PATHS OF DEVELOPMENT IN OPEN ECONOMIES: THE ROLE OF LAND*

María Dolores Guilló and Fidel Pérez-Sebastián**

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Corresponding author: Mª D. Guilló: Universidad de Alicante, Departamento de Fundamentos del Análisis Económico, Campus de San Vicente s/n, 03690 Alicante, Spain E-mail: guillo@merlin.fae.ua.es

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** Mª D. Guilló: Universidad de Alicante; F. Pérez-Sebastián: Universidad de Alicante. E-mail: fidel@merlin.fae.ua.es

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ABSTRACT

This paper shows, within a Heckscher-Ohlin version of the two-sector neoclassical growth model, that land, besides having long-run effects, is also a main determinant of the speed of convergence toward the steady state when there are cross-sector capital share differences. This result stands in sharp contrast to the predictions of standard neoclassical growth frameworks, and calls for a reinterpretation of the conditional-convergence and the resource-curse findings. More specifically, the model predicts that the former finding requires the existence not only of diminishing returns but also of relatively small differences in capital shares across sectors. With respect to the latter finding, our results imply that it may be a consequence of purely transitional effects of natural riches on growth, and that it can not be interpreted as evidence that natural inputs necessarily harm long-run welfare. We produce empirical evidence on the relationship between land, income levels, and growth rates, and present data on cross-sector capital shares. We claim that most of that evidence is consistent with the predictions of the model.

Keywords: Small-Open Economy, land, long-run income, convergence speed

JEL Classification: O41, F43.

1 Introduction

Standard neoclassical growth models imply that differences in labor productivities affect only the position of a country along the development process. In other words, they predict that country-specific factors not related to "deep" parameters have only long-run effects with no influence on the speed of convergence. In sharp contrast to these predictions, this paper shows, within an open-economy version of the two-sector neoclassical growth framework, that a country's relative land endowment, besides having a long-run effect, is also a main determinant of the speed of convergence when there are cross-sector capital share differences. Furthermore, the long-run effect and the transitional effect of land can go in opposite directions. As a consequence, if two economies start with the same income level but have different land endowments, the economy that approaches a balanced-growth path with larger income levels can show lower average growth rates along most of the transition path.

Besides the theoretical appeal, these results are interesting because they call for a reinterpretation of two of the main empirical regularities about post-WWII cross-country economic growth: the conditional convergence and the resource curse findings. Barro (1991) shows that, after controlling for differences in long-run income levels, poorer economies tend to grow faster than richer ones. That is, he finds conditional convergence in the cross section of nations. The main theoretical explanation for this empirical regularity comes from the standard neoclassical growth framework. Which establishes that, if the degree of economic integration across nations is low, diminishing returns over accumulable inputs generate a decreasing income growth-rate path as economies approach their long-run income levels. Our model predictions, on the other hand, tell that the existence of diminishing returns are necessary, but may not be sufficient to explain the evidence in favor of conditional convergence found in the literature. The model implies that the conditional convergence finding requires as well the existence of production technologies that exhibit capital shares that do not vary much across activities.

Another important regularity affected by our model results is that natural-resources usually appear as a curse in the cross section of countries. In particular, Sachs and Warner (2001), among others, find that natural riches tend to slow down rather than promote economic growth. Most current explanations for the curse have a crowding-out logic. For example, Matsuyama (1992) and Galor and Mountford (2004) emphasize that a larger natural endowment can reduce the incentives to allocate resources to more growth-enhancing activities such as manufacturing and education, generating permanent differences in growth rates across countries. Most explanations then interpret the finding as evidence that natural resources harm growth and long-run income. We show that this does not need to be the case, because the empirical finding might be capturing just a transitional effect. In our model, natural riches can be a short-run curse for growth but a long-run blessing for income.[1]

Our setup is similar to Atkeson and Kehoe's (2000). 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 model with consumption and investment goods, extended to include land as a specific factor in the consumption sector. The two sectors can have different input intensities. All Nations posses identical preferences and production technologies, but they may differ regarding their land endowment. Some countries, the developed world, have already reached their steady states, while other countries begin to develop.

In the model, cross-sector differences in labor elasticities drive the effect of land on steady-state income, whereas differences across sectors in capital-input shares drive the land impact on the convergence speed. In particular, a larger land endowment leads to higher long-run welfare levels if the investment-goods are more capital intensive. However, if the consumption-goods sector is relatively labor intensive, a larger stock of land has such a negative influence on capital accumulation that leads the economy to permanently lower income. The model also predicts that land speeds up convergence if investment goods are relatively capital intensive; land reduces the speed of convergence otherwise. These pervasive negative effects of land only arise if the economy transfers resources from one sector to the other, and their capital shares differ. When the economy specializes in production, or capital shares are the same, it behaves as a one-sector model in the sense that steady-state output always increases with land, and the speed of convergence is independent of the natural stock.

An additional interesting result is that the model with land prevents a developing economy from remaining permanently poorer than a developed country with the same

[1] Our results could help, for example, to reconcile the contradictory evidence found by Sala-i-Martin (1997) and Doppelhofer *et al.* (2004). Consistent with the resource curse tradition, they estimate a significant negative correlation between the fraction of primary exports on total exports and growth. But, at the same time, they find a strong positive association between the fraction of GDP in Mining and growth. In our model, the sign of the effect of the natural input on growth depends on the position of the country along its development path.

land endowment. This is in contrast to the predictions of the standard dynamic two-sector Heckscher-Ohlin model. In particular, Atkeson and Kehoe (2000) show that, in this last framework, developing countries that are identical to developed nations in all aspects except for the capital stock remain permanently poorer. The difference between the two models is due to the uniqueness of the aggregate capital-labor ratio compatible with a given return to capital in the model with land. More specifically, when the return to capital has converged across economies, different capital-labor ratios and income per capita levels are possible in the standard two-sector model through cross-sector input movements. However, the specificity of land to one industry implies that only one 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 related papers that present models of international trade and growth are Ventura (1997) and Mountford (1998).[2] They use more or less standard two-sector neoclassical growth models. Our model shares with them that the main results are driven by the flow of resources across domestic sectors. Flow that in open economies is not constrained by potentially low elasticities of domestic demand, because world markets are assumed to be relatively large. However, they do not consider industry-specific inputs.

As us, Ventura (1997) reinterprets the conditional convergence finding. He shows that one can not use the conditional convergence result as sole evidence of diminishing returns. He finds that when economies are integrated and factor prices per efficiency unit are equalized across countries, diminishing returns are not sufficient to guarantee conditional convergence among nations. In his model, besides diminishing returns, it is necessary a sufficiently large elasticity of substitution between capital and labor to make poorer countries grow faster than rich ones, holding constant differences in labor productivity. Unlike him, we use Cobb-Douglas production functions with a unitary elasticity of substitution, and maintain the international relative price of

[2] Within closed-economy scenarios, recent literature such as Caselli and Coleman (2001), Galor, Moav and Vollrath (2005), and Gollin, Parente and Rogerson (2002a,b) have already emphasized the importance of land in the growth and development process of real economies. Land is a peculiar production factor because is non-mobile, its supply is fixed, and its use is specific to some sectors such as agriculture. Exploiting these peculiar characteristics, the above papers propose land as a main determinant of the industrialization-process take-off, and cross-country labor-productivity and income differences. Other papers include Kögel and Prskawetz (2001), Hansen and Prescott (2002), and Restuccia, Yang and Zhu (2004).

goods constant. In this way, we guarantee that the forces that drive Ventura's (1997) results are absent in our model.

The paper provides as well empirical evidence in favor of the model's main prediction that a country's relative land endowment can have a significant transitional effect on growth. In particular, we follow Mankiw, Romer and Weil (1990) (MRW), and run steady-state level and growth regressions. We consider a cross-section of 85 nations for the period 1967 to 1996. We find the typical MRW result that investment rates, average educational attainment, and population growth rates can explain about 76% of the cross-country output variance, with no improvement when we introduce land. However, in the growth regression, the introduction of land significantly improves the explanatory power of the regression, even when we control for potential endogeneity problems. More specifically, the estimates reveal that land has a negative impact on the convergence speed. This is consistent with our model if consumption-goods production has a larger capital elasticity than investment-goods manufacturing. We provide data on capital shares, and claim that the evidence supports this view, even though the growth literature has typically assumed the opposite.

The rest of the paper is organized as follows. Section 2 describes the economic environment. Section 3 studies the developed-world's diversified production equilibrium. Sections 4 analyzes the effect of a nation's land endowment on its development path. A numerical exploration of the model predictions is carried out in section 5. Section 6 presents the empirical evidence. Section 7 concludes.

2 The Economy

Consider a world economy consisting of a large number of small open economies that differ only in their land input endowment and in their level of development. There are two goods, and three inputs of production. The production of the consumption and the investment goods needs capital and labor inputs, which can freely move across sectors. In addition, the consumption-goods sector uses a specific factor, land. 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.

Infinitely-lived consumers discount future utility with the factor ρ, and have preferences only over consumption. In particular, their preferences are given by

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

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

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

where the evolution of capital is governed by

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

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 own 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 programing problem is

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

It is standard. It says that the growth rate of consumption depends on the present-utility value of the rate of return to saving. This return reflects that giving up a unit of present consumption allows today buying $1/p_t$ units of the investment good that, after contributing to the production process, will covert themselves tomorrow in $1 + r_{kt+1}/p_{t+1} - \delta$ units that can be sold at a price p_{t+1}.

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

$$Y_{ct} = A K_{ct}^{\alpha} N^{\beta} L_{ct}^{1-\alpha-\beta} = A L_{ct} k_{ct}^{\alpha} n_{ct}^{\beta}, \quad \alpha, \beta \in (0,1). \tag{5}$$

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

$$Y_{xt} = B K_{xt}^{\theta} L_{xt}^{1-\theta} = B L_{xt} k_{xt}^{\theta}, \quad \theta \in (0,1). \tag{6}$$

Above, K_{it} and L_{it} denote, respectively, the amount of capital and labor devoted in period t to the production of good i; and $n_{ct} = N/L_{ct}$, $k_{it} = K_{it}/L_{it}$, for all $i = c, x$.

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 own by each individual will equal the country's capital-labor ratio. Hence, the constraints on labor and capital within a country can be written as follows:

$$l_{ct} + l_{xt} = 1, \tag{7}$$

$$l_{ct}k_{ct} + l_{xt}k_{xt} = k_t. \tag{8}$$

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), and assuming that capital and labor can freely move across sectors, production efficiency implies that

$$\begin{aligned} r_{kt} &= \alpha A k_{ct}^{\alpha-1} n_{ct}^{\beta} = p_t \theta B k_{xt}^{\theta-1}, & (9) \\ r_{nt} &= \beta A k_{ct}^{\alpha} n_{ct}^{\beta-1}, & (10) \\ w_t &= (1-\alpha-\beta) A k_{ct}^{\alpha} n_{ct}^{\beta} = (1-\theta) p_t B k_{xt}^{\theta}. & (11) \end{aligned}$$

Of course, these equalities will hold only for the technologies that coexist in equilibrium. The following two results establish the firms that open in equilibrium.[3]

Proposition 1 *For any wage rate w_t and capital rental rate r_{kt}, it is profitable to operate the consumption technology.*

Proposition 2 *Domestic firms will enter the investment-goods market if and only if*

$$\hat{p}_t > \frac{A}{B}\left(\frac{\alpha}{\theta}\right)^{\theta}\left(\frac{1-\alpha-\beta}{1-\theta}\right)^{1-\theta} n^{\beta}\hat{k}_t^{\alpha-\theta}; \tag{12}$$

where $n = N/L$; and $\hat{p}_t$ and $\hat{k}_t$ denote equilibrium values when only consumption goods are produced in the domestic economy.

The right side of expression (12) determines a minimum price above which it becomes profitable for investment-goods producers to enter the market. This minimum price depends on the relative endowment of land, the stock of capital per capita,

[3] The proofs of the propositions presented in the paper are contained in appendix A.

and factor intensities, let us denote it by $p^{\min}(k_t; n)$. An small open economy then specializes in the production of c goods if $p^{\min}(k_t; n)$ is greater than or equal to the international price p_t. More specifically, closing the investment-products sector becomes more appealing as n increases and as p_t declines or, in other words, as the consumption-goods activity becomes relatively more productive for given k_t. Larger values of k_t have the same effect as larger stocks of n when the share of capital is greater in the consumption sector, but they have the opposite effect when the share of capital is larger in the investment sector. In addition, notice that under diversification, $p^{\min}(k_{ct}; n_{ct})$ must equal the international price level p_t at every point in time t for the market-equilibrium zero-profit condition to hold, a property that will prove helpful in our analysis.

We conclude that consumption items will always be supplied by domestic producers because they require a specific factor that is in positive supply. The economy, however, may not manufacture investment goods. This will depend on prices, and on the economy's endowments of land and capital relative to labor.

3 The Developed-World's Diversified-Production Equilibrium

Suppose that all but one of these countries have already reached the steady-state. We can think of this group of nations as the developed world. In addition, assume that all developed countries share the same endowments. Next, we study the steady-state allocations of the developed world.

In equilibrium, identical countries make the same choices. So the equilibrium for this developed world economy 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

$$c_t = A l_{ct} k_{ct}^{\alpha} n_{ct}^{\beta}, \quad (13)$$

$$x_t = B l_{xt} k_{xt}^{\theta}. \quad (14)$$

In equilibrium, the world economy will produce positive amounts of both goods. Define the relative factor price $\omega_{kt} = w_t / r_{kt}$. The efficiency conditions in production (9) and (11) determine the optimal allocations of capital as a function of the relative factor price:

$$k_{xt} = \left(\frac{\theta}{1-\theta}\right)\omega_{kt}, \tag{15}$$

$$k_{ct} = \left(\frac{\alpha}{1-\alpha-\beta}\right)\omega_{kt}, \tag{16}$$

It follows from (15) and (16) that consumption goods will be more capital intensive if and only if $\theta(1-\beta) < \alpha$, and that $k_{ct} > k_{xt}$ if $\alpha > \theta$. We next determine the labor allocations. Equations (9), (15) and (16) imply

$$l_{ct} = n\left[\frac{A\alpha^{\alpha}(1-\alpha-\beta)^{1-\alpha}}{B\theta^{\theta}(1-\theta)^{1-\theta}}\left(\frac{\omega_{kt}^{\alpha-\theta}}{p_t}\right)\right]^{\frac{1}{\beta}}. \tag{17}$$

The labor share l_{ct} depends negatively on the relative output price and positively on the per capita amount of land. The labor share is also affected by the relative input price of labor to capital, but the effect of this price on l_{ct} will depend on the relative capital shares across sectors. The effect will be positive if $\alpha > \theta$, and negative otherwise. From (17), we can obtain as a residual the labor allocation l_{xt}, using the economy's labor constraint (expression (7)).

Let us now focus on the steady-state equilibrium path. Over there, 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

$$r_k^* = p^*\left[\rho^{-1}+\delta-1\right]. \tag{18}$$

The interest rate in terms of investment goods at steady state is exclusively pin down by consumers' preferences.

Using the expression for r_k^* and condition (9), we obtain the steady state capital-labor ratio in investment-goods production:

$$k_x^* = \left(\frac{\theta B}{\rho^{-1}+\delta-1}\right)^{\frac{1}{1-\theta}}. \tag{19}$$

Equations (15), (16), (18) and (19) determine the values of the relative factor prices and the capital-labor ratio in the consumption-goods sector at the steady state equilibrium. Notice that, at the world's diversified-production equilibrium, the steady state capital-labor ratios do not depend on the natural resource endowment. This occurs because k_c and k_x are a function of factor intensities and the relative factor price ω_{kt}, but at the steady state ω_k^* is exclusively determined by consumers' preferences and factor intensities in the x sector.

The aggregate stock of capital in the economy can be derived from equations (3), (9), (14) and (18). At steady-state,

$$k^* = \left(\frac{\rho^{-1} + \delta - 1}{\theta\delta}\right) l_x^* k_x^*. \tag{20}$$

Clearly, the stock of capital must be completely split among its different uses given, in relative terms, by equation (8). This market-equilibrium condition determines p^*. More specifically, combining equations (7), (8), (15), (16), (17), (19) and (20), we obtain

$$p^* = \frac{\left(\frac{1-\alpha-\beta}{1-\theta}\right)^{1-\alpha} \left(\frac{\alpha}{\theta}\right)^{\alpha}}{\frac{B}{A}\left(\frac{\theta B}{\rho^{-1}+\delta-1}\right)^{\frac{\theta-\alpha}{1-\theta}}} \left\{1 + \frac{\alpha\delta\left(1-\theta\right)}{\left(1-\alpha-\beta\right)\left[\rho^{-1}+\delta\left(1-\theta\right)-1\right]}\right\}^{\beta} n^{\beta}. \tag{21}$$

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.

Another important variable that we are particularly interested in is aggregate output, defined as the weighted sum of consumption- and investment-goods production,

$$y_t = l_{ct} y_{ct} + p_t l_{xt} y_{xt}. \tag{22}$$

Using expressions (5) to (7), (9), (15) and (16), and taking into account that $\omega_{kt} = w_t / r_{kt}$, we can write a developed nation's GDP level per capita as

$$y_t = \frac{w_t}{1-\theta}\left[1 + l_{ct}\left(\frac{\alpha+\beta-\theta}{1-\alpha-\beta}\right)\right]. \tag{23}$$

It is interesting to note that the economy's GDP can decrease with a larger allocation of labor into the production of consumption items if this activity is more labor intensive than investment-goods manufacturing. From expression (23), we can use (15), (17) to (19), and (21) to obtain y^*.

We have derived the equations that characterize the diversified equilibrium, and obtained the steady-state for the developed world. Next, we focus on the adjustment paths implied by the model for developing nations.

4 Development Paths

Consider now the other small nation that is still moving along its adjustment path and suppose that it has initially a capital stock $k_0 < \min\{k_c^*, k_x^*\}$. 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 world economy, whereas we remove the time subscript to denote the steady state values for the less developed country. The next proposition describes the initial pattern of production of the latter economy.

Proposition 3 *Let k^d be the value that solves the equation $p^* = p^{\min}(k^d; n)$. In particular,*

$$k^d = k_c^* \cdot \left(\frac{n/n^*}{1 + \frac{\alpha\delta(1-\theta)}{(1-\alpha-\beta)(\rho^{-1}+\delta(1-\theta)-1)}} \right)^{\beta/(\theta-\alpha)} . \tag{24}$$

A less developed country with a land/labor endowment equal to n and with an initial capital/labor ratio given by k_0 will initially diversify production if $k_0 > k^d$ for $\alpha < \theta$, or if $k_0 < k^d$ for $\alpha > \theta$. It will specialize in consumption-goods production otherwise.

Let us now study, separately, the development paths for each of the two possible initial scenarios: specialization and diversification.

4.1 *The diversified-production case*

Suppose first that $\theta > \alpha$. As mentioned above, the late-bloomer starts its development path diversifying production if $k_o > k^d$. In this case it continues to produce both goods at all times in the future since its $p_t^{\min}$ decreases with k_t and the world price is fixed at p^*. That is, it will diversify production and accumulate capital until its rental rate falls down to the world's rate r_k^*, which is by equation (18) exclusively determined by consumers' preferences and p^*. Next, notice that equations (15) to (19) describe the behavior of all our economies, regardless of their resource endowment, as long as they lie within the diversification cone. Therefore, at the steady state, expressions (15) to (19) imply that $k_x = k_x^*$, $\omega_k = \omega_k^*$, and $k_c = k_c^*$. And from expressions (9) to (11), $n_c = n_c^*$, $r_n = r_n^*$, and $w = w^*$. In sum, in the long run, factor-price equalization will hold, and the country will be using the same techniques as the rest of developed nations. Notice that we obtain factor-price equalization because the x-goods technology only uses mobile-factors, and pins down the relative factor prices for the whole economy.

Suppose now that $\theta < \alpha$. In this case, at the world's diversified production equilibrium, we have that $k_x^* < k^* < k_c^*$, and the late-bloomer starts its development path diversifying production if $k_o < k^d$. Now $p_t^{\min}$ increases with k_t and so switching to specialization cannot, in principle, be ruled out. However, taking into account that $k_o < k_x^*$, it is easy to show that diversification will continue at all times in the future whenever its land/labor endowment n is not too large relative to n^*. To see this, note that under these conditions expression (24) implies that $k^d > k_c^*$.

The difference with the world economy will come regarding the overall capital stock of the developing nation and the labor allocations. Notice that the equality $n_c = n_c^*$ implies that a lower endowment of land will make optimal to allocate a lower fraction of labor to consumption-goods production. That is, if n is lower than the devoloped world's average n^*, then $l_c < l_c^*$. In that case, expressions (8), (15) and (16) evaluated at the steady state, imply that $k > k^*$ if $\theta > \alpha/(1-\beta)$, and $k < k^*$ if $\theta < \alpha/(1-\beta)$. On the other side, if n is greater than n^*, we have that $l_c > l_c^*$ and the opposite effects follows for k. That is, a relatively land-abundant nation achieves a steady-state stock of capital that is larger (smaller) than the world's average if consumption-goods are relatively more (less) capital intensive.

The next proposition summarizes the main results.

Proposition 4 *Suppose a small late-blooming nation with $k_0 < \min\{k_c^*, k_x^*\}$ that starts its development process producing positive amounts of both goods. Then, for all k_c and k_x, it stays in a diversified-production equilibrium at all times and accumulates capital until factor-price equalization holds if $\alpha < \theta$. But if $\alpha > \theta$, then it will diversify production in the long run only if n/n^* is not too large. Under a diversified production equilibrium, the country's steady-state income y will decrease with n if the share of labor in consumption-goods production is larger than in investment-goods manufacturing; y will increase with n otherwise.*

Figure 1 illustrates the above development paths. It shows the phase diagram of the dynamic system in the plane (k, c), for given n, for the developing nation, assuming that $\alpha < \theta$. The CC schedule represents the Euler equation for consumption when c is stationary. From equations (4), (7) to (9), (15) and (16), we have that the

CC line represents

$$\frac{c_{t+1}-c_t}{c_t}=\rho^{\frac{1}{\sigma}}\left[\theta B\left(\frac{\theta}{1-\theta}\right)^{\theta-1}\omega_{kt}^{\theta-1}+1-\delta\right]^{\frac{1}{\sigma}}-1=0; \tag{25}$$

where ω_{kt} is implicitly given by

$$p^*=\left[\frac{n\omega_{kt}^{\frac{\alpha-\theta}{\beta}}}{\frac{(1-\alpha-\beta)(1-\theta)}{\alpha-\theta(1-\beta)}\left(\frac{k_t}{\omega_{kt}}-\frac{\theta}{1-\theta}\right)}\right]^{\beta}\frac{A\alpha^{\alpha}(1-\alpha-\beta)^{1-\alpha}}{B\theta^{\theta}(1-\theta)^{1-\theta}}. \tag{26}$$

The KK schedule comes from the capital motion equation, expression (3), when this variable is stationary, and is composed of two different pieces. To the left of k^d, the economy specializes and then investment equals $p^*x_t=y_{ct}-c_t$. To the right of k^d, the economy diversifies and $p^*x_t=y_t-c_t$. With diversification, the line is less concave because the reallocation of resources between sectors ameliorates the effect of diminishing returns to capital accumulation. From equations (3), (5) to (8), (11), (15) and (23), the KK line is given by

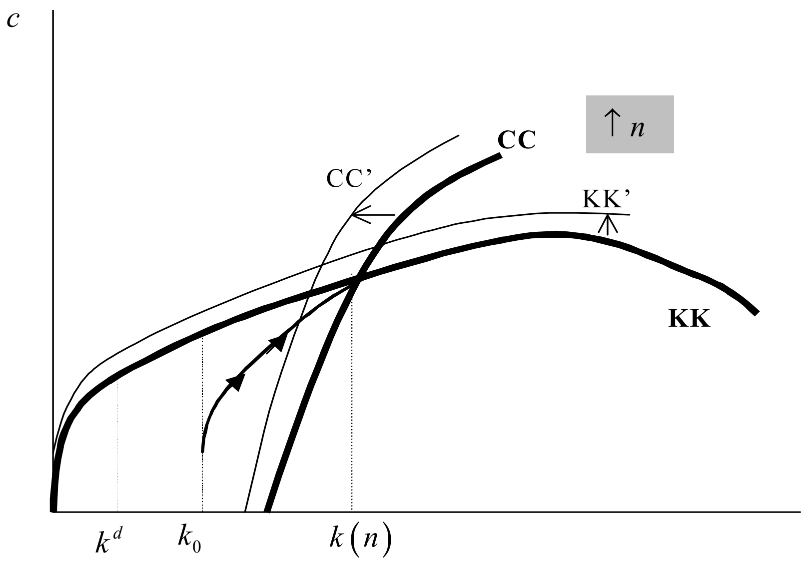
$$k_{t+1}-k_t=\left(\frac{y_t-c_t}{p^*}\right)-\delta k_t=0; \tag{27}$$

where

$$\begin{aligned} y_t &= Ak_t^{\alpha}n^{\beta} \quad \text{if } k_t\le k^d; \\ &= p^*B\left(\frac{\theta}{1-\theta}\right)^{\theta}\omega_{kt}^{\theta}\left[1+\frac{(\alpha+\beta-\theta)(1-\theta)}{\alpha-\theta(1-\beta)}\left(\frac{k_t}{\omega_{kt}}-\frac{\theta}{1-\theta}\right)\right] \quad \text{if } k_t>k^d. \end{aligned}$$

The phase diagram in Figure 1 looks very much like the one in a standard Cass-Koopmans one-sector model. In our case, the steady state solution depends on the value of n. Assuming that investment goods are more capital intensive (i.e., $\theta(1-\beta)>\alpha$), an increase in n will shift the curve KK upwards and the curve CC to the left. To understand the last statement, note that an increase in n will increase income for any given capital, so consumption must rise to control the flow of investment and keep capital stationary (the curve KK shifts upwards). Similarly, an increase in n implies an increase in the share of labor allocated to the consumption sector to keep marginal productivity at the steady-state interest rate level. This, in turn, requires a lower stock of capital for any given level of consumption (the CC locus shifts to the left). As a result of these shifts, the new steady state levels of capital and consumption could be above or below the former ones. We know that the

Figure 1: The case of diversified production



steady state level of capital decreases with land, so the new capital stock must be to the left of $k(n)$; but with respect to consumption, the new steady state level will be below $c(n)$ only if we assume that the consumption sector is more labor intensive than the investment sector.[4]

4.2 *The specialized-production case*

The late-bloomer starts its development path specializing in consumption goods if $k_o \leq k^d$ when $\alpha < \theta$, or if $k_o \geq k^d$ when $\alpha > \theta$. The scenario of specialization has also very interesting implications for the path of development. Unlike in the standard dynamic Heckscher-Ohlin model without an immobile factor, the late bloomer does not necessarily end up in a specialized-production steady-state equilibrium.

A small developing country that initially produces only consumption goods will remain specilized in the long-run if $\alpha > \theta$. The reason is that, in this case, $p^{\min}(k_t; n)$ increases with k_t and p^* is fixed. But if $\alpha < \theta$, at some point in the future the small economy can start manufacturing the investment good and remain inside the diversification cone thereafter. The reason is that now $p^{\min}(k_t; n)$ decreases with

[4] The phase diagram for $\alpha > \theta$ would be very similar. The main difference being that we would have the less concave diversification piece to the left of k^d, and specialization would occur to the right of k^d.

k_t and it becomes more likely that $p^{\min}$ falls below p^*. Nevertheless, whether the developing country remains specialized in the long run will depend crucially on its endowment of the specific factor relative to the developed world's.

Consider the situation where the developing nation is specialized in the long run. The economy accumulates capital through imports of investment goods, with $k_t = k_{ct}$ and $l_{ct} = 1$ for all t, until the domestic rate of return on capital equals the world's rate, $r_k = r_k^*$. At that point, the firms' efficiency condition (9), and the world's production techniques, n_c^* and k_c^*, imply that

$$k = \left(\frac{n}{n_c^*}\right)^{\frac{\beta}{1-\alpha}} k_c^*. \tag{28}$$

For this specialized-production situation really to be an equilibrium for the late-blooming country, it must be also true that domestic investment-goods firms do not find profitable to operate. That is, that condition (12) does not hold when capital is given by (28). Substituting (28) into (12), we can easily find that the late-bloomer will never diversify production in the long run if its relative land endowment satisfies

$$n \geq n_c^*. \tag{29}$$

If the nation converges to a specialized-production equilibrium, conditions (29) and (28) imply that $k \geq k_c^*$. Note that this inequality implies that $k > k^*$ when consumption goods are more capital intensive than investment goods. Moreover, under specialization, both the long-run capital-labor ratio and income level are positively related to n, because an increase in land endowment can no longer induce a resource stealing effect on other sectors. Therefore, for n sufficiently large, the specialized country can accumulate enough capital so that its long run level of income, $y = An^\beta k^\alpha$, be above the developed world's average.

Suppose now that condition (29) is not satisfied and that $\alpha < \theta$. Then, it follows that the late-blooming economy with $k_0 \leq k^d$ will switch to diversified production at some point in time $t > 0$, when k_t is still smaller than its steady-state level. Once the economy enters its diversification cone, it will stay there thereafter and the results established in proposition 3 will hold.

Proposition 5 *Suppose a small open-economy that initially specializes in consumption-goods production. Then, specialization will persist in the long-run if $\alpha > \theta$ or if $\alpha < \theta$ and $n \geq n_c^*$. Contrary to the diversified-production scenario, under specialization the country's long-run income per capita always rises with the land endowment.*

4.3 *Does the timing of development matter?*

Let us finish this section by analyzing whether in our model a developing economy can remain permanently poorer than an advanced nation with the same relative land endowment. Put differently, we are asking whether the time when an economy starts its development path towards the steady state matters. As Atkeson and Kehoe (2002) show, it does in the dynamic Heckscher-Ohlin version of the neoclassical two-sector model. The reason is that a late-bloomer that begins with less capital per capita than the world economy accumulates capital until factor prices are equalized across nations. At that point, the late-bloomer has a lower capital stock than the world economy, but it has already reached its long-run equilibrium. This occurs because, with less capital, it can still use the world-wide optimal techniques, by simply allocating more labor than the rich nations do to the less capital intensive activity.

However, this result is not possible in our framework since the steady-state fraction of labor that goes to each sector is exclusively pinned down by the size of the land/labor endowment. The consequence is that two identical nations allocate the same fraction of labor between sectors in the long-run, and then end up with the same capital and income levels, regardless of their timing of development, and regardless of their initial trade pattern.

To better understand this result, let us compare, in more detail, the steady-state outcome reached by the less developed country (i.e., the late-bloomer) with that of an advanced nation (i.e., an early-bloomer) that has the same land/labor endowment as it has. Let us also open the possibility that this particular advanced nation may have a different land endowment than the rest of the developed world. In addition, suppose that the developing nation possesses the same initial capital as the early-bloomer had when it started to develop. 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^*. Therefore, both will end up with the same long-run value of n_c. But if they have the same n_c, the characteristics of the long-run equilibrium described in propositions 3 and 4 hold as well for the advanced economy. In particular, both countries end up with the same level of income at the steady state. Whether they diversify production or not at the steady state will depend only on their land endowment, which by assumption is identical. If their n is smaller than n_c^*, they diversify, and at steady-state both of them will use the same techniques n_c^*, k_c^* and k_x^*. In addition, since n is fixed, the steady state fraction of labor devoted to consumption-goods production l_c will also be the same in both economies, and therefore so will be the capital stock and income per capita. On the other hand, if their n is larger than n_c^*, they specialize; in that case, their steady-state capital is given by (28) and we achieve the same conclusion. Put differently, in the long-run the threshold level of capital k^d that determines the production pattern (given by (24)) is the same for both countries.

The timing of development, however, does affect production patterns along the adjustment path. The reason is that a late-bloomer and an early-bloomer face different world prices of goods at the time they start to develop. A late-bloomer faces a constant price p^*at all times, whereas the early-bloomer faces a sequence of world prices p_t that converges to p^*. Therefore, the threshold level of capital that determines the production pattern of an early-bloomer when it starts to develop k_o^d (i.e., k_o^d is such that $p^{\min}(k_0^d; n) = p_0$) is different from its long-run level k^d, which is the same as the one that determines the late-bloomer's initial pattern of production. For instance, if the two countries diversify production in the long-run and $\alpha > \theta$, it must be true that their common long-run stock of capital k is below k^d. Then, $k_0 < k$ implies that $k_0 < k^d$ and so the late-bloomer diversifies production initially, but the early-bloomer could have started diversifying or not since k_0 can be below or above k_0^d.

The next proposition summarizes these results.

Proposition 6 *If two countries possess the same stock of land per capita, they converge to the same long-run income per capita level, regardless of their timing of development. However, their trade patterns may differ along the adjustment path.*

5 Income Levels and Convergence Rates

Our next task is to conduct a numerical experiment to evaluate the possible impact of a country's relative land endowment on its steady-state level of output and speed of convergence. After that, we will use this information to reinterpret the conditional-convergence and resource-curse findings in terms of our model.

5.1 Calibration

In order to advance in that direction, we need to calibrate the model parameters. We calibrate the parameters so that the steady state equilibrium of the developed world is consistent with main US growth facts. We choose 0.95 for the discount factor ρ, 1 for the inverse of the intertemporal elasticity of consumption σ, and 0.08 for the depreciation rate δ. These values are standard in the literature. In addition, we normalize B equal to 1, and set p^* equal to 0.64, the price of equipment relative to consumption for the U.S. reported by Eaton and Kortum (2001). The developed-world's land-labor ratio n^* is set equal to 1.69, the U.S. average for the period 1967 to 1996, obtained from the Food and Agriculture Organization (FAO) of the United Nations.[5]

Regarding the production technology parameters, we do not have any available estimates for the consumption and investment sectors. However, we do have information about the shares of the different inputs in GDP. Parente and Prescott (2000) report that a share of capital of 0.25, a land share of 0.05, and a labor share of 0.70 are consistent with the U.S. growth experience. In addition, we can obtain an estimate of the sectoral composition of GDP employing investment shares. For the period 1980 to 1990, the average investment share for the U.S. is 0.21. This number implies a steady-state value for the share of investment-goods of

$$\frac{p^* y_x^* l_x^*}{y^*} = \frac{p^* \delta k^*}{y^*} = 0.21.$$

Hence, the one for consumption products is

$$\frac{y_c^* l_c^*}{y^*} = 0.79.$$

This sectoral composition and the share of capital for the whole U.S. economy deliver the following relationship between the capital shares in the two production activities:

$$0.21\theta + 0.79\alpha = 0.25. \tag{30}$$

In addition, the share of land in GDP requires that

$$\beta\left(\frac{y_c^* l_c^*}{y^*}\right) = 0.05 \quad \Rightarrow \quad \beta = 0.064. \tag{31}$$

In accordance with (30), we consider the following set of values for the capital shares:

$$(\alpha, \theta) = \{(0.21, 0.40), (0.24, 0.30), (0.25, 0.25), (0.27, 0.17), (0.29, 0.09)\}.$$

[5] Detailed description of the data used in the paper is provided in the data appendix.

5.2 Results

We compute, for a developing nation, its relative steady-state income level with respect to the developed-world economy, and its speed of convergence for different values of the land per worker endowment.

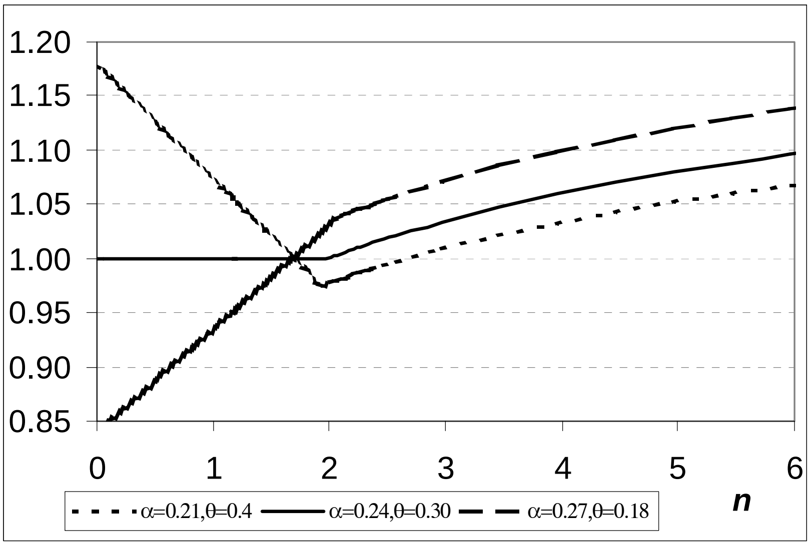
Figure 2 shows a country's relative-income steady-state level as a function of its land endowment for three sets of parameters. The domain of n is the interval $[0.002, 6.72]$ that contains all values of arable-land hectares per worker across nations (averages for the period 1967-1996) in FAO statistics. It illustrates the relationship already established in Propositions 3 and 4. When $(\alpha, \theta) = (0.21, 0.40)$ (dotted line in chart), the labor share in the consumption-goods sector is relatively larger than the labor share in the investment-goods sector. As a consequence, long-run output in diversified-production economies decline with n. Under diversification, the schedule is linear because factor-price equalization holds and, then, equations (17) and (23) define a linear relationship between y and n. Under specialization, on the other hand, output equals $An^{\beta}k^{\alpha}$. Hence, equation (28) implies that the relationship between y and n is strictly increasing and concave to the right of n_c^*. When $(\alpha, \theta) = (0.21, 0.40)$, we observe that $n_c^* = 2.0$. This value of n_c^* implies that 95 percent of countries in FAO statistics would be operating within the diversification cone.

In the intermediate case (solid line), $(\alpha, \theta) = (0.24, 0.30)$, labor shares in both activities are the same. The difference with respect to the previous case is that now land does not affect output in economies that operate within the diversification cone. The third scenario (dashed line), $(\alpha, \theta) = (0.27, 0.18)$, depicts a bigger labor share in the investment-goods sector. Thus, steady-state income always increases with land. If we look at the numerical value of the predicted income differences, they are significant although relatively small. For example, focusing in the last scenario, the highest income level is only 18% larger than the developed-world's average, and 37% bigger than the one of the predicted poorest nation.

Next, we study the speed of convergence.[6] Differences in the stock of land have a similar effect on long-run per capita income y. Under diversified production we have

[6] As previous literature, we linearize the equilibrium-dynamics system, given by expressions (25) and (27), around the steady state, and then compute the speed of convergence. Because the model is written in discrete time, the asymptotic speed of convergence is given by *one* minus the largest eigenvalue located inside the unit circle. This numerical exercise also reveals that the transition is characterized by a one-dimensional stable saddle-path, which in turn implies that the adjustment path is asymptotically stable and unique. The program was written in Mathematica, and is available from the authors upon request.

Figure 2: Long-run relative income level as a function of the land endowment



that $w = w^*$. So, the income equation (23) establishes that if the late-bloomer is more land abundant than the developed nations, its level of income will be above y^* if and only if $\alpha + \beta - \theta > 0$. Interestingly, if the production of consumption goods is the most labor intensive activity, land abundant countries will enjoy, under diversified production, lower long-run income per capita levels than the world's average.

The first interesting finding is that the convergence rate is independent of n only if, along the adjustment path, the economy transfers resources between two sectors that have the same capital share. We can see this in Table 1. When the sector that employs land has a lower capital share (first row of results), larger amounts of land increase the speed of convergence. When the capital shares are the same in both activities (second row), the speed is independent of n. Notice that this finding also implies that in a specialized economy, the convergence speed is independent of the land endowment. Finally, if the land-using activity has a higher capital share (third and forth rows) more land generates a lower speed. Comparing the third and fourth rows of results, we observe as well that convergence-rate differences increase with the capital share gap. In particular, when α rises from 0.27 to 0.29, the ratio of the largest speed to the lowest one goes from 2.1 up to 3.0.

The intuition behind these results is simple. Analyses of the one-sector growth

Table 1: Speeds of convergence for different parameterizations, percentage

α	θ	n = 0.40	0.81	1.20	1.69
0.21	0.40	20.1	33.6	42.9	55.1
0.25	0.25	12.8	12.8	12.8	12.8
0.27	0.18	8.6	6.3	5.1	4.1
0.29	0.09	6.0	3.6	2.6	2.0

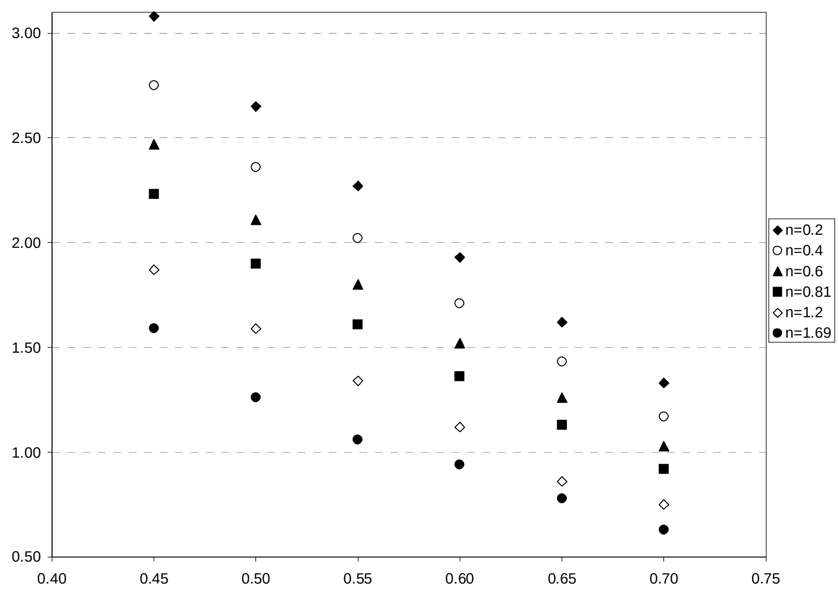
model have taught us that the speed of convergence depends on how fast the marginal productivity of capital falls, and this is inversely related to the capital share. In our model, there are two sectors that employ capital. Therefore, the economy-wide capital share (EWCS) depends on the weight of each sector in GDP. If the sector that displays a larger (smaller) capital share increases its weight, the EWCS will rise (decrease), and then the speed will diminish (increase). But if both sectors have identical capital shares, the EWCS is fixed and does not depend on the sectorial composition of output. That is, if we denote the share of the consumption-goods sector in aggregate output by s_c, then we can express the economy-wide capital share as $EWCS = (\alpha - \theta)\, s_c + \theta$. Now, notice that when the value of the land/labor ratio goes up, the weight of the consumption-goods sector in GDP rises. Hence, if $\alpha < \theta$, the EWCS decreases with n and the speed rises; whereas when $\alpha > \theta$, the EWCS rises with n and the speed falls. Finally, if $\alpha = \theta$, the EWCS does not depend on n.

Table 1 also shows that the speed decreases with the capital share in the consumption-goods sector, but it is positively related to the capital share in the non-specific factor sector. It is interesting to notice that the values obtained when $\alpha > \theta$ are the ones consistent with the empirical evidence. In particular, estimated values of the speed of convergence vary from the 0.4 percent reported by Barro and Sala-i-Martin (1995) to the 10 percent found by Caselli *et al.* (1996).

5.3 Reinterpreting the conditional convergence and resource curse findings

Taken together, the above results on long-run income and on the speed are very interesting. They say that, in sharp contrast to the predictions of the standard neoclassical growth framework, our model implies that two nations that are at the

Figure 3: Average annual growth rate (y-axis, %), 26-year period, as a function of the initial below-trend income level (x-axis) and the land endowment (n)



same distance of their specific steady-states do not necessarily convergence at the same speed. Furthermore, if capital shares in the two sectors are different, the country that in the long-run becomes relatively richer converges at a lower speed than the nation that in the long-run becomes poorer. The first statement has implications for the interpretation of the conditional convergence evidence, whereas the second one does it for the resource curse finding.

To improve our understanding of the potential effects of land and cross-sector capital-share differences on the interpretation of these two empirical regularities, let us focus on the $(\alpha, \theta) = (0.29, 0.09)$ scenario, and assume that the asymptotic speed of convergence drives the whole convergence process. Figure 3 plots average growth rates for economies that start the convergence process with different initial relative income levels and land/labor ratios for that case. The average growth rate is computed over a 26-period interval. Since the model was calibrated with annual data, this time interval is the one used, for example, by MRW, and Nonneman and Vanhoudt (1996).

In Figure 3, we see that the time series of growth rates is driven by diminishing returns to capital accumulation. That is, when we fix the n, average growth rates decrease as the economy gets closer to its steady state. In the cross section, however, economies that start closer to the balanced-growth path can show larger average growth rates. For example, the growth rate when $n = 0.2$ and initial income is 0.55 is larger than the growth rates shown by any $n \geq 0.81$ with initial income bigger or equal than 0.45. If we have a sufficiently large sample, this does not seem to be a problem, because the average across different land-labor ratios is clearly downward sloping and driven by diminishing returns. But if we use a relatively small sample, we may not find a negative relationship between initial income and posterior growth. For example, suppose that our small sample is composed by the economies depicted in the chart that deliver average growth rates between 1.05 and 1.50 percent. If we ran a linear regression of growth rates on initial income, the estimated coefficient would be 0.20, thus suggesting a positive relationship.

Therefore, our model implies that the conditional convergence finding does provide evidence of diminishing returns, as most of the previous literature has pointed out, but also of the existence of relatively small differences in cross-sector capital shares. That is, the fact that conditional convergence has been found in many different studies that use relatively small samples, which is the rule in growth empirics, suggests that capital shares cannot differ too much across sectors.

Let us now concentrate on the implications of the model's predictions regarding the resource-curse finding. The two-sector neoclassical growth framework with land predicts, as we see in Figure 3, that resource-rich countries show lower average growth rates along most of the convergence process. This is consistent, for example, with the growth experience of most East Asian countries. We see that they operate in very low levels of n but have been able to grow relatively faster than most countries with higher levels of n. However, the model implies as well that the resource-curse finding can not be interpreted as evidence that natural inputs are bad for the economy. The reason is that the estimated coefficient may be capturing a purely transitional effect. That is, the model leaves open the possibility that the natural input, land in our case, is a short-run curse for growth but a long-run blessing in terms of income.

6 Empirical Evidence

In this section, we test empirically the main predictions of the model. In particular, we carry out a cross-country empirical investigation of the relationship between long-run income and the land-labor ratio, and between average income-growth and the

Table 2: Unconditional cross-sectional correlations between explanatory variables

	X1	X2	X3	X4	X5
X1: Investment rate	1				
X2: Average educational attainment	0.661	1			
X3: Active population growth rate	−0.256	−0.462	1		
X4: Real GDP per worker in 1967	0.508	0.839	−0.477	1	
X5: Arable land per worker	0.001	0.203	0.048	0.263	1

land-labor ratio. Given that our main goal is to test whether land has an important transitional effect on income, we follow the methodology proposed by MRW.

6.1 *Data*

Our sample is constructed using data series from FAO, Barro and Lee (2001), and the Penn World Table (PWT) version 6.1. The FAO statistics provide arable land, and active population. Barro and Lee (2001), on the other hand, provide average years of education of the labor force. Finally, from PWT, we collect data on GDP and investment rates. The final sample is chosen by requiring that data on these five variables are available for all years. It ends up being composed of data series for 85 nations from 1967 to 1996.

Table 2 reports for the same sample the unconditional correlations among the explanatory variables that will be employed in the estimation. We observe that except for real GDP per worker, the other explanatory variables are not highly correlated. A remarkable feature is that the land per worker proxy is the variable that shows the smallest correlations in absolute terms.

6.2 *Empirical specification and results*

In line with MRW, we consider the following unrestricted empirical specification to explain long-run income levels:

$$\ln y_{i1996} = \alpha_0 + \alpha_1 \ln s_{ki} + \alpha_2 \ln s_{hi} + \alpha_3 \ln\left(GPOP_i + g + \delta\right) + \alpha_4 \ln n_i;$$

where s_{ki}, s_{hi}, $GPOP_i$, and n_i are, respectively, the investment rate, the average educational attainment, the active population growth rate, and the land-labor ratio for country i, and are calculated as the mean value for the period 1967 to 1996; the

Table 3: Coefficient estimates from OLS regressions on 85-Country sample

	Level regression		Growth regression	
Constant	4.860^{***} (1.154)	4.803^{***} (1.126)	2.037^{*} (1.097)	1.748 (1.054)
Investment rate	0.476^{***} (0.179)	0.451^{**} (0.177)	0.400^{***} (0.129)	0.340^{***} (0.119)
Average educational attainment	1.113^{***} (0.160)	1.126^{***} (0.163)	0.425^{***} (0.089)	0.414^{***} (0.086)
Active population growth rate	-1.436^{***} (0.348)	-1.419^{***} (0.347)	-0.721^{**} (0.283)	-0.641^{**} (0.262)
Real GDP per worker in 1967			-0.376^{***} (0.089)	-0.340^{***} (0.090)
Arable land per worker		-0.048 (0.046)		-0.107^{***} (0.031)
Adjusted R^2	0.765	0.765	0.387	0.450

Notes: White's heteroskedasticity-consistent standard errors are given in parentheses. ***Significantly different from zero at the 1% level. **Significantly different from zero at the 5% level. *Significantly different from zero at the 10% level.

other variable, y_{i1996}, represents the level of real GDP per worker in country i in 1996. From the last expression, we derive the following steady-state output growth regression:

$$\ln y_{i1996} - \ln y_{i1967} = \alpha_0 + \alpha_1 \ln s_{ki} + \alpha_2 \ln s_{hi} + \alpha_3 \ln (GPOP_i + g + \delta) + \alpha_4 \ln n_i - \ln y_{i1967}.$$

Table 3 presents results excluding and including land from the set of explanatory variables. We can see that the standard MRW result holds in our sample. Investment rates, average educational attainments, and population growth rates are highly significant, and explain a relatively large fraction of the income level variance observed across nations, around 76%. We also see that the land-labor ratio is not significant in the level regression. However, it has a very strong explanatory power in the growth regression. In particular, the estimated coefficient implies that a country with a larger relative land endowment converges, on average, at a lower speed to its steady-state equilibrium.

We interpret these results as supporting the main predictions of our model. In the numerical section, we found that the impact of land on long-run output was not very large. In addition, this long-term effect works in part through capital accumulation. For example, when the consumption-goods sector is less labor intensive, economies with larger land endowments become richer because they have more land, and also because of the induced additional capital accumulation. Therefore, it is reasonable to think that other factors already pointed out in the literature, such as institutions and technology, affect at a much larger extent capital variables, and leave land a negligible role as explanatory variable of the cross-country income variance. Land does help to predict, on the other hand, output growth rates. Moreover, given the lack of power of land in explaining long-run levels once we control for other variables, the obtained evidence strongly suggests that land can have an important role in determining the speed of convergence, as the theoretical model predicts.

6.3 Robustness of the results

Our estimation results are clearly subject to endogeneity problems. For this reason, we now use instrumental variables (IV) to try to control for such problems.

Recently, Gallup *et al.* (1999), and Bloom *et al.* (2003), among others, suggest that geographical variables are suitable instruments in economic growth regressions. Following them, we employ the following eight instruments: the percentage of land area within 100 km of the coast; an indicator variable that is one for landlocked countries and zero otherwise; water area (lakes and ocean); the absolute value and the value of the latitude of the country's centroid; index of ethnic fragmentation; index of cultural fragmentation; and average annual rain precipitation in millimeters during the 20th century.[7] Because some of these variables are not available for all nations in our original sample, the sample size is now reduced to 82 nations.[8]

Table 4 present the results. The value of the estimated coefficients and their significance using GMM methods vary with respect to the OLS counterparts. For example, in most regressions shown in table 4, either the investment rate or the average educational attainment are significant, but never both at the same time. This is not very surprising, since it is well known that GMM usually delivers relatively large variances and, in addition, the physical capital and human capital variables are highly correlated ($corr(s_k, s_h) = 0.66$). However, the main results concerning the effect of land on per-worker income levels and growth rates do not vary much with

[7] The data and definitions of the geographical variables can be found at http://www.cid.harvard.edu/ciddata/ciddata.html. The fragmentation data is supplied by Fearon (2003). Finally, the rainfall data (rain-weighted) is computed by Mitchell *et al.* (2003) and Jefferson and O'Connell (2004), and can be accessed at http://www.acad.swarthmore.edu/rain-econ/Framesets/Data.htm.

[8] The countries excluded were Barbados, Cyprus, and Guyana.

Table 4: Coefficient estimates from GMM regressions on 82-Country sample

	Level regression		Growth regression	
Constant	2.736 (4.624)	2.134 (3.680)	2.152 (2.706)	2.898 (1.943)
Investment rate	0.434 (0.937)	0.359 (0.580)	0.458 (0.535)	0.671** (0.323)
Average educational attainment	1.211** (0.574)	1.244*** (0.371)	0.546 (0.441)	0.333 (0.346)
Active population growth rate	−2.175** (0.976)	−2.318** (0.972)	−1.176** (0.555)	−0.918** (0.450)
Real GDP per worker in 1967			−0.527*** (0.140)	−0.458*** (0.134)
Arable land per worker		−0.035 (0.053)		−0.061** (0.029)

GMM standard errors are given in parentheses.
***Significantly different from zero at the 1% level. **Significantly different from zero at the 5% level. *Significantly different from zero at the 10% level.

respect to our previous OLS findings. In particular, land shows again a significant direct effect on income growth, but not on income levels, and the growth effect is negative. Our main findings, therefore, seem to be robust to potential endogeneity problems.

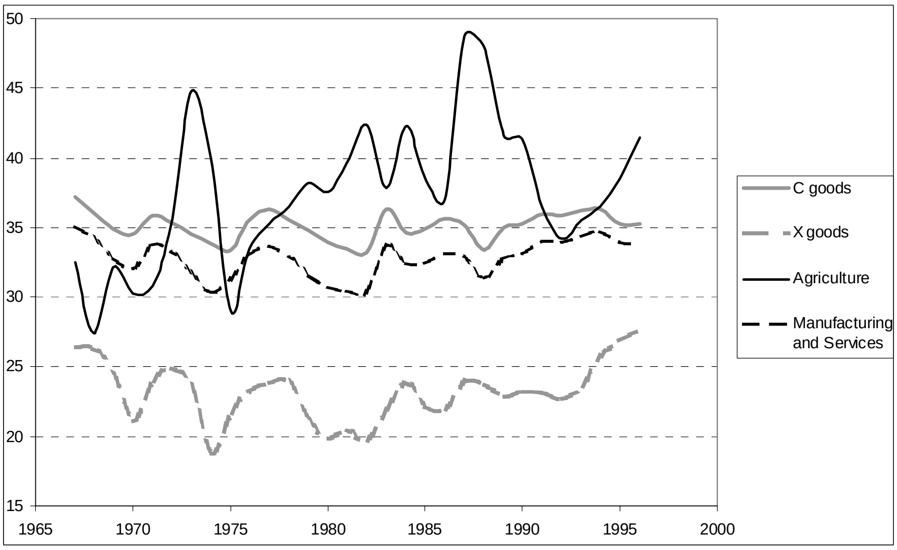
6.4 Capital shares across sectors

Actually, in order to make the model predictions match the evidence, we need to show that consumption-goods production is more capital intensive than investment-products manufacturing. This, at first glance, seems at odds with the standard assumption that most of the theoretical two-sector growth literature makes. Starting with the work of Uzawa (1964), the production of investment-goods has usually been assumed to be the relatively capital-intensive activity. Nevertheless, as we will see, the data suggest the opposite conclusion.

In Figure 4, we show time series of the capital share in different sectors from 1967 to 1996 for the U.S. economy. We use Dale Jorgenson's data on 35 2-digit industries. We consider that consumption goods are composed of agricultural goods, service products, and manufacturing non-durables, and that investment goods are manufacturing durables.[9] In the chart, investment goods always give lower capital shares

[9] A more detailed description of the data source and construction of the groups is given in the appendix.

Figure 4: Capital shares for selected U.S. industries (%)



than consumption goods. In addition, the difference in capital shares is substantial. For example, the average values for the whole period are 35.1% for c-products and 23.2% for the x-goods. Therefore, unlike it is usually assumed by growth models, consumption-goods production seems to be the relatively capital-intensive activity.

We can still think that given that the non-reproducible natural input is what drives the model predictions, the right test is to see whether industries in which land is intensively used show larger capital shares than the ones that do not use it. Figure 2 also shows capital shares for manufacturing-plus-services, and the agricultural sector. We see that agriculture gives larger capital shares than manufacturing plus services in most years, and always after 1976. The average values for the 1967-1996 period are 37.4% for the former and 32.8% for the latter activities. The difference is larger if we focus on the last ten years, because agriculture has become a more and more capital intensive industry over time. For the period 1987-1996, agriculture provides a mean value of 40.2%, and manufacturing plus services an average capital share of 33.5%. Additional evidence is provided, for example, by Echevarria (1997). She employs national-accounts data from 13 OECD nations for the period 1976-1985 to estimate labor shares. She concludes that agriculture is more capital intensive than manufacturing and services, with an estimated capital share in the primary sector more than 20 percentage-points larger than in the other two.

Still, we could consider that there is a caveat with the previous exercise. The reason is that the share of land does not appear separately in the national accounts; it is actually included in either capital or labor, and there is no easy method to remove it. There is evidence that even controlling for the land share, the capital elasticity in agriculture is large. For example, Echevarria (2000) finds a capital share of 43% in agriculture for the Canadian economy once the value of land is excluded. Early cross-country studies focusing on the agricultural sector, however, such as Hayami and Ruttan (1985), seem to find smaller capital shares after controlling for the contribution of land. These studies estimate an average share of structures and equipment of around 10 percent. Which has led to the growth literature concerned with cross-country income disparities to assume that agriculture is less capital intensive than manufacturing.[10] This conclusion is not correct when we take into account that capital in agriculture is composed not only of structures and equipment but also of livestock and orchards, as Mundlak, Larson and Butzed (2000), among others, point out. Taken both components together, and controlling for the contribution of land, the estimated elasticity of capital in agricultural output by the early studies is between 33% and 47%. In addition, Mundlak, Larson and Butzed (1999) that surveys this early literature criticizes it for not correcting for potential temporal and cross-country fixed-effect problems. These authors employ a balanced data panel of 37 developed and developing countries for a 21-year period, 1970-1990. Using appropriate techniques for panel data estimation, they conclude that, after controlling for land, the agricultural sector is more capital intensive than the non-primary activities, with a capital share above 40%.

Taken together, the evidence suggests that consumption-goods production is a more capital intensive activity than investment-goods production. Moreover, most studies show that primary-products have also larger capital elasticities than non-primary industries. Therefore, the usual assumption made by a big part of the growth literature that consumption-goods production and agriculture are less capital intensive is not well founded. Most of the evidence points to the opposite direction. As a consequence, the predictions of the model are consistent with most of the evidence.

[10] See, for example, Gollin, Parente and Rogerson (2002), and Caselli and Coleman (2001).

7 Conclusion

This paper has studied an open-economy version of the two-sector neoclassical growth model with land. In sharp contrast to the predictions of the standard neoclassical growth framework, in the two-sector model with land two economies that are at the same distance of their steady states do not converge at the same speed if they have different land endowments. Moreover, an economy that is closer to its long-run equilibrium can show larger growth rates. The reason is that our model predicts that land, besides having long-run effects, has also transitional growth effects. More specifically, even though the share of land in GDP is only around 5 percent, calibration has shown that its transitional effects on output growth can be substantial, and more important than its direct impact on long-run income. This is the case when capital shares differ across sectors.

We have argued that these results offer an alternative interpretation of the conditional convergence and resource curse findings. The model suggests that the former finding does provide evidence of diminishing returns, as most of the previous literature has pointed out, but also of relatively small cross-sector capital-share differences. Regarding the latter finding, the model predicts that the lower growth rates shown by resource-richer economies does not lead to the conclusion that natural riches are a long-run curse. The reason is that the resource curse evidence may be capturing a purely transitional phenomenon due to the effect of natural riches (land in our model) on the speed of convergence.

The predictions of our setup regarding long-run income levels of developing nations are also in sharp contrast to the ones of more standard open-economy two-sector neoclassical growth models that only include mobile factors. First, nations that start their development paths at the same date may converge to different income levels. This occurs if they have distinct land endowments. Second, identical nations that differ only in their timing of development converge to the same long-run income level. Finally, long-run specialization does not necessarily imply a level of per capita income lower than the world's average. The key to this results is the uniqueness of the aggregate capital-labor ratio compatible with a given return to capital in the model with land.

Finally, the paper has presented empirical evidence that tests the predictions of the model. Unlike previous studies, we have focused on the effect of land on growth and income levels. Both OLS and IV regression results suggest that land has a negative impact in transitional growth, with no statistically-significant independent-effect on long-run income levels. This finding does not mean that land has no effect in long-run income. It suggests that its effect works primarily through other variables such as capital investment and institutions already pointed out by the literature. We have also provided data that supports that capital shares are larger in land-intensive sectors. This last piece of evidence should lead the growth literature to revise the widely-used assumption that consumption-goods and agriculture are less capital intensive activities than investment-goods and manufacturing, respectively. In sum, we have argued that the empirical evidence is consistent with the model predictions.

A Proofs

Proof of proposition 1. Suppose that the agricultural technology is not used. A firm that has access to this technology will like to open if it makes profits for the prices (say $\hat{r}_k$, $\hat{w}_t$, $\hat{r}_n$ and $\hat{p}$) that prevail in the equilibrium where the economy is located. In particular, given $N > 0$, this firm chooses K_{at} and L_{at} to maximize profits Π_{at}, which is equivalent to maximizing

$$A\left(\frac{K_{at}}{N}\right)^{\alpha}\left(\frac{L_{at}}{N}\right)^{1-\alpha-\beta} - \hat{r}_{kt}\frac{K_{at}}{N} - \hat{w}_t\frac{L_{at}}{N} - \hat{r}_{nt}. \tag{32}$$

The maximum level of profits, per unit of land, then equals

$$\frac{\Pi_{at}}{N} = \beta A^{\frac{1}{\beta}}\left(\frac{1-\alpha-\beta}{\hat{w}_t}\right)^{\frac{1-\alpha-\beta}{\beta}}\left(\frac{\alpha_k}{\hat{r}_{kt}}\right)^{\frac{\alpha}{\beta}} - \hat{r}_{nt}. \tag{33}$$

In an equilibrium in which this type of firm does not operate, it must be true that $\hat{r}_{nt} = 0$. Hence, in expression (33) maximum profits are strictly positive, for all w_t and r_{kt}, and domestic firms will always supply agricultural products. ■

Proof of proposition 2. Manufacturers' profits equal

$$\Pi_{xt} = p_t B K_{mt}^{\theta} L_{mt}^{1-\theta} - r_{kt}K_{mt} - w_t L_{mt}. \tag{34}$$

At the maximum, it must hold that

$$\max_{\substack{0\le K_{mt}\le K_t \\ 0\le L_{mt}\le L}} \Pi_{mt} = K_{mt}\left[r_{kt}\left(\frac{1-\theta}{\theta}\right) - w_t\left(\frac{r_{kt}}{\theta p_t B}\right)^{\frac{1}{1-\theta}}\right]. \tag{35}$$

Manufacturing firms will want to enter the market if and only if they make profits, that is, if and only if

$$p_t B > \left(\frac{r_k}{\theta}\right)^{\theta}\left(\frac{w_t}{1-\theta}\right)^{1-\theta}, \tag{36}$$

From optimality conditions (9) and (11) for agricultural-goods producers, we obtain expression (12) for $r_k = \hat{r}_k$, $w_t = \hat{w}_t$ and $p_t = \hat{p}_t$. ■

Proof of proposition 3. The value k^d comes from its definition, and equations (12), (15), (16), (19) and(21). In addition, we know that the developing country will initially specialize in consumption goods if and only if $p^* < p^{\min}(k_0; n)$, and that $p^{\min}(k; n)$ decreases with k if and only if $\theta > \alpha$, it increases with k when $\theta < \alpha$. Hence, we are done. ■

Proof of proposition 4. It directly follows from the text except for the pattern of production when $\alpha > \theta$. In that case, the economy will remain diversified in the long run as long as $k^d \geq k_x^*$. Taking into account (15), (16) and (24) this condition holds whenever $n/n^* \leq \left(\frac{\alpha(1-\theta)}{\theta(1-\alpha-\beta)}\right)^{\frac{\alpha-\theta}{\beta}}\left(1 + \frac{\alpha\delta(1-\theta)}{(1-\alpha-\beta)(\rho^{-1}+\delta(1-\theta)-1)}\right)$, where both terms in brackets are greater than one. ■

Proof of proposition 5. It directly follows from the text. ■

Proof of proposition 6. It directly follows from the text. ■

B Data Appendix

- *Income (GDP), and investment rates* [Source: PWT 6.1]

Cross-country real GDP per capita (dollars, chain index), real investment shares, and population size (thousands of people) are taken from the Penn World Tables, Version 6.1 (PWT 6.1), on-line at http://datacentre2.chass.utoronto.ca/pwt/. Income series are expressed in 1996 international prices.

- *Labor force, and arable land* [Source: FAO]

The cross-country data set on active population (thousands of workers) and arable land (thousands of hectares) comes from the Food and Agriculture Organization of the United Nations Statistics, FAOSTAT. Worker for the active population variable is usually a census definition based on economically active population. Arable land per worker is measured in hectares.

- *Education* [Source: Barro and Lee (2001)]

Annual data on educational attainment are the sum of the average number of years of primary, secondary and tertiary education in labor force for the population group over age 15.

- *Capital shares* [Source: Dale Jorgenson]

Annual data on the value of capital inputs and the value of labor inputs per sector are obtained form Dale Jorgenson's web site, http://post.economics.harvard.edu/faculty/jorgenson/data/35klem.html. The database is described, for example, in Jorgenson and Stiroh (2000). It covers 35 sectors at the 2-digit SIC level for the U.S. economy.

We group sectors as follows. *Services* includes: transportation; communications; electric utilities; gas utilities; trade; finance insurance and real estate; and other services. *Manufacturing durables* includes: lumber and wood; furniture and fixtures; stone, clay, glass; primary metal; fabricated metal; machinery, non-electrical; electrical machinery; motor vehicles; transportation equipment & ordnance; instruments; and misc. manufacturing. *Manufacturing non-duranbles* is composed of the sectors: food and kindred products; tobacco; textile mill products; apparel; paper and allied; printing, publishing and allied; chemicals; petroleum and coal products; rubber and misc. plastics; and leather.

Table A: Average annual values of data, 1967-1996, 85-country sample

Country	y_{1996}/y_{1967}	Inv. share	Ed. Att.	Lab. F. growth	y_{1967}	Land per worker
Algeria	1.341	0.192	3.13	0.034	11232	1.347
Argentina	1.295	0.176	7.20	0.015	21018	2.267
Australia	1.449	0.241	10.34	0.021	31633	6.453
Austria	2.105	0.262	7.57	0.006	21685	0.441
Bangladesh	1.513	0.100	1.79	0.023	2015	0.211
Barbados	2.185	0.172	8.31	0.014	13000	0.143
Belg-Lux	2.192	0.227	8.63	0.005	31121	0.212
Benin	1.253	0.070	1.30	0.022	1986	0.761
Bolivia	0.856	0.092	4.86	0.025	7644	0.869
Botswana	5.862	0.188	3.69	0.031	2369	0.996
Brazil	1.792	0.212	3.56	0.030	8420	0.756
Cameroon	1.469	0.078	2.61	0.023	3180	1.518
C.A.R	0.538	0.044	1.57	0.017	3434	1.491
Canada	1.303	0.220	10.38	0.024	33163	3.835
Chile	1.590	0.141	6.43	0.024	14217	1.009
China	3.335	0.164	5.21	0.021	1472	0.195
Colombia	1.445	0.117	4.34	0.033	9786	0.379
Cyprus	2.893	0.257	7.17	0.013	11113	0.348
Denmark	1.426	0.231	9.12	0.008	30435	0.971
Dominican R.	1.712	0.134	3.97	0.033	5411	0.469
Ecuador	1.562	0.200	5.35	0.031	6599	0.624
Egypt	2.037	0.075	3.34	0.024	4625	0.161
El Salvador	0.822	0.068	3.56	0.028	12631	0.342
Finland	1.893	0.268	7.79	0.006	20251	1.066
France	1.812	0.250	6.62	0.007	25539	0.749
Gambia	1.040	0.058	1.30	0.033	1995	0.477
Germany	1.679	0.238	9.05	0.005	25189	0.316
Ghana	1.254	0.077	3.49	0.028	2133	0.387
Greece	1.760	0.256	6.98	0.009	17048	0.767
Guatemala	1.296	0.081	2.57	0.030	7741	0.505
Guyana	0.941	0.182	5.30	0.021	7224	1.679
Haiti	2.253	0.051	2.16	0.012	1782	0.204
Honduras	1.080	0.120	3.41	0.034	5411	1.243
Hong Kong	3.889	0.243	7.97	0.026	13072	0.004
India	2.293	0.114	3.42	0.020	2121	0.536
Indonesia	3.562	0.136	3.68	0.027	2309	0.301
Ireland	2.837	0.185	7.83	0.009	16496	0.969
Israel	2.208	0.271	9.09	0.030	17975	0.227
Italy	1.942	0.240	6.09	0.006	24066	0.418
Jamaica	0.897	0.183	4.20	0.021	8443	0.190
Japan	2.754	0.323	8.45	0.010	16532	0.075
Jordan	1.222	0.145	4.83	0.046	10577	0.514
Kenya	1.371	0.116	3.14	0.035	1856	0.470

Table A: Average annual values of data, 1967-1996, 85-country sample, cont'd

Country	y_{1996}/y_{1967}	Inv. share	Ed. Att.	Lab. F. growth	y_{1967}	Land per worker
Korea Rep.	4.907	0.305	8.10	0.026	5997	0.133
Lesotho	1.484	0.150	3.80	0.023	2065	0.561
Malawi	1.487	0.152	2.56	0.027	1013	0.408
Malaysia	3.060	0.212	5.24	0.031	7602	0.224
Mali	1.084	0.078	0.56	0.024	1362	0.552
Mexico	1.145	0.180	5.21	0.035	16240	1.037
Nepal	1.768	0.122	1.04	0.021	1533	0.309
Netherlands	1.467	0.240	8.39	0.016	31416	0.142
New Zealand	1.089	0.207	11.12	0.019	34031	1.780
Nicaragua	0.392	0.102	3.38	0.035	12562	1.426
Niger	0.524	0.075	0.62	0.028	3206	1.108
Norway	1.886	0.323	9.21	0.013	25988	0.446
Pakistan	2.226	0.124	2.57	0.031	2142	0.637
Panama	1.390	0.198	6.55	0.030	9991	0.652
Papua N.G.	1.275	0.128	1.87	0.021	5644	0.016
Paraguay	1.898	0.117	5.17	0.031	7577	1.247
Peru	0.860	0.173	5.80	0.030	14251	0.560
Philippines	1.283	0.151	6.51	0.028	6102	0.236
Portugal	2.186	0.203	3.90	0.011	12534	0.560
Rwanda	1.317	0.037	1.77	0.017	1461	0.277
Senegal	0.972	0.072	2.15	0.026	3412	0.906
Sierra Leone	0.926	0.029	1.71	0.015	2877	0.351
Singapore	4.956	0.445	5.80	0.033	10856	0.002
South Africa	1.070	0.130	4.95	0.027	16649	1.150
Spain	1.759	0.245	5.77	0.011	20453	1.090
Sri Lanka	1.843	0.110	5.58	0.022	4149	0.153
Sweden	1.347	0.219	9.46	0.010	28706	0.701
Switzerland	1.147	0.269	9.67	0.011	38991	0.119
Syrian A.R.	2.135	0.135	3.95	0.034	6122	2.078
Tanzania	0.910	0.268	2.74	0.030	997	0.243
Thailand	3.916	0.320	4.90	0.027	3129	0.639
Togo	0.718	0.069	2.18	0.027	2985	1.728
Trin. & Tob.	1.191	0.098	6.62	0.020	18347	0.167
Tunisia	2.219	0.173	3.08	0.029	6916	1.470
Turkey	1.989	0.151	3.64	0.021	7121	1.249
U.K.	1.678	0.181	8.39	0.005	24141	0.251
Uganda	1.497	0.020	2.19	0.027	1118	0.638
Uruguay	1.497	0.120	6.55	0.010	13935	1.099
U.S.A.	1.566	0.188	11.05	0.016	36032	1.688
Venezuela	0.546	0.169	4.93	0.039	32181	0.580
Zambia	0.728	0.188	3.91	0.024	3063	2.109
Zimbabwe	1.727	0.233	3.19	0.031	3519	0.768

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