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The Stability of Economic Integration and Endogenous Growth

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Abstract

This paper examines the transitional dynamics of economic integration in the two country endogenous growth model of Rivera-Batiz and Romer (1991) and in an extension by Rivera-Batiz and Xie (1992). It is shown that, in the absence of knowledge flows across countries, economic integration will generically lead to a corner solution where only one country does all the R&D and the other specializes in manufactures. When countries are symmetric, the world growth rate in this equilibrium will always be higher than in autarky. When countries differ in their human capital endowment, the world growth rate with trade is always greater than the autarky growth rate of the 'low-growth' country, but may or may not be greater than the autarky growth rate of the 'high-growth' country.

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Introduction

In an influential paper, Rivera-Batiz and Romer (1991) (henceforth RBR) analyze the effects of economic integration between two countries in a model of endogenous growth. In their model, economic agents make purposeful investments in R&D in return for the monopoly rights to the sales of new intermediate products. The possibility for sustained growth comes from the public good nature of technological knowledge on the productivity of R&D[1]. Comparing across balanced growth paths before and after integration, they show that economic integration may have both *level* effects and *growth* effects, depending upon the nature of the R&D process and on the possibility for free flow of technological information across borders. Specifically, when the R&D process uses only skilled labour and the available stock of technological knowledge, they argue that free trade between identical countries has no effect on world growth rates if the flow of ideas across borders is inoperative[2]. Although growth rates will be temporarily affected as producers in each country respond to a larger market, in a new balanced growth path the resources that each country devotes to R&D will remain unchanged, and growth will be the same as if both economies were in autarky.

RBR examine a model where countries are structurally identical. In an extension of this basic structure, Rivera-Batiz and Xie (1992) (henceforth RBX) evaluate the effects of integration when countries have differences in their endowments of the skilled human capital that is required for R&D. They argue that trade liberalization, while unifying world growth rates, will tend to *reduce* growth rates for high (autarky) growth countries and *raise* growth rates for low-growth countries.

This note re-examines the model of RBR and a two country version of the extension by RBX. Our specific intent is to focus on the stability of the transitional dynamics associated with a trade liberalization. We report two principal findings. First, we show that the results of RBR and RBX stated above will only hold in a knife-edge case. In the model of RBR, their results require that immediately after trade liberalization, each country's

[1] Grossman and Helpman (1991) survey these types of models in great detail.

[2] This is what they refer to as the 'knowledge-driven' R&D specification. With a free flow of ideas, they show that economic integration will raise world growth rates. This may even happen without trade, if producers in different countries avoid duplication of research findings.

stock of useful research knowledge be exactly half that of the world stock. In the model of RBX, their results require that the *low growth* country begin, immediately after trade liberalization, with *greater than half* of the world's stock of useful research knowledge.

Our analysis implies that the equilibria focused on by RBR and RBX are unstable. Our second finding relates to the implications of this. In the model of RBR, we show that if the condition on country shares fails to hold, then the country with the higher stock of technological knowledge will increase its share of skilled labour in R&D, while the other country will systematically reduce its share in R&D. The end result is that all R&D will be concentrated in the country with the initial advantage, with the other country devoting all of its skilled labour to the production of manufacturing goods. We show, however, that this must lead to a *rise* in world growth rates of income and consumption. Thus, even in the environment with no international flow of ideas, free trade in commodities alone will increase world growth rates, as long as there are even slight differences in the levels of national income between the countries.

In the model of RBX, a similar result applies. If the low growth (in autarky) country begins with a share of world research knowledge below the critical share, it will progressively lose its share and will eventually specialize in manufacturing. In that case, the world growth rate rises above that of the high growth country's autarky rate. If, on the other hand, the low growth country has an initial share above the critical share, then it will continue to raise its share. In that case, the new steady state will involve the initial high growth country specializing in manufactures. World growth in a new steady state then exceeds that of the initial low-growth country, but may fall below that of the initial high-growth country.

An Economy with Knowledge Driven Innovation

The basic model we follow is identical to that of Romer (1990), RBR, and RBX. Take a single economy. In the economy, production is carried out in three sectors: consumption goods, capital goods, and R&D. The consumption goods sector uses unskilled labour, skilled labour (or human capital), and a set of specific capital goods to produce a homogeneous output. The specific capital goods sector has a production technology identical to that for consumption goods. All manufacturers produce either capital goods or consumption goods taking input and output prices as given. Thus, the two sectors may be aggregated into one manufacturing sector.

The right to supply each specific capital good is owned by a single patent holder with an infinitely lived title. Patent holders will engage manufacturing firms to produce their specific capital good as desired and then rent the goods out at the monopoly profit maximizing price. The production function for manufacturing is given as

$$Y = L^{(1-\alpha-\beta)} H_y^{\beta} \int^{A} x(i)^{\alpha} di \tag{1}$$

Here L is unskilled labour, held fixed throughout (and for simplicity we set L=1 henceforth), H_y is the employment of skilled labour in manufacturing, while x(i) is the use of capital of type i in production of manufactures. 'A' represents the total measure of available specific capital goods at a given time. The variable $K = \int^{A} x(i)di$ then represents the economy's total capital stock, valued at cost of production.

The infinite patent on a new type of capital good can be acquired by engaging in basic research and producing a design. If one unit of skilled labour is applied for Δt units of time, $\delta A \Delta t$ new designs for capital goods are produced. Thus, the rate of change of new designs in the economy is

$$\dot{A}/A = \delta(\bar{H} - H_y) \tag{2}$$

where $\bar{H}$ is the economy's fixed stock of skilled labour.

The representative agent in this economy has iso-elastic preferences defined over consumption paths as follows

$$U = \int_{0}^{\infty} e^{-\rho t} \left[\frac{C(t)^{1-\sigma}}{(1-\sigma)} \right] dt \tag{3}$$

Households receive income from wages in both skilled and unskilled occupations, as well as rental payments from their ownership of patents. To satisfy aggregate feasibility, manufacturing output must add up to consumption plus the production of new capital goods

$$C + \dot{K} = H_y^{\beta} \int^{A} x(i)^{\alpha} di \tag{4}$$

The derivation of the balanced growth path for a single economy is done in Romer (1990) and RBR. Assuming that output in the R&D sector is always positive, then the wage paid to skilled labour in manufacturing and R&D should be equated, so that, setting the price of the manufactured good equal to unity, we have

$$\beta H_y^{\beta-1} \int^A x(i)^\alpha di = \delta P_A A \tag{5}$$

where P_A is the market price of a new design. The manufacturing sector demand for each specific capital input is implicitly given by

$$\alpha H_y^\beta x(i)^{\alpha-1} = p(i) \tag{6}$$

where $p(i)$ is the price of the i^{th} intermediate good.

The patent holder of each specific capital good i will choose the rental price $p(i)$ to maximize profits, taking H_y and r as given, where r is the real rate of interest on a bond (in equilibrium, bonds will be in zero net supply). This leads to the markup pricing rule $p = r/\alpha$. Thus, all capital goods will be priced identically, and from (6), all will be used in the same proportion in manufacturing. Thus, we may write $x(i) = x$, and from (5)

$$H_y = \psi(P_A x^{-\alpha})^{-1/(1-\beta)} \tag{7}$$

where $\psi \equiv (\delta/\beta)^{-1/(1-\beta)}$.

Looking at the behaviour of households, it must be the case that an optimal intertemporal consumption path satisfies

$$\sigma \frac{\dot{C}}{C} = r - \rho \tag{8}$$

With free entry into R&D, the price of a new design must be

$$P_A = \int_t^\infty e^{-\int_t^\tau r(s)ds}(px(1-\alpha))d\tau$$

where $px(1-\alpha)$ represents the per period profits accruing to the owner of the design, beginning with zero capital stock[3]. Differentiating this, we have the condition

$$\dot{P}_A = -px(1-\alpha) + rP_A. \tag{9}$$

This is the standard arbitrage condition, which must hold if agents are to hold both bonds and designs as assets.

Finally, from (6), (7), and the markup rule, we may write the real interest rate implied by equilibrium in the market for skilled labour and specific capital goods as

$$r = \alpha^2 \psi^\beta P_A^{-\beta/(1-\beta)} x^{-(1-\alpha-\beta)/(1-\beta)} \tag{10}$$

Substituting (7) into (2), we derive the economy's growth rate of R&D as

$$\dot{A}/A = \delta\left[\bar{H} - \psi(P_A x^{-\alpha})^{-1/(1-\beta)}\right]. \tag{11}$$

We may use (4), (8), (9), (10), and (11) to derive three differential equations in C/K, x, and P_A. They will determine the path of the economy both on a balanced growth path and away from it. At any point in time, both x and A are predetermined. Equivalently, the aggregate capital stock, $K = Ax$, and the stock of patents, A, are predetermined. Adjustment towards a balanced growth path will take the form of changes in the ratio of K to A (i.e. adjustments in x). If the economy begins with a very low K/A, then there will be a period during which manufacturing output grows faster than R&D [4]. Along a balanced growth path, consumption, K, and A will all grow at the same rate, and P_A will be constant at $x(1-\alpha)/\alpha$. The balanced growth rate, g, and the balanced growth value

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[3] Given the institutional structure assumed, where patent holders purchase capital directly and rent it out to manufacturers, we derive this in the following way. P_A must be equal to the present value of a new patent holder's maximized cash flow, i.e.

$$P_A(t) = max \int_t^\infty e^{-\int_t^\tau r(s)ds}(p(x,t)x - i)d\tau,\ subject\ to\ \dot{x} = i,\ and\ x(t) = 0$$

(since the patent holder starts out with zero capital stock). Here $p(x,t)$ denotes the demand schedule given by (6). It is easy to see that the optimal pricing policy is $p = r/\alpha$, and along the optimal price path, the integrand is as written above.

[4] The stability properties of this system are analyzed in Devereux and Lapham (1992).

for x are [5]

$$g = \frac{\alpha(1-\alpha)\delta\bar{H} - \rho\beta}{\sigma\beta + \alpha(1-\alpha)} \tag{12}$$

$$x = \left[\frac{\alpha^2\phi^\beta + \sigma\delta\phi}{\rho + \sigma\delta\bar{H}}\right]^{(1-\beta)/(1-\alpha)} \tag{13}$$

where $\phi = \psi(\alpha/(1-\alpha))^{1/(1-\beta)}$.

Two Country World Economy

We now extend this single economy structure to examine the effect of two economies that suddenly open to trade in goods and assets with one another at date $t = 0$ [6]. We assume that these economies have identical preferences and technology and are both initially in the balanced growth equilibrium described above.

If the two countries have identical stocks of skilled human capital, then autarky levels of g, x, and P_A are identical across countries. Even in this case, however, it is quite possible to have differences in the stock of patents across countries. This amounts to differences in the *level* of GNP. In an endogenous growth environment, persistent level differences in GNP arise from varying initial conditions across countries. In autarky, there are no forces that work to eliminate these difference over time, even though the *rates of growth* will be equalized along a balanced growth path if the structure of preferences, technology and endowments of skilled labour are the same.

We assume that while there is free trade in commodities, there is no flow of ideas across countries. Thus, the productivity of basic R&D in a country is unaffected by the stock of technological knowledge derived from the other country's past innovations.

A separate issue is the degree of overlap between the designs at the time of liberalization. To maintain simplicity, we assume zero overlap between the innovations. Thus, the home and foreign economy are assumed to have invested in an entirely different range of

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5 To establish (12) and (13), use (8), (9), (10), and (11), setting $\dot{P}_A = 0$ and $\frac{\dot{C}}{C} = \frac{\dot{A}}{A} = g$.

6 We also implicitly assume that this liberalization is not anticipated. The anticipation of open trade would have two quite separate effects in this environment. First, it would lead to the standard rational expectations response of investment in light of future changes in its rate of return. Secondly, it would lead to an avoidance of the duplication of R&D, as firms in the domestic economy would attempt to preempt the possibility of any foreign competition in the post trade situation.

designs before trade liberalization. Thus, letting $\tilde{A}$ denote the world stock of technological knowledge, we have $\tilde{A} = A + A^*$[7].

We proceed under the assumption that both countries engage in positive amounts of R&D activity initially. The aim of the analysis is to determine the conditions under which this will be true in a new balanced growth path. For the home and foreign economies, H_y and H_y^* are determined by

$$\beta H_y^{\beta-1}\left[\int^{A} x^{\alpha}(i)di + \int^{A^*} x^{\alpha}(i^*)di^*\right] = P_A A\delta \tag{14}$$

$$\beta H_y^{*\beta-1}\left[\int^{A} x^{*\alpha}(i)di + \int^{A^*} x^{*\alpha}(i^*)di^*\right] = P_A A^*\delta. \tag{15}$$

Here, $x(i)$ and $x(i^*)$ denote domestic demand for home and foreign capital goods, and $x^*(i)$ and $x^*(i^*)$ give analogous demands for the foreign country. For the home country, these demands may be written as

$$x(i) = p(i)^{-1/(1-\alpha)}(\alpha H_y^{\beta})^{1/(1-\alpha)} \tag{16}$$

$$x(i^*) = p(i^*)^{-1/(1-\alpha)}(\alpha H_y^{\beta})^{1/(1-\alpha)}, \tag{17}$$

where $p(i)$ ($p(i^*)$) is the price of the home (foreign) good i (i^*). $x^*(i)$ and $x^*(i^*)$ are derived analogously. Patent holder i at home supplies $x(i) + x^*(i)$ and foreign patent holder i^* supplies $x^*(i) + x^*(i^*)$. As before, both home and foreign firms will price as a constant markup over the common world interest rate – all capital goods are sold at price $p = r/\alpha$. Therefore, the home manufacturers use of capital goods will be the same for each good and analogously for foreign manufacturers. Thus, all patent holders supply equal amounts of capital goods, irrespective of the country they are in. Instead of selling x to the home manufacturing sector, however, they will now sell the amount νx to the home country manufacturers and $(1-\nu)$ to the foreign manufacturers, where

$$\nu = \frac{H_y^{\beta/(1-\alpha)}}{H_y^{\beta/(1-\alpha)} + H_y^{*\beta/(1-\alpha)}}.$$

[7] This assumption is innocuous. We could allow for some overlap as long as only one firm is allowed to retain the patent right following the liberalization.

Since, across countries, the interest rate is the same, sales per firm are the same, and costs of production are the same, the value of a new patent must be the same [8]. Thus, P_A is common across countries.

Let x be the common stock of specific capital per patent holder in either country. Then using $x = x(i) + x^*(i) = x(i^*) + x^*(i^*)$ and (14)-(17), we derive an expression for the interest rate implied by factor market equilibrium as

$$r = \alpha^2 x^{-(1-\alpha-\beta)/(1-\beta)} P_A^{-\beta/(1-\beta)} \psi^\beta \Gamma, \tag{18}$$

where $\Gamma = \left[\theta^{-\beta/(1-\alpha-\beta)} + (1-\theta)^{-\beta/(1-\alpha-\beta)}\right]^{(1-\alpha-\beta)/(1-\beta)}$ and $\theta = A/(A+A^*)$ is the share of the home country in the world stock of designs. This affects the interest rate because from (14) (or (15)), the home country share of intermediates affects the domestic (foreign) wage and, therefore, domestic (foreign) employment in manufacturing. Substitute (18) into (16)-(17) and then back into (14)-(15) to derive H_y and H_y^* as

$$H_y = x^{\alpha/(1-\beta)} P_A^{-1/(1-\beta)} \psi \left[\Gamma^\alpha \theta^{(1-\alpha)}\right]^{-1/(1-\alpha-\beta)} \tag{19}$$

$$H_y^* = x^{\alpha/(1-\beta)} P_A^{-1/(1-\beta)} \psi \left[\Gamma^\alpha (1-\theta)^{(1-\alpha)}\right]^{-1/(1-\alpha-\beta)}. \tag{20}$$

Note that for $A^* > A$, we have $\theta < \frac{1}{2}$ and $H_y > H_y^*$. This is due to the fact that, for a common value of P_A, the wage will be higher in the foreign country. This is because with both countries diversifying, the wage is equal to the marginal product of skilled labour in R&D in each country.

Households in each country will face a common interest rate. Thus, consumption growth for each country and for world consumption must be defined as in equation (8). Define the aggregate world consumption and capital stock as $\tilde{C} = C + C^*$ and $\tilde{K} = (A + A^*)x$, respectively. Then using (19), (20) and world commodity market clearing, $\tilde{C} + \dot{\tilde{K}} = Y + Y^*$, we may derive

$$\tilde{C} + \dot{\tilde{K}} = \tilde{K} x^{-(1-\alpha-\beta)/(1-\beta)} P_A^{-\beta/(1-\beta)} \psi^\beta \Gamma. \tag{21}$$

[8] To see this more clearly, note that for the home country, P_A is determined by $\dot{P}_A + ((1-\alpha)/\alpha)rx = rP_A$. The expression for the foreign country is $\dot{P}_A^* + ((1-\alpha)/\alpha)rx = rP_A^*$. Since only the P_A terms differ in these expressions, if values are determined by fundamentals, then $P_A = P_A^*$ must hold.

Substituting (19) and (20) into the R&D production functions for each country and adding, we derive the growth rate of world technology as

$$\frac{\dot{A}+\dot{A}^*}{A+A^*}=\delta[\theta\bar{H}+(1-\theta)\bar{H}^*]-\delta x^{\alpha/(1-\beta)}P_A^{-1/(1-\beta)}\psi\Gamma. \tag{22}$$

Now, collecting all the pieces, the two country economy may be described as a dynamic system in the variables $\tilde{C}$, A, A^*, x, and P_A. By transformation of variables, we may rewrite this in stationary form as the system $\mathcal{S}$ of four differential equations in the variables $c=\tilde{C}/\tilde{K}$, x, P_A, and θ:

$$\frac{\dot{c}}{c}=[\frac{\alpha^2-\sigma}{\sigma}]\left[x^{-(1-\alpha-\beta)}P_A^{-\beta}\right]^{1/(1-\beta)}\psi^\beta\Gamma+c-\frac{\rho}{\sigma} \tag{$\mathcal{S}1$}$$

$$\frac{\dot{x}}{x}=\left[x^{-(1-\alpha-\beta)}P_A^{-\beta}\right]^{1/(1-\beta)}\psi^\beta\Gamma-c-\delta\left[\theta\bar{H}+(1-\theta)\bar{H}^*\right]$$
$$+\delta\left[x^{-\alpha}P_A\right]^{-1/(1-\beta)}\psi\Gamma \tag{$\mathcal{S}2$}$$

$$\frac{\dot{P}_A}{P_A}=\alpha^2\left[x^{-(1-\alpha-\beta)}P_A^{-1}\right]^{1/(1-\beta)}\psi^\beta\Gamma\left[P_A-((1-\alpha)/\alpha)x\right] \tag{$\mathcal{S}3$}$$

$$\frac{\dot{\theta}}{\theta}=\delta(1-\theta)\left[\bar{H}-\bar{H}^*-H_y+H_y^*\right]. \tag{$\mathcal{S}4$}$$

where Γ is the function of θ described above. In this system, x and θ are predetermined by initial conditions. Let these be given by $x(0)$ and $\theta(0)$. If the system satisfies saddle point stability, the variables c and P_A can adjust to ensure terminal constraints.

Before we analyze the issue of stability, for comparison we take note of the *interior balanced growth path* (IBGP) implied by $\mathcal{S}$. This is defined by a balanced growth path in which $0<\theta<1$. The IBGP solutions, $\hat{x}$, $\hat{g}$, and $\hat{\theta}$ are implicitly described by

$$\hat{x}=\left[\frac{(\alpha^2\phi^\beta+\sigma\delta\phi)\Gamma}{\rho+\sigma\delta(\hat{\theta}\bar{H}+(1-\hat{\theta})\bar{H}^*}\right)\right]^{(1-\beta)/(1-\alpha)} \tag{23}$$

$$\hat{g}=\frac{\alpha(1-\alpha)\delta[\hat{\theta}\bar{H}+(1-\hat{\theta})\bar{H}^*]-\rho\beta}{\sigma\beta+\alpha(1-\alpha)} \tag{24}$$

$$\bar{H}-\bar{H}^*=\hat{x}^{-(1-\alpha)/(1-\beta)}\phi\Gamma^{-\alpha/(1-\alpha-\beta)}\left[\hat{\theta}^{-\eta}-(1-\hat{\theta})^{-\eta}\right], \tag{25}$$

where $\eta=(1-\alpha)/(1-\alpha-\beta)$.