative (but not necessarily absolute) advantage in manufacturing, on the other hand, may successfully industrialize by relying heavily on foreign trade through importing agricultural products and raw materials and exporting manufacturing products, as recent experiences in the Newly Industrialized Economies in East Asia suggest.

In an attempt to highlight the point made above, this paper presents a two-sector model of endogenous growth. The model is essentially of the Ricardo-Viner-Jones variety, with one mobile factor (called labor) combined with diminishing returns technologies. There are two additional features. First, preferences are non-homothetic and the income elasticity of demand for the agricultural good is less than unitary. Second, manufacturing productivity rises over time because of learning-by-doing. For the closed economy case, an exogenous increase in agricultural productivity shifts labor to manufacturing and thereby accelerates economic growth. The model therefore provides a formalization of the conventional wisdom, which asserts that agricultural revolution is a precondition for industrial revolution. For the open economy case, however, there exists a negative link between agricultural productivity and economic growth. An economy with less productive agriculture allocates more labor to manufacturing and will grow faster. For a sufficiently small discount rate, it will achieve a higher welfare level than the rest of the world. The productive agricultural sector, on the other hand, squeezes out the manufacturing sector and the economy will de-industrialize over time, and, in some cases, achieve a lower welfare level. The model is also used to illustrate the Dutch Disease phenomena.

Once stated, the contrast between the results in the closed and open economies is quite intuitive, but has often escaped the attention that it deserves. It suggests that the openness of economies should be an important factor to be kept in mind when planning development strategies and predicting growth performances. At the turn of the century, those schooled in the conventional wisdom might have predicted that Argentina, with her fertile and vast pampas land, would grow faster than Japan, with her mountainous land and limited natural resources. To them, what happened to these two economies during the last ninety years may be puzzling. Or, to many, it provides prima-facie evidence that cultural or political factors are important determinants of economic development.[3] The result for the open economy case arguably offers an economic explanation for this "puzzle." The results here can be also considered as a caution to the readers of the recent empirical work, such as Romer (1987), which, in order to test implications of closed economy models of endogenous growth, uses cross-country data and treats all economies in the sample as if they were isolated from each other.

The rest of the paper is organized as follows. Section 2 presents the closed economy case, which also serves as a benchmark for the open economy case. Section 3 turns to the open economy. Section 4 discusses related work in the literature. The limitations of the model and suggestions for future research are given in Section 5, followed by two appendices.

2. The Closed Economy

The economy consists of two sectors: manufacturing and agriculture. Both sectors employ labor. The size of the population is constant and equal to L. The total labor supply is also constant and normalized to one. (As discussed below and demonstrated in Appendix A, the absolute size of the economy itself has no effect in this model.) Technologies in the two sectors are given by,

$$X_t^M = M_t F(n_t) , \qquad F(0) = 0,\ F' > 0, \text{ and } F'' < 0, \tag{1}$$

$$X_t^A = AG(1-n_t) , \qquad G(0) = 0,\ G' > 0, \text{ and } G'' < 0, \tag{2}$$

where n_t is the fraction of labor employed in manufacturing as of time t (time is continuous). Both sectors operate under diminishing returns. Agricultural productivity, A, which may reflect the level of technology, land endowment, and climate, among other things, is constant over time and treated as an exogenous parameter. On the other hand, productivity in the manufacturing sector, M_t, which represents knowledge capital as of time t, is predetermined, but endogenous. Knowledge accumulates as a by-product of manufacturing experience, as follows:

$$\dot{M}_t = \delta X_t^M , \qquad \delta > 0. \tag{3}$$

These learning-by-doing effects are purely external to the individual firms that generate them. With complete spillovers, each manufacturing firm treats M_t as given when making production and employment decisions. Thus, competition between the two sectors for labor leads to the following equilibrium condition in the labor market:

$$AG'(1-n_t) = p_t M_t F'(n_t) , \tag{4}$$

where p_t is the relative price of the manufacturing good.

All consumers in this economy share identical preferences, given by,

$$W = \int_0^\infty [\beta \log(c_t^A - \gamma) + \log(c_t^M)] e^{-\rho t} dt , \qquad \beta,\ \gamma,\ \rho > 0 , \tag{5}$$

where c_t^A and c_t^M denotes consumption of the agriculture good (food for simplicity) and the manufacturing good, as of time t. The parameter γ represents the subsistence level of food consumption and satisfies,

$$AG(1) > \gamma L > 0 . \tag{6}$$

The first inequality states that the economy's agricultural sector is productive enough to provide the subsistence level of food to all consumers.

With a positive γ, preferences are non-homothetic and the income elasticity of demand for food is less than unitary. The low income elasticity is introduced partly because of its central role in the logic behind the conventional view and partly because of the empirically indisputable Engel's Law; see Crafts (1980). It is also assumed that all consumers have enough income to purchase more than γ units of food. Then, from (4), demand for the two goods by a consumer satisfies $c_t^A = \gamma + \beta p_t c_t^M$. Aggregation over all consumers yields

$$(7) \qquad C_t^A = \gamma L + \beta p_t C_t^M ,$$

where the upper case letters denote aggregate consumption.

To proceed further, let us assume that the economy is a closed system. This requires that $C_t^M = X_t^M = M_t F(n_t)$ and $C_t^A = X_t^A = AG(1-n_t)$. Combining them with equations (4) and (7) yields

$$(8) \qquad G(1-n_t) - \beta G'(1-n_t)F(n_t)/F'(n_t) = \gamma L/A .$$

Note that the left hand side is strictly decreasing in n_t and equal to $G(1)$ at $n_t = 0$ and negative at $n_t = 1$. Therefore, from (6), (8) has a unique solution in (0,1). Since the right hand side is decreasing in A, this solution can be written as

$$n_t = \nu(A) , \qquad \text{with } \nu'(A) > 0 .$$

Thus, the employment share of manufacturing is constant over time and positively related to A. From (3), output in manufacturing grows at a constant rate, $\delta F(\nu(A))$, also positively related to A. Aggregate food consumption and production stay constant at the level given by,

$$C^A = X^A = AG(1-\nu(A)) = \gamma L + A\beta G'(1-\nu(A))F(\nu(A))/F'(\nu(A)) ,$$

which is also increasing in A. Under the closed economy assumption, the model predicts that an increase in agricultural productivity releases labor to manufacturing, and immediately increases its output and accelerates its growth. It also causes a permanent increase in the level of food production. Therefore, the utility of the representative consumer, who consumes C^A/L and C^M_t/L, unambiguously increases with agricultural productivity. These results can thus be considered as a formalization of the conventional wisdom, which asserts that agricultural revolution is a precondition for industrial revolution and support the development strategy that emphasizes the Green Revolution. Although the underlying mechanism is very simple, this is, to my best knowledge, the first attempt to model a positive link between agricultural productivity and the growth rate of the economy.[4]

Before turning to the open economy case, several points about the model above deserve special emphasis. First, Engel's Law plays a crucial role here. If γ is zero, the solution to (8) is independent of A, and thus agricultural productivity has no effect on growth. If γ is negative, and so food is a luxury good, then a rise in agricultural productivity slows down the economy.[5] This result does not depend on the particular functional form chosen. To see this, consider a more general instantaneous utility function,

$$u(c^A,c^M) = \begin{cases} [f(c^A)c^M]^{(1-\sigma)}/(1-\sigma) , & \text{for } \sigma > 0,\ \sigma \neq 1; \\ \log f(c^A) + \log(c^M) , & \text{for } \sigma = 1 , \end{cases}$$

where f is a positive, increasing function and needs to satisfy the additional restriction necessary to make $u(c^A,c^M)$ strictly concave. Also, assume that all consumers are identical. Then, it is straightforward to show that the employment share of manufacturing, and thus its growth rate, are constant over time. Furthermore, they are positively related to agricultural productivity if and only if $f'(c^A)c^A/f(c^A)$ is decreasing in c^A, which is exactly the condition for the income elasticity of demand for food to be less than one. All qualitative results thus carry over for this general specification. Nevertheless, the special case is assumed in (5) because $f(c^A) = (c^A-\gamma)^\beta$ allows for a simple aggregation, and because $\sigma = 1$ makes the instantaneous utility function additively separable in c^A and c^M, which substantially simplifies the welfare analysis of the open economy in the presence of international capital markets, as will be seen in the next section.

Second, in the present model, the labor market is competitive and the wage rate is equalized across the two sectors, as seen in equation (4). The standard assumption in the development literaure, on the other hand, is that there are wage differentials between the "modern" manufacturing and the "traditional" agricultural sectors. It is commonly argued that labor migration from agriculture to manufacturing contributes to total productivity gains to the extent that labor has higher productivity in manufacturing. Much effort has been devoted to estimate wage-gaps, as well as the Harberger Triangle, representing the allocative losses associated with this labor market failure; see Williamson (1988) for a survey. The presence of wage-gaps, if exogenous, would not affect the result. Although wage-gaps and factor market distortions may be substantial in reality, they are assumed away to simplify the exposition. Incidentally, the analysis here has shown that labor reallocation to manufacturing increases total producitivity growth <u>even</u> in the absence of wage-gaps, once productivity growth is endogenized.

Third, one might infer from the model that, <u>ceteris paribus</u>, a larger country (in terms of labor force) has a bigger manufacturing sector, and thus, the model predicts that China or India would experience a faster growth than South Korea or Taiwan, at least under autarky. Such an inference is unwarranted for two reasons. First, a large country does not necessarily mean a large economy. It may simply consist of a large number of regional economies. Second, it crucially depends on the nature of external effects of learning-by-doing. If spillover occurs through some local informational exchange or by observing the experiences of neighbors, it would be more reasonable to suppose that the density of manufacturing activity, instead of its absolute size, determines the speed of knowledge accumulation. Then, all variables in the model should be considered as representing per capita terms. Appendix A shows more formally how this can be done.

Finally, one counterfactual implication of the results obtained above is the constant share of employment and value of output in each sector. As documented by Clark (1940), Kuznets (1966), and Chenery and Syrquin (1975), the share of agriculture in labor force and total output declines in both cross-section and time series as income per capita increases. Appendix B shows that, by using a different class of utility function, the model can be easily altered to explain these stylized facts as well as the positive link between agricultural productivity and the growth rate. However, I have chosen not to use this alternative model, because the model above is much simpler and the constant employment share proves to be a useful benchmark when discussing regional divergence results in the open economy case.

3. The Open Economy

The positive link between agricultural productivity and the growth rate demonstrated above crucially depends on the closed economy assumption. To see this, suppose that there are a continuum of economies in the world, each of which is infinitesimally small. Labor is immobile across economies. One of them, called the Home, is exactly the same as the closed economy considered above. The rest of the world is homogeneous, but differs from the Home only in that their agricultural productivity and the initial knowledge capital in manufacturing are given by A^* and M_0^*, instead of A and M_0. Finally, it is assumed that learning-by-doing effects do not spill over across economies.

The world economy evolves just as in the closed economy above, with the relevant variables starred. In particular, the world manufacturing sector grows at the constant rate, $\delta F(\nu(A^*))$, and the relative price of the manufacturing good, p_t, satisfies

$$A^*G'(1-n^*) = p_t M_t^* F'(n^*) \quad , \tag{9}$$

where $n^* = \nu(A^*)$. In the absence of any barriers to trade, and under incomplete specialization, the Home manufacturing employment is determined jointly by (4) and (9). Taking the ratios of each side of these two equations, n_t satisfies

$$\frac{F'(n_t)}{G'(1-n_t)} = \frac{AM_t^*}{A^*M_t} \cdot \frac{F'(n^*)}{G'(1-n^*)} \quad . \tag{10}$$

First, by setting $t = 0$ in (10) and noting that $F'(n)/G'(1-n)$ is decreasing in n, one can conclude that,

$$n_0 \gtreqless n^*, \qquad \text{if and only if} \qquad A^*/M_0^* \gtreqless A/M_0 \quad . \tag{11}$$

or, manufacturing accounts for a larger (smaller) share of the Home employment, compared to the rest of the world, if the Home economy has a comparative advantage in manufacturing (agriculture). Next, differentiating (10) with respect to time yields

$$\left[\frac{G''(1-n_t)}{G'(1-n_t)} + \frac{F''(n_t)}{F'(n_t)} \right] \dot{n}_t = \delta(F(n^*) - F(n_t)) \quad , \tag{12}$$

as long as $n_t \in (0,1)$, where use has been made of the no spillover assumption, $\dot{M}_t/M_t = \delta F(n_t)$ and $\dot{M}_t^*/M_t^* = \delta F(n^*)$. Since the expression in the square bracket is negative, the manufacturing employment in the Home will rise over time if $n_t > n^*$, and decline if $n_t < n^*$. Thus, equations (11) and (12) jointly state that, when the Home initially has a comparative advantage in manufacturing (agriculture), its manufacturing productivity will grow faster (slower) than the rest of the world and accelerate (slow down) over time.[6] The learning-by-doing effects will perpetuate and in fact intensify the initial pattern of comparative advantage. Equation (12) also implies that $\lim_{t\to\infty} n_t = 0$ if $n_0 < n^*$, and $\lim_{t\to\infty} n_t = 1$ if $n_0 > n^*$. Whether the economy will completely specialize in finite time depends on the properties of F and G at the origin. For example, suppose that $F(n) = n^\alpha$ and $G(1-n) = (1-n)^\alpha$ for $0 < \alpha < 1$, then (12) becomes

$$\dot{n}_t = [\delta/(1-\alpha)]n_t(1 - n_t)((n_t)^\alpha - (n^*)^\alpha) \quad ,$$

thus $n_t \in (0,1)$ for all t. On the other hand, if $F(n) = n/(1+n)$ and $G(1-n) = (1-n)/(2-n)$, then

$$\dot{n}_t = [\delta/6(1+n^*)](2 - n_t)(n_t - n^*) \quad ,$$

and so the economy will specialize in finite time unless $n_0 = n^*$.

Equations (10)-(12) also suggest that the time path of the manufacturing employment, n_t, and therefore, that of its productivity growth rate, $\delta F(n_t)$, shifts down if A increases. Thus, under the open economy assumption, the model predicts a negative link between agricultural productivity and economic growth. In an economy with less productive agriculture, the manufacturing sector attracts more labor, and therefore, grows faster. On the other hand, the productive agriculture sector squeezes out the manufacturing sector, and the economy will de-industrialize over time.

The model also suggests a perverse welfare implication of agricultural productivity. To simplify the argument, suppose that the initial level of knowledge capital in manufacturing is identical in all economies ($M_0 = M_0^*$). The Home economy, if its agriculture is less productive ($A < A^*$), is better off than the rest of the world. This does not depend on the availability of international lending and borrowing. To see this, let $Y_t = AG(1-n_t) + p_t M_t F(n_t)$ be national income and $E_t = C_t^A + p_t C_t^M$ be national expenditure, with food being the accounting unit. From (5) and (7), it can be shown that the indirect utility of the representative agent, who consumes C_t^A/L and C_t^M/L, is equal to

$$(1+\beta)\int_0^\infty \log(E_t/L - \gamma)e^{-\rho t}dt \ ,$$

plus a constant term, which depends on the time path of the relative price. How this welfare measure relates to Y_t depends on whether international lending and borrowing are possible. If no international capital markets exist, $Y_t = E_t$ for all t. Thus,

$$(13) \qquad W_1 = (1+\beta)\int_0^\infty \log(Y_t/L - \gamma)e^{-\rho t}dt \ .$$

On the other hand, if perfect capital markets exist, the Home economy can lend and borrow at the constant world interest rate, equal to the (common) discount rate, ρ.[7] This allows complete consumption smoothing and the Home economy spends the constant amount, $\rho\int_0^\infty Y_t e^{-\rho t}dt$, at every moment, so that

$$(14) \qquad W_2 = (1+\beta)\rho^{-1}\log(\rho\int_0^\infty Y_t e^{-\rho t}dt/L - \gamma).$$

If $A = A^*$ so that the Home is identical to the rest of the world, one can show from (9) that Y_t is equal to $Y^* = A^*[G(1-n^*) + G'(1-n^*)F(n^*)/F'(n^*)]$. Thus,

$$W_1 = W_2 = (1+\beta)\rho^{-1}\log(Y^*/L - \gamma) \ .$$

On the other hand, if $A < A^*$, then Y_t is not constant, so that $W_1 < W_2$. Therefore, it suffices to show the possibility of

$$(1+\beta)\int_0^\infty \log(Y_t/L - \gamma)e^{-\rho t}dt > (1+\beta)\rho^{-1}\log(Y^*/L-\gamma) \ ,$$

or

$$(15) \qquad \int_0^\infty \log[(Y_t - \gamma L)/(Y^* - \gamma L)]e^{-\rho t}dt > 0,$$

for $A < A^*$. But, $Y_t = AG(1-n_t) + p_t M_t F(n_t)$ grows unbounded. Thus, condition (15) is satisfied for a sufficiently small ρ.

Let me quickly add that these results should be interpreted with caution. Certainly, it should not be taken as a suggestion to destroy a country's agriculture for the sake of faster growth. First of all, whether it actually accelerates growth depends on the openness of the economy. Here, only the extreme case of a small open economy is considered. Second, even if it does, the long run gain from faster growth outweighs the short run loss only when the agents are sufficiently patient.

It is also worth pointing out that the welfare effect of agricultural productivity is asymmetric. That is, the Home economy, with more productive agriculture ($A > A^*$), is not necessarily worse off than the rest of the world, even for a sufficiently small discount rate. To see this, it suffices to note that, if A is large enough, then $Y_t > AG(1) \geq Y^*$ for all t. thus the Home welfare is clearly higher. An economy with a rich endowment of arable land (and natural resources), such as Australia (and Kuwait), may grow slower, but does not necessarily have a lower standard of living. Of course, if $AG(1) < Y^*$, then the Home economy is worse off than the rest of the world for a sufficiently small ρ, because $\lim_{t\to\infty} Y_t = \lim_{t\to\infty} \{AG(1-n_t) + p_t M_t F(n_t)\} = AG(1) < Y^*$ from $\lim_{t\to\infty} n_t = \lim_{t\to\infty} p_t M_t = 0$. This result also does not depend on the presence or absence of international capital markets.

The model may be also used to illustrate the so-called Dutch Disease phenomena. The term Dutch Disease refers to the permanent adverse effect on the manufacturing sector of a temporary boom in the natural resource sector. Often mentioned examples include the gold discoveries in Australia in the eighteen fifties, the natural gas discoveries in the Netherlands in the nineteen sixties, and the effects of the North Sea Oil on British and Norwegian manufacturing; see Corden (1984). Suppose that the Home economy initially has identical productivity to the rest of the world ($A = A^*$, $M_0 = M_0^*$), and experiences an increase in A from t = 0 to t = T. In the absence of such a change in A, employment in manufacturing would stay constant, and its output would grow at the constant rate, $\delta F(n^*)$. The temporary increase in A induces migration of labor from the manufacturing sector, thereby reducing the rate of knowledge accumulation through learning-by-doing. When A eventually returns to the original level, A^*, at t = T, the economy still has a comparative advantage in agriculture ($A/M_T = A^*/M_T > A^*/M_T^*$), since manufacturing in the rest of world has grown faster ($M_T < M_T^*$). Thus, from

(10), $n_T < n^*$, and from (12), the economy will continue to de-industrialize.

4. Related Work in the Literature

Murphy, Shleifer and Vishny (1989) demonstrated a positive link between agricultural productivity and the extent of industrialization, captured by the number (the measure, to be precise) of manufacturing sectors employing the increasing returns technique. (There are a continuum of manufacturing goods sectors in their model.) They also showed that a boom in the export sector has similar effects. Non-homotheticity of preferences and the nontradeable nature of manufacturing goods play the key roles in their analysis. Their model is static, and thus has no implication on the relation between agricultural productivity and economic growth.

Elsewhere [Matsuyama (1990)], I discussed the role of agricultural productivity in industrialization in an open economy. The model is a dynamic sectoral adjustment model. Increasing returns in manufacturing generates multiple steady states with different levels of manufacturing employment. It was shown that reducing agricultural productivity causes a global bifurcation in the differential equation system, thereby creating a take-off path; that is, an equilibrium path along which the economy traverses from the state of pre-industrialization to the steady state with high employment in manufacturing. The significance of the open economy assumption in the negative link between agricultural productivity and the possibility of take-off was discussed, but not formally demonstrated.

Recent years have witnessed renewed interest in learning-by-doing in the context of trade and growth; see Van Wijnbergen (1984), Krugman (1987), Boldrin and Scheinkman (1988), Lucas (1988, sec. 5), Stokey (1988) and Young (1989). Van Wijnbergen and Krugman discussed, in the terminology of Corden

(1984), the spending effect of the Dutch Disease, while the present analysis focused on the resource movement effect of the Dutch Disease. As Corden noted, the spending effect of the Dutch Disease is analytically equivalent to the transfer problem. Krugman, Boldrin and Scheinkman, Lucas and Young discussed regional divergence. They demonstrated that learning-by-doing would intensify the initial pattern of comparative advantage, but did not discuss the source of the initial pattern. They also did not allow lending and borrowing to occur across economies. Stokey and Young considered learning-by-doing as an engine of growth and discussed endogenous, unbounded growth. Although many recent studies on endogenous growth have considered alternative engines of growth, such as investment in human capital [Lucas (1988, sec. 4) and Stokey (1990)] and R & D activity [Aghion and Howitt (1989), Romer (1989) and Grossman and Helpman (1989)], what is crucial for the present analysis is a positive link between the relative size of resource base available to the manufacturing sector and its growth rate. Such a scale effect on the growth rate seems pervasive in most endogenous growth models, and so, the results are by no means peculiar to learning-by-doing.

5. Concluding Remarks

This paper has constructed a model of endogenous growth to demonstrate that the relation between agricultural productivity and growth performance can be extremely sensitive to the assumption concerning the openness of an economy. Needless to say, the model is extremely special and only the two polar cases of the closed economy and small open economy were discussed. For example, the presence of the nontradeable third sector, such as a service sector, whose output demand has a higher income elasticity, may affect the patterns of structural change in a nontrivial way.

Throughout the paper it is assumed that agricultural productivity is determined purely exogenously. While useful for the purpose of the present analysis, this assumption makes the model inadequate as a description of structural changes associated with an industrialization process. To some extent, learning experiences in manufacturing should be useful in agriculture. There must also be some learning-by-doing in agriculture itself. More importantly, the technological advances in manufacturing would certainly improve agricultural productivity by supplying better and cheaper intermediate goods, such as fertilizer, pesticide, drainage pipes and harvesting equipment. Modifying the model to capture such a feedback effect of industrialization on agriculture is essential for a better understanding of the role of agriculture in economic development.

Probably the most serious omission is capital accumulation. First of all, an explicit consideration of capital accumulation introduces real intertemporal maximization. Second, it may help to relax the assumption that all knowledge in manufacturing is disembodied. It would be more reasonable to make certain types of knowledge embodied in capital goods and to allow for accumulation of such goods. Then, one could also link the extent of knowledge spillover across economies to that of international trade in capital goods, for the reason suggested by Ethier (1982) in a different context. Third, in the presence of certain capital market imperfections, domestic savings may be required to finance investment in capital goods. It is highly desirable to incorporate such market imperfections, as well as a variety of trade impediments, both natural and artificial, in such a way that the openness of economies can be parameterized, and then to examine how these factors would affect the role of agricultural productivity in economic development.

Appendices

Appendix A

This appendix shows that the absolute size of the economy has no implication in the model. Suppose that there are three primary facors, labor, N, entrepreneurial capital, K, and land, T. The endowments of these factors are fixed. Both sectors operate under constant returns of scale. Manufacturing uses only labor and entrepreneurial capital, and agriculture uses labor and land only. Thus,

$$(A.1) \qquad X_t^M = M_t f(N_t/K)K \ , \qquad f(0) = 0,\ f' > 0, \text{ and } f'' < 0,$$

$$(A.2) \qquad X_t^A = Ag([N-N_t]/T)T \ , \qquad g(0) = 0,\ g' > 0, \text{ and } g'' < 0.$$

where N_t represents labor employed in manufacturing. Knowledge capital in manufacturing accumulates with manufacturing experience <u>per entrepreneur</u>, as follows:

$$(A.3) \qquad \dot{M}_t = \delta X_t^M/K \ ,$$

Then, with complete spillovers, competition in the labor market leads to

$$(A.4) \qquad Ag'([N-N_t]/T) = p_t M_t f'(N_t/K) \ .$$

The consumption side of the model is just the same as in the text. From (A.1)-(A.4), (7) and $C_t^M = X_t^M$ and $C_t^A = X_t^A$,

$$(A.5) \qquad \dot{M}_t/M_t = \delta f(N_t/K) \ ,$$

$$(A.6) \qquad g([N-N_t]/T)T - \beta g'([N-N_t]/T)f(N_t/K)K/f'(N_t/K) = \gamma L/A \ .$$

Let $n_t = N_t/N$ be the share of manufacturing in employment and define $F(n;N/K)$

$= f(nN/K)$ and $G(1-n;N/T) = g([1-n]N/T)$. Then, F and G satisfy the properties given in equations (1)-(2), and (A.5)-(A.6) can be rewritten as

$$\text{(A.7)} \qquad \dot{M}_t/M_t = \delta F(n_t;N/K) \ ,$$

$$\text{(A.8)} \qquad G(1-n_t;N/T) - \beta G'(1-n_t;N/T)F(n_t;N/K)/F'(n_t;N/K) = (\gamma/A)(L/T) \ .$$

If one suppresses N/T and N/K, then (A.8) is identical to equation (8) as long as L in (8) is interpreted as the population density. Furthermore, (A.7)-(A.8) imply that an equiproportional change in K, L, N, and T has no effect on the share of employment in each sector and the growth rate of the economy.[8]

Appendix B

This appendix shows that, by changing the specification of instantaneous utility function, the model can be made capable of explaining the declining share of the agriculture sector both in labor force and in total output, in addition to the positive link between agricultural productivity and the growth rate. First, from (4), the ratio of the value of output in manufacturing to that in agriculture, $p_t M_t F(n_t)/AG(1-n_t)$ is equal to $[G'(1-n_t)/G(1-n_t)][F(n_t)/F'(n_t)]$. This expression is increasing in n_t, thus it suffices to show that $\dot{n}_t > 0$ and $\partial n_t/\partial A > 0$ for all t. Now assume that preferences are given by, instead of (5),

$$\text{(B.1)} \qquad W = \int_0^\infty [\beta(c_t^A-\gamma)^\theta + (c_t^M)^\theta]e^{-\rho t}dt \ , \qquad 0 < \theta < 1,$$

where $1/(1-\theta) > 1$ is the elasticity of substitution. Then, aggregate consumption satisfies, instead of (7),

$$\text{(B.2)} \qquad C_t^A = \gamma L + C_t^M(\beta p_t)^{1/(1-\theta)} \ ,$$

Thus, n_t is determined by, instead of (8),

$$M_t^{\theta} = \frac{\beta AG'(1-n_t)}{F'(n_t)} \left[\frac{F(n_t)}{AG(1-n_t)-\gamma L} \right]^{(1-\theta)} . \tag{B.3}$$

Since the right hand side of (B.3) is an increasing function of n_t, and the left hand side is growing over time, it immediately follows that $\dot{n}_t > 0$. Note that (B.3) would be equivalent to (8) if $\theta = 0$. A larger substitution ($\theta > 0$) implies that, as the manufacturing sector becomes effcient, the economy substitutes the manufacturing good for the agriculture good, which implies the declining share of the agricultural sector both in employment and in output.

Finally, differentiating (B.3) with respect to A shows that $\partial n_t/\partial A > 0$ if $\theta AG(1-n_t) < \gamma L$ and $\partial M_t/\partial A \geq 0$. Since $\dot{n}_t > 0$ and $\dot{M}_t/M_t = \delta F(n_t)$, it suffices to have

$$\theta AG(1-n_0) < \gamma L . \tag{B.4}$$

This conditon is satisfied for a sufficiently small β, since (B.3) for $t = 0$ suggests that $AG(1-n_0) \to \gamma L < \gamma L/\theta$ as $\beta \to 0$. Note again that $\gamma > 0$ plays a crucial role here.

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Footnotes:

1. My samples include Gillis, Perkins, Roemer, and Snodgrass (1983), Herrick and Kindleberger (1983), Timmer (1988), and Todaro (1989).

2. The effect of continuous wars on the British Industrial Revolution remains in dispute. In particular, the extent to which trade in food was disrupted has been questioned, given the closer integration of the Irish and British economies during the period; see Thomas (1982).

3. For example, one political scientist argues that liberal theory, by which he means economics as commonly taught in North American universities, "tends to neglect the political framework,..., yet the process of economic development cannot be divorced from political factors." He then asks "How else can one explain the remarkable economic achievements of resource-poor Japan and the troubles of resource-rich Argentina? (Gilpin [1987, p.269])"

4. By the growth rate of the economy, I mean the rate of expansion in the production possibility frontier in general and the output in manufacturing in particular. The growth rate of GNP, of course, depends on the choice of the accounting unit. If food is chosen, then GNP is constant, because the relative price of food grows at $\delta F(\nu(A))$, which offsets an output increase in the manufacturing sector. If the manufacturing good is chosen, GNP grows at the rate equal to $\delta F(\nu(A))$. If the utility index, $[(c^A-\gamma)^\beta c^M]^{1/(1+\beta)}$, is chosen, then GNP grows at the rate equal to $\delta F(\nu(A))/(1+\beta)$.

5. This result is suggestive of how the presence of a service sector might affect the growth rate of the economy.

6. The growth rate in output, $\dot{X}_t^M/X_t^M = \delta F(n_t) + (F'(n_t)/F(n_t))\dot{n}_t$, may not be monotone.

7. The equilibrium interest rate on the bond indexed to food is equal to ρ, because food consumption is constant, and the instantaneous utility function in (5) is additively separable. The equilibrium interest rate on the bond indexed to the manufacturing good is equal to $\rho + \delta F(n^*)$, because the marginal utility of the manufacturing good declines at the rate $\delta F(n^*)$.

8. This setup seems a natural framework within which to examine the relation between factor proportions and the growth rate, the topic outside the scope of this paper. I hope to investigate this issue in a separate paper.