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REGIONAL SPILLOVERS AND ECONOMIC GROWTH

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Abstract

This paper presents estimates of indexes of external economies arising from regional spillovers. A country's economic growth rate is shown to depend not only on its domestic investment rate but also on the investment rate of its neighboring countries. The evidence for such positive regional spillovers is strong, accounting for 14 to 18 percent of a country's growth rate. The parameter estimates suggest that regional spillovers from human capital and physical capital are equally important. The paper also shows that in general, there are *two* important rates of convergence in a model with regional spillovers. The first can be intrepreted as a convergence rate between countries within a region, and the second as a convergence rate between regions within the world. The *within-region* convergence rate is estimated to be about 0.5 to 0.8 percent higher than the *between-region* convergence rate. Since poorer countries are usually located in a common region (Africa) and richer countries are clustered together in another region (Europe), regional spillovers slow down the convergence of income differentials and widen steady state income differentials between countries located in different regions. The inclusion of these regional spillover variables in standard cross-country regressions can also explain away much of the significance of the African and Latin American continent dummies.

KEY WORDS: Spillovers, Externalities, Economic Growth, Development

Introduction

Endogenous growth models stressing external economies and increasing returns have recently flooded the theoretical literature.[1] The empirical support for such externalities are however lacking and almost nonexistent at the aggregate level.[2] This paper will use the Summers-Heston aggregate country data to measure regional spillovers between neighboring countries. The empirical papers on spillovers to date have offered no clear way of rejecting one form of spillovers over another, for example, the importance of learning by doing as emphasized by Arrow (1962) relative to the human capital externalities discussed in Lucas (1988). There is also no definite evidence on the magnitudes of these spillover effects and whether therefore these externalities are in fact important enough to justify the recent attention on endogenous growth models. This paper will attempt to fill that gap by estimating parameters which one, quantify the importance of regional spillovers, and second, weigh the importance of human relative to physical capital spillovers.

Technological spillovers between neighboring countries is a common phenomenon. Ideas and capital are more likely to flow quickly and easily across national borders rather than across oceans and continents. Citizens of a neighbouring country are always more familiar and attentive to the technological improvements made next door. Frequent cross-border flows of goods, services, capital and labor facilitates this transmission of knowledge. At a macro level, countries are unlikely to capture the full social return of their investments. Neighboring countries can benefit from the externalities generated through imitation, reverse-engineering, learning-by-doing and learning-by-watching, without necessarily having to compensate the country source for the spillovers.[3] If geographical proximity is an important factor for such regional spillovers, who your neighbors are will matter. Countries that border prosperous

[1] To sample a few, see Lucas (1988), Barro (1990), Romer (1990), and Grossman and Helpman (1991).

[2] There have been attempts to provide evidence of externalities, but these empirical efforts have not been very convincing. Caballero and Lyons (1989) provide evidence of external economies in U.S. manufacturing industries. Rauch (1991), and Glaeser, Kallal, Scheinkman and Shleifer (1991) provide evidence of externalities from geographic concentration of human capital in cities. De Long and Summers (1990) intrepret the strong association between machinery and equipment investment with growth as evidence of externalities.

[3] The term "learning-by-doing" originates from Arrow (1962). The term "learning-by-watching" is borrowed from Shleifer (1990).

neighbors investing substantial amounts in capital accumulation are likely to benefit from the technological spillovers generated in the process. Likewise, countries that are surrounded by oceans or landlocked by deserts will not have this exogenous blessing. A country's growth will thus not only depend on domestic investments but also on the investments of its regional neighbors.

Examples of geographical spillovers are common. Guangdong, a provincial capital in southern China, grew an average of 12 percent annually for the past decade, fuelled by capital and expertise from neighboring Hong Kong and Taiwan.[4] That figure is more than twice China's average growth rate of 5.8 percent.[5] Johor Bahru, a southern town in Malaysia, and Batam Island, an Indonesian island, have become popular sites for labor-intensive manufacturing industries relocating from neighboring Singapore. These cross-border flows of knowledge and jobs have generated booming towns, to an extent that the Johor-Singapore-Batam link has been nicknamed the "triangle of growth" within ASEAN.[6] Both Johor and Batam have become the fastest growing regions in their respective countries. Casual inspection of a map of Africa reveals that some of the fastest growing African countries are geographically located next to South Africa, such as Bostwana, Zimbabwe and Lesotho, and north of the continent next to the Mediterranean Sea, such as Morocco, Algeria and Tunisia. These northern African countries are but a few miles by boat away from the south of Spain and Italy. Even more striking is the geographical clustering of nine African countries which have experienced negative average per capita growth rates in the centre of the African continent: Angola, Central African Republic, Chad, Ethiopia, Ghana, Mozambique, Sudan, Zaire, and Zambia.[7] To take another example, not many economists would deny that other Latin American countries are envious of Mexico's growing economic links to the United States, a privilege extended solely from geography.

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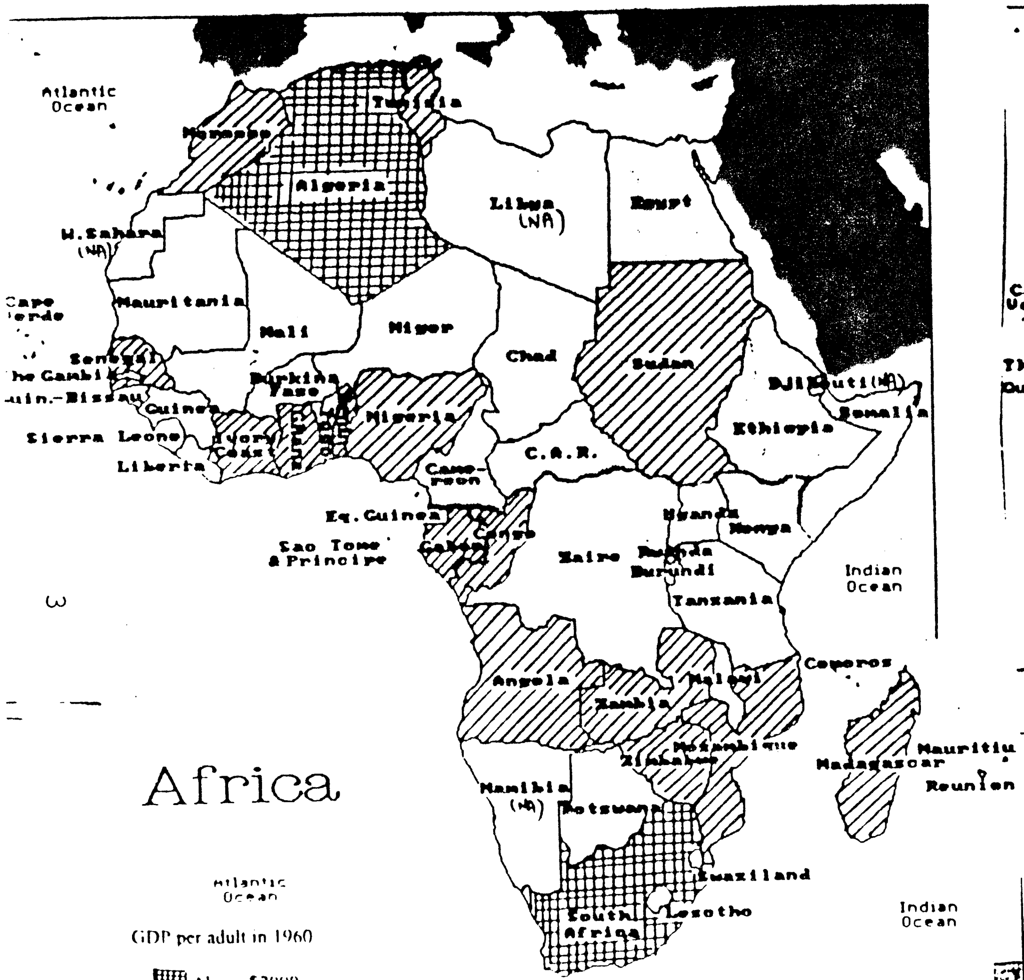
[4] If Guangdong were a country, it would be considered the fastest-growing in the world. See "The Fifth Tiger is on China's Coast," BusinessWeek, April 6, 1992.

[5] Growth in income per capita averaged over 1970-80.

[6] "Off with the Straitjacket," Far Eastern Economic Review, March 8, 1990.

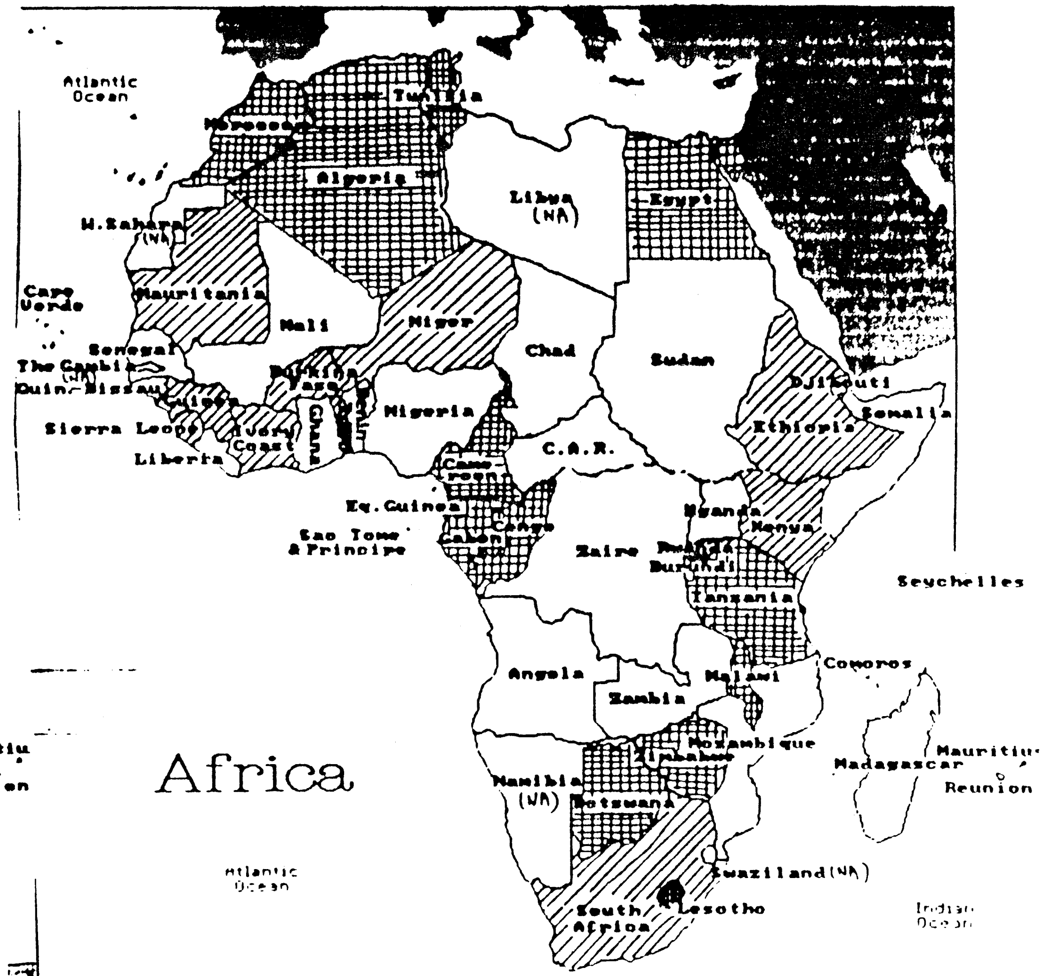
[7] The negative average per capita growth rates pertain to the period 1960 to 1985. Other Sub-Saharan African countries which have registered negative per capita growth rates over the period include Benin, Senegal, Somalia, Togo, Liberia, Madagascar, and Guinea.



GDP per adult in 1960

Above $2000
Between $1000 and $2000
Below $1000

Notes: Data unavailable for W.Sahara, Libya, Djibouti and Namibia.



Average GDP per person growth rate (1960-85)

Growth rate above 2%
Growth rate between 0.5% and 2%
Growth rate below 0.5%

Notes: Data unavailable for Libya, W.Sahara, Namibia, The Gambia and Swaziland

More concretely, regional spillovers can arise in various ways. First, well-developed public infrastructure in a country, such as a port or a major airport, can benefit its regional neighbours. It is often difficult to price-discriminate the users of infrastructure facilities, and prices charged are usually below the prices that users are willing to pay. Foreigners often do not pay a price that much different from native users. Improvements in roads, highways, railroads, and construction of airports and ports in regions nearby clearly increases accesibility and reduces time wasted in transporting goods or persons. Infrastructure in neighbouring countries are especially important for "land-locked" countries, where passage of goods and people from and to ports must involve crossing another "transit" country. Of the 28 land-locked countries in the world, fourteen are in Africa: Bostwana, Burundi, Central African Republic, Chad, Lesotho, Malawi, Mali, Niger, Rwanda, Swaziland, Uganda, Burkina Faso, Zambia and Zimbabwe.[8] Since inter-continental trade in Africa accounts for only a small fraction of total trade volume and the bulk of international trade involves transportation across bodies of water, coastal access is an important determinant of accessibity to world markets. The economic growth of these land-locked countries are therefore inevitably dependent on the quality of the infrastructure in neighbouring "transit" countries.

Second, countries often allow foreign labor from neighboring countries to come in and work. The form of work can range from simple manual tasks, such as weaving and sewing, to more sophisticated handling of machineries. Foreign workers are no less likely to benefit from the learning-by-doing and learning-by-watching activities emphasized by Arrow (1962). Lucas (1988) elaborates on this learning process whereby individuals become more productive when there are other productive people in the locality to learn from.

Third, learning-by-interacting and learning-by-talking with your neighbours is an important source of externalities. Geographical proximity facilitates communication. Neighbours often analyse one another's policy successes and investment decisions as lessons of their own. National newspapers often have extended coverage on the economic and political news in their own respective region, with news

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[8] The other land-locked countries are Afghanistan, Austria, Bolivia, Czechoslovakia, Hungary, Laos, Lichtenstein, Luxembourg, Mongolia, Nepal, Paraguay, San Marino, Switzerland and the Vatican. For an interesting discussion on the limitations imposed on African land-locked countries, see Cervenka (1973).

on the rest of the world given much less weight. Information about regional developments are also more readily available through radio and television. There will also often be a regional bias in the translation of knowledge from one generation to the next. Trade blocs and trade agreements are often formed in a regional context. Such regional trade and investments further increase the possibility of extensive communication and externality generating activities.

The first section of this paper presents a simple regional spillovers model which accounts for external economies in a Solow-type framework. The steady state values for domestic output and regional output are solved for and tested across cross-country data. The second section examines the transitional behaviour of output out of steady state. A conditional convergence equation is derived and tested to check its consistency with the data. The third section presents a special case which offers some intuitive insights on the transitional dynamics of output.

I. A Regional Spillovers Model

A. The Model

Consider the familiar one-good aggregative neoclassical labor-augmenting production function for country i. Output is produced by the currently existing stocks of physical capital K(t), human capital H(t) and labor L(t). Thus,

$$(1) \quad Y_i(t) = F\ [K_i(t),\ H_i(t),\ B_i(t)\ L_i(t)]$$

where F[.] is a production function exibiting constant returns to scale and diminishing marginal rates of substitution. The current efficiency of labor is measured by B(t). Now, rather than assuming that technical progress B(t) proceeds at a given exogenous rate, allow B(t) to reflect geographical spillovers arising from physical and human accumulation in neighbouring countries. The hypothesis is that technical progress for country i depends on the *average* level of physical(K) and human capital(H) (defined in efficiency units) in region R,

$$(2) \quad B_i(t) = A(t)\ \mathrm{K}_{iR}(t)^{\varphi}\ \mathrm{H}_{iR}(t)^{\zeta}$$

A, K and H are treated as exogenously provided public inputs which are nonexcludable and nonrival, which is consistent for example with the assumptions made in Solow (1956), Lucas (1988) and Arrow (1962).[9] The regional inputs (K and H) receive no compensation and are a consequence of unintentional spillovers arising from capital accumulation in neighboring countries. This formulation supports a decentralized equilibrium.

Hypothesizing that technical progress depends on the *average* rather than the *aggregate* regional capital stock seems reasonable in light of the unusual predictions models using the latter assumption have uncovered. Arrow (1962), Sheshinski (1967), and Romer (1986) for example postulate learning-by-doing spillovers where technical progress B(t) is a function of the *aggregate* physical capital stock (or cumulated gross investment). In the endogenous growth versions, such models however predict scale effects where growth rates should depend on population size. Cross-sectional studies of growth convergence regressions have not revealed any scale effects.[10] The neoclassical growth versions of such learning-by-doing models where aggregate physical capital is used likewise predict paradoxical results. Sheshinki (1967) noted for example that on the balanced growth path, a higher labor force growth implies a higher wage growth rate. Such a paradox arises (Arrow (1962)) because a higher growth rate of labor induces more investment, which in turn raises labor's efficiency and the wage rate. These arguments extend to the human capital side. Postulating a production function that depends on aggregate human capital rather than average human capital likewise predicts implausible scale effects.

Lucas (1988) analyses a production function which considers both the *internal effect* of human capital which is the effect of an individual's human capital on his own productivity, and an *external effect*, which is the effect of the average human capital on the productivity of all factors of production. The equivalent idea is extended in this model to an aggregate production function where H represents the average human capital of the regional countries that influences the country's productivity. The effect is external, appropriately labelled in this setup, since no country is assumed to have an appreciable effect on the regional average human capital, and no country will take this externality into account when

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[9] A purely *nonrival* good has the property that its use by one firm or person in no way limits its use by another. A good is *nonexcludable* if the owner cannot prevent others from using it. For a discussion of these properties, see Romer (1990) and Barro and Sala-i-Martin (1991b).

[10] See Barro (1991), and Backus, Kehoe and Kehoe (1990).

determining their investment decisions. The *internal* effects of human capital have already been extensively shown in cross-country regressions to be an important determinant of a country's growth rate.[11] Moreover the incorporation of (internal) human capital can also help explain the apparent slow rate of convergence amongst countries. Less is however empirically known about the effects of *external* human capital - what Lucas (1988) in fact assigns a central role to in his models for explaining income disparities and what he labels as the 'force' that can account for certain features of aggregative development including the role of cities.

Assume labor and A(t) grow at the constant rate n and g respectively. Define the usual per capita quantities measured in terms of efficiency of labor but using A(t) rather than B(t). A(t) can then be thought of as the usual 'technology' term whose determinants are outside the bounds of this current inquiry. B(t) incorporates this technology term as well as the regional spillovers. We can then rewrite equation (1) in the form,

$$(3) \quad y_i(t) = f\,[\, k_i(t),\ h_i(t),\ \kappa_{iR}(t)^{\varphi}\ \mathrm{H}_{iR}(t)^{\xi}]$$

where

$$y(t) = \frac{Y(t)}{A(t)L(t)}\ , \quad k(t) = \frac{K(t)}{A(t)L(t)}\ , \quad h(t) = \frac{H(t)}{A(t)L(t)}\ .$$

Define **K** and **H** as logarithmic averages,

$$\ln \kappa = \frac{1}{m}\sum_{1}^{m} \ln k_i\ ,\ \ln \mathrm{H} = \frac{1}{m}\sum_{1}^{m} \ln h_i$$

where m is the number of countries in the relevant region. For a Cobb-Douglas production function,

$$(4) \quad y_i(t) = k_i(t)^{\alpha}\ h_i(t)^{\beta}\ \kappa_{iR}(t)^{(1-\alpha-\beta)\varphi}\ \mathrm{H}_{iR}(t)^{(1-\alpha-\beta)\xi}$$

[11] See Barro (1991) and Mankiw, Romer and Weil (1992).

Without loss of generality, rewrite

$$(5) \quad y_i(t) = k_i(t)^{\alpha}\, h_i(t)^{\beta}\, \kappa_{iR}(t)^{\epsilon}\, H_{iR}(t)^{\sigma}\ , \quad \textit{where} \quad \epsilon = (1-\alpha-\beta)\ \varphi\ , \quad \sigma = (1-\alpha-\beta)\ \xi$$

The parameters ϵ and σ in the model capture the degree of cross-border spillovers. The parameters ϵ and σ are the elasticities of domestic output with respect to average regional physical capital and average regional human capital respectively. The parameters α and β are the usual elasticities of domestic output with respect to domestic physical and human capital respectively. This paper will extend the empirical approach used by Mankiw, Romer and Weil (1992) to estimate the parameters α, β, ϵ and σ. Notice that the externality parameters, ϵ and σ, can take either positive or negative values. Positive values correspond to external spillover *economies* whereas negative values correspond to external *diseconomies*. If cross-border spillovers are absent altogether, then the spillover parameters should equal zero, $\epsilon=\sigma=0$.

The spillover parameters are important for several reasons. First, if these spillover parameters (ϵ and σ) are quite high, the evidence will point in favor of the endogenous growth models employing such spillover externalities rather than the standard Solow growth model. If $\alpha+\beta+\epsilon+\sigma$ sums to one, meaning that there is constant returns to scale to the factors that can be accumulated, then countries belonging to such a region can grow indefinitely at that endogenous growth rate. This is possible simply because the *social* marginal product of capital for the *region* does not diminish with additional capital accumulation. Note that increasing returns ($\epsilon+\sigma>0$) is not a sufficient (nor necessary) condition for endogenous growth. What is required is strong increasing returns, or a high value for $\sigma+\epsilon$ such that $\alpha+\beta+\epsilon+\sigma$ sum to one.

Second, the relative magnitudes of ϵ and σ will indicate whether human or physical capital spillovers are more important. A priori, it is difficult to tell whether a country investing in a machine rather than in its people will benefit her neighours by more or less. There seems to be a bias in the recent literature suggesting that investments in human capital are more likely to generate spillovers. The justification often stresses the public good nature of knowledge which seems more intimately linked with human capital rather than physical capital. Knowledge is often passed on from one person to another, usually without any need for compensation. Learning from people (for most) moreover seems easier than learning from machines. For physical capital investments, the issue of spillovers is usually stressed on machinery or equipment investment, brought about presumably by learning-by-doing. De Long and Summers (1991), noting the rather large coefficient on equipment investment when included in cross-country regressions, argue that equipment investment generate large externalities and conclude that the social return to equipment investment is on the order of 30 percent each year. The literature to date however offers no conclusive theoretical argument or empirical evidence on the *relative* importance of human versus physical capital spillovers. Third, the existence of such spillovers matter for policy. Given that countries do not account for the benefits accrued to neighbouring countries when making their investment decisions, uncoordinated investments in physical and human capital are suboptimal. Coordinated increases in investments by countries belonging to the region can be welfare-improving for all countries. Moreover, if regional spillovers are more likely to occur with a *certain* form of investment (human or physical), then a regional policy which shifts the *distribution* of savings towards that form of investment can increase the regional growth rate.

As in Solow (1956) and Mankiw, Romer and Weil (1992), I assume a constant domestic saving rate s_k for physical capital and s_h for human capital. Empirical studies on the determinants of the savings rate have generally found that saving is insensitive to changes in the rates of return. Though there is some evidence to suggest that saving rate rises with income per capita, Ross and Levine (1992) find that this relationship is fragile with the addition of other explanatory variables.[12] Constant saving rates seem therefore a reasonable approximation. The usual capital accumulation equations are therefore

$$(6) \quad \frac{dk(t)}{dt} = s_k\, y(t) - (n+g+\delta)\, k(t)$$

[12] Testing whether the dependent variable, investment share (1960-89) is correlated with real GDP(1960), Levine and Renelt (1992) find that adding "other variables" on the right-hand side such as the share of government spending and the number of revolutions and coups causes the coefficient on real GDP to become insignificant and to switch signs. They conclude therefore that the dependence of investment rate on real GDP is fragile.

$$(7) \quad \frac{dh(t)}{dt} = s_h\, y(t) - (n+g+\delta)\, h(t)$$

The same production function is assumed to apply to physical capital, human capital and consumption. Said differently, a unit of consumption can be changed costlessly into either a unit of human or physical capital.

B. Aggregation and Dynamics of the Regional Capital Stock

Let q(t) be the (logarithmic) average of the output produced by countries in the relevant region. From the definitions of average physical capital and human capital in (3), it follows that the average output in the region can be expressed in terms of the average physical and human capital in the region.

$$(8) \quad q\ (t) = \kappa(t)^{\theta+\alpha}\ \mathrm{H}(t)^{\sigma+\beta}$$

The expression for regional output *internalizes* the effects of the spillover externalities into the production function since the unit of concern encompasses the boundary limits of the externality. Using the definition of the average regional capital stock in equation (3) and aggregating over the countries in the relevant region gives the evolution of the average regional capital stock. The average capital stock of the region is defined as follows,

$$(9) \quad \ln \kappa_t = \frac{1}{m} \sum_1^m \ln k_{it}$$

Diferentiate with respect to time and substituting for dk/dt from equation (6),

$$(10) \quad \frac{1}{\kappa_t}\frac{d\kappa_t}{dt} = \frac{1}{m} \sum_1^m s_{ik} \frac{y_{it}}{k_{it}} - \frac{1}{m} \sum_1^m (\delta_k + n_i + g)$$

Rearranging the terms and introducing average regional output q,

One can then define the regional saving rate as follows where (y_i/q) and (k_i/K) can be intrepreted as the

$$(11)\quad \frac{d\kappa_t}{dt} = [\frac{1}{m}\sum_1^m s_{ik}(\frac{y_{it}}{q_t})(\frac{\kappa_t}{k_{it}})]\, q_t - \kappa_t \frac{1}{m}\sum_1^m (\delta_k + n_i + g)$$

weights attached to country i's saving rate for the accumulation of the average regional saving rate. Country i's contribution to the average regional saving rate for physical capital increases if any of the following variables increases: the ratio of domestic output to regional average output (y/q), the ratio of regional average physical stock to domestic capital stock (K/k), and country i's savings rate for physical capital (s_k). The weights reflect the marginal product of capital of the country relative to the regional marginal product of capital. We can then rewrite equation (11) in a simplified form, defining the regional saving rate as follows.

$$(12)\quad \frac{d\kappa_t}{dt} = s_{Rk} q_t - (\delta_k + n' + g)\,\kappa_t$$

$$\text{where}\quad s_{Rk} = [\frac{1}{m}\sum_1^m s_{ik}(\frac{y_{it}}{q_t})(\frac{\kappa_t}{k_{it}})]\ ,\ (\delta_k + n' + g) = \frac{1}{m}\sum_1^m (\delta_k + n + g)$$

Similarly, the evolution of the average regional human capital stock can be described as follows,

$$(13)\quad \frac{dH_t}{dt} = s_{RH}\, q_t - (\delta_h + n' + g)\, H_t$$

$$\text{where}\quad s_{RH} = \frac{1}{m}\sum_1^m s_{ih}(\frac{y_{it}}{q_t})(\frac{H_t}{h_{it}})\ ,\ (\delta_h + n' + g) = \frac{1}{m}\sum_1^m (\delta_h + n + g)$$

To construct a model that one can easily test, there must be some connection between the variables in the model and those that can be actually measured. The above derivation shows that the dynamic accumulation equations for capital in (6) and (7) where the unit of observation is *the country* can likewise be written with the unit of observation as *the region*, with the regional saving rate appropriately defined as shown in equations (12) and (13). We can therefore think of the region as some larger country with its own relevant saving rate, which however internalizes the spillover effects of its capital accumulation. I make the simplifying assumption here that the regional saving rate can also be treated as approximately constant. This will be true if the weights (y/q), (k/K) and (h/H), do not change by very much over the timespan relevant for the empirical test, an assumption which is consistent with the data spanning the period 1960-85.

C. Solving for the Steady-State

The steady-state capital stocks and output can be solved from the accumulation equations for k,h, K and H, given by equations (6), (7), (12) and (13). The steady state level of income per effective labor, $y(t)^*$ is therefore

$$(14)\ \ln y^* = \frac{\alpha}{1-\alpha-\beta}\ln s_k + \frac{\beta}{1-\alpha-\beta}\ln s_h - \frac{\alpha+\beta}{1-\alpha-\beta}\ln(n+g+\delta) + \frac{\epsilon(1-\beta)+\sigma\alpha}{(1-\alpha-\beta)(1-\alpha-\beta-\epsilon-\sigma)}\ln s_{RK} + \frac{\epsilon\beta+\sigma(1-\alpha)}{(1-\alpha-\beta)(1-\alpha-\beta-\epsilon-\sigma)}\ln s_{RH} - \frac{\epsilon+\sigma}{(1-\alpha-\beta)(1-\alpha-\beta-\epsilon-\sigma)}\ln(n'+g+\delta)$$

The steady state income level per efficiency unit increases when the regional average saving rates for physical and human capital increases, and when the regional population growth rate decreases. The expression for steady state average regional output is likewise

$$(15)\ \ln q^* = \frac{\alpha+\epsilon}{1-\alpha-\beta-\epsilon-\sigma}\ln s_{RK} + \frac{\beta+\sigma}{1-\alpha-\beta-\epsilon-\sigma}\ln s_{RH} - \frac{\alpha+\beta+\epsilon+\sigma}{1-\alpha-\beta-\epsilon-\sigma}\ln(n'+g+\delta)$$

The equation shows that the average regional output depends positively on the regional saving rate for physical and human capital, and negatively on the regional population growth rate.

D. Specification

Both equations (14) and (15) are testable specifications. The values of α, β, ϵ and σ can be identified from the coefficients on the domestic and regional rates of saving for physical and human capital, and the domestic and regional population growth rates.

I assume that the exogenous growth rate, g, and the depreciation rate, δ, are identical across countries. There is apriori no convincing reason why these variables might vary greatly across countries. Following Mankiw, Romer and Weil (1992), I assume that $\delta+g$ sum to 0.05, where $\delta=0.03$ and $g=0.02$.[13] The A(0) technology term is allowed to reflect country-specific differences across countries, such as resource endowments, religion, climate, culture, or political institutions. Assume therefore that

$$\ln A(0) + gt = a + u,$$

where a is a constant (for any given time, t is some constant) and u is a country-specific shock. Incorporating this into equation (14) gives

$$(16)\ \ln[\frac{Y}{L}] = a + \frac{\alpha}{1-\alpha-\beta}\ln s_k + \frac{\beta}{1-\alpha-\beta}\ln s_h - \frac{\alpha+\beta}{1-\alpha-\beta}\ln(n+g+\delta) + \frac{\epsilon(1-\beta)+\sigma\alpha}{(1-\alpha-\beta)(1-\alpha-\beta-\epsilon-\sigma)}\ln s_{RK}$$
$$+ \frac{\epsilon\beta+\sigma(1-\alpha)}{(1-\alpha-\beta)(1-\alpha-\beta-e-\sigma)}\ln s_{RH} - \frac{\epsilon+\sigma}{(1-\alpha-\beta)(1-\alpha-\beta-e-\sigma)}\ln(n'+g+\delta) + u.$$

Likewise, equation (15) can be rewritten as

$$(17)\ \ln[\frac{Q}{L}] = a + \frac{\alpha+\epsilon}{1-\alpha-\beta-\epsilon-\sigma}\ln s_{RK} + \frac{\beta+\sigma}{1-\alpha-\beta-e-\sigma}\ln s_{RH} - \frac{\alpha+\beta+\epsilon+\sigma}{1-\alpha-\beta-e-\sigma}\ln(n'+g+\delta) + u.$$

The saving rates and population rates are assumed to be independent of country-specific factors shifting the production function. In other words, s_k, s_h, n, n', s_{RK} and s_{RH} are independent of u. This assumption implies that equations (16) and (17) can be estimated with ordinary least squares.[14]

Equation (16) is estimated using ordinary least squares and non-linear least squares. In the

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[13] The value δ is chosen to match the available data. Capital consumption allowance is about 10 percent of GNP in U.S. data. If we take a capital-output ratio of about three, δ is about 0.03. Romer (1989) presents a calculation for some OECD countries and concludes that δ is about 0.03 or 0.04, and that the capital-output ratio range from 2.8 to 3.9. Maddison (1987) reaches a similar conclusion about the capital-output ratio for a sample of industrialised countries. The exogenous growth rate (g) is taken to match the growth in income per capita of the U.S., which is about 1.7 percent per year.

[14] In any models in which saving and population growth are endogenous but preferences are isoelastic, saving rates and population growth are unaffected by u. Under isoelastic utility therefore, permanent differences in technology levels do not affect saving rates or population growth rates. In such a model, if the elasticity of marginal utility is $-\theta$, it can be shown that for some reasonable parameter values, the rate of saving is constant at the value $1/\theta$. (Barro and Sala-i-Martin (1993), Chapt 1).

ordinary least squares regression, the values for α, β, ϵ and σ are inferred from the coefficients on s_k, s_h, s_{RK} and s_{RH}. In the non-linear least squares case, I consider first an unrestricted regression case where the coefficients on the population variables are unconstrained. The coefficients on the saving variables are as specified in equation (16). In this unrestricted case, there is an equal number of parameters as there are of independent variables. In the restricted regression, I estimate equation (16) directly, constraining both the coefficients on the population and saving variables to be a function of α, β, ϵ and σ, as predicted by the regional spillovers model. The restricted regression will therefore have two less degrees of freedom. If the model is incorrect, we should be able to reject the null hypothesis implied by these restrictions. Equation (17) is also tested by imposing the restriction that the coefficients on $\ln(s_{RK})$, $\ln(s_{RH})$ and $\ln(n'+g+\delta)$ sum to zero.

E. The Dataset

The data is taken from the Appendix in the paper by Mankiw, Romer and Weil, "A Contribution to the Empirics of Economic Growth," Quarterly Journal of Economics, May 1992. A reproduction of this dataset is given in the appendix. The data was taken from the Real National Accounts constructed by Summers and Heston (1988). The data are annual and cover the period 1960-85. Population growth (n) is measured as the average rate of growth of the working-age population, where working age is defined as 15 to 64. The saving rate (s_k) is the average share of real investment (including government investment) in real GDP from 1960-85. Output per capita (Y/L) is real GDP in 1985 divided by the working age population in that year. The saving rate for human capital (s_h) is the average percentage of the working age population in secondary school for the period 1960-85.

Since the concept of regional spillovers apply most directly when countries are geographically located close to one another, the classification used for *region* is that of *bordering countries*. Under this classification, the relevant region for country i will be all countries that border country i. Mexico and Canada, for example, will be the relevant region for the United States. Chile, Paraguay, Brazil, Ecuador and Panama will be the relevant region for Argentina. Such a definition prevents any subjective selectivity on what countries a certain region should include. The problem with this classification is the treatment of island countries, such as Japan, Madagascar and the Philippines, which do not have any, strictly speaking, bordering neighbors. For island countries, the nearest neighboring countries which lie across straits, channels or small bodies of water are used as the relevant region. There are in total 94 bordering countries and 9 island countries. The relevant regions for each country under this classification is summarised in the Appendix.

Proxies for the exogenous variables s_{RK} and s_{RH} have to be constructed. Since data is unavailable for the stocks of human and physical capital, some simplifying assumption is necessary. I assume that the ratio of a country's human capital stock to the regional average human capital stock (h/H) is approximately equal to the ratio of a country's physical capital stock to the regional average physical capital stock (k/K). Then,

$$(18) \quad \frac{y_i}{q} = \left(\frac{k_i}{K}\right)^{\alpha}\left(\frac{h_i}{H}\right)^{\beta} \approx \left(\frac{k_i}{K}\right)^{\alpha+\beta}$$

Provided that the ratio (y/q) does not change by very much over the relevant timespan, the regional average savings rate for physical capital can be approximated by

$$(19) \quad s_{RK} = \frac{1}{m}\sum_{1}^{m} s_{ik}\left(\frac{y_{it}}{q_t}\right)\left(\frac{K_t}{k_{it}}\right) \approx \frac{1}{m}\sum_{1}^{m} s_{ik}\left(\frac{y_{io}}{q_o}\right)^{-\left(\frac{1-\alpha-\beta}{\alpha+\beta}\right)}$$

Likewise, the regional average saving rate for human capital can be approximated by

$$(20) \quad s_{RH} = \frac{1}{m}\sum_{1}^{m} s_{ih}\left(\frac{y_{it}}{q_t}\right)\left(\frac{H_t}{h_{it}}\right) \approx \frac{1}{m}\sum_{1}^{m} s_{ih}\left(\frac{y_{io}}{q_o}\right)^{-\left(\frac{1-\alpha-\beta}{\alpha+\beta}\right)}$$

I considered different weights on (y/q) for the construction of the regional average saving rate. First, I use the parameter values suggested by Mankiw, Romer and Weil (1992), $\alpha=\beta=1/3$. Second, I consider the parameter values for α and β suggested by the first empirical exercise, $\alpha+\beta=0.6$. The parameter estimates are not sensitive to the weights chosen for (y/q). Hence I report the empirical results only for the case where $\alpha+\beta=0.6$, weights which are consistent with the final empirical estimates.

In constructing the regional average saving rate for country i, I exclude country i's savings rate from the calculation. The exclusion of the country's savings rate is simply to prevent any bias that may result because of the different weights attached to a country's domestic savings as a result of differences in the number of bordering countries. The exclusion makes the regression results more convincing and less suspect.

Four samples of countries are considered. The first sample (94 countries) is that of *bordering countries*, which are countries that have at least one other country bordering it. The second sample (103 countries) includes both *bordering and island countries*. The third and fourth sample are the same groupings used by Mankiw, Romer and Weil (1992), and serves as a useful basis for comparison. The third sample (88 countries), the *nonoil countries*, excludes the oil producers since the bulk of recorded gross domestic product for these countries represents the extraction of existing resources, as opposed to value added. One should not expect a standard neoclassical growth model to explain the change in GDP in these countries.[15] The fourth sample (75 countries), the *intermediate sample*, excludes the countries whose data receive a "D" grade from Summers and Heston or whose population is less than one million in 1960. The "D" grade categorises countries whose real income figures are based on little primary data. Measurement error is likely to be a major problem for these countries. The small countries are omitted because the determination of their real income may be dominated by idiosyncratic factors.

F. Results

Table 1 summarises the results from the ordinary least squares regression for specification (16). The elasticities α, β, σ and ϵ are calculated from the coefficients on ln(I/GDP), ln(school), regional average (I/GDP), and regional average schooling, or s_k, s_h, s_{RK}, s_{RH} respectively. Table 2 summarises the estimation of equation (17) for regional output (q).

[15] The countries excluded on this basis are Bahrain, Gabon, Iran, Iraq, Kuwait, Oman, Saudi Arabia, and the United Arab Emirates. Mankiw, Romer and Weil (1992) also excludes Lesotho on the basis that the sum of private and government consumption far exceeds GDP in every year of the sample, indicating that labor income from abroad constitutes an extremely large fraction of GNP.

The overall results support the regional spillovers model. First, the coefficients on regional investment, regional schooling, and regional population have signs that accord with the model's predictions. Second, the coefficients on the regional investment (s_{RK}) and regional schooling (s_{RH}) are significant for both samples. Third, the null hypothesis imposed by equation (16) on the coefficients on the saving and population variables cannot be rejected.[16] Likewise, the model predicts that the coefficients on $\ln(s_{RK})$, $\ln(s_{RH})$ and $\ln(n'+g+\delta)$ sum to zero for regression (17) on regional output. The bottom half of Table 2 shows that for all four samples, this restriction is not rejected. Fourth, the parameter estimates of α, β, σ and ϵ are reasonable. Fifth, adding the regional variables improves the regression fit for both samples. Lastly, as Table 3 shows, the inclusion of these regional variables reduces the magnitude of the coefficients on the continent dummy variables, and removes the significance of the Latin American dummy altogether.

The output elasticity of domestic physical capital (α) is estimated at about 0.33, slightly higher than the Mankiw, Romer and Weil (1992) estimates. The output elasticity of domestic human capital (β) is estimated at about 0.20. The value of α is still consistent with the factor share of physical capital in income, which is roughly one third. The estimates of σ (regional physical capital) and ϵ (regional human capital) are unfortunately quite different for the two samples. The relative importance between the two forms of capital is therefore difficult to gauge. The point estimate of $(\epsilon+\sigma)$, the sum of the spillover parameters, however has a smaller standard error, and ranges from about 0.12 to 0.16. The sum of the domestic capital shares, $(\alpha+\beta)$, ranges from 0.50 to 0.54. These estimates confirm the existence of positive externalities and regional spillovers. However, the magnitudes of ϵ and σ do not add up to the numbers required to generate endogenous growth. Said differently, the sum $(\alpha+\beta+\epsilon+\sigma)$ is only about 0.65, which is still less than one though higher than the sum of factor shares suggested in Mankiw, Romer and Weil (1992). These parameter estimates are however based on the steady-state assumption. Section II considers transitional behaviour out of steady state.

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[16] The unrestricted regression allows the coefficients on the population variables to take on independent values. The restricted regression imposes the parametric restrictions implied by equation (16). The test is carried out using non-linear least squares. The asymptotic F-Statistic for the null is 0.78 for the nonoil sample and 1.01 for the intermediate sample.

Table 1: Estimating the Regional Spillovers Model (Steady State)

Dependent Variable: log GDP per working-age person in 1985				
Sample	Non-Oil	MRW(92)	Inter-mediate	MRW(92)
Observations	97	97	75	75
Constant	0.651 (1.056)	0.377 (1.053)	0.942 (1.018)	0.941 (0.990)
ln(I/GDP)	0.665 (0.110)	0.689 (0.130)	0.700 (0.130)	0.705 (0.141)
ln(school)	0.307 (0.084)	0.646 (0.071)	0.469 (0.123)	0.717 (0.092)
ln(n+g+δ)	-0.470 (0.479)	-1.846 (0.410)	-0.762 (0.491)	-1.595 (0.391)
ln(regional (I/GDP) average)	0.370 (0.168)		0.432 (0.193)	
ln(regional school average)	0.495 (0.121)		0.283 (0.140)	
ln(regional (n'+g+δ) average)	-0.818 (0.531)		-0.351 (0.539)	
Adjusted R^2	0.85	0.79	0.83	0.80
s.e.e.	0.414	0.497	0.391	0.440
α (dom phy cap)	0.337 (0.045)	0.295 (0.045)	0.323 (0.052)	0.291 (0.048)
β (dom hum cap)	0.156 (0.040)	0.277 (0.034)	0.216 (0.052)	0.29[illegible] (0.03[illegible]
σ (reg phy cap)	0.127 (0.051)		0.045 (0.058)	
ϵ (reg hum cap)	0.028 (0.051)		0.070 (0.059)	
$\alpha + \beta$	0.493 (0.028)	0.572 (0.019)	0.539 (0.028)	0.587 (0.020)
$\epsilon + \sigma$	0.155 (0.026)		0.114 (0.026)	
$\alpha + \beta + \epsilon + \sigma$	0.647 (0.019)		0.653 (0.021)	

Note: Standard errors are in parentheses. The following equation is estimated using OLS. The parameters α, β, ϵ and σ are retrieved from the coefficients on the saving variables.

$$(16)\quad \ln[\frac{Y}{L}] = c_1 + \frac{\alpha}{1-\alpha-\beta}\ln s_k + \frac{\beta}{1-\alpha-\beta}\ln s_h + c_2\ln(n+g+\delta) + c_3\ln(n'+g+\delta) + \frac{\epsilon(1-\beta)+\sigma\alpha}{(1-\alpha-\beta)(1-\alpha-\beta-\epsilon-\sigma)}\ln s_{RK} + \frac{\epsilon\beta+\sigma(1-\alpha)}{(1-\alpha-\beta)(1-\alpha-\beta-\epsilon-\sigma)}\ln s_{RH} + u$$

Table 2: Estimating the Regional Spillovers Model (Regional Output)

Dependent Variable: average regional GDP per working-age person (q) in 1985				
Sample	Border & Islands	Border	Nonoil	Interm
Observations	103	94	97	75
Constant	0.570 (0.825)	0.396 (0.825)	-0.003 (0.820)	0.197 (0.841)
ln(regional (I/GDP) average)	0.656 (0.141)	0.692 (0.156)	0.633 (0.134)	0.617 (0.157)
ln(regional school average)	0.974 (0.071)	0.964 (0.072)	0.964 (0.069)	0.920 (0.080)
ln(regional ($n'+g+\delta$) average)	-1.608 (0.323)	-1.644 (0.326)	-1.847 (0.322)	-1.831 (0.337)
Adjusted R^2	0.87	0.88	0.89	0.87
s.e.e.	0.363	0.349	0.338	0.341
Restricted Regression:				
Constant	0.534 (0.522)	0.377 (0.561)	0.436 (0.496)	0.646 (0.568)
ln(reg (I/GDP)) - ln($n'+g+\delta$)	0.652 (0.126)	0.689 (0.135)	0.671 (0.121)	0.674 (0.135)
ln(reg school) - ln($n'+g+\delta$)	0.974 (0.071)	0.964 (0.072)	0.967 (0.069)	0.923 (0.079)
Adjusted R^2	0.87	0.88	0.89	0.87
s.e.e.	0.361	0.347	0.337	0.340
Test of Restriction: (F-Stat)	0.003	0.001	0.453	0.526
$\alpha + \epsilon$ (phy capital)	0.248 (0.041)	0.260 (0.043)	0.254 (0.039)	0.259 (0.045)
$\beta + \sigma$ (hum capital)	0.371 (0.032)	0.363 (0.033)	0.367 (0.031)	0.355 (0.035)
$\alpha + \beta + \epsilon + \sigma$	0.619 (0.013)	0.623 (0.013)	0.621 (0.012)	0.615 (0.014)

Note: Standard errors are in parentheses. The following regression is tested using OLS.

Restricted Regression:

$$\ln q^* = c + \frac{\alpha+\epsilon}{1-\alpha-\beta-\epsilon-\sigma}(\ln s_{RK} - \ln(n'+g+\delta)) + \frac{\beta+\sigma}{1-\alpha-\beta-\epsilon-\sigma}(\ln s_{RH} - \ln(n'+g+\delta))\ u.$$

Table 3. Regional Spillovers and Continent Dummies (Steady State)

Dependent Variable: log GDP per working-age person in 1985			
Sample	Nonoil Countries	Nonoil Countries	Nonoil Countries
Observations	97	97	97
Constant	0.622 (1.069)	3.675 (1.245)	1.826 (1.204)
ln(I/GDP)	0.697 (0.133)	0.734 (0.119)	0.694 (0.101)
ln(school)	0.654 (0.073)	0.400 (0.086)	0.254 (0.079)
ln($n+g+\delta$)	-1.745 (0.042)	-0.848 (0.450)	-0.162 (0.463)
ln(regional (I/GDP) average)			0.509 (0.170)
ln(regional school average)			0.310 (0.145)
ln(regional ($n'+g+\delta$) average)			-0.717 (0.495)
Latin Amer Dummy		-0.301 (0.157)	-0.085 (0.137)
Sub-Saharan Africa Dummy		-0.870 (0.170)	-0.459 (0.180)
Asia Dummy		-0.514 (0.166)	-0.463 (0.144)
Adjusted R^2	0.78	0.83	0.88
s.e.e.	0.508	0.451	0.377

Note: Standard errors are in parentheses. Similar results hold for the other samples.

II. Convergence and Regional Spillovers

A. Solving for the Rate of Convergence

In this section, I derive conditional convergence equations for output per capita and regional output per capita using the regional spillovers model. These convergence conditions are then tested to examine whether the predictions of the model for the transitional dynamics out of steady state are consistent with cross-country data.

To analyze the transitional path, I use a log-linear approximation of the system around the steady state for the variables h, k, H and K. A country's output (y) will simply be a linear function of these four variables. Regional output (q) is likewise a linear function of H and K. Denoting steady state values by the superscript *, we have:

$$(21)\quad \frac{d}{dt}\begin{vmatrix} \ln k_t \\ \ln h_t \\ \ln \kappa_t \\ \ln H_t \end{vmatrix} = M \;x\; \begin{vmatrix} \ln k_t - \ln k^* \\ \ln h_t - \ln h^* \\ \ln \kappa_t - \ln \kappa^* \\ \ln H_t - \ln H^* \end{vmatrix}$$

$$M = \begin{vmatrix} -(1-\alpha)(n+g+\delta) & \beta(n+g+\delta) & \epsilon(n+g+\delta) & \sigma(n+g+\delta) \\ \alpha(n+g+\delta) & -(1-\beta)(n+g+\delta) & \epsilon(n+g+\delta) & \sigma(n+g+\delta) \\ 0 & 0 & -(1-\alpha-\epsilon)(n'+g+\delta) & (\beta+\sigma)(n'+g+\delta) \\ 0 & 0 & (\alpha+\epsilon)(n'+g+\delta) & -(1-\beta-\sigma)(n'+g+\delta) \end{vmatrix}$$

Since the matrix M is upper block triangular, the eigenvalues can be solved for easily. The first pair of characteristic roots can be computed from the (2x2) upper left corner matrix. The second pair of roots can be computed from the (2x2) lower right corner matrix.[17] The eigenvalues for the above system are

[17] A more rigorous proof can be found in Watkins, David. Fundamentals of Matrix Computations(1991), Theorem 4.2.5, pg. 206. A simple proof is to realize that because $(\lambda I-A)$ is block triangular, $\det(\lambda I-A) = \det(\lambda I-A_{11}).\det(\lambda I-A_{22})...\det(\lambda I-A_{mm})$ for a (m x m) matrix A. Thus the set of roots of the charateristic polynomial of A equals the union of the roots of the charateristic polynomials.

$$-\lambda_1 = -(1-\alpha-\beta)(\delta+n+g)\ ,\ -\lambda_2 = -(\delta+n+g)\ ,$$

$$-\lambda_3 = -(1-\alpha-\beta-\sigma-\epsilon)(\delta+n'+g)\ ,\ -\lambda_4 = -(\delta+n'+g).$$

Since the eigenvalues are all negative, the system is globally stable. Notice that λ_1 and λ_2 are the same eigenvalues derived in Mankiw, Romer and Weil (1992). λ_1 can be thought of as the convergence rate without spillovers in the Solow model augmented for human capital. λ_3 however is also a function of the spillover parameters ϵ and σ, and can be intrepreted as a between-region rate of convergence. Think of the region as another country which internalizes the effects of its capital accumulation where regional output, $q = K^{\alpha+\epsilon}H^{\beta+\sigma}$. The rate of convergence λ_3 can therefore be intrepreted as the convergence rate between regions. If n' is about the same size as n, then $\lambda_3 < \lambda_1$ when there are external economies ($\epsilon+\sigma>0$). Suppose the parameters take the following values, $(n+g+\delta) = 0.07$, $\alpha+\beta=0.33$, $\epsilon+\sigma=0.06$, then $\lambda_1 = 0.023$ and $\lambda_3 = 0.015$. Regional spillovers slows down the decrease in the regional growth rate since diminishing returns sets in more slowly. Regional output therefore takes a longer period of time to reach steady state. Regional spillovers can therefore help explain why countries within a common region tend to converge much more quickly, while countries located in different regions such as Europe and Africa tend to take much longer to converge.

We can use these eigenvalues to solve for the eigenvectors. The (log-linearized) transitional path of output (y) about the steady state is therefore of the form

$$(22)\ \ln y_t - \ln y_o = -(1-e^{-\lambda_1 t})\ln y_o + (1-e^{-\lambda_1 t})\left(\frac{\alpha}{1-\alpha-\beta}\ln s_k + \frac{\beta}{1-\alpha-\beta}\ln s_h\right)$$
$$+\ g(K_o,H_o,s_{RK},s_{RH},\phi,\phi';\lambda_3,\lambda_4,\alpha,\beta,\epsilon,\sigma)$$

where g(y;x) is some non-linear function of the respective exogenous y variables, with parameters x.[18] Note that λ_1 and λ_2 do not enter into the g function. Consistent estimates of the convergence rate λ_1, the factor shares α and β, and the spillover parameters ϵ and σ require knowledge of all six exogenous variables K_o, H_o, s_{RK}, s_{RH}, $(n+g+\delta)$ and $(n'+g+\delta)$. There is however no empirical data available for the initial stocks of physical and human capital. The above equation is nevertheless

[18] I have not included the exact solution, that is the eigenvectors and the eigenvalues for the above system, since the solution is complicated and not very insightful. The last section offers a simplification which provides some intuitive results. For those interested however, the exact solution is available on request.

tested using ordinary least squares for the available right-hand side variables. The first three terms are identical to the terms derived in Mankiw, Romer and Weil (1992). In addition to the usual Solow variables, the regional spillovers model predicts that a country's growth rate should depend positively on the regional investment rate (s_{RK}), positively on the regional schooling rate (s_{RH}), and negatively on the regional population growth rate.

The (log-linearized) transitional path of regional average output (q) about the steady state is

$$(23)\quad \ln q_t - \ln q^* = (\ln q_o - \ln q^*)\, e^{-\lambda_3 t}$$

We can then subsitute in the steady-state value for $\ln q^*$ and derive a conditional convergence equation for regional average output (q).

$$(24)\ \ln q_t - \ln q_o = -(1-e^{-\lambda_3 t}) \ln q_o + (1-e^{-\lambda_3 t}) \frac{\alpha+\epsilon}{1-\alpha-\beta-\epsilon-\sigma} \ln s_{RK}$$

$$+(1-e^{-\lambda_3 t}) \frac{\beta+\sigma}{1-\alpha-\beta-\epsilon-\sigma} \ln s_{RH} + (1-e^{-\lambda_3 t}) \frac{\alpha+\beta+\epsilon+\sigma}{1-\alpha-\beta-\epsilon-\sigma} \ln(n'+g+\delta)$$

The above conditional convergence equation for regional average output can be tested. The parameters λ_3, $(\alpha+\epsilon)$, and $(\beta+\sigma)$ can be retrieved from the coefficients in the regression.

The two different conditional convergence regressions for domestic output and regional output implies that we should observe a higher rate of convergence *between countries within a region* and a slower rate of convergence *between regions in the world*. Regional spillovers increases the convergence of income differentials between countries located within a common region. This simply says that we should not expect the income levels of Belgium and the Netherlands, or Columbia and Venezuela to diverge by much over time. However, poor countries tend to be located in a common region to begin with (Africa), and richer countries tend to be clustered in another region (Europe). Income differentials between regions converge slowly because regional spillovers slows down the decrease in the social marginal rate of return of capital. Regional spillovers hold back the growth rate of the relatively poor (African) countries located in one common region, and slows down the decrease in the growth rate of the relatively richer (European) countries located in another region along the transitional path. In other words, regional spillovers lower the between-region convergence rate. As a result, income differentials between countries in a common region may converge rather quickly over time while the income differentials between different regions (or countries located in different regions) may take much longer to converge. In addition to these "convergence effects", as section I has shown, regional spillovers also raises the steady-state income differential between different regions ("level effects").

C. Results

The least squares regression for the conditional convergence of output per capita are reported in Table 5 for the nonoil and the intermediate sample. Table 6 reports the OLS results for the conditional convergence of regional output per capita.

What is most striking about the regressions with the spillover variables is how much the fit of the regression improves by as compared to the augmented Solow model. As shown in Table 5, the adjusted R^2 jumps from 0.50 to 0.66 for the full sample, and from 0.48 to 0.63 for the nonoil and intermediate countries. The coefficients on the regional average investment rate and the regional average schooling rate are both positive and significant. These regional investment variables can also help account for the significant continent dummies. Table 4 shows growth regressions with both continent dummies and spillover variables. The first regression shows that the fit improves from an adjusted R^2 of 0.51 to 0.57 when continent dummies are used. The Latin American and Sub-Saharan African dummies are significantly negative, consistent with the findings of other empirical studies (Barro (1991), Levine and Renelt (1992)). The second regression includes the regional spillover variables. The coefficients on both the Latin America and Africa dummies fall by half and loses their significance. The adjusted R^2 rises to 0.68. The inclusion of these regional variables can explain away the significance of the Sub-Saharan and Latin American dummy. The continent dummies in the first regression are simply proxying for the omitted regional variables. This result rules out the notion that the continent dummies proxied for intrinsic cultural differences or political regime differences across continents.

As Table 6 shows, the sum of the elasticity of output with respect to domestic physical capital (α) and to external physical capital (ϵ) is estimated to be about 0.39. The sum of the elasticity of output with respect to domestic human capital (β) and to external human capital (σ) is estimated to be about 0.36. The sum of these parameters ($\alpha+\beta+\epsilon+\sigma$) are estimated at about 0.75, with a small standard error. Since $\alpha+\beta+\epsilon+\sigma$ is still less than one, the overall evidence still favors traditional neoclassical growth models rather than endogenous growth models. Nevertheless, a value of 0.75 implies a regional convergence rate of about 1.6%, instead of the standard convergence rate of 2.5% in the augmented-Solow model. This implies that regional output per capita could take as long as 44 years to reach halfway to steady state, rather than the usual 28 years suggested in the augmented Solow-model. [19] The empirical estimate of $(\alpha+\beta+\epsilon+\sigma)$ at about 0.75 is moreover consistent with the parameter estimate of the regional rate of convergence of about 1.4% (Table 6).

[19] An endogenous growth theorist could argue that the estimated regional convergence rate is about 1.4%. Since λ_3 is equal to $(1-\alpha-\beta-\epsilon-\sigma)(n'+g+\delta)$ and $(n'+g+\delta)$ is really about 0.10 (instead of the assumed value of 0.07), then $\alpha+\beta+\epsilon+\sigma$ sum to 0.86. Such a high value therefore supports the use of endogenous growth models as a fair approximation.

Table 4. Regional Spillovers, Convergence, and Continent Dummies

Dependent Variable: log difference GDP per working-age person 1960-85			
Sample	All Bordering & Islands	All Bordering & Islands	All Bordering & Islands
Observations	103	103	103
Constant	-0.581 (0.668)	0.651 (0.828)	0.070 (0.816)
ln(init y 1960)	-0.297 (0.048)	-0.331 (0.056)	-0.420 (0.051)
ln(I/GDP)	0.549 (0.085)	0.582 (0.082)	0.566 (0.071)
ln(school)	0.210 (0.057)	0.102 (0.065)	0.052 (0.058)
ln(n+g+δ)	-0.570 (0.245)	-0.292 (0.255)	0.077 (0.295)
ln(regional output(q) 1960)			0.111 (0.077)
ln(regional (I/GDP) average)			0.363 (0.124)
ln(regional school average)			0.095 (0.113)
ln(regional (n'+g+δ) average)			-0.091 (0.356)
Latin Amer Dummy		-0.232 (0.100)	-0.127 (0.088)
Sub-Saharan Africa Dummy		-0.397 (0.120)	-0.204 (0.124)
Asia Dummy		0.048 (0.125)	0.061 (0.122)
Adjusted R^2	0.51	0.57	0.68
s.e.e.	0.327	0.314	0.268

Note: Standard errors are in parentheses. The estimation uses ordinary least squares. Similar results hold for the other samples.

Table 5: Conditional Convergence with Regional Spillovers

Dependent Variable: log difference GDP per working-age person 1960-85				
Sample	Nonoil Countries	MRW (92)	Inter-mediate Countries	MRW (92)
Observations	97	97	75	75
Constant	-0.240 (0.681)	-0.654 (0.670)	-0.090 (0.633)	-0.244 (0.651)
ln(y 1960)	-0.412 (0.057)	-0.296 (0.059)	-0.443 (0.061)	-0.371 (0.063)
ln(I/GDP)	0.531 (0.071)	0.519 (0.084)	0.540 (0.081)	0.532 (0.093)
ln(school)	0.087 (0.060)	0.228 (0.057)	0.136 (0.084)	0.262 (0.075)
ln(n+g+δ)	0.013 (0.309)	-0.606 (0.279)	-0.149 (0.308)	-0.655 (0.269)
ln(regional output(q) 1960)	0.061 (0.075)		0.056 (0.076)	
ln(regional I/GDP average)	0.290 (0.110)		0.332 (0.119)	
ln(regional school average)	0.243 (0.090)		0.163 (0.101)	
ln(regional (n'+g+δ) average)	-0.244 (0.349)		-0.104 (0.341)	
Adjusted R^2	0.63	0.48	0.63	0.48
s.e.e.	0.265	0.313	0.240	0.284

Note: Standard errors are in parentheses. The regression equation is estimated using ordinary least squares. Similar results hold for the bordering and full sample.

Table 6: Estimating the Conditional Convergence of Regional Output

Dependent Variable: log difference of regional GDP per working-age person (q) 1960–85				
Sample	Border & Islands	Border	Nonoil	Interm
Observations	103	94	97	75
Constant	−1.112 (0.430)	−1.143 (0.433)	−0.910 (0.423)	−0.731 (0.416)
ln(regional output(q) 1960)	−0.279 (0.043)	−0.258 (0.046)	−0.272 (0.045)	−0.301 (0.046)
ln(regional (I/GDP) average)	0.431 (0.073)	0.392 (0.082)	0.419 (0.070)	0.431 (0.078)
ln(regional school average)	0.372 (0.051)	0.354 (0.053)	0.392 (0.050)	0.398 (0.052)
ln(regional (n'+g+δ) average)	−0.731 (0.172)	−0.735 (0.176)	−0.637 (0.180)	−0.644 (0.183)
Adjusted R^2	0.65	0.62	0.69	0.69
s.e.e.	0.184	0.179	0.173	0.167
Restricted Regression:				
Constant	−1.234 (0.284)	−1.161 (0.303)	−1.204 (0.273)	−0.998 (0.299)
ln(regional q 1960)	−0.279 (0.042)	−0.258 (0.046)	−0.280 (0.044)	−0.308 (0.046)
ln(reg (I/GDP)) − ln(n'+g+δ)	0.419 (0.065)	0.390 (0.072)	0.395 (0.064)	0.397 (0.069)
ln(reg school) − ln(n'+g+δ)	0.373 (0.050)	0.354 (0.053)	0.394 (0.050)	0.402 (0.052)
Adjusted R^2	0.65	0.62	0.69	0.69
s.e.e.	0.183	0.178	0.173	0.167
Test of Restriction: (F–Stat)	0.143	0.003	0.829	0.852
Regional Conv Rate λ_3	0.0131 (0.0024)	0.0120 (0.0025)	0.0130 (0.0025)	0.0147 (0.0026
$\alpha + \epsilon$ (phy cap)	0.391 (0.051)	0.389 (0.058)	0.370 (0.050)	0.359 (0.051)
$\beta + \sigma$ (hum cap)	0.348 (0.040)	0.354 (0.045)	0.369 (0.039)	0.363 (0.041)
$\alpha + \beta + \epsilon + \sigma$	0.739 (0.021)	0.742 (0.023)	0.740 (0.021)	0.722 (0.020)

Note: Standard errors are in parentheses. The following restricted regression is tested.

$$(30)\ \ln q_t - \ln q_o = a_o - (1-e^{-\lambda_3 t}) \ln q_o + (1-e^{-\lambda_3 t})\frac{\alpha+\epsilon}{1-\alpha-\beta-\epsilon-\sigma}(\ln s_{RK} - \ln(n'+0.05))$$
$$+ (1-e^{-\lambda_3 t})\frac{\beta+\sigma}{1-\alpha-\beta-\epsilon-\sigma}(\ln s_{RH} - \ln(n'+0.05)) + u$$

III. *Within-Region* and *Between-Region* Rates of Convergence

A. A Benchmark Case

The conditional convergence derived above for output is complex and not very intuitive. This section tries to offer some insights into the transitional dynamics by making a simplifying assumption about population growth rates. If one assumes that the domestic population growth rate (n) is approximately equal to the regional population growth rate (n'), the problem simplifies dramatically.[20] This can be seen from the (4x4) matrix M in equation (21), where now we can just pull the multiplicative $(n+g+\delta)$ term out of the matrix.

We can then solve for the transitional dynamics of income per capita for the above system with $n = n'$. The transitional dynamics of income per capita (y) can be expressed in the following manner using the definition for q,

$$(25)\quad \ln y_t - \ln y_o = -(1-e^{-\lambda_1 t})(\ln y_o - \ln y^*) + (e^{-\lambda_3 t}-e^{-\lambda_1 t})(\ln q_o - \ln q^*).$$

Substituting the respective steady state values for y^* and q^*,

$$(26)\ \ln y_t - \ln y_o = (1-e^{-\lambda_1 t})[-\ln y_o + \frac{\alpha}{1-\alpha-\beta}\ln s_k + \frac{\beta}{1-\alpha-\beta}\ln s_h - \frac{\alpha+\beta}{1-\alpha-\beta}\ln(n+g+\delta)] + (e^{-\lambda_3 t}-e^{-\lambda_1 t})\ln q_o$$

$$+ \left(\frac{\epsilon(1-\beta)+\sigma\alpha}{(1-\alpha-\beta)(1-\alpha-\beta-\sigma-\epsilon)} + \frac{\alpha}{1-\alpha-\beta}e^{-\lambda_1 t} - \frac{\alpha+\epsilon}{1-\alpha-\beta-\epsilon-\sigma}e^{-\lambda_3 t}\right)\ln s_{RK}$$

$$+ \left(\frac{\epsilon\beta+\sigma(1-\alpha)}{(1-\alpha-\beta)(1-\alpha-\beta-\epsilon-\sigma)} + \frac{\beta}{1-\alpha-\beta}e^{-\lambda_1 t} - \frac{\beta+\epsilon}{1-\alpha-\beta-\epsilon-\sigma}e^{-\lambda_3 t}\right)\ln s_{RH}$$

$$- \left(\frac{\epsilon+\sigma}{(1-\alpha-\beta)(1-\alpha-\beta-\epsilon-\sigma)} + \frac{\alpha+\beta}{1-\alpha-\beta}e^{-\lambda_1 t} - \frac{\alpha+\beta+\epsilon+\sigma}{1-\alpha-\beta-\epsilon-\sigma}e^{-\lambda_3 t}\right)\ln(n'+g+\delta)$$

Equation (26) is estimated since all the exogenous variables are available. The trick here is that the regional human and physical capital stocks have been expressed in terms of regional output (q) which is a value that can be constructed. The two convergence rates λ_1 and λ_3, the domestic factor shares α and β, and the spillover parameters ϵ and σ can then be retrieved from the regression coefficients.

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[20] The correlation between domestic population growth rate and regional population growth rate is about 0.7, which seems high enough to justify the approximation.

B. A Simple Graphical Example

A simple benchmark case is presented here to elaborate the distinctive features of the regional spillovers model and the Solow growth model. Consider the case of four countries and two regions. Countries A and B are relatively well-endowed countries located in one common region (Europe). Countries C and D are poorer countries located in another region (Africa). Spillovers occur only between countries located in a common region. Let the respective saving rates and population growth rates be identical across all four countries. Only the initial income per capita levels are different. Since steady-state income per capita depends only on the respective saving rates and population growth rates, and are independent of initial conditions, all four countries will converge eventually to the same steady-state income per capita. It also follows that the average regional output (q) and domestic output (y) are the same in steady-state. From equation (23) and the estimate of $\lambda_3 = 1.5\%$,

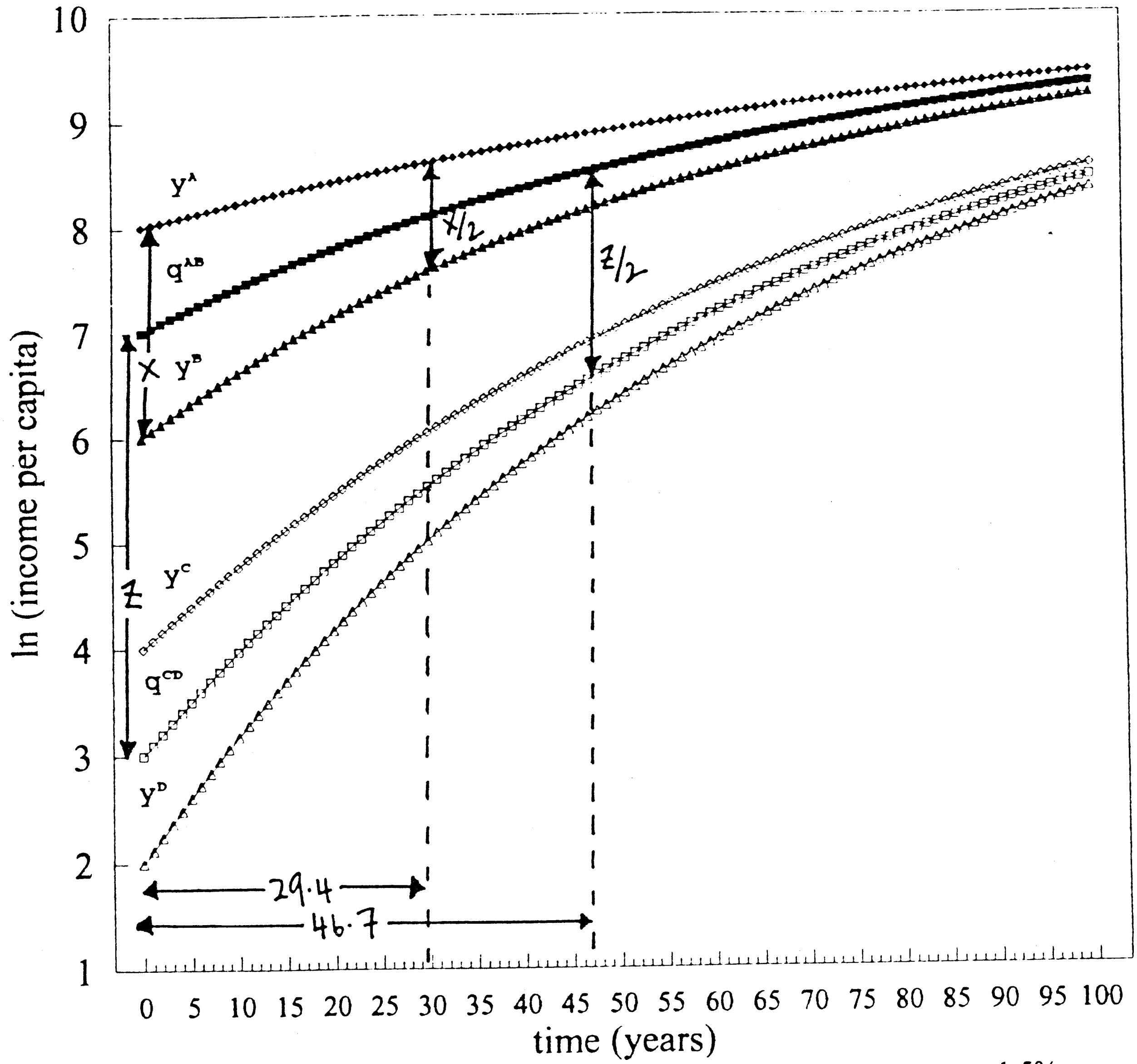
$$(27) \quad \ln q_t - \ln q^* = (\ln q_o - \ln q^*)\, e^{-\lambda_3 t}$$

the time taken for average regional output to reach halfway to steady state is about 47 years. λ_3 is referred to as the "between-region" convergence rate. From conditions (25) and (27), we can derive the following expression.

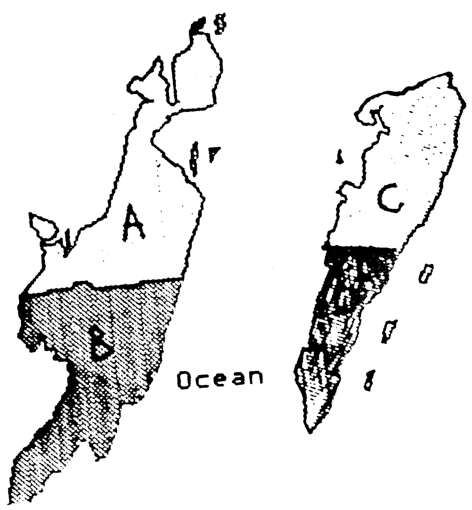
$$(28) \quad \ln y_t - \ln q_t = (\ln y_o - \ln q_o)\, e^{-\lambda_1 t}$$

This equation shows that the difference between a country's output(y) and its regional output (q) shrinks or converges at the rate λ_1, which is estimated at about 2.2%. λ_1 can therefore be appropriately referred to as a "within-region" convergence rate. For a within-region convergence rate of 2.2%, the time taken for domestic output (y) to reduce the difference with its regional output (q) by half is about 29.4 years. The example is illustrated in the respective diagram.

Graph 1: Regional Spillovers and Convergence



Note: Within-region convergence rate = 2.2%, Between-region convergence rate = 1.5%



C. Specification

Equation (26) is tested using non-linear least squares. Since the model here assumes equal population growth rates, I tried the regression using domestic population growth only, regional population growth only, and both. The choice does not affect the coefficients of the other independent variables significantly and so I have reported the results with the inclusion of both domestic and regional population growth rates as control variables. The model however imposes strong restrictions on the convergence rates. I run a restricted regression imposing the null hypothesis:

$$\text{Ho: } \lambda_1 = (1-\alpha-\beta)(n+0.05)$$

$$\lambda_3 = (1-\alpha-\beta-\epsilon-\sigma)(n'+0.05)$$

The degrees of freedom are reduced by two. The results are summarised in Tables 7 and 8.

D. Results

The within-region convergence rate (λ_1) is estimated at about 2.2% while the between-region convergence rate (λ_3) at about 1.7%. The estimated values are consistent with.expected magnitudes. We cannot reject the restrictions on the convergence rates for the nonoil and intermediate samples. The null hypothesis is rejected for the bordering and full sample. These parameter estimates confirm the observation that regions converge at a much slower rate relative to the rate at which countries within a region converge.

The output elasticity of domestic physical capital (α) is estimated at a relatively high value of about 0.45. The output elasticity of domestic human capital (β) is estimated at a lower than expected value of 0.15. Mankiw, Romer and Weil (1992) (Tables 6 and 7) estimate these parameters to be about 0.40 and 0.20 in their model. One explanation for why α is so high might be the imprecise measure of the human investment variable. Another explanation might be that α is capturing both the private and social returns of domestic physical capital at the within-country context. A high value of α suggests possibly that the social returns to domestic physical investment for the country (not the region) is considerably higher than the private returns. Such an intrepretation would be consistent with a similar model as this one for example where one aggregates across various industries or states within the country. The aggregated (or regionalized) capital for the country will in general capture the social returns as well. Such an argument for example is consistent with De Long and Summers (1991) who stress the importance of externalities from domestic equipment investment.

The estimates of ϵ and σ unfortunately do not offer any definite conclusion on whether one form of spillovers is any more important than the other. The size of ϵ and σ nevertheless provide strong support that both forms of spillovers are important and cannot be dismissed. This is even more apparent when one considers the estimate of $(\epsilon+\sigma)$ which ranges from about 0.16 to 0.20.

Probably the most dramatic result in Tables 7 and 8 is the high value of $(\alpha+\beta+\epsilon+\sigma)$. These estimates range from about 0.75 to 0.79 with a small standard error. Such a high sum stands in stark contrast to the sum estimated in Mankiw, Romer and Weil (1992) where $\alpha+\beta$ is estimated at about 0.70. Convergence behaviour is very sensitive to the values of $(\alpha+\beta+\epsilon+\sigma)$ when this value approaches one. An increase from 0.70 to 0.80 for example implies that the time required to reach halfway to steady state increases from about 33 to 50 years. Some theorists argue that for practical purposes, a value of 0.80 is high enough to be consistent with the empirical predictions of endogenous growth models. Without committing to any viewpoint, these high estimates of $(\alpha+\beta+\epsilon+\sigma)$ do support the observation that income per capital for certain countries do take a very long time to converge.

Table 7. Convergence and Regional Spillovers (Unrestricted Regression)

Dependent Variable: log difference GDP per working-age person 1960-1985				
Sample	Border & Islands	Border	Nonoil	Interm
Observations	103	94	97	75
Conv Rate: λ_1	0.0213 (0.003)	0.0220 (0.003)	0.0213 (0.004)	0.0234 (0.004)
Conv Rate: λ_3	0.0173 (0.004)	0.0174 (0.005)	0.0173 (0.003)	0.0196 (0.005)
α (dom phy cap)	0.532 (0.059)	0.516 (0.065)	0.515 (0.061)	0.483 (0.070)
β (dom hum cap)	0.070 (0.051)	0.066 (0.058)	0.084 (0.051)	0.121 (0.067)
ϵ (reg phy cap)	0.036 (0.070)	0.065 (0.073)	0.031 (0.071)	0.077 (0.080)
σ (reg hum cap)	0.133 (0.063)	0.127 (0.066)	0.135 (0.064)	0.070 (0.073)
$\alpha + \beta$	0.602 (0.034)	0.582 (0.039)	0.600 (0.035)	0.604 (0.032)
$\sigma + \epsilon$	0.170 (0.036)	0.192 (0.043)	0.166 (0.030)	0.147 (0.036)
$\alpha + \beta + \epsilon + \sigma$	0.771 (0.026)	0.774 (0.029)	0.766 (0.030)	0.751 (0.028)
s.e.e.	0.270	0.276	0.265	0.240
Adjusted R^2	0.66	0.66	0.63	0.63
Sum of Squared Residuals	6.944	6.464	6.169	3.817

Note: Standard errors are in parentheses. The following regression is estimated using non-linear least squares.
Unrestricted Case:

$$(UR)\ \ln\left(\frac{Y}{L}\right)_t - \ln\left(\frac{Y}{L}\right)_o = a_o + (1-e^{-\lambda_1 t})\left[-\ln y_o + \frac{\alpha}{1-\alpha-\beta}\ln s_k + \frac{\beta}{1-\alpha-\beta}\ln s_h\right] - k_1 \ln(n+g+\delta)$$

$$+\left(\frac{\epsilon(1-\beta)+\sigma\alpha}{(1-\alpha-\beta)(1-\alpha-\beta-\sigma-\epsilon)} + \frac{\alpha}{1-\alpha-\beta}e^{-\lambda_1 t} - \frac{\alpha+\epsilon}{1-\alpha-\beta-\epsilon-\sigma}e^{-\lambda_3 t}\right)\ln s_{RK}$$

$$+\left(\frac{\epsilon\beta+\sigma(1-\alpha)}{(1-\alpha-\beta)(1-\alpha-\beta-\epsilon-\sigma)} + \frac{\beta}{1-\alpha-\beta}e^{-\lambda_1 t} - \frac{\beta+\epsilon}{1-\alpha-\beta-\epsilon-\sigma}e^{-\lambda_3 t}\right)\ln s_{RH}$$

$$-k_2 \ln(n'+g+\delta) + (e^{-\lambda_3 t} - e^{-\lambda_1 t}) \ln q_o + u$$

Table 8. **Convergence and Regional Spillovers (Restricted Regression)**

Null Hypothesis H_o: $\lambda_1 = (1-\alpha-\beta)(n+0.05)$
$\lambda_3 = (1-\alpha-\beta-\epsilon-\sigma)(n'+0.05)$

Dependent Variable: log difference GDP per working-age person 1960-1985				
Sample	Border & Islands	Border	Nonoil	Interm
Observations	103	94	97	75
α (dom phy cap)	0.461 (0.048)	0.441 (0.052)	0.452 (0.046)	0.428 (0.054)
β (dom hum cap)	0.131 (0.041)	0.140 (0.045)	0.120 (0.041)	0.164 (0.052)
ϵ (reg phy cap)	0.123 (0.063)	0.144 (0.069)	0.100 (0.061)	0.144 (0.069)
σ (reg hum cap)	0.070 (0.058)	0.059 (0.061)	0.096 (0.057)	0.028 (0.062)
$\alpha + \beta$	0.592 (0.029)	0.581 (0.032)	0.571 (0.029)	0.592 (0.028)
$\sigma + \epsilon$	0.193 (0.029)	0.203 (0.035)	0.195 (0.031)	0.172 (0.027)
$\alpha + \beta + \epsilon + \sigma$	0.785 (0.025)	0.784 (0.028)	0.766 (0.025)	0.764 (0.027)
Test of Rest:F-Stat	8.96 **	8.86 **	3.26	1.12
s.e.e.	0.293	0.300	0.271	0.241
Adjusted R^2	0.64	0.64	0.63	0.66
Sum of Squared Residuals	8.256	7.813	6.626	3.947

Note: Standard errors as in parentheses. Estimation uses non-linear least squares. For the restriction test, ** implies the null hypothesis is rejected at the 1% level and * at the 5% level.

Conclusion

This paper tries to empirically quantify several important variables. The evidence strongly supports the idea that differences in regional investment rates and regional education rates can help explain cross-country differences in levels and growth rates of income per capita. Cross-country regressions confirm the existence of positive externalities arising from regional spillovers between neighboring countries. These regional spillovers can account for as much as fifteen to twenty percent of a country's growth rate. A production function that is consistent with the empirical results would be

$$Y = (AL)^{0.40}\ K^{0.30}\ H^{0.30}\ \mathrm{K}_R^{\ 0.08}\ \mathrm{H}_R^{\ 0.08}$$

Using the regional spillovers model, we can identify two important rates of convergence from the cross-country regressions. The first is the standard Solow model (augmented for human capital) *within-region* convergence rate which is estimated to be about 2.2%. The second is a *between-region* convergence rate which is estimated to be about 1.5%. The existence of different within-region and between-region convergence rates can help explain why income differentials between countries in the same region tend to converge much more quickly relative to income differentials between countries located in different regions.

The parameter estimates of $\sigma = \epsilon = 0.08$ suggest that externalities and increasing returns are important and present in a regional context. Estimates of σ relative to β (ϵ relative to α) suggest that the social marginal product of human capital (physical capital) is larger than the private marginal product of human capital (physical capital). The magnitude of ϵ relative to α (or σ relative to β) suggest however that the regional social returns should not be overwhelmingly larger than the private returns to capital. The magnitude of these spillover parameter estimates are clearly not as strong as Summers and De Long (1991) suggest. Overall, these estimates of ϵ and σ provide some empirical backbone for both the models which emphasize human capital spillovers (Lucas (1988)) and those which emphasize physical capital spillovers (Arrow (1962)).

Estimates of $(\alpha+\beta+\epsilon+\sigma)$ being less than one support traditional neoclassical rather than endogenous growth models. The estimate of $(\alpha+\beta+\epsilon+\sigma)$ at about 0.78 and the low regional convergence rate of λ_3 may however be high enough to justify the empirical plausibility of endogenous growth models. Positive values of ϵ and σ imply that income per capita in steady state will be different from that suggested in the Solow model since income per capita in steady state also depend positively on regional physical and human investment rates and negatively on regional population growth rate. If global distribution of capital endowments across regions are unequal to begin with, regional spillover effects can further worsen income distribution across countries. First, there is a *level effect* in which regional spillovers widen the steady state income differentials between countries located in a well-endowed region (Europe) and a poorly-endowed region (Africa). Second, there is a convergence effect *between* regions where spillovers slow down the decrease in the growth rates of the countries located in the relatively richer (European) countries. As a result, the income differentials between different regions may take much longer to converge. Third, there is also a convergence effect which takes place *within* regions where spillovers hasten the convergence of income differentials between countries located within a common region.

A natural extension is the application of the above model on U.S. states to see whether the relative importance of human versus physical capital spillovers holds true within a country context. Some preliminary work suggests that there are human spillovers between neighboring U.S. states but that the transitional dynamics, in particular, the size of the regional rate of convergence does not accord with the above model. Further empirical investigation at a disaggregated level would be needed to identify the exact sources of externalities. The case for spillovers from physical investment for example might be strengthened if one uses equipment investment data as opposed to an aggregated investment figure. Human capital spillovers might also depend on population densities and the geographical proximity of cities. The model also allows some leeway in the intrepretion of a "region". Instead of the geographic dimension, a region may be more broadly defined as countries which have some common denominator. Language, trade, foreign direct investments, political systems and colonial links are potential candidates. Some micro-foundation justifying an aggregate production function that depends on average regional physical and human capital could shed light on what other factors might be important in generating these spillovers.

Appendix. Region Classification: Bordering Countries (& Islands)

1. Algeria	Morocco, Mali, (Libya), Tunisia, Niger, Mauritania
2. Angola	Zaire, Zambia, (Namibia), Congo
3. Benin	Nigeria, Togo, Burkina Faso, Niger
4. Botswana	S.Africa, Zimbabwe, (Namibia)
5. Burkina Faso	Mali, Niger, Ivory Coast, Ghana, Benin,Togo
6. Burundi	Tanzania, Rwanda, Zaire
7. Cameroon	Nigeria, Chad, Central African Rep, Congo, Gabon
8. Cent Afr Rep	Zaire, Chad, Sudan, Cameroon, Congo
9. Chad	Sudan, Cent Afr Rep, Niger, Cameroon, (Libya), Nigeria
10. Congo	Zaire, Gabon, Cameroon, Cent Afr Rep, Angola
11. Egypt	Sudan, Israel, (Libya)
12. Ethiopia	Sudan, Somalia, Kenya
13. Gabon	Congo, Cameroon
14. Gambia	Senegal
15. Ghana	Togo, Ivory Coast, Burkina Faso
16. Guinea	Mali, Sierra Leonne, Ivory Coast, Liberia, Senegal,(Guinea-Bissau)
17. Ivory Coast	Liberia, Ghana, Guinea, Burkina Faso, Mali
18. Kenya	Uganda, Ethiopia, Tanzania, Somalia, Sudan
19. Lesotho	South Africa
20. Liberia	Guinea, Sierra Leonne, Ivory Coast
21. Madagascar ISLAND	Mauritius, Mozambique
22. Malawi	Mozambique, Zambia, Tanzania
23. Mali	Mauritania, Algeria, Burkina Faso, Guinea, Niger, Ivory Coast, Senegal
24. Mauritania	Mali, Senegal, Algeria, (W.Sahara)
25. Mauritius ISLAND	Madagascar
26. Morocco	Algeria, (W.Sahara)
27. Mozambique	Malawi, Zimbabwe, Tanzania, South Africa, Zambia, Swaziland
28. Niger	Nigeria, Chad, Algeria, Mali, Burkina Faso, Benin, (Libya)
29. Nigeria	Cameroon, Niger, Benin, Chad
30. Rwanda	Burundi, Zaire, Tanzania, Uganda
31. Senegal	Mauritania, Gambia, Mali, Guinea, (Guinea-Bissau)
32. Sierra Leonne	Guinea, Liberia
33. Somalia	Ethiopia, Kenya, (Djibouti)
34. South Africa	Botswana, (Namibia), Lesotho, Mozambique, Swaziland, Zimbabwe
35. Sudan	Ethiopia, Chad, Egypt, Central African Rep, Zaire, Uganda, (Libya), Kenya
36. Swaziland	South Africa, Mozambique
37. Tanzania	Kenya, Mozambique, Malawi, Burundi, Uganda, Zambia, Rwanda
38. Togo	Ghana, Benin, Burkina Faso
39. Tunisia	Algeria, (Libya)
40. Uganda	Kenya, Zaire, Sudan, Tanzania, Rwanda
41. Zaire	Angola, Congo, Zambia, Central African Rep, Uganda, Sudan, Burundi, Rwanda
42. Zambia	Zaire, Angola, Malawi, Zimbabwe, Mozambique, Tanzania, (Namibia)
43. Zimbabwe	Mozambique, Botswana, Zambia, South Africa
44. Afghanistan	Pakistan, Iran, (China), (USSR)
45. Bahrain	South Africa, (Qatar)
46. Bangladesh	India, Burma
47. Burma	Thailand, India, (Laos), Bangladesh, (China)
48. Hong Kong ISLAND	(Taiwan), (China)
49. India	Bangladesh, (China), Pakistan, Nepal, Burma,(Bhutan)
50. Iran	Iraq, Pakistan, Turkey, (USSR), (Afghanistan)
51. Iraq	Iran, Syria, Saudi Arabia, Turkey, Kuwait, Jordan
52. Israel	Egypt, Jordan, Syria

53. Japan ISLAND	South Korea, (China)
54. Jordan	Saudi Arabia, Syria, Israel, Iraq
55. South Korea	(North Korea), Japan
56. Kuwait	Iraq, Saudi Arabia
57. Malaysia	Indonesia, Thailand, Singapore, (Brunei)
58. Nepal	India, (China)
59. Oman	Saudi Arabia, United Arab Emirates, Yemen
60. Pakistan	India, Iran, (China), (Afghanistan)
61. Philippines ISLAND	Indonesia, (Brunei), (Vietnam)
62. Saudi Arabia	Yemen, Jordan, Oman, United Arab Emir, Iraq, Kuwait, (Qatar)
63. Singapore	Malaysia
64. Sri Lanka ISLAND	India
65. Syria	Turkey, Iraq, Jordan, Israel, (Lebanon)
66. Taiwan ISLAND	Hong Kong, (China)
67. Thailand	Malaysia, Burma, (Laos), (Cambodia)
68. UAE	Saudi Arabia, Oman, (Qatar)
69. Yemen	Saudi Arabia, Oman
70. Austria	Fed Rep Germany, (Czechoslovakia), Italy, Switzerland, (Hungary), (Yugoslavia), (Liechtens)
71. Belgium	France, Netherlands, Fed Rep Germany, Luxembourg
72. Cyprus ISLAND	Turkey, Syria, (Lebanon)
73. Denmark	Fed Rep Germany
74. Finland	Norway, Sweden, (USSR)
75. France	Spain, Belgium, Switzerland, Italy, Fed Rep Germany, Luxembourg, (Monaco)
76. Fed Rep Germany	Austria, Netherlands, France, Switzerland, Belgium, Luxembourg, Denmark, (Czechslovakia)
77. Greece	Turkey, (Bulgaria), (Albania), (Yugoslavia)
78. Iceland ISLAND	Norway, United Kingdom
79. Ireland	United Kingdom
80. Italy	Switzerland, France, Austria, (Yugoslavia)
81. Luxembourg	Belgium, Fed Rep Germany, France
82. Malta ISLAND	Italy, Greece, (Libya), Egypt
83. Netherlands	Fed Rep Germany, Belgium
84. Norway	Sweden, Finland, (USSR)
85. Portugal	Spain
86. Spain	Portugal, France
87. Sweden	Norway, Finland
88. Switzerland	Italy, France, Fed Rep Germany, Austria
89. Turkey	Syria, (USSR), Iran, Iraq, (Bulgaria), Greece
90. United Kingdom	Ireland
91. Barbados ISLAND	Trinidad & Tobago
92. Canada	United States
93. Costa Rica	Panama
94. Dominican Rep	Haiti
95. El Salvador	Honduras, Guatemala
96. Guatemala	Mexico, Honduras, El Salvador, (Belize)
97. Haiti	Dominican Republic
98. Honduras	Nicaragua, El Salvador, Guatemala
99. Jamaica ISLAND	Haiti, (Cuba)
100. Mexico	United States, Guatemala, (Belize)
101. Nicaragua	Honduras, Costa Rica
102. Panama	Costa Rica, Colombia
103. Trin & Tob ISLAND	Barbados, Venezuela
104. United States	Canada, Mexico
105. Argentina	Chile, Paraguay, Brazil, Bolivia, Uruguay
106. Bolivia	Brazil, Peru, Chile, Argentina, Paraguay

107. Brazil	Bolivia, Venezuela, Colombia, Peru, Paraguay, Argentina, Uruguay, Suriname
108. Chile	Argentina, Bolivia, Peru
109. Colombia	Peru, Venezuela, Brazil, Ecuador, Panama
110. Ecuador	Peru, Colombia
111. Guyana	Brazil, Venezuela, Suriname
112. Paraguay	Argentina, Brazil, Bolivia
113. Peru	Colombia, Brazil, Ecuador, Bolivia, Chile
114. Suriname	Guyana, Brazil, (French Guinea)
115. Uruguay	Brazil, Argentina
116. Venezuela	Brazil, Colombia, Guyana
117. Australia ISLAND	New Zealand, Indonesia, Papua New Guinea
118. Fiji ISLAND	Papua New Guinea, Australia, New Zealand
119. Indonesia	Malaysia, Papua New Guinea
120. New Zealand ISLAND	Australia, Fiji
121. Papua New Guinea	Indonesia

Notes: Data unavailable for countries in parentheses.

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