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Agricultural Productivity and Economic Growth: Role of Tax Revenues and Infrastructures

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To encourage economic growth in a developing economy, higher agricultural productivity has been believed to enhance the manufacturing sector's development, which provides the transition into industrialization. Although this positive linkage between agricultural productivity and economic growth has been judged to be incorrect, based upon the comparative advantage argument in a model of small-open economies by Matsuyama (1992), this article revisits the linkage by extending Matsuyama's model by introducing the revenue-generating effect, which is missing in his model. As agriculture is an important source of taxation in an early stage of economic development, higher agricultural productivity generates more tax revenues and facilitates spending on infrastructure. By introducing government taxation and infrastructure expenditure, we show that under proper conditions, higher agricultural productivity creates a positive growth effect via the revenue generation that dominates the negative growth effect through the comparative advantage. Moreover, introducing infrastructure expenditure may shift the manufacturing sector's original comparative disadvantage into comparative advantage, thereby enabling a trapped economy to take off and eventually industrialize. From the early stages of economic development in Japan, Taiwan, and Korea, we can quantitatively assess an obvious net positive effect of agricultural productivity upon labor allocation and economic growth.

JEL Classification: F43, O11, O41

1. Introduction

Development economists such as Rostow (1960) and Ranis and Fei (1961) have stressed a positive linkage between agricultural productivity and industrialization. The positive link, however, has been argued to be nonexistent by Matsuyama (1992) in a two-sector endogenous growth model of small-open economies with a low elasticity of agricultural goods and the existence of learning-by-doing only in the domestic manufacturing sector.[1] As a result of comparative advantage, higher

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[1] We should remark that Matsuyama also asks readers to interpret his results cautiously and to be aware of several shortcomings of the model that could potentially alter the results.

agricultural productivity solicits labor inputs from the manufacturing sector in his model, leading to lower learning-by-doing and economic growth.

Matsuyama's results, however, may not be consistent with what has actually happened in Japan and other East Asian economies. In Japan a land reform has been implemented, and allocation of resources to agricultural research has been increased since the Meiji Restoration. As a result of agricultural technical progress,[2] agricultural productivity in Japan is much higher than before the Meiji Restoration. In particular, evidence has shown that the agricultural technical change after the Meiji Restoration tends to increase nonagricultural output by pushing resources out of the agricultural sector into the non-agricultural sector. For example, see Yamaguchi and Binswanger (1975, table 7) for the quantitative effects of the agricultural technical change in Japan on nonagricultural output (column 3) and on input reallocation (columns 5 and 7) in 1880–1965. Similarly, the agricultural technical change was higher in Korea's and Taiwan's early stages of economic development, as they have founded agricultural research institutes and farmers' associations during the Japanese colonial period[3] and implemented land reforms after World War II. For evidence, see Mason et al. (1980, chapter 7) for the case of Korea and Thorbecke (1979) for the case of Taiwan. A World Bank (1982, p. 45) study reports that for the 23 developing countries whose agricultural growth rate in the 1970s exceeded 3% a year, 17 countries had a GDP growth rate above 5% a year in the same period. Finally, using cross-country data for 14 Asian developing countries in 1960–1986, Mellor (1995) finds a positive and significant relationship between growth rate of per capita agricultural and nonagricultural GDPs, in which both agricultural and nonagricultural sectors grow more rapidly than 31 sub-Saharan and 20 Latin American countries. These above observations lead to interesting questions as to what mechanism lies in the positive impact of accelerated agricultural growth on nonagricultural growth. What policies might increase the efficiency with which a productive agricultural sector moves a nonagricultural sector forward?

The purpose of this study is to revisit the linkages between agricultural productivity and economic growth with a government policy. Our model is based on Matsuyama's (1992) framework, with a small twist, so that we can clearly identify the mechanism leading to a positive relationship. The departure in this article lies in introducing a government, which collects taxes and then conducts expenditures on infrastructures. An important role played by higher agricultural productivity in an early stage of economic development is the one by which it renders the government larger tax revenues, so that larger expenditure on infrastructures is facilitated.[4] In a study investigating Taiwan's rice-for-fertilizer bartering system in the 1950s and 1960s, Koo (1996, table 2) finds that the resulting hidden taxes on rice alone account for 10–20% of total tax revenue in the period extending from 1950 to 1969. Along with other taxes, the agricultural sector is thus an important source of government revenue in a developing economy.[5] Following Barro (1991), public expenditure on infrastructures is assumed to be productive, in that the learning-by-doing effect of the manufacturing sector becomes enhanced with public expenditure on infrastructures. Examples of productive public spending are

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[2] The progress includes applications of new irrigation systems, fertilizers, new seeds, and progress in biochemical innovation and farm mechanization.

[3] In Taiwan, for example, the Agricultural Research Institute was founded in 1903, and a number of experimental stations were established in subsequent years. The farmers' associations were also created in major agricultural towns to perform such important functions as improvement of seeds and farming techniques, extension of knowledge to farmers, training of agricultural technicians, and purchase of fertilizers and farm equipment.

[4] There are other intersectoral linkages between agriculture and other sectors in an early stage of economic development, such as capital flows from the agricultural to the nonagricultural sector (e.g., Lee 1971, ch. 6).

[5] These taxes include salt tax, mining lot tax, agricultural commodity tax, agricultural land tax, agricultural land value tax, house tax, household tax, and slaughter tax. See also Thorbecke (1979) about agriculture acting as a supporting sector, providing vital resources to the rest of the economy in Taiwan.

abundant (e.g., roads, electric power, harbors, public education, and experimental and research institutions).[6] The effect of productive public expenditures has received great attention in one-sector endogenous growth models, such as those proposed by Glomm and Ravikumar (1994), Turnovsky (2000), and Chen (2003, 2006).

There are two effects for higher agricultural productivity in our model. First, similar to what was described by Matsuyama (1992), there is a static *comparative advantage effect*, in that the agricultural sector would attract additional units of labor because of its higher productivity level. As a result, the factor inputs employed in the manufacturing sector are dropped instantaneously, which reduces the learning-by-doing effect and thereby economic growth. Secondly, different from what was described by Matsuyama (1992), there is a *revenue generation effect*, in that higher agricultural productivity raises agricultural output, which increases tax revenues and public spending on infrastructures. Large infrastructures, in turn, enhance the learning-by-doing effect and, thus, economic growth. By introducing productive public expenditure, whether or not a small-open economy with higher agricultural technical changes will increase or decrease the manufacturing size in equilibrium is not solely determined by the initial comparative advantage of the manufacturing vis-à-vis the agriculture relative to the rest of the world, as in Matsuyama (1992). Rather, if a higher agricultural technical change generates a sufficiently strong revenue generation effect, the higher agricultural productivity enhances economic growth and eventually raises manufacturing size. We derive a proper condition, under which the positive effect via revenue generation effect dominates the negative effect via comparative advantage.

Moreover, our model can also be used to envisage the industrialization issue of less-developed economies. Matsuyama (1991) and Chen and Shimomura (1998), among others, have studied this question recently. Coordinating expectations about the future payoffs in the manufacturing sector is one of the possible ways to remove an economy from a trapped (de-industrialized) equilibrium, according to these works. In our framework, fiscal policy has a role to play. We find that by raising taxes and spending the revenues in productive infrastructures, the government may be able to change an original comparative disadvantage in manufacturing into a comparative advantage, such that the economy can eventually become industrialized.

In order to assess the growth effect of higher agricultural productivity, the model is calibrated to help explore the promise of ideas. Since the transition of Japan, South Korea, and Taiwan from an agriculture-based to a manufacturing-based economic structure is an important experience, we quantitatively evaluate the effects of higher agricultural productivity on labor allocation and economic growth rates for these three economies at their earlier stages of development. These results indicate a positive relationship between the agricultural productivity and the industry sector's employment as well as economic growth.

The organization of this article is as follows. The next section sets up the framework for a closed economy, the equilibrium of which can be thought as the whole world economy. Our extension to addition of the taxes and public expenditure reconfirms a positive relationship between agricultural productivity and economic growth in a closed economy. Section 3 forms the main body of the article, which studies the effects of higher agricultural productivity upon manufacturing employment and economic growth and the possibility of a big push in a small-open economy. Finally, section 4 quantifies

[6] In a study using data from the United States, Aschauer (1989) has documented positive impacts of public expenditure on the productivity of private capital. Aschauer's study generates extensive research efforts aimed at determining the robustness of a positive effect. See Gramlich (1994) for a survey of this empirical literature, most of which is for the United States. Lynde and Richmond (1993) find that public capital has played an essential role in enhancing the productivity growth of U.K. manufacturing.

the model using data from Japan, Korea, and Taiwan in order to evaluate the effects of agricultural productivity on employment allocation and economic growth. We offer concluding remarks in section 5.

2. A Closed-Economy Model

The basic framework for a closed-economy model follows closely with that of Matsuyama (1992). The economy is populated by a continuum of identical households that live indefinitely. The total population of households is constant over time and equals N. There are agricultural and manufacturing sectors, and labor is the only input. The total labor supply is also constant and is normalized to unity.

The representative household in the economy has the preference given by the following equation:

$$Max\ U = \int_0^\infty (c_t^A - \gamma)^\alpha (c_t^M)^\beta e^{-\rho t} dt, \quad \alpha, \beta, \gamma, \rho > 0, \tag{1}$$

In this equation, c_t^A and c_t^M are consumption of agricultural and manufacturing goods in time t, respectively. Parameter γ is the subsistence level of agricultural consumption.

P_t denotes the price of the manufacturing goods (expressed in terms of agricultural goods). The representative household optimally chooses the consumption in each period, and aggregating the optimal consumption choices over all N households leads to

$$C_t^A = \gamma N + \frac{\alpha}{\beta} P_t C_t^M, \tag{2}$$

in which C_t^A and C_t^M denote the aggregate consumption of agricultural and manufacturing goods, respectively.

Second, the technology in the manufacturing is $X_t^M = M_t F(n_t)$ and in the agriculture is $X_t^A = AV(1 - n_t)$, $F(0) = 0$, $F' > 0$, $F'' < 0$, $V(0) = 0$, $V' > 0$, $V'' < 0$, where n_t is the fraction of labor employed in the manufacturing sector in time t.[7] While labor is the only input in this and the next section, we extend the framework to consider land and capital as inputs in the Appendix. Whereas agricultural productivity is exogenous, manufacturing productivity is endogenous.[8] Manufacturing productivity represents knowledge capital determined as of time t, with external learning-by-doing effects via the total production in the manufacturing sector, and evolves as follows:

$$\dot{M}_t = X_t^M H(G_t), \quad H'(G_t) > 0 > H''(G_t), H(0) > 0, H(\infty) = \bar{H} < \infty. \tag{3}$$

Learning-by-doing as shown in (3) above was initiated by Boldrin and Sheinkman (1988). The key difference between Matsuyama's work and others' lies in the effect of productive infrastructures G: large infrastructures enhance the learning-by-doing effects of firms in the manufacturing sector with a decreasing marginal effect.[9] Many existing works have observed the contribution of public

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[7] In equilibrium, n_t also represents the size of the manufacturing sector and, thus, the degree of industrialization.

[8] That only the manufacturing sector has the learning-by-doing effect is a feature shared by Matsuyama (1991, 1992), but other setups would work similarly, as long as the physical infrastructure is more beneficial to the learning-by-doing effect in manufacturing than to that in agriculture.

[9] The Industrial Technology Research Institute (ITRI), which was established in 1973 in Hsinchu in northern Taiwan, and the Science-based Industrial Park, which opened in 1980 in Hsinchu and later in Taichung in central Taiwan and in Tainan in southern Taiwan, where foreign and domestic manufacturing firms operate in close proximity to ITRI laboratories and where the government is willing to take up to 49% equity in each venture, are examples of productive infrastructures that enrich manufacturing sectors' learning-by-doing effect and make Taiwan's electronics products competitive in the world market (e.g., Wade 1990). Similar examples may be found in South Korea and in Japan at an early stage of development (e.g., Pilat 1994).

infrastructure to productivity. For example, in a review of infrastructure's impact on economic growth, Kessides (1996) argued that infrastructure contributes to economic development by increasing productivity (section 12.2) and provides the key to modern technology in practically all sectors (section 12.3.2). Our formulation in Equation 3 is similar to the positive effect of public capital on production in Barro (1991), in which the marginal productivity of private capital, net of the time preference rate and the discount rate, increases with public capital, and, therefore, for given tax rates, the economic growth rate increases in public capital (see Barro and Sala-i-Martin 1995, p. 154).

We assume an upper bound for the learning-by-doing effect. Consider Condition Transversality Condition (TVC): $\bar{H} < \frac{\rho}{F(1)\beta}$.

Under Condition TVC, the economic growth rate is attained with bounded lifetime utilities. If the TVC is not satisfied, the perpetual economic growth rate will in the long run lead to manufacturing and agricultural consumption that are so high that the discounted lifetime utility level in Equation 1 is unbounded. In order to avoid this, we thus impose the TVC (see Seierstad and Sydsaeter [1987, p. 33] and Barro and Sala-i-Martin [1995, p. 142]).

Our formulation is reduced to Matsuyama's formulation when there is no productive public spending, and in this case, the learning-by-doing parameter becomes $H(0) > 0$. Of course, the government conducts productive infrastructure spending in our model, which is a feature shared with Barro (1991). All the parametric results reported in this article will be based on the exponential form

$$H(G) = \delta_0 + \delta_1 \frac{G}{\chi + G}, \quad \chi > 0, \tag{4}$$

where $\chi > 0$ is an exogenous parameter.[10] Therefore, $H(0) = \delta_0$, the case modeled in Matsuyama (1992). When $G > 0$, the learning effect is improved but is bounded by $\bar{H} = \delta_0 + \delta_1 < \frac{\rho}{F(1)\beta}$.

Finally, there is a passive government. Such a government collects income taxes in order to conduct public spending. Assume that the government taxes production/income in both sectors at the same flat tax rate, τ, in order to maintain symmetric distortions to both sectors. Since the government spends all the tax revenues, its flow budget must satisfy the following constraint:[11,12]

$$\tau(P_t X_t^M + X_t^A) \equiv T_t = G_t. \tag{5}$$

Each firm in the manufacturing sector treats productivity, M_t, as a given. Assuming no costs associated with moving from one sector to another, optimal allocation of labor is determined by

$$(1-\tau)AV'(1-n_t) = P_t(1-\tau)M_t\, F'(n_t). \tag{6}$$

The optimal allocation of labor between sectors is independent of the tax rate and is thus free from a tax-rate distortion because of a symmetric tax-rate setup. In the Appendix, when the model is extended to include physical capital inputs, although capital accumulation is affected, the allocation of capital in both sectors is independent of the tax rate as well.

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[10] Other functional forms for learning (e.g., an exponential form) will lead to qualitatively similar results.

[11] To simplify the algebra, we assume the same tax rate in both sectors, although different tax rates will not alter the results. We assume further that the government balances its flow budget. There is neither bond finance nor budget surplus. This will ensure that there are no other distortions. Of course, it is easy to extend the "periodic" balance of government budget to an infinite-lifetime manner (see Turnovsky 1995). Yet this will not bring any different qualitative results, except for algebraic complications.

[12] If a fraction of taxes goes to public consumption and/or public transfers, G_{ct}, then $T_t = G_t + G_{ct}$, in which $G_t = \kappa T_t$ and $G_{ct} = (1-\kappa)T_t$. In this alternative setting, the results are qualitatively similar if κ is large enough. In the calibration below, we only consider the real public productive expenditure in accordance with the model.

The equilibrium in the closed economy is determined by Equation 2–Equation 6 and the commodity-market clearing conditions $C_t^A = (1-\tau)X_t^A$ and $C_t^M = (1-\tau)X_t^M$. The conditions and Equation 2 become

$$\phi(n_t) = \frac{\gamma N}{A(1-\tau)}, \tag{7}$$

where $\phi(n_t) = V(1-n_t) - \frac{\alpha}{\beta}\frac{V'(1-n_t)F(n_t)}{F'(n_t)}$, with $\phi(0) > 0$, $\phi(1) < 0$, and $\phi'(n_t) < 0$.

Therefore, there exists an interior fraction of labor input in the manufacturing sector $0 < n^* < 1$ that satisfies Equation 7 in equilibrium, and the fraction does not change over time. We find that $n^* = n(A)$, $G = G_t^*(n^*)$, and, thus, the growth rate of productivity, $\frac{\dot{M}}{M} = H(G_t^*[n^*])F(n^*)$. Moreover, n^* increases in agricultural productivity A, and so does the growth rate in the manufacturing sector.[13] Although taxes and public spending are introduced, higher agricultural productivity is beneficial to growth in the manufacturing sector in a closed economy.

3. Small-Open Economy

We now turn to an open-economy world with a small-open Home economy and the rest of countries, which have identical economic structures to the above closed economy. Learning by doing does not spill over and labor is immobile across countries. The rest of the countries differ from the Home country only in agricultural productivity, initial manufacturing productivity, and tax rates, given by A^*, M_0^*, and τ^*, respectively.

Optimization and Equilibrium

The above setup implies that the evolution of a world economy in equilibrium will behave just as the equilibrium path of the closed economy, as described in section 2. As a result, the relative price of manufacturing goods in the world market, in term of agricultural goods, is determined by:

$$\frac{(1-\tau^*)A^*V'(1-n^*)}{(1-\tau^*)M_t^*F'(n^*)} = P_t^* = \frac{(1-\tau)AV'(1-n_t)}{(1-\tau)M_t\,F'(n_t)}. \tag{8}$$

Facing world prices, the labor allocation in the Home country is in the second equality in Equation 8.

Total output in terms of agricultural goods is $Y_t = X_t^A + P_t^*X_t^M = AV(1-n_t) + P_t^*M_tF(n_t)$. If we use Equation 8 to determine n_t, the economic growth rate is determined by

$$\frac{\dot{Y}}{Y_t} = \frac{AV'(1-n_t) - P_t^*M_tF'(n_t)}{Y_t}\frac{dn_t}{dt} + \frac{\dot{M}}{M_t}\frac{P_t^*M_tF(n_t)}{Y_t} = \psi(n_t)\frac{\dot{M}}{M_t}, \tag{9}$$

where $\psi(n_t) = \frac{1}{1+AV(1-n_t)/(P_t^*M_tF[n_t])}$, with $\psi'(n_t) > 0$.

The economic growth rate is proportional to the growth rate of productivity in the manufacturing sector, with the proportion equaling the share of the manufacturing output in total output and increasing in the size of the manufacturing sector. Moreover, when the size of the manufacturing sector increases, $\frac{\dot{M}}{M_t}$ increases. As n_t approaches 1 in the limit, $\psi = 1$, and, therefore, $\frac{\dot{M}}{M_t}$ approaches $\frac{\dot{Y}}{Y_t}$.

[13] $n'(A) = -\frac{\gamma L}{\phi'(n_t)A^2(1-\tau)} > 0$, and $\frac{\partial}{\partial A}(\frac{\dot{M}_t}{M_t}) = H'\tau[V + \frac{V'F}{F'} - A(\frac{V''F}{F'} + \frac{V'F''}{(F')^2})n'(A)]F + HF'n'(A) > 0$.

Without abuse of terminology, in what follows, we refer to $\frac{\dot{M}}{M_t}$ as economic growth. In order to guarantee a bounded discounted lifetime utility, consider the following:

Condition TVC′: $\bar{H} < \frac{\rho}{F(1)\beta}(1 + \frac{\beta}{\alpha+\beta})$.

To see how n_t changes over time, differentiating Equation 8 yields

$$\frac{dn_t}{dt} = -\frac{\Phi_t}{\Omega_t}, \tag{10}$$

where $\Omega_t = \frac{V''(1-n_t)}{V'(1-n_t)} + \frac{F''(n_t)}{F'(n_t)} < 0$ and $\Phi_t = H(G_t)F(n_t) - H(G_t^*)F(n^*) \gtreqless 0$, which implies $sign[\frac{dn_t}{dt}] = sign[H(G_t)F(n_t) - H(G_t^*)F(n^*)]$.

The above condition also satisfies in $t = 0$. The manufacturing size dynamics in the Home country are determined by the critical manufacturing size, n^c, which is determined by

$$\Phi(n^c, \tau) \equiv H(G_t(n^c, \tau))F(n^c) - H(G_t^*)F(n_t^*) = 0. \tag{11}$$

Thus, as long as $H(G_t^*)F(n_t^*) > 0$, there exists a critical manufacturing size $n^c > 0$ such that[14]

$$\frac{dn_t}{dt} \gtreqless 0 \quad \text{if and only if } n_0 \gtreqless n^c. \tag{12}$$

Then two possible equilibrium paths emerge, depending upon whether the initial manufacturing size lies above or below the critical level characterized in Equation 12. To demonstrate equilibrium paths in Figure 1, suppose that the critical level is at n_0^c. When the initial manufacturing size is $n_0^1 > n_0^c$ (i.e., Point B), the manufacturing size increases over time along Path BD and eventually approaches 1. This economy industrializes and ultimately specializes in manufacturing. Alternatively, when the initial manufacturing size is $n_0^2 < n_0^c$ (i.e., Point J), the manufacturing size shrinks along Path JK. This economy de-industrializes and eventually specializes in agriculture.

Finally, to characterize the critical manufacturing size, substituting government budget constraint (Eqn. 5) and labor allocation conditions (Eqn. 8) into Equation 11 yields

$$H(G_t[n^c, \tau, A])F(n^c) = H(G_t^*[\tau^*, A^*])F(n_t^*[A^*]),$$

which leads to $n^c = n^c(\tau, A, \tau^*, A^*)$. Examining the properties of function n^c, we obtain

Proposition 1. Under Condition TVC′ there exists a positive n^c, such that n_t increases (decreases) over time if $n_0 >(<)\ n^c$. Value n^c decreases in τ and A and increases in τ^* and A^*.

The reason for Proposition 1 is simple. For example, a higher domestic income tax rate distorts both sectors symmetrically, but it increases tax revenues and thus public spending on infrastructures. This revenue generation effect enhances the learning by doing, so the left-hand side of the above equation determining n^c increases. As a result, a smaller n^c is necessary in order to balance the two sides of the equation (i.e., manufacturing productivity between Home country and the rest of the countries).

We remark that a higher domestic tax rate lowers the threshold, but this cannot be literally interpreted to imply that the optimal tax rate is one. A higher tax rate reduces the disposable income and thus the amount of consumption and lowers the welfare of the representative household. The optimal tax rate needs to trade off between the resulting loss in welfare in the short run and the gains in economic growth in the long run.

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[14] As $F(n^c) = 0$ when $n^c = 0$ and $H(G_t(n^c))F(n^c)$ is strictly increasing in n^c, Condition $H(G_t^*)F(n_t^*) > 0$ guarantees the existence of a positive n^c.

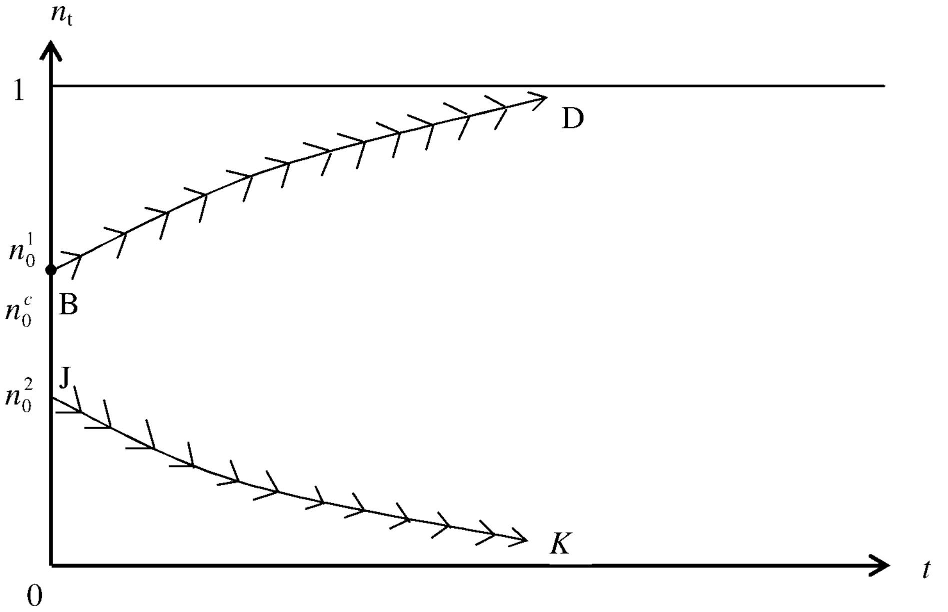

Figure 1. Equilibrium Paths of n_t

When the initial size of the manufacturing in the Home country is larger than the threshold (n^c), the size of the manufacturing increases over time. As time goes to infinity, the size of the manufacturing approaches 1. Then the growth rate of the economy is $\frac{\dot{Y}}{Y_t} = \frac{\dot{M}}{M_t} = \bar{H}F(1)$, a growth rate governed by learning by doing. However, total output $Y_t = X_t^A + P^* X_t^M = AV(1 - n_t) + P^* M_t F(n_t)$ approaches $Y_\infty = AV(0) + P^* F(1)\int_0^\infty M_0 e^{\bar{H}F(1)t} dt$, which becomes infinite. The situation in which infinite amount of output as time goes to infinity is a feature in an economy with perpetual growth. Because of this, we have imposed Condition TVC′, a transversality condition, in order to avoid an unbounded lifetime utility.

Agricultural Productivity Linkage

We now examine the effect of domestic agricultural productivity on the manufacturing size. Higher domestic agricultural productivity generates two effects. The *instantaneous comparative advantage effect* is that the agricultural sector gains labor. The manufacturing size is reduced, via the learning-by-doing effect, exhibiting a detrimental effect on economic growth. Specifically, under given international prices, Equation 8 indicates the instantaneous reduction in the manufacturing size as

$$\frac{dn_t}{dA} = \frac{V'F'}{A(F'V'' + V'F'')} < 0.$$

There is a *subsequent revenue generation effect*, through which higher agricultural productivity enables public spending on infrastructures. The learning-by-doing effect is subsequently boosted, thereby improving manufacturing productivity and thus enabling the manufacturing sector to hire more labor.

To see the net effect, differentiating Equation 10 with respect to A yields

$$\frac{d(dn_t/dt)}{dA} = \frac{1}{-\Omega_t}\frac{d\Phi_t}{dA} + \frac{\Phi_t}{\Omega_t^2}\frac{d\Omega_t}{dA}, \tag{13}$$

where $\frac{d\Phi_t}{dA} = [HF' + \tau FH'(p^*MF' - AV')]\frac{dn_t}{dA} + \tau H'VF$, and $\frac{d\Omega_t}{dA} = \left[\frac{-F'V''' + V'F''}{V'F'} + \frac{-(V'F'')^2 + (F'V'')^2}{(V')^2(F')^2}\right]\frac{dn_t}{dA}$.

Examining Equation 13, the first term includes two elements. While element via $dn_t/dA < 0$ is an instantaneous, negative comparative advantage effect, element $\tau H'VF > 0$ is a subsequent, positive revenue generating effect.[15] The second term in Equation 13 also represents a comparative advantage effect via the evolution in the (logarithmic) marginal productivity of manufacturing, relative to agriculture, but this effect is on the second and third orders and is thus minor. In order to more clearly see when the subsequent, positive effect exceeds the instantaneous, negative effect, we follow Matsuyama (1992) to assume $F(n) = n^\theta$ and $V(1 - n) = (1 - n)^\theta$, where $0 < \theta < 1$. Then, under learning function (Eqn. 4) and $n^*(A^*, \tau^*)$ in Equation 7, the critical level n_0^c is solved by

$$\left[\delta_0 + \delta_1 \frac{\tau_0 A(1-n)^{(1-\theta)}}{\chi + \tau_0(1-n)^{(1-\theta)}}\right](n^c)^\theta = H(G^*[A^*, \tau^*])F(n^*[A^*]) \equiv H^*F^*. \tag{14}$$

Define $z_1 = \frac{\tau A[2\theta(\delta_0+\delta_1)-\delta_1]-2\Delta^{1/2}}{2\delta_0\theta\chi}$, and $z_2 = \frac{\tau A[2\theta(\delta_0+\delta_1)-\delta_1]+2\Delta^{1/2}}{2\delta_0\theta\chi}$, where $\Delta = [2\theta(\delta_0 + \delta_1) - \delta_1]^2 - \delta_0\theta[\delta_0 - \delta_1\tau^2A^2] > 0$. Then, consider

Condition PG (Positive Growth Effect): $\max\{n_0^c, 1 - (z_2)^{\frac{1}{1-\theta}}, \frac{1}{2}\} < n_0 < 1 - (z_1)^{1/1-\theta}$.

Condition PG is sufficient (but not necessary) for a positive sign in Equation 14. Condition PG is easier to meet if $\Delta^{1/2}/(2\delta_0\theta\chi)$ is larger, which is more likely to be realized if θ and χ are smaller and if A, τ, and δ_1 are larger. Intuitively, while a higher δ_1 and a lower χ both reflect the efficiency in the effect of public spending on the knowledge formation, a higher A represents a higher productivity in the agricultural sector. Finally, a higher tax rate, all other things being equal, implies larger public spending, and private production is externally enhanced. Summarizing the above results, we obtain

Proposition 2. Higher agricultural productivity produces an instantaneous, negative effect on the growth rate of manufacturing productivity via comparative advantages and a subsequent positive effect on the growth rate of manufacturing productivity via revenue generations. Under Condition PG, the positive effect dominates the negative effect.

Using Figure 2 to illustrate the growth effect upon manufacturing productivity, assume that the critical level is n_0^c and that the economy is initially at Point B (c.f. n_0^1), with the equilibrium moving along Path BD. Suppose that when the equilibrium evolves to Point L in time t_0, the agricultural productivity is permanently increased. An instantaneous effect of such a change, via the comparative advantage effect, is to drop manufacturing size from Point L to Point N. Notice that the critical level also drops, say, to n_1^c. Subsequently, higher agricultural productivity increases the economy's total output, which generates more tax revenues. More tax revenues increase public spending and thereby enhance the learning-by-doing effect and raise the growth rate of manufacturing productivity. Under Condition PG, the revenue generation effect dominates the comparative advantage effect, so that the

[15] Effect $dn_t/dA < 0$ also generates a positive revenue effect through term $-\tau FH'AV'dn_t/dA > 0$ and a negative effect through term $\tau FH'p^*MF'dn_t/dA = \tau FH'AV'dn_t/dA < 0$. As a result, their net effect is zero.

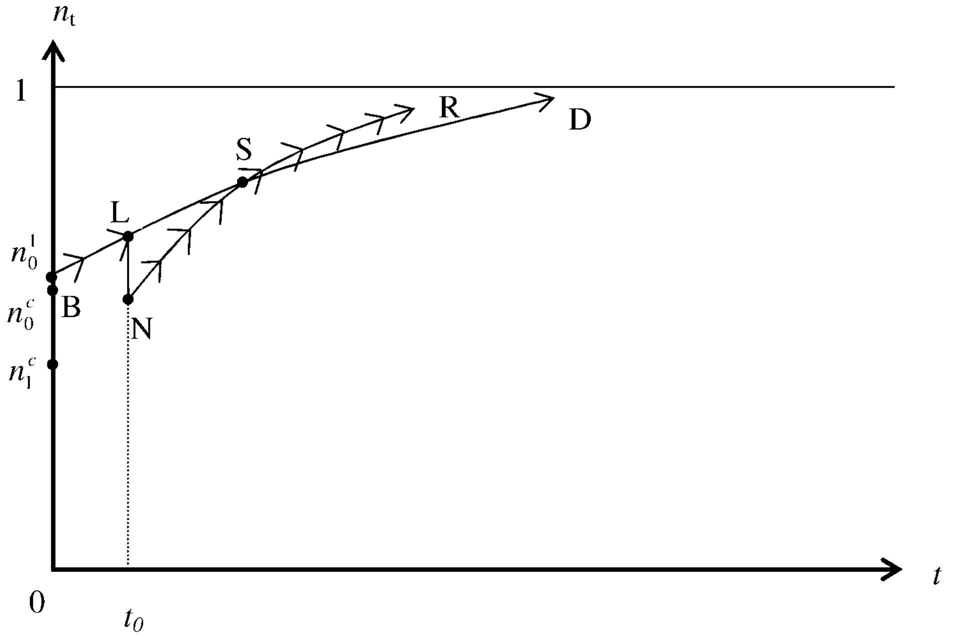

Figure 2. Effect of Larger Agricultural Productivity

new equilibrium Path NR surpasses the original path in a finite period (see Point S), increasing the manufacturing size and, thus, economic growth gradually.

Takeoff

Another situation is that the initial condition for perpetual growth is not met. Under this condition, is it possible to remove the economy from this trapped equilibrium? This is an issue related to spurring economic development in big push. In our model, the fiscal policy on infrastructures plays a role.

To illustrate, assume τ_0 as the domestic tax rate and $n_0^2 < n_0^c$ in Figure 1 as the initial manufacturing size. Presenting part of the diagram below n_0^c into Figure 3, the economy de-industrializes, and the equilibrium evolves along Path JK. The economy would therefore become trapped into specializing in the agricultural sector, eventually with no positive economic growth.

In order to push the economy out of the development trap, the government can increase the tax rate and then increase productive spending. To illustrate how this works, recall that relationship that determines critical level n^c (i.e., $\Phi[n^c, \tau_0] = 0$) in Equation 11 is solved as Equation 14, which is rewritten as follows:

$$\tau_0 A[(\delta_0 + \delta_1)(n^c)^\theta - H^*F^*] = \chi(1 - n^c)^\theta[H^*F^* - \delta_0(n^c)^\theta]. \quad (15)$$

To examine Equation 15, the left-hand side increases in n^c, with the value in the vertical axis $-\tau_0 AH^*F^* < 0$ at $n = 0$ and $\tau_0 A(\delta_0 + \delta_1 - H^*F^*) > 0$ at $n = 1$.[16] This is presented as the positively sloping LH locus in Figure 4, which intersects horizontal axis at $0 < \hat{n}^c \equiv H^*F^*/(\delta_0 + \delta_1) < 1$. Notice that Point $\hat{n}^c$ is smaller if δ_1 is larger. On the other hand, the right-hand side decreases in n^c, with

[16] Equation 10 implies $\delta_0 + \delta_1 > (\delta_0 + \delta_1)(n^c)^\theta > H^*F^*$, as $\tau_0(1 - n)^{(1-\theta)}/[\chi + \tau_0(1 - n)^{(1-\theta)}] < 1$.

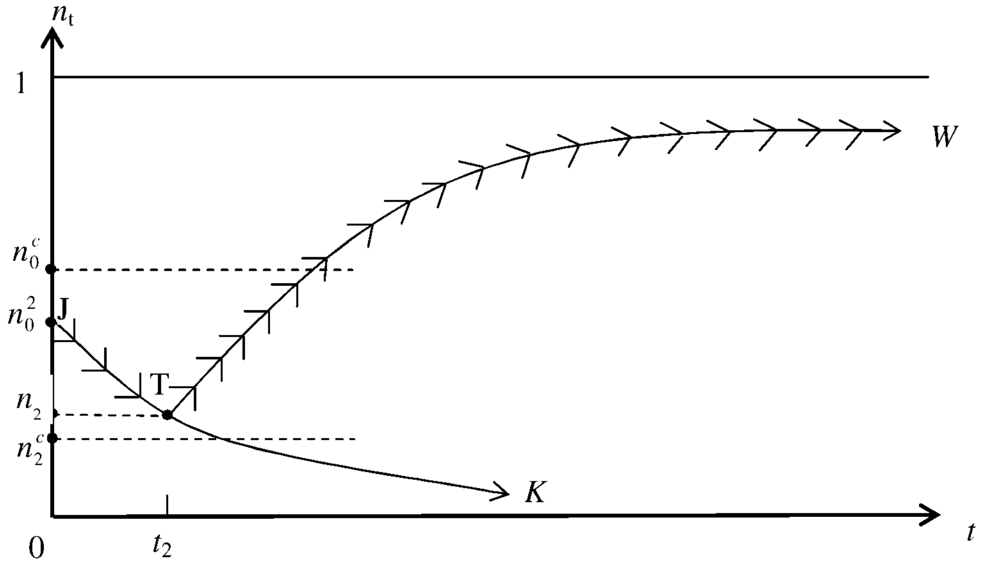

Figure 3. Big Push

a value in the vertical axis of $\chi H^*F^* > 0$ at $n = 0$ and 0 at $n = 1$. It is presented as the negatively sloping RH locus in Figure 4.[17] The LH and RH loci intersect at Point Z, which determines the critical point n_0^c such that $\Phi(n_0^c, \tau_0) = 0$ (c.f. point n_0^c in Figure 3). We also locate the position of the initial n_0^2 in Figure 3 as Point n_0^2 in Figure 4, with the initial manufacturing size $n_0^2 < n_0^c$. This indicates that $\Phi(n_0^2, \tau_0) < \Phi(n_0^c, \tau_0) = 0$, and therefore $dn_t/dt < 0$ when $n_t = n_0^2 < n_0^c$, according to Equation 13. Thus, the manufacturing size evolves along Path JTK in Figure 3, with the size shrinking over time.

Suppose the economy evolves to Point T in time t_2 in Figure 3, with manufacturing size $n_2 < n_0^2$. For illustration, Points J and T and size n_2 ($<n_0^2$) in Figure 3 are also demonstrated in Figure 4, with $n_2 > \hat{n}^c$. Now, consider that the government raises tax rates and spends the tax revenues in productive infrastructures. While higher tax rates do not influence Locus RH in Figure 4, they rotate Locus LH counterclockwise around $\hat{n}^c$. As a result, the intersection of Loci RH and LH′ determines a new critical point n_2^c. As long as tax rate τ_1 is large enough, n_2^c is smaller than n_2. Therefore, the manufacturing sector changes from a comparative disadvantage to a comparative advantage, making $\Phi(n_2, \tau_1) > 0$, and, therefore, $dn_t/dt > 0$, according to Equation 13. Representing the corresponding points n_2^c and n_2 in Figure 4 into Figure 3, the evolution of manufacturing size changes the course from Path TK to Path TW. Note that there is no instantaneous comparative advantage effect under a change in tax rate.[18] The economy thus takes off and eventually industrializes. We thus obtain

Proposition 3. Provided $n < \hat{n}^c \equiv H^*F^*/(\delta_0 + \delta_1)$, it is possible for a government to raise the taxes and spend in infrastructures, changing the manufacturing sector from a comparative disadvantage to a comparative advantage and industrializing an otherwise trapped economy.

The issue of how one could get an economy out of a development trap has been studied in the works by Matsuyama (1991) and Chen and Shimomura (1998). Similar to this study, the two existing articles propose models with two sectors: agriculture and manufacturing. While Matsuyama (1991)

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[17] Point χH^*F^* in Figure 4 can be larger or smaller than Point $\tau_0 A(\delta_0 + \delta_1 - H^*F^*)$.

[18] Examining the static optimal labor allocation condition in Equation 11, it is obviously not affected by the tax rate.

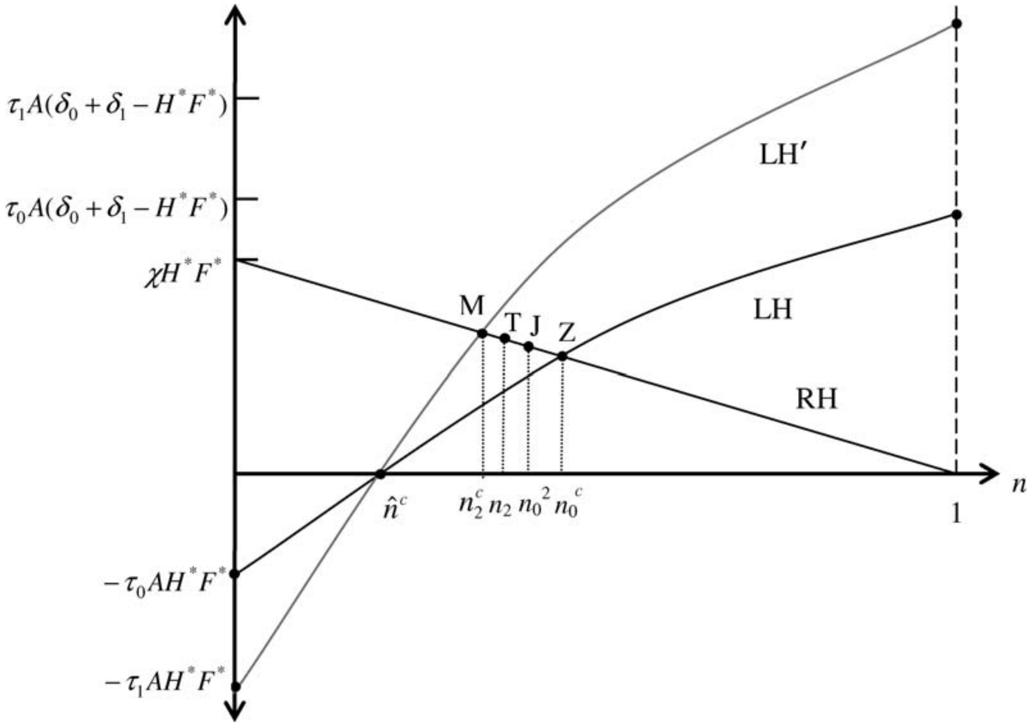

Figure 4. Fiscal Policy and Threshold Change

does not study economic growth, Chen and Shimomura (1998) propose a model with perpetual economic growth in which the engine of growth lies in the modern sector. Self-fulfilling, pessimistic expectations are the mechanism that leads an economy to settle in the steady state, with zero manufacturing size according to Matsuyama (1991) or without economic growth in Chen and Shimomura (1998). In order to lead the economy to take off and then industrialize, it is necessary to coordinate expectations about future payoffs in the modern sector in Chen and Shimomura (1998) and also in Matsuyama (1991) when the history cannot pin down the equilibrium. These two articles analyze neither the effect of the taxation nor productive public spending.

In our model, self-fulfilling expectations do not play any role. As a result of a comparative advantage in the agricultural sector, the economy in our model evolves to become more specialized in agriculture. Therefore, in order to rid the economy of such an equilibrium trap, the key policy is to change the dynamic comparative disadvantage in manufacturing vis-à-vis that in agriculture. By taxing both of the sectors and then spending in physical infrastructures that benefit education in manufacturing, the comparative advantage in the manufacturing sector is improved. If the comparative advantage in manufacturing is improved sufficiently, this economy would expand its manufacturing size and would gradually industrialize.

Finally, a remark should be made with regard to the distortion of tax effects. In the current model, since the only input is labor employment that is not accumulated over time, the symmetric tax rate has no impact upon the labor allocation across sectors. In the Appendix when we extend the model, taking into account capital as well as land inputs, the distortion merges. As capital is accumulated over time, the tax rate has an adverse effect upon capital demands. In that case, while productive government expenditure increases the learning-by-doing effects in the manufacturing sector, the tax rate reduces capital accumulation that decreases the manufacturing output and thus the learning-by-doing effect. There is, therefore, an inverted-U relationship between the tax rate and the learning-by-doing effects with a tax rate threshold. If the tax rate is above the threshold, however, public spending through an increase in the tax rate reduces the learning-by-doing effect. Under this latter condition, the fiscal policy is not able to push an economy out from a trapped equilibrium. The argument in Proposition 3 holds if fiscal policy is conducted based upon an income tax rate that is below the threshold.

4. Quantitative Assessment

Further insights into the effects of larger agricultural productivity upon growth and industrialization can be obtained by carrying out a quantitative analysis of the model. We calibrate the model into Taiwan and Korea (South), in light of their experience in the period of structural change from agriculture to manufacturing.

Data and Parameter Calibration

While the data period is 1961–1973 for Taiwan, it is 1967–1980 for Korea. Although the available time period is not long, our quantitative analysis below can still provide some quantitative support for the significant role of agricultural productivity with regard to economic growth in the transition from agriculture to manufacturing. The data show that exports and imports as a fraction of gross domestic product have been as high as 77% in 1973 for Taiwan and as high as 70% for Korea in 1980, and these rates have been a bit lower for Korea and higher for Taiwan after the 1980s (e.g., 90% for Taiwan and 63% for Korea in 1990). Such a degree of trade openness seems to indicate that both Korea and Taiwan were open economies and that their experiences were thus consistent with the open economy assumption in section 3. The proposed linkage between agriculture and manufacturing via infrastructure holds under both closed and small-open economy regimes in our model. We use the industry sector to represent the manufacturing industry because of the availability of data and because more than 85% of the industry sector is value added, with employment being accounted for by manufacturing. The beginning years represented within this data are limited by the availability of data, whereas the ending years are chosen when the employment share of the industry sector reaches 50%, after which point an economy will be mature, so that the tertiary industry will dominate the economy sooner or later.[19]

To calculate the data, we have deflated the time-series, value-added data of the agricultural sector and the industry sector using either the GDP or the GNP deflator and have divided them by the number of employees in each industry to obtain X_t^a and X_t^m, respectively.[20] We then use the resulting time-series data to compute the real economic growth rate of value added per capita for each of these two sectors: $\dot{X}_t^a/X_t^a$ and $\dot{X}_t^m/X_t^m$. In order for the data to be consistent with the theoretical model in which the manufacturing sector grows and the agricultural sector does not grow, we calculate $\dot{X}_t^m/X_t^m - \dot{X}_t^a/X_t^a$, which gives the model-consistent growth rate of manufacturing, $\dot{X}_t^M/X_t^M$ and, thus, $\dot{M}/M_t$. Using the employment data, we calculate the industry sector's annual employment share series (n_t) and the

[19] Detailed sources of data and the method used to calculate the variables are available upon request.

[20] While Taiwan's income data is in terms of GDP, the Korea data is in terms of GNP. We do not have the GDP data at market prices for Korea. Nevertheless, we believe the results using the GNP data should be the same as those using the GDP data.

Table 1. Set of Parameter Values in Case IV, Taiwan[a]

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Parameters given											
χ	1	1	1	1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
δ_0	0.035	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.02	0.02	0.02
δ_1	0.025	0.03	0.02	0.01	0.03	0.02	0.01	0.02	0.04	0.02	0.01
Parameters calibrated											
θ	0.464	0.3427	0.2959	0.2471	0.7132	0.5674	0.3980	0.7873	0.6335	0.2888	0.6178
A	0.727	0.6971	0.6858	0.6742	0.7936	0.7542	0.7107	0.8145	0.7718	0.6841	0.6318
M_0	2.133	1.8392	1.7374	1.6369	2.8904	2.4196	1.9678	3.1638	2.6225	1.7223	1.3057

[a] Parameter values for χ, δ_0, and δ_1 are given, and θ, A, and M_0 are then derived by using these parameters. Case IV is used to generate results in Figure 6.

agriculture sector's annual employment share series $(1 - n_t)$. Moreover, we also calculate the government productive expenditure series G_t. The government productive expenditure as a fraction of agricultural and manufacturing GDP is 5% in both countries in the period under study, which is higher than in other countries.[21]

Next, in order to utilize the learning function $H(G_t) = \delta_0 + \delta_1 G_t/(\chi + G_t)$, we need to use the parameter values for δ_0 and δ_1, but there is no data or existing works available from which to infer δ_0 and δ_1. To overcome the difficulty, we use many sets of values for $\{\delta_0, \delta_1\}$ in order to cover a broad range. We also normalize the unit of government productive expenditure G_t by choosing proper values for χ. Two parameter values of χ are used, 1 and 0.1, the difference being large enough to cover a wide range. Tables 1 and 2 list the sets of $\{\delta_0, \delta_1, \chi\}$ values for Taiwan and Korea, respectively. These parameter values must satisfy Condition TVC′.

Moreover, under one set of parameter values for $\{\delta_0, \delta_1, \chi\}$ in Tables 1 and 2, we use production functions, together $\dot{X}_t^M/X_t^M$ series and thus $\dot{M}/M_t$ series, to acquire the parameter value for θ. The resulting θ values under different sets of $\{\delta_0, \delta_1, \chi\}$ are reported in Tables 1 and 2. As seen from the tables, for given values of χ, the calibrated θ values are smaller if either value of δ_0 and δ_1 is smaller. Moreover, for given values of δ_0 and δ_1, a smaller value of χ leads to a larger calibrated value of θ. Intuitively, a smaller value of δ_0 and δ_1 and a larger value of χ would reduce the learning effect. Since $F(n)$ is strictly concave and $0 \leq n \leq 1$, a smaller θ value is necessary to attain a given growth rate of the industry sector. Finally, we calibrate initial values for parameters A and M (i.e., A_0 and M_0) and the flat tax rates. Under each θ value, A_0 and M_0 are obtained by employing the initial year's X_0^a, X_0^m, and n_0 data along with the two production functions. The resulting A_0 and M_0 are reported in Tables 1 and 2. The annual X_t^a, X_t^m, and G_t data, together with Equation 5, are utilized to calculate the implied annual tax rates. The flat tax rate τ is obtained by taking an average of these annual tax rates.

Equipped with the calibrated value for θ and values for M_0, A_0, and τ, we compute the equilibrium for Home country. Optimal employment allocation condition in Equation 8 is used to determine n_0, which is the industry sector's equilibrium employment share from the beginning period. Production functions are then used to find out the beginning period's output in both sectors, X_0^A and X_0^M. The government budget constraint in Equation 5, together with the flat tax rate τ, determines the beginning period's government productive expenditure G_0, with Equation 3 used to determine economic growth rate from the first period, which in turn establishes M_1 as the industry sector's

[21] For example, the corresponding share is less than 2% in most of Latin America and about 2% in the United States and the United Kingdom in the early 1980s. See IMF (various years).

Table 2. Set of Parameter Values for Case IV, Korea[a]

	I	II	III	IV	V	VI	VII	VIII	IX	X
Parameters given										
χ	1	1	1	1	0.1	0.1	0.1	0.1	0.1	0.1
δ_0	0.035	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.02	0.02
δ_1	0.025	0.03	0.02	0.01	0.03	0.02	0.01	0.02	0.04	0.02
Parameters calibrated										
θ	0.2300	0.1267	0.1012	0.0748	0.3927	0.2939	0.1800	0.4778	0.3073	0.0657
A	0.3115	0.3063	0.3051	0.3037	0.3200	0.3148	0.3090	0.3241	0.3155	0.3033
M_0	0.7424	0.6112	0.5824	0.5541	1.0125	0.8385	0.6761	1.1735	0.8600	0.5446

[a] Parameter values for χ, δ_0, and δ_1 are given, and θ, A, and M_0 are then derived by using these parameters. Case IV is used to generate results in Figure 7.

productivity level from beginning of the second period. With the M_1, θ, and A_0 values, we sequentially calculate all the endogenous variables in equilibrium, for the next period and the future. Therefore, the equilibrium values are completely obtained.

Effect of Larger Agricultural Productivity

We next quantify how the manufacturing size and the economic growth rate respond to larger agricultural productivity in the two calibrated economies. The quantitative results help explore the relative effects between the instantaneous negative, comparative advantage effect and the subsequent, revenue generation effect brought by a higher tax rate and the resultant public expenditure on infrastructure, thereby quantitatively shedding light on the relationship between agricultural productivity and economic growth.

To illustrate the results, we utilize one set of parameter values of θ, M_0, and A_0 in both Tables 1 and 2 to quantify the effects. The results using other sets of parameter values are quantitatively similar. Using the set of parameter values in Case IV from Table 1 for Taiwan and in Case IV from Table 2 for Korea, we compute the resulting equilibrium paths for the industry sector's employment share and the economic growth rate in the calibrated economies. These equilibrium paths are illustrated using light dotted points in Figures 5 and 6.

We then quantify how a change in agricultural productivity, A_0, affects the equilibrium paths of employment share and economic growth rate. We start by increasing the parameter value for A_0 in each of the two economies by 10%. The results are demonstrated using the light line in Figures 5 and 6 (lines indicated by A_0 * 1.1). Comparing the light dotted points with the light lines in the figures, the industry sector's employment share *drops instantaneously* for both economies (see upper panels in the figures) as a result of the instantaneous comparative advantage effect. Yet, because of the revenue generation effect that enhances the learning by doing of manufacturing, the light lines move in a more steep direction than do the light dotted points over time, meaning that the manufacturing size is *subsequently increased*. Moreover, as a result of the stronger learning-by-doing effect, the economic growth is higher than the original rate in Taiwan, starting from the second period, and starting from the sixth period in Korea (in the lower panel in Figures 5 and 6). Next, the parameter value A_0 in each of the two economies decreases by 10%. The results are illustrated using discrete points in Figures 5 and 6 (lines indicated by A_0 * 0.9). Clearly, from these figures, the resulting equilibrium paths for employment share and economic growth rate are opposite to those of the increasing A_0 by 10% as already shown. Furthermore, we experiment with a large increase of A_0 by 50%. Under such a sizable

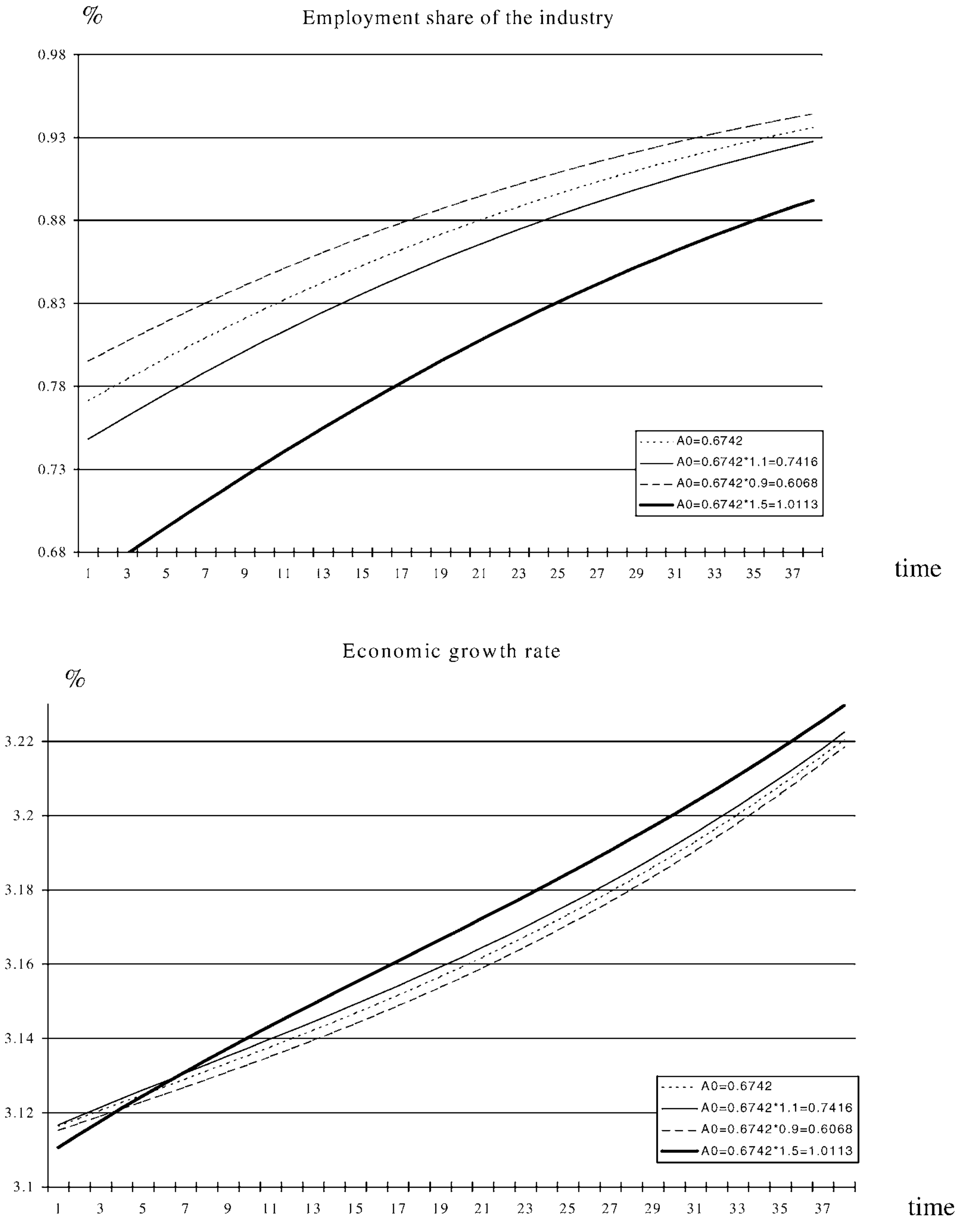

Figure 5. Changes in Employment Share and Economic Growth Rate in Taiwan ($\chi = 1$, $\delta_0 = 0.03$, and $\delta_1 = 0.01$)

change, the instantaneous reallocation of labor employment from manufacturing into agriculture is so large that the economic growth rate is lower than the original rate in early periods, as seen from the bold lines in Figures 5 and 6 (lines indicated by A_0 * 1.5). Yet, as tax revenues, and thus government productive expenditure, also increase greatly, this in turn generates a large learning-by-doing effect, which causes the new economic growth rate to surpass the original rate in six periods for Taiwan and

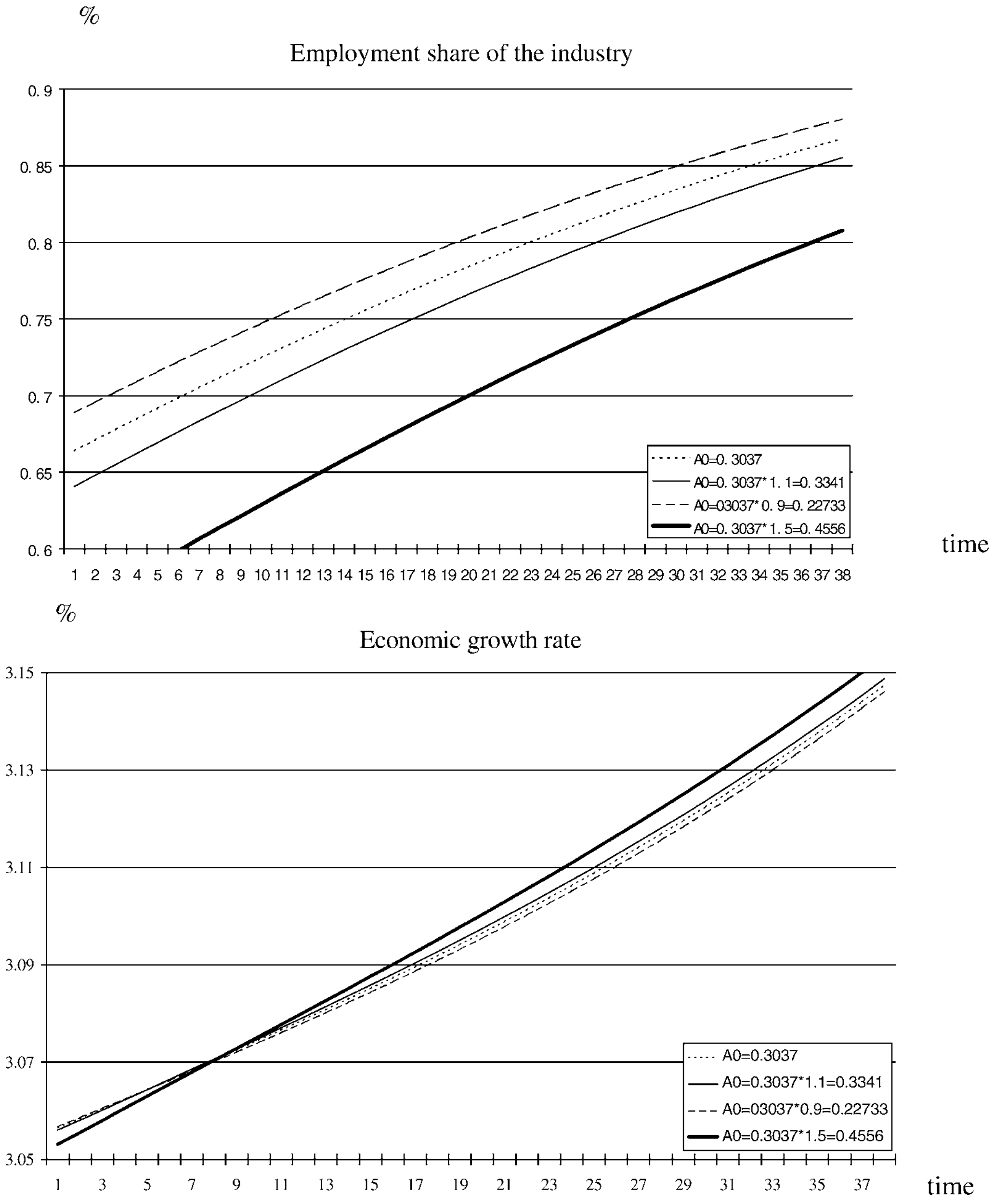

Figure 6. Changes in Employment Share and Economic Growth in South Korea ($\chi = 1$, $\delta_0 = 0.03$, and $\delta_1 = 0.01$)

in 11 periods for Korea. Asymptotically, the industry's employment share approaches 1 and the economic growth rate approaches the upper bound of the learning-by-doing effects. We have found that the equilibrium approaches the limit level in about 250 periods.

Finally, we also document Japan's experience. The earliest year that data is available is 1952, and the share of the industry had reached 50% by 1960. Like Korea, Japan's income data is GNP. Although time period extending from 1952 to 1960 is short, and although Japan may have industrialized in 1952, the quantitative exercise below can still shed some light on the relationship between agriculture and manufacturing. We should note that the fraction of exports and imports in GDP was 21% in 1960 in Japan and remained at 21% in the 1990s, indicating the trade openness in Japan in 1960. Following a procedure similar to the one described above, we have calibrated the parameters (see Table 3). We then compute the equilibrium paths for the industry's employment share and for economic growth (see Figure 7). Finally, we change the agricultural productivity. Although the resulting equilibrium paths for the industry's employment share are similar to those of Taiwan and Korea, the equilibrium paths for the economic growth rates differ quantitatively. Here, the revenue generation effect dominates the comparative advantage effect from the first period, so that the new economic growth rate has been higher than the original rate since the beginning. This strong revenue generation effect may be due to the fact that in the beginning year of our data, Japan is industrialized. Nevertheless, along with evidence in Taiwan and Korea, the evidence in Japan supports a positive relationship between agricultural productivity and the industry sector's employment as well as economic growth in the long run.

We should remark that in practice, there is governmental ''unproductive expenditure,'' and government productive expenditure accounts for only a fraction of total government expenditure, say, $\kappa < 1$. Our main results hold provided that κ is above a threshold. In our calibration simulation, we only consider the government productive expenditure in order to remain consistent with the theoretical model, and as a result, we cannot obtain the threshold for κ. Given the evidence that government productive expenditure as a fraction of the agricultural and manufacturing GDP is 5% in the three East Asian countries, it is about 2.5% of total GDP in the three countries. The size of government is about 15% in Korea and Taiwan and 20% in Japan (IMF, various years). Therefore, κ could be as small as 16% in Korea and Taiwan and as small as 12% in Japan, which provides an upper bound for the threshold.

5. Concluding Remarks

This article has extended Matsuyama's (1992) two-sector endogenous growth model into one with taxes and public expenditure on infrastructures in order to reexamine the relationship between agricultural productivity and economic growth. It finds that, under a proper condition, in which the revenue generation effect dominates the comparative advantage effect, higher agricultural productivity enhances industrialization and increases long-run economic growth. The role of government is credited with spurring a de-industrialized economy to gradually industrialize. Moreover, the effect of agricultural productivity is quantitatively assessed, based on the experiences during early stages of economic development in Japan, Taiwan, and Korea. Higher agricultural productivity is determined to increase the industry sector's employment subsequently and to enhance economic growth.

Given the nonavailability of compatible data for other Asian countries and other countries in the world, we have not documented such a linkage. Demonstrating that the proposed positive linkage between agriculture and manufacturing via productive public spending is relevant for other Asian countries or for developing countries in general is a direction for the future research.

Finally, can an external debt be considered as an alternative source to finance productive infrastructure that helps the manufacturing? We tend to believe so, if the amount of external debt is below a threshold, in the sense that it is compatible with the income tax rate (in the model in the Appendix). Notice that eventually taxation is necessary to finance debt. The successful experience in

Table 3. Set of Parameter Values for Case VIII, Japan[a]

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII
Parameters given																	
χ	1	1	1	1	1	1	1	1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
δ_0	0.035	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.02	0.02	0.02	0.01	0.01
δ_1	0.025	0.03	0.02	0.01	0.03	0.04	0.02	0.01	0.03	0.02	0.01	0.02	0.04	0.02	0.01	0.02	0.01
Parameters calibrated																	
θ	1.0456	0.9003	0.8586	0.8153	0.4843	0.5413	0.4244	0.3613	1.2997	1.1484	0.9746	1.4023	1.1873	0.8279	0.5888	0.3738	0.0103
A	1.6748	1.5628	1.5320	1.5007	1.2818	1.32170	1.2087	1.2087	1.8905	1.7589	1.6191	1.9852	1.7918	1.5069	1.3472	1.2159	1.0226
M_0	6.6025	5.7348	5.5074	5.2812	3.8308	4.0485	3.3998	3.3998	8.4487	7.2949	6.1631	9.3325	7.5759	5.3251	4.2394	3.4415	2.4189

[a] Parameter values for χ, δ_0, and δ_1 are given, and θ, A, and M_0 are then derived by using these parameters. Case VIII is used to generate results in Figure 5.

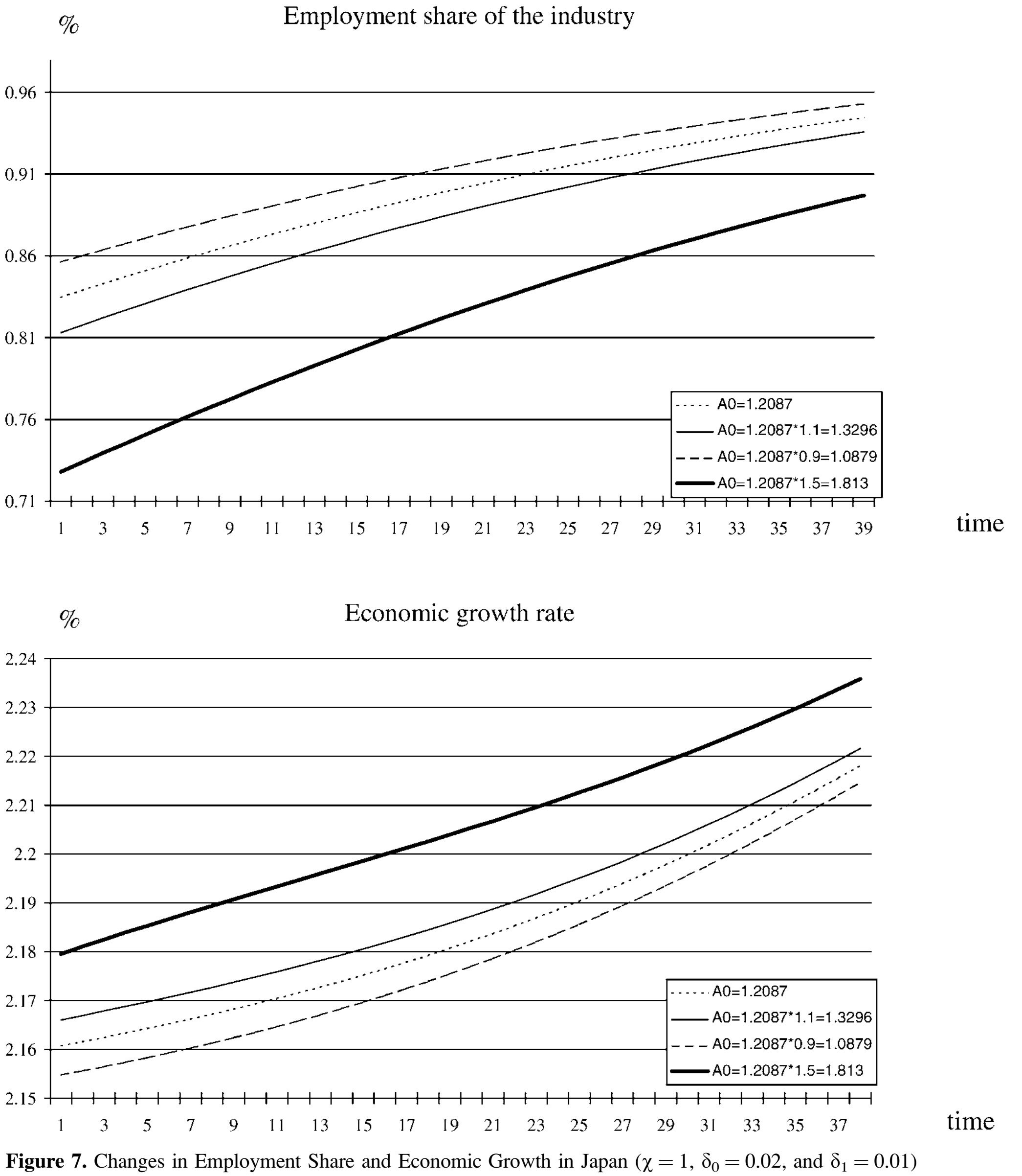

Figure 7. Changes in Employment Share and Economic Growth in Japan ($\chi = 1$, $\delta_0 = 0.02$, and $\delta_1 = 0.01$)

Korea may serve as an example (e.g., Amsden 1989, pp. 94–6). Then we had to make a remark on Latin American experiences, as many countries in Latin America finance infrastructure with external debts. First, the government productive expenditure as a fraction of gross domestic income in Latin America is much lower than in the three East Asian countries under calibration, according to the data in the IMF (various years) that we have cited in section 4-1. Second, the public expenditure may not be so productive in Latin America. The infrastructure in Latin America cannot enhance economic growth due to international and domestic competitive barriers arising from protectionism and the entry barriers, thus resulting in low Latin total factor productivity, as Cole et al. (2005) have argued. Finally, there are other reasons that caused the economies in Latin America to stagnate in the 1970s and 1980s. Market failures and incorrect public policies are some of the reasons (e.g., Lopez 2003).

Appendix

An Extended Model of Section 3 Using Additional Input in Land and Capital

This Appendix extends the model presented in section 3 to include land and capital as inputs. In the extension, all aspects of the model remain unchanged, with the exception of including the use of the two extra inputs in the production in the manufacturing and agricultural sectors. The Home country freely exports and/or imports goods. Capital mobility across small-open economies, however, is not considered here, as physical capital may fly instantaneously across countries if the rates of returns to capital are different across countries (c.f., Barro and Sala-i-Martin 1995, ch. 3). The time preference is similar to Equation 1 in section 2, except for exhibiting a constant intertemporal elasticity of subsistence, $1/\sigma$, in accordance with a sustainable growth framework with capital accumulation, thus:

$$Max\ U = \int_0^\infty \frac{[(C_t^A - \gamma)^\alpha (C_t^M)^\beta]^{1-\sigma} - 1}{1-\sigma} e^{-\rho t} dt, \quad \alpha, \beta, \gamma, \rho > 0, \quad \sigma > 1, \tag{A1}$$

while the budget constraint is modified as follows:

$$\dot{K}_t = (1-\tau)(P_t^* X_t^M + X_t^A) - P_t^* c_t^M - c_t^A. \tag{A2}$$

The two technologies with labor, land, and capital inputs are

$$X_t^M = M_t F(n_t, L_t^M, K_t^M) = M_t (n_t)^\eta (L_t^M)^\mu (K_t^M)^\nu, \quad 0 < \eta + \mu + \nu < 1, \tag{A3a}$$
$$X_t^A = AV(1-n_t, L_t^A, K_t^A) = A(1-n_t)^\eta (L_t^A)^\mu (K_t^A)^\nu, \tag{A3b}$$

in which K_t^M (resp. L_t^M) and K_t^A (resp. L_t^A) are capital (resp. land) inputs employed in the manufacturing and agriculture sector, respectively. By using this functional form, both capital and land affect the marginal productivity of labor, and these factor inputs are pareto complements in a technology and are substitutes across technologies. In accordance with the Matsuyama's setting, we assume the same share of an input in both sectors, and when $\mu = \nu = 0$, the forms of the technology are the ones used in Matsuyama and adopted in our model in section 3. While total amount of land is assumed to be fixed at L, total amount of capital in t is predetermined at K_t. The resource constraints are

$$L = L_t^M + L_t^A, \quad K_t = u_t K_t + (1-u_t)K_t \equiv K_t^M + K_t^A. \tag{A4a}$$

While knowledge capital, as in section 3, is increased by

$$\dot{M}_t = X_t H(G_t) = M_t F(n_t, L_t^M, K_t^M) H(G_t), \tag{A4b}$$

the flow of the government budget constraint is the same as Equation 5, thus: $G_t = \tau(P_t^* X_t^M + X_t^A)$.

The Home country takes as a given the relative price of manufacturing goods in terms of agriculture goods, P_t^*, determined by the world market in the same way as Equation 8. The rental price of capital, r_t, the rental rate of land, R_t, and the wage rate, w_t, on the other hand, are determined by the domestic market. Taking P_t^*, r_t, R_t, and w_t as given, the competitive firm in the Home Country optimally allocates capital, land, and labor so as to equate the marginal productivity of input between the sectors and is equal to the factor price. The optimality conditions for capital allocation are

$$r_t = (1-\tau)\frac{\nu P_t^* M_t n_t^\eta (L_t^M)^\mu}{(u_t K_t)^{1-\nu}} = (1-\tau)\frac{\nu A(1-n_t)^\eta (L - L_t^M)^\mu}{[(1-u_t)K_t]^{1-\nu}}. \tag{A5}$$

The optimal conditions for the consumption in the two sectors lead to

$$\frac{\dot{C}_t^M}{C_t^M} = \frac{r_t - \rho}{(\sigma-1)(\alpha+\beta)+1}, \quad \frac{\dot{C}_t^A}{C_t^A} = \left(1 - \frac{\gamma}{C_t^A}\right)\frac{r_t - \rho}{(\sigma-1)(\alpha+\beta)+1}, \tag{A6}$$

that indicates a positive consumption growth rate in both sectors if the rental rate of capital is above the time preference rate and the agricultural consumption is above the subsistence level. Other things being equal, a higher capital tax rate reduces the return to capital stock, according to Equation A5, which indirectly reduces the growth rate of consumption, according to Equation A6.

Using the optimal conditions, we derive the factor demands for land, capital, and labor thus:

$$L_t^M = n_t L = L_t^M(n, L),\ L_t^A = L - n_t L = L_t^A(n, L), \tag{A7a}$$
$$K_t^A = (1-n_t)K_t = K_t^A(n),\ K_t^M = n_t K_t = K_t^M(n). \tag{A7b}$$
$$n_t = (B_t + 1)^{-1}, \tag{A7c}$$

where $B_t \equiv [A/(P_t^* M_t)]^{1/[1-(\eta+\mu+\nu)]}$.

The aggregate income is $Y_t \equiv P_t^* X_t^M + X_t^A$, and using Equation A7a–Equation A7c yields

$$\frac{\dot{Y}}{Y_t} = n_t\left(\frac{\dot{M}}{M_t} + \frac{\dot{P}_t^*}{P_t^*}\right) + \nu\frac{\dot{K}}{K_t}, \tag{A8}$$

where $\frac{\dot{K}}{K_t} = (1-\tau)P_t^* \frac{L^\mu}{n_t^{1-(\eta+\mu+\nu)}} \frac{M_t}{K_t^{1-\nu}} - \frac{\alpha+\beta}{\beta} P_t^* \frac{C_t^M}{K_t} + \frac{\gamma}{K_t}$.

The growth rate of capital depends on the productivity in the manufacturing sector, because of the pareto complements among inputs in the technology. Therefore, the economic growth rate is determined mainly by the growth rate of the productivity in the manufacturing sector. The growth rate of productivity in the manufacturing sector is $\dot{M}/M_t = H(G_t(n_t, A, \tau, L))F(n_t, L_t^M(n_t, L), K_t^M(n_t))$, which depends upon how the size of the manufacturing sector changes over time, as shown in section 3.

Examining Equation A7a–Equation A7c, while factor allocations between sectors are independent of the tax rate, a higher income tax rate reduces capital inputs in both the manufacturing and agricultural sectors. Fiscal policy now involves a positive growth effect on the learning by doing of the manufacturing sector via larger public infrastructure and has a negative growth effect on capital, according to Equations A6 and A8. The tax rate must not be so high that the negative growth effect dominates the positive growth effect (and, thus, there exists a tax rate threshold). Below such a threshold, fiscal policies are effective, as remarked upon in section 3. Therefore, public capital/infrastructure can be used as a substitute for private capital in enhancing the productivity growth in the manufacturing sector only when an income tax rate is below the threshold. When income tax rates are above the threshold, public infrastructure does not have such substitutability.

Changes in the Size of Manufacturing Sector over Time

To see how n_t changes over time, if we differentiate Equation A7c with respect to time and use the condition that the world market is in the long-run equilibrium, so that n_t^* and L_t^*M are constant and $\frac{\dot{K}_t^{*A}}{K_t^{*A}} - \frac{\dot{K}_t^{*M}}{K_t^{*M}} = 0$ and $\frac{\dot{P}*}{P_t^*} = -\frac{\dot{M}*}{M_t^*}$, together with knowledge accumulation form Equation A5, we obtain

$$\frac{dn_t}{dt} = \frac{1}{1-(\eta+\mu+\nu)} n_t(1-n_t)\left(\frac{\dot{M}}{M_t} + \frac{\dot{P}_t^*}{P_t^*}\right) = -\frac{\tilde{\Phi}_t}{\tilde{\Omega}_t}, \tag{A9}$$

where $\tilde{\Omega}_t = -\frac{1-(\eta+\mu+\nu)}{n_t(1-n_t)} < 0$, and $\tilde{\Phi}_t = F(n_t, L_t^M, K_t^M)H(G_t) - F(n_t^*, L_t^{*M}, K_t^{*M})H(G_t^*) \gtreqless 0$.

Form Equation A9 is similar to Equation 10, with the evolution of the manufacturing size determined by

$$sign\left(\frac{dn_t}{dt}\right) = sign[F(n_t, L_t^M, K_t^M)H(G_t) - F(n_t^*, L_t^{*M}, K_t^{*M})H(G_t^*)]. \tag{A10a}$$

Then, as long as $F(n_t^*, L_t^{*M}, K_t^{*M})H(G_t^*) > 0$, there exists a critical size n^c satisfying $F(n^c, L_t^M(n^c, L), K_t^M(n^c))\, H(G_t(n^c, \tau, A, L)) = F(n_t^*, L_t^{*M}(n_t^*), K_t^{*M}(n_t^*))\, H(G_t^*(n_t^*, \tau^*, A^*, L^*))$, such that

$$\frac{dn_t}{dt} \gtrless 0 \quad \text{if and only if } n_0 \gtrless n^c. \tag{A10b}$$

Agricultural Productivity Linkage

When A is higher, the *instantaneous* effects upon the size of the manufacturing sector can be obtained by differentiating the optimal labor allocation condition, taking P^* and M_t as given,

$$\frac{dn_t}{dA} = -\frac{1}{P^* M_t} \frac{n_t^{2-(\eta+\mu+\nu)}(1-n_t)^{\eta+\mu+\nu}}{1-(\eta+\mu+\nu)} < 0.$$

There is a *subsequent* effect through the revenue effect and the reallocation in land and capital, which is obtained by differentiating Equation A9 with respect to A

$$\frac{d(dn_t/dt)}{dA} = \frac{1}{-\tilde{\Omega}_t}\frac{d\tilde{\Phi}_t}{dA} + \frac{\tilde{\Phi}_t}{\tilde{\Omega}_t^2}\frac{d\tilde{\Omega}_t}{dA}, \tag{A11}$$

where $\frac{d\tilde{\Omega}_t}{dA} = \frac{1-(\eta+\mu+\nu)}{[n_t(1-n_t)]^2}(1-2n_t)\frac{\partial n_t}{\partial A}$, and $\frac{d\tilde{\Phi}_t}{dA} = H\frac{\partial F}{\partial A} + FH'\frac{\partial G}{\partial A} = H\frac{\partial F}{\partial A} + \tau FH'(p^* M_t \frac{\partial F}{\partial A} + V + A\frac{\partial V}{\partial A}) = HF\frac{\eta+\mu+\nu}{n_t}\frac{\partial n}{\partial A} + \tau FH'V$.
If we use form $H(G) = \delta_0 + \delta_1\frac{G}{\chi+G}$ in Equation 4 to derive $H'(G) = \frac{\delta_1\chi}{(\chi+G)^2}$, we rewrite Equation A11 as

$$\frac{d(dn_t/dt)}{dA} = \frac{n_t(1-n_t)\,F}{1-(\eta+\mu+\nu)}\left[\left(\delta_0 + \frac{\delta_1 G}{\chi+G}\right)\frac{\eta+\mu+\upsilon}{n_t}\frac{\partial n}{\partial A} + \tau\frac{\delta_1 G}{\chi+G}(1-n_t)^{\eta+\mu+\upsilon}H^\mu K_t^\nu\right] + \frac{(1-2n_t)\tilde{\Phi}}{1-(\eta+\mu+\nu)}\frac{\partial n}{\partial A}. \tag{A12}$$

Examining the terms in Equation A12, the first large brackets include two elements, with the first element being negative and the second element being positive. The last term in Equation A12 is positive (negative) if n_t is larger (smaller) than ½. Given the existence of positive and negative effects, as in section 3, there exists a sufficient condition like that in Condition PG, such that higher agricultural productivity leads to a larger size of the manufacturing sector and, thus, to economic growth. Therefore, the results in Proposition 2 are qualitatively unchanged even when capital is an input.

Changes in Land Supplies

While an increase in L may be interpreted as bringing new land into use, a decrease in L may be interpreted as reducing land availability. First, it is easy to show that there is no instantaneous effect of changes in land supplies upon the size of manufacturing sector. This is verified if we differentiate Equation A7c with respect to L and obtain $dn_t/dL = 0$. There are, however, subsequent effects of changes in land supplies upon the size of the manufacturing sector. Specifically, we obtain from Equation A7a–Equation A7b that $\partial L_t^M/\partial L = F/L > 0$, $\partial L_t^A/\partial L = V/L > 0$, $\partial L_t^A/\partial L = V/L > 0$, and $\partial K_t^M/\partial L = \partial K_t^A/\partial L = 0$. As a result, a larger land supply increases the size of the manufacturing sector, as can be seen by differentiating Equation A9 with respect to L to obtain

$$\frac{d(dn_t/dt)}{dL} = \frac{n_t(1-n_t)}{[1-(\eta+\mu+\nu)]}\frac{HF+\tau FH'Y_t}{L} > 0. \tag{A13}$$

Intuitively, larger land supplies increase both manufacturing and agricultural output and thus the tax revenues and public infrastructure. While larger manufacturing production increases the learning-by-doing effects in the manufacturing sector, larger public infrastructure enhances the efficiency of learning by doing in the manufacturing sector. As a consequence, the size of the manufacturing sector is increasing. As a corollary, when the availability of land decreases, the size of the manufacturing sector decreases as a result of the resulting reduction in the manufacturing production and the tax revenues and, thus, public infrastructure. This slows the growth of the learning-by-doing effect and thus the growth of the manufacturing sector and economic growth.

A remark is made with regard to the impact on the subsistence farming sectors as land is converted from subsistence farming in the agricultural sector to industrial agricultural and industries in the manufacturing sector. As the manufacturing sector grows and the size of the manufacturing sector increases, given the higher productivity in the manufacturing sector, more land must be converted to the manufacturing sector. When the size of the manufacturing sector approaches 100%, the agricultural production in the Home country is negligible and is not enough to meet the demand for agricultural goods. Nevertheless, as the Home country is a small-open economy, its excess demand for agricultural goods is met by imports. Imports of agricultural goods are never a problem, as the Home country exports manufacturing goods.

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