Paths of Development for Early- and Late-Bloomers with Land

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Abstract

Heckscher-Ohlin versions of the two-sector neoclassical growth model predict that late-blooming nations can remain permanently poorer. This is an important result that warns us about the dangers of international trade. We show, however, that the result vanishes once inputs in fixed supply such as land are introduced into the model.

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1 Land is an important production input. See Smith (1776), Schultz (1967), Galor and Weil (2000), and Caselli and Coleman (2001), among many others.

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1 Introduction

In a recent contribution, Atkeson and Kehoe (2000) prove that in the standard dynamic two-sector Heckscher-Ohlin model developing countries that are identical to developed nations in all aspects except for the capital stock can remain permanently poorer. We show, however, that this interesting result that warns us about the dangers of international trade heavily depends on the characteristics of production inputs, and that it vanishes once land is introduced into the analyses.1

We consider the same economy as Atkeson and Kehoe (2000) with the only difference that firms can also use in production a natural input that is in fixed supply, land. The economy is composed of a large number of small open economies. Each country has the production structure of the standard two-sector neoclassical growth

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model with consumption and investment goods. The two sectors employ land, capital and labor, and can have different input intensities. All nations possess identical preferences and production technologies. Some countries, the early-bloomers, have already reached their steady states, while other countries, the late-bloomers, begin to develop.

It is the property that land is an input in fixed supply that causes our main result. More specifically, when the return to capital has converged across economies, different capital-labor ratios and, as a consequence, different income per capita levels are possible in the standard two-sector model through cross-sector input movements. However, because land is in fixed supply, only one pair of labor allocations and, therefore, capital-labor ratio can accommodate the long-run rental rate on capital in our framework, thus making differences in steady-state income levels between identical economies impossible.

Other papers that use multi-sector models of international trade and growth include Ventura (1997), Mountford (1998), Bajona and Kehoe (2006), Galor and Mountford (2006, forthcoming), and Guilló and Perez-Sebastian (2007, 2008). Although none of them focus on whether the timing of development matters for long-run income, one of the results in Bajona and Kehoe is related to our findings. They show that, for a given elasticity of substitution between traded goods, convergence in relative incomes depends on the pattern of trade over time. In our model two small economies that have the same land endowment will end up having the same long run income independently of their trade patterns along the adjustment path.

2 The Economy

Consider a world economy consisting of a large number of small open economies that can differ only in their level of development. There are two goods, and three inputs of production. The production of consumption and investment goods need capital, labor and land inputs, which can freely move across sectors. For concreteness, we assume that consumption-goods production is less capital intensive and more land intensive than the investment sector.\(^2\) There is free trade in goods, but international movements of inputs are prohibited. All markets are perfectly competitive. Population is constant and its size equals \(L\).

\(^2\)This is without loss of generality. It can be shown that our main results also hold if consumption goods are less land intensive and/or more capital intensive than investment goods.
Infinitely-lived consumers discount future utility with the factor $\rho$, and have preferences only over consumption. In particular, their preferences are given by

$$\sum_{t=0}^{\infty} \rho^t \left( \frac{c_{t+1}^{1-\sigma} - 1}{1 - \sigma} \right), \quad \rho \in (0, 1), \quad \sigma > 0. \quad (1)$$

Individuals offer labor services and rent capital and land to firms. The total amount of land in the economy is fixed over time, equals $N$, and is uniformly distributed across all individuals. Since in each period international trade must be balanced, consumers in each country face the following budget constraint

$$c_t + p_t x_t = r_{kt} k_t + r_{nt} n_t + w_t, \quad (2)$$

where the evolution of capital is governed by

$$k_{t+1} = (1 - \delta) k_t + x_t. \quad (3)$$

In the above expressions, $c_t$ is the per capita demand for consumption goods; $x_t$ is the per capita demand for investment goods, whose price is $p_t$; $r_{kt}$, $r_{nt}$, and $w_t$ are, respectively, the rental rates on capital, land, and labor; $n_t$ and $k_t$ denote the amount of the natural input and capital owned by the individual at date $t$, respectively. The consumption good is the numeraire.

Consumers in each country will maximize $(1)$ subject to $(2)$ and $(3)$, taking as given the world output prices and the domestic rental rates for production factors. The Euler equation corresponding to this dynamic programming problem is standard:

$$\frac{c_{t+1}}{c_t} = \left[ \frac{p_t}{p_{t+1}} \rho \left( \frac{\overline{r}_{kt+1}}{p_{t+1}} + 1 - \delta \right) \right]^{1/\sigma}. \quad (4)$$

In each nation, production of the consumption good ($Y_{ct}$) is given by

$$Y_{ct} = AK_{ct}^\alpha N_{ct}^\beta L_{ct}^{1-\alpha-\beta} = AL_{ct}k_{ct}^\alpha n_{ct}^\beta, \quad \alpha, \beta \in (0, 1). \quad (5)$$

And manufacturing of the investment good ($Y_{xt}$) by

$$Y_{xt} = BK_{xt}^\theta N_{xt}^\gamma L_{xt}^{1-\theta} = BL_{xt}k_{xt}^\theta n_{xt}^\gamma, \quad \theta, \gamma \in (0, 1). \quad (6)$$

Above, $K_{it}$, $N_{it}$ and $L_{it}$ denote, respectively, the amount of capital and labor devoted in period $t$ to the production of good $i$; and $n_{it} = N_{it}/L_{it}$, $k_{it} = K_{it}/L_{it}$, for all $i = c, x$. In order to ensure that $c$-goods production is less capital intensive but more land
intensive, we need to assume that \( \theta (1 - \beta) < \alpha (1 - \gamma) \) and \( \beta (1 - \theta) > \gamma (1 - \alpha) \), respectively.

Denote the labor share in the production of good \( i \) by \( l_{it} = L_{it}/L \). Notice that because consumers are alike, the amount of capital and land owned by each individual will equal the country’s capital-labor and land-labor ratios, respectively. Hence, the constraints on labor, capital and land within a country can be written as follows:

\[
\begin{align*}
    l_{ct} + l_{xt} &= 1, \quad (7) \\
    l_{ct}k_{ct} + l_{xt}k_{xt} &= k_t, \quad (8) \\
    l_{ct}n_{ct} + l_{xt}n_{xt} &= n, \quad (9)
\end{align*}
\]

Firms in each country will maximize profits taking as given world prices and the domestic rental rates on production factors. From the production functions (5) and (6), production efficiency implies that

\[
\begin{align*}
    r_{kt} &= \alpha Ak_{ct}^{\alpha - 1} n_{ct}^\beta = p_t \theta B k_{xt}^{\theta - 1} n_{xt}^\gamma, \quad (10) \\
    r_{nt} &= \beta Ak_{ct}^{\alpha} n_{ct}^{\beta - 1} = \gamma p_t B k_{xt}^{\theta} n_{xt}^{\gamma - 1}, \quad (11) \\
    w_t &= (1 - \alpha - \beta) A k_{ct}^{\alpha} n_{ct}^{\beta} = (1 - \theta - \gamma) p_t B k_{xt}^{\theta} n_{xt}^{\gamma}. \quad (12)
\end{align*}
\]

Of course, these equalities will hold only for the technologies that coexist in equilibrium. More specifically, domestic firms will produce both goods if the international price of investment goods is in the interval \( [p_t^{\text{min}}, p_t^{\text{max}}] \), they will not produce investment goods if \( p_t \leq p_t^{\text{min}} \), and they will not produce consumption goods if \( p_t \geq p_t^{\text{max}} \). It is easy to show that the minimum and maximum price that define this diversification interval are, respectively:

\[
\begin{align*}
    p_t^{\text{min}} &= \frac{A}{B} \left( \frac{\alpha}{\theta} \right)^\theta \left( \frac{\beta}{\gamma} \right)^\gamma \left( \frac{1 - \alpha - \beta}{1 - \theta - \gamma} \right)^{1-\theta-\gamma} k_t^{\alpha - \theta} n^{\beta - \gamma} \quad (13) \\
    p_t^{\text{max}} &= \frac{A}{B} \left( \frac{\alpha}{\theta} \right)^\alpha \left( \frac{\beta}{\gamma} \right)^\beta \left( \frac{1 - \alpha - \beta}{1 - \theta - \gamma} \right)^{1-\alpha-\beta} k_t^{\alpha - \theta} n^{\beta - \gamma} \quad (14)
\end{align*}
\]

Let us focus on the diversified-production equilibrium, and define the relative factor prices \( \omega_{kt} = w_t/r_{kt} \) and \( \omega_{nt} = w_t/r_{nt} \). The efficiency conditions in production

\[\text{Equation (13)} \quad \text{[Equation (14)] is obtained forcing profits of x-goods [c-goods] firms to be positive when input prices are given by optimality conditions (10) to (12) for the c-goods [x-goods].}\]
(10) and (12) determine the optimal allocations of capital as a function of the relative factor price:

\[ k_{xt} = \left( \frac{\theta}{1 - \theta - \gamma} \right) \omega_{kt}, \]  
\[ k_{ct} = \left( \frac{\alpha}{1 - \alpha - \beta} \right) \omega_{kt}. \]  
\[ n_{xt} = \left( \frac{\gamma}{1 - \theta - \gamma} \right) \omega_{nt}, \]  
\[ n_{ct} = \left( \frac{\beta}{1 - \alpha - \beta} \right) \omega_{nt}. \]  

Similarly, (11) and (12) imply that

\[ y_t = l_{ct}y_{ct} + p_t l_{xt}y_{xt} = \frac{w_t}{1 - \theta - \gamma} \left[ 1 + l_{ct} \left( \frac{\alpha + \beta - \theta - \gamma}{1 - \alpha - \beta} \right) \right] \]  
\[ p_t = \frac{A}{B} \left( \frac{\alpha}{\gamma} \right) \left( \frac{\beta}{\gamma} \right) \left( \frac{1 - \alpha - \beta}{1 - \theta - \gamma} \right)^{1 - \gamma \beta - \theta} k_{xt}^{\alpha - \theta} n_{xt}^{\beta - \gamma}. \]  

Notice that under diversification, \( p_{min}(k_{ct}, n_{ct}) = p_{max}(k_{xt}, n_{xt}) = p_t \) for the market-equilibrium zero-profit condition to hold.

The above expressions apply to all economies, regardless of their level of development. Next, we describe the equilibrium focusing first on the early-bloomers and then on the late-bloomers.

3 The early-bloomers

Suppose that all but one of our small-open countries have already reached the steady-state. In addition, assume that all these early-blooming countries share the same endowments. In equilibrium, identical countries make the same choices. So the equilibrium for these economies will be the same as the equilibrium for a single large and closed economy, and it will not be affected by the behavior of the small (still developing) country. Therefore, we can write the world market clearing conditions for final goods as

\[ e_t = Al_{ct}k_{ct}^{\alpha}n_{ct}^{\beta}, \]  
\[ x_t = Bl_{xt}k_{xt}^{\theta}n_{xt}^{\gamma}. \]
On the steady-state equilibrium, early-bloomers diversify production, and variables in per capita terms, relative employment of inputs and prices will remain invariant. Denoting by an asterisk \((*)\) steady-state outcomes, the consumers’ optimality condition (4) implies that the interest rate in terms of investment goods at steady state is exclusively pinned down by consumers’ preferences:

\[
r_k^* = p^* \left[ \rho^{-1} + \delta - 1 \right].
\]

In addition, the appendix shows that the relative price is given by

\[
p^* = \frac{A}{B} \left( \frac{\alpha}{\beta} \right) \left( \frac{1}{1-\alpha-\beta} \right) \left( \frac{B\theta}{p^{\gamma + 1 - \gamma - 1}} \right) \left( \frac{\beta (1-\theta) - \gamma (1-\alpha)}{1-\gamma} \right) n^{\beta (1-\theta) - \gamma (1-\alpha)}.
\]

The result is quite intuitive. As \(c\) production becomes more profitable than \(x\) manufacturing because land is more abundant, the economy devotes relatively more resources to the production of consumption goods, making investment products relatively scarcer and, as a consequence, more expensive.

Recall that it must be the case that \(p^* = p_{\text{min}}(k_c^*; n_c^*) = p_{\text{max}}(k_x^*; n_x^*)\); and that \(n_c^* > n_x^*\) and \(k_c^* < k_x^*\) by assumption. These conditions will prove useful later in Section 5. Finally, an expression for \(y^*\) can be obtained from (19) using (7), (12), (26), (27) and (29).

4 The late-bloomer

Consider now the other small nation with the same land endowment as the early bloomers that starts developing later with an initial capital stock \(k_0 < \min\{k_c^*, k_x^*\}\), and is still moving along the adjustment path. We can think of this late-blooming nation as a developing country that faces the steady-state relative output price obtained above for the developed world – i.e., \(p_t = p^*\) for all \(t\). From here on, the asterisk \((*)\) denotes the international diversified-production equilibrium for the early-bloomers, whereas we remove the time subscript to denote the steady state values for the less developed country.

Along the adjustment path, the small developing country will accumulate capital until its domestic rate of return falls down to the world’s rate \(r_k^*\).\(^4\) The pattern of

\(^{4}\)In numerical analysis of the model, we have found that, for a wide set of reasonable parameter values, its transition is characterized by a one-dimensional stable saddle-path that implies that the adjustment path is asymptotically stable and unique.
production along this adjustment path will be determined by expressions (13) and (14). In a steady state diversified production equilibrium, equations (10) to (12), and (23) imply that the long-run capital-labor ratio in the investment sector will equal the one of the world economy, $k_x = k_x^*$. This and expressions (15) to (18) and (23) guarantee that, in the long run, international factor-price equalization holds, and that the country will be using the same techniques as the rest of the developed nations; that is, $k_c = k_c^*$, $w = w^*$, $n_c = n_c^*$, $n_x = n_x^*$ and $r_n = r_n^*$.

5 Does the Timing of Development Matter?

Now, we answer the key question of whether the time when an economy starts its development path towards the steady state affects its long-run performance. For that purpose, it is interesting to briefly recall first why late-blooming nations can remain permanently poor in the more standard dynamic Heckscher-Ohlin model.5

Suppose that land is not present in the model, that is, $\beta = \gamma = 0$. Because $k_0 < \min\{k_c^*, k_x^*\}$, the developing nation starts its development path specialized in c-goods production. From (5), this means that output per capita is given by $y_t = A k_0^\alpha$. As explained above, the economy will continue accumulating capital until $r_{kt} = r_k^*$, which is pinned down by preferences. Notice that this equality will hold as soon as $k = k_c^*$, and that for this capital stock the specialization condition $p^* \leq p_{\min}(k)$ will hold because $p^* = p_{\min}(k_c^*)$. Hence, $k < k^* \in (k_c^*, k_x^*)$, and $y < y^*$.

To fully understand the reason, consider a late-bloomer that starts its development path diversifying production with $k_0 \in (k_c^*, k_x^*)$. This economy is already in long-run equilibrium. It just needs to choose $l_x$ such that $(1 - l_x)k_c^* + l_x k_x^* = k_0$, and the return to capital already equals the one of the rest of the world. But if $k_0 < k^*$ then $y < y^*$; that is, the late bloomer remains permanently poorer.

Let us go back to our case, and consider strictly positive values of $\beta$ and $\gamma$. In the long-run, all economies regardless of their timing of development will face the same equilibrium price $p^*$ and the same interest rate $r_k^*$. Suppose first that the late-bloomer is diversifying production at the steady state. The late-bloomer will end up using the same production techniques as the rest of the world, $k_i = k_i^*$ and $n_i = n_i^*$ ($i = c, x$). In addition, because the developing economy has the same land endowment as early-blooming nations, it will have the same long-run labor allocation, $l_c = l_c^*$, by

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equilibrium conditions (7) and (9), and the same long-run income $y$ by (19).

The only scenario in which the developing economy can remain permanently poorer is, therefore, long-run specialization. Because $k_0 < \min \{k_c^*, k_x^*\}$, the developing nation starts its development path specialized in $c$-goods. Long-run international interest-rate equalization means that $r_k = r_k^*$, and then $k = k_c^*(n/n_c^*)^{\beta/(1-\alpha)}$ by (10). The issue is whether this capital stock is consistent with the specialization condition $p^* \leq p_{\min}$. Remember that we can write $p^* = p^{\min}(k_c^*; n_c^*)$ by (13). Hence, the last inequality becomes $p^{\min}(k_c^*; n_c^*) \leq p^{\min}(k; n)$, which implies that $k \leq k_c^*(n/n_c^*)^{(\beta-\gamma)/(\theta-\alpha)}$. The assumption that $c$-goods are more land intensive, in turn, implies that $n_{ct} > n_{xt}$ for all $t$; as a result, $n/n_c^* < 1$. Simple algebra, then, leads to the conclusion that the two conditions for $k$ are compatible if and only if $\beta (1 - \theta) \leq \gamma (1 - \alpha)$. However, the same assumption requires that $\beta (1 - \theta) > \gamma (1 - \alpha)$, which is a contradiction. Therefore, the developing economy always enters the diversification cone before arriving at long-run equilibrium and, because of that, converges to the income levels of the identical early bloomers. All you need is that both types of nations that differ only in the timing of development face the same prices at steady state.

6 Conclusion

In a dynamic two-sector Heckscher-Ohlin model with land we have shown that two small open economies with identical land-labor endowments will have the same long-run income independently of their timing of development. It is the property that land is an input in fixed supply that drives this result. A main feature of this scenario of international trade and growth is that the return on capital in poor and rich countries is equalized at steady state. When land is not present, this makes possible that a late-blooming economy with a lower capital stock than the rest of the world reaches a long-run equilibrium in which it remains permanently poorer. The reason is that it can use the world-wide optimal techniques by simply allocating more labor than rich nations to the less capital intensive activity. Adding land as a factor of production, however, eliminates this possibility: a fixed supply of land implies that identical economies have to allocate the same amount of labor across activities.
References


A Obtaining expression (24)

From (7), (8), (15) and (16), it is possible to write $k_t$ as a function of $k_{xt}$ and $l_{xt}$:

$$k_t = k_{xt} \left[ (1 - l_{xt}) \frac{(1 - \theta - \gamma)\alpha}{\theta(1 - \alpha - \beta)} + l_{xt} \right].$$  

(25)

From (7), (9), (17) and (18) it follows that

$$n = n_{xt} \left[ (1 - l_{xt}) \frac{(1 - \theta - \gamma)\beta}{\gamma(1 - \alpha - \beta)} + l_{xt} \right].$$  

(26)

It is also possible relating $n_{xt}$ and $k_{xt}$. In particular, equation (10) implies that

$$n_{xt} = \frac{r_k k_{xt}^{(1-\theta)}}{p_t \rho \theta}^{1/\gamma}.$$  

(27)

Using (22) and (10), we can write output of investment goods as a function of the interest rate and capital, the resulting expression for investment output must satisfy the steady state condition of (3):

$$\delta k^* = \frac{r_k^*}{p^* \theta} l_k^* k_x^*.$$  

(28)

Then using (25) we can solve for the steady state labor allocation in the investment sector:

$$l_x^* = \frac{\delta (1 - \theta - \gamma) \alpha}{(1 - \alpha - \beta) (\rho^{-1} - 1) + \delta ((1 - \beta) (1 - \theta) - \alpha \gamma)}.$$  

(29)

Substituting this result into (26) we can solve for $n_x^*$, which yields from (26) and (23) the value of $k_x^*$. Finally, taking the resulting expressions for $n_x^*$ and $k_x^*$ into (20) give (24).