Real exchange rate and human capital in the empirics of economic growth

Delfim Gomes Neto*

June 2004

Abstract

This paper proposes a new perspective about the relative importance of transitional dynamics and steady state issues on growth. That is, we ask if the speed of convergence of economies to the steady state is, respectively, low or high. According to cross-section studies, the speed of convergence is around 2-3%, but following panel data studies it will be around 10%. Both lines of research are criticized on an important issue: the treatment of the (unobservable) initial level of technology. We use the real exchange rate (an observable variable) and take into account an open economy model where all variables have the same dynamics. Econometric evidence using the real exchange rate provides support for the low values of the speed of convergence found in previous cross-country studies. Moreover, we explicitly derive a role for human capital in growth regressions.

JEL Classification: F43, O41, O47
Keywords: real exchange rate, convergence, growth

---

*I am grateful to François Bourguignon, Daniel Cohen, Peter Klenow, Arnaud Lefranc, Philippe Martin, Gilles Saint-Paul and Thierry Verdier for comments and suggestions and to seminar participants at Banco de Portugal. I gratefully acknowledge the hospitality and financial support of Banco de Portugal. I am also grateful to Fundação para a Ciência e Tecnologia for financial support. Address: Facultade de Ciencias Económicas e Empresariais, Universidade de Vigo, Campus As Lagoas-Marcosende, 36310 Vigo, Spain. Tel: +34 986 813531. Fax: +34 986 812401. Email: dneto@uvigo.es

1 Introduction

One lasting issue of the debate on growth and convergence is whether the economies are most of the time in transitional dynamics or around their steady state. This an important issue as it has implications on the action of governments and international organizations. But there is an uncertainty in this debate because the conclusions of the empirical work differ markedly in cross-sections and in panels. The former studies point to low speed of convergence and to the importance of considering the transitional dynamics of economies. The later studies, when using fixed effects, point to high speed of convergence and to the conclusion that economies are around their steady state.

This paper argues that it is also important to consider the transitional dynamics of economies, instead of concentrating only on steady state issues and its determinants.

We propose a new perspective on this debate using the real exchange rate and taking into account a model where all variables are characterized by the same transitional dynamics.

It is important to point out that our analysis does not have to deal with a problem of an unobserved variable, the level of technology, which appears in the studies of convergence based on GDP and the exogenous growth model[1]. Instead, the real exchange rate is an observable variable. Moreover, based on an endogenous growth model, the equation for GDP takes into account, explicitly, human capital and not the level of technology. This gives the possibility of comparing the speed of convergence of the real exchange rate and of GDP. It also follows that we can present an interpretation for human capital and its relation with growth in convergence regressions.

The consensus on the speed of convergence now is one of uncertainty, after many years of research[2]. Moreover, both lines of research are criticized on an important issue: the treatment of the unobservable initial level of technology in the equation of convergence. In a cross-section of countries, Mankiw et al. (1992) assume that the initial level of technology is not related to the other regressors in a convergence regression. This assumption, made for econometric convenience, leads in fact to a problem of omitted variables

[1] In cross-section, see Mankiw, Romer and Weil (1992). In panel, see Caselli, Esquivel and Lefort (1996).

[2] See the surveys by Durlauf and Quah (1999) and Temple (1999).

if there is a correlation between the initial level of technology and the other explanatory variables. Using panel data techniques, Islam (1995) and Caselli et al. (1996) solve this problem with fixed effects that take into account precisely the unobservable variable. However, in solving this problem, they are creating another one: with fixed effects their analysis is only considering the variation of the growth rate of a country around its mean (over time) and not the cross-country variation, important for the analysis of convergence of economies. It is also possible that these studies are taking principally into account business cycle effects.

There is an important literature on the role of human capital in growth and how it may be specified in empirical work, surveyed in Krueger and Lindahl (2001). We would like to point out that these explanations of the role of human capital are based mainly on growth accounting, its effect on the steady state growth rate of GDP, existence of externalities or the impact of growth on schooling, as opposed to the role we propose explicitly for transitional dynamics[3].

The paper is organized as follows. Section 2 reviews the Solow model with labor augmenting technology and the equations supporting the growth regressions. A discussion of the problems associated with the unobservable initial level of technology in cross-section and panel data regressions is presented. In Section 3 we present the endogenous growth open economy model used for interpretation of the empirical analysis. Conditional and unconditional convergence regressions for GDP and the real exchange rate are presented in Section 4, where we also discuss the role of human capital in growth regres-

[3]Mankiw et al. (1992) point out that the steady state level of human capital per unit of effective labor determines the steady state level of GDP per unit of effective labor. In Lucas (1988), the growth rate of human capital determines the steady state growth rate of GDP, with or without externalities of human capital. Romer (1990) links the level of human capital to the development of more ideas, increasing the technological innovation, and in this way leading to a greater steady state growth rate of GDP. Benhabib and Spiegel (1994) discuss the role of human capital in growth accounting and also find evidence for the level of human capital. In the spirit of Nelson and Phelps (1966), they argue that human capital is a condition for the adoption of technology from abroad by a country. This effect is seen as an externality of human capital on growth. The study of Bils and Klenow (2000) introduces a new specification for human capital. Based on the micro Mincer regressions, they relate human capital to schooling in an exponential way. They develop a model to show that the prospect of growth can lead to higher levels of schooling. In this way they claim that the high coefficients associated with human capital in growth regressions are not revealing a causal relation but may be evidence of reverse causality.

sions taking into account our model. The main conclusions are presented in Section 5.

2 The empirics of economic growth: from theory to cross-section and panel data regressions

This section presents some problems associated with empirical analysis of convergence using the GDP per capita. First we present the equations of convergence following the Solow model. Then we point out the problem of considering, or not, the initial level of technology in the empirical studies. Finally, we discuss the solutions for this problem of omission of variable and their limits.

2.1 Equations of convergence

Let the production function of the economy be represented by[4]:

$$Y_t = K_t^{\alpha} \left(A_t L_t\right)^{1-\alpha},$$

where Y_t represents the output, K_t represents physical capital, L_t represents labor and A_t represents the level of technology. In this specification, technological progress is labor augmenting. We assume that $0 < \alpha < 1$. Labor and the level of technology are assumed to have a constant exogenous growth rate, respectively n and g:

$$L_t = L_0 e^{nt},$$
$$A_t = A_0 e^{gt}.$$

The saving rate, s_K, represents the constant fraction of output that is saved. Output per unit of effective labor and capital per unit of effective labor are represented respectively by $\hat{y} = \frac{Y}{AL}$ and $\hat{k} = \frac{K}{AL}$. The production function can be written in an intensive form as $\hat{y} = \hat{k}^{\alpha}$ and the equation for capital accumulation is given by:

$$\dot{\hat{k}}_t = s_K \hat{y}_t - (n + g + \delta)\hat{k}_t,$$

[4]For an exposition of the Solow model with labor augmenting technology, see for example Barro and Sala-i-Martin (1995).

$$\dot{\hat{k}}_t = s_K \hat{k}_t^{\alpha} - (n+g+\delta)\hat{k}_t,$$

where δ represents a constant depreciation rate of capital.

The steady state level of capital per unit of effective labor and output per unit of effective labor[5] are given by:

$$\hat{k}^* = \left(\frac{s_K}{n+g+\delta}\right)^{\frac{1}{1-\alpha}},$$

$$\hat{y}^* = \left(\frac{s_K}{n+g+\delta}\right)^{\frac{\alpha}{1-\alpha}}.$$

Now we linearize around the steady state the equation of capital accumulation. With this new equation, we can obtain the dynamics of GDP per capita and its speed of convergence. Given that $\frac{\dot{\hat{k}}_t}{\hat{k}_t} = s_K \hat{k}_t^{\alpha-1} - (n+g+\delta)$:

$$\frac{\dot{\hat{k}}_t}{\hat{k}_t} \cong s_K(\alpha-1)\left(\hat{k}^*\right)^{\alpha-2}\left(\hat{k}_t - \hat{k}^*\right),$$

$$\frac{\dot{\hat{k}}_t}{\hat{k}_t} \cong -\lambda \log \frac{\hat{k}_t}{\hat{k}^*},$$

where

$$\lambda = (1-\alpha)(n+g+\delta) \tag{1}$$

represents the speed of convergence. Notice that $s_K = (\hat{k}^*)^{1-\alpha}(n+g+\delta)$ and $\frac{\hat{k}_t - \hat{k}^*}{\hat{k}^*} \cong \log \frac{\hat{k}_t}{\hat{k}^*}$.

Knowing that $\hat{k} = \hat{y}^{\frac{1}{\alpha}}$ and $\frac{\dot{\hat{k}}_t}{\hat{k}_t} = \frac{1}{\alpha}\frac{\dot{\hat{y}}}{\hat{y}}$, we obtain the expression for GDP:

$$\frac{\dot{\hat{y}}}{\hat{y}} \cong -\lambda \log \frac{\hat{y}_t}{\hat{y}^*}.$$

One can write the solution of this differential equation for output per efficient unit of labor at date t and $t+T$, as[6]:

$$\log \hat{y}_{t+T} - \log \hat{y}^* = \left(\log \hat{y}_t - \log \hat{y}^*\right) e^{-\lambda T}.$$

[5]In the Solow model s_K or $\hat{k}^*$ determines $\hat{y}^*$. In Mankiw et al. (1992) human capital will also appear, s_H or $\hat{h}^*$, as stated in their equations (11) and (12).

[6]With $x_t = \log \frac{\hat{y}_t}{\hat{y}^*}$ and $\dot{x}_t = \frac{\dot{\hat{y}}}{\hat{y}}$, the solution for the previous differential equation is given by $\log \hat{y}_t - \log \hat{y}^* = \left(\log \hat{y}_0 - \log \hat{y}^*\right) e^{-\lambda t}$.

The equation supporting the empirical studies of convergence is the following:

$$\log \hat{y}_{t+T} - \log \hat{y}_t = -(1 - e^{-\lambda T}) \log \hat{y}_t + (1 - e^{-\lambda T}) \log \hat{y}^*. \tag{2}$$

2.2 Estimation problems, their solutions and their limits

There are some problems for estimating this equation. If we are interested in conditional convergence, the steady state level of output per efficient unit of labor, $\hat{y}^*$, will be different for each country. Given that we will be considering the same speed of convergence for all countries, then one needs to assume that g, δ et n are the same constants for all countries and that the specificity of countries appear in the saving rate s_K. Notwithstanding, Mankiw et al. (1992) use the same model and let the population growth rate n be different for each country. Notice the contradiction with equation (1), that gives the expression for the constant speed of convergence.

Besides these two issues, there is a more important problem: we do not observe $\hat{y}$. Only GDP per capita, $y = \frac{Y}{L}$, is observed. Transforming equation (2) and seeing that $\log \hat{y}_{t+T} = \log y_{t+T} - \log A_0 - g(t+T)$ and that $\log \hat{y}_t = \log y_t - \log A_0 - gt$, we have:

$$\begin{aligned} \frac{1}{T}\left(\log y_{t+T} - \log y_t\right) = g\frac{\left(t + T - te^{-\lambda T}\right)}{T} + \frac{\left(1 - e^{-\lambda T}\right)}{T} \log A_0 - \\ - \frac{\left(1 - e^{-\lambda T}\right)}{T} \log y_t + \frac{\left(1 - e^{-\lambda T}\right)}{T} \log \hat{y}^*. \end{aligned} \tag{3}$$

To estimate the speed of convergence following this equation, one needs to take into account the problems associated with the term A_0, representing the initial level of technology. This variable is not observed. If it is not correlated with the other independent variables of the model, it can be omitted without creating a bias in the other estimated coefficients[7].

However, countries with higher level of technology have in general higher rates of investment and higher levels of output per efficient unit of labor. These countries will also have higher initial levels of GDP per capita. In these conditions, there will be a problem of an omitted variable, leading to a bias in the coefficient that gives the speed of convergence. If there is a positive

[7] This is the strategy adopted by Mankiw et al. (1992).

correlation between the initial level of technology and the initial GDP per capita, then the coefficient of this variable will have a positive bias[8]:

$$\frac{1}{T}\log y_{t+T} = g\frac{\left(t+T-te^{-\lambda T}\right)}{T} + \frac{\left(1-e^{-\lambda T}\right)}{T}\log A_0 + \frac{e^{-\lambda T}}{T}\log y_t + \frac{\left(1-e^{-\lambda T}\right)}{T}\log \hat{y}^*.$$

It follows that the estimated speed of convergence will be negatively biased, as its coefficient comes from $\frac{\left(1-e^{-\lambda T}\right)}{T}$.

One can give a solution to the problem of an omitted variable using panel data. The term A_0 is represented by a fixed effect for each country[9]. Taking into account the previous equation with different countries, i, the fixed effect will be given by $\mu_i = \frac{\left(1-e^{-\lambda T}\right)}{T}\log A_{i,t_0}$. And $\eta_t = g\frac{\left(t+T-te^{-\lambda T}\right)}{T}$ will represent a time effect. In a panel regression, one will have:

$$\frac{1}{T}\log y_{i,t+T} = \mu_i + \eta_t + \frac{e^{-\lambda T}}{T}\log y_{i,t} + \frac{\left(1-e^{-\lambda T}\right)}{T}\log \hat{y}_i^*.$$

The estimated values for the speed of convergence using panel data show that the bias associated with the omission of variables can be quantitatively important. With cross-section studies the value of the speed of convergence is about 2-3%[10]. With panel data and using fixed effects, the values for the speed of convergence are higher[11]: Islam (1995) riches values between 3.75% and 9.13% and Caselli et al. (1996) obtain a value of 10%. An implication of a speed of convergence of 2% is a half-life of convergence of 35 years[12]. On the other hand, a speed of convergence of 10% leads to a half-life of about 7 years only. The economies will be in general around their steady state. The

[8] For a discussion of this bias in the context of this literature, see Caselli et al. (1996). Instrumental variables could be a solution for this problem. But it is not easy to find instruments correlated with the explicative variables and not correlated with the initial level of technology.

[9] Islam (1995) presents calculations for the initial level of technology using the fixed effects in a panel regression. There is an important variation in the estimated initial levels of technology. Hall and Jones (1999) also present values for this variable, in a cross-section analysis.

[10] See Barro and Sala-i-Martin (1995).

[11] For a discussion of other studies using panel data, see Durlauf and Quah (1999).

[12] The expression for the half-life is given by $\frac{\log 2}{\lambda}$.

economic policy should concentrate on issues related to what has an influence in the steady state, like institutions.

The importance attached to the dynamics of transition is strongly reduced in this last situation.

The analysis of convergence with panel data shows the difficulty of estimating the speed of convergence and points out problems with the estimations with cross-section regressions. Notwithstanding, the solution proposed with panel data also has limitations for the study of convergence[13]. In fact, the studies in panel have problems for analyzing the convergence among countries. Firstly, and more importantly, introducing fixed effects for each country leads to taking into account only the variation of each country over time. This implies that we do not take into account anymore the variation among countries, in the center of the debate of convergence of countries. Secondly, one might ask if by considering only the time variation of growth rates it gives relatively more importance to business cycles effects. This point also asks for the appropriate time interval that minimizes the business cycles effects. Using cross-section of countries for a large interval of time seems more appropriate for the analysis of long-term convergence among economies.

Summing up, both types of analysis of convergence have estimation problems. Given these results, there is an uncertainty about the speed of convergence. The importance of this issue arises when considering its policy implications: should countries give more attention to the transitional dynamics of economies or to steady state equilibrium and policies related to structural variables like institutions?

In what follows, we want to propose another view of convergence without having the problem associated with the initial level of technology. Using an open economy model, we can analyze its transitional dynamics with an observable variable: the real exchange rate. Moreover, the GDP over human capital also has the same dynamics and speed of convergence.

[13] See the criticisms of Barro (1997), Durlauf and Quah (1999) and Temple (1999).

3 An open economy model for the analysis of convergence

We have seen above that the analysis of convergence using GDP per capita can lead to a problem of omitted variables because of the initial level of technology, A_0. Using an open economy model with a tradable and a nontradable sector, the analysis of convergence can be done with another variable: the real exchange rate. We will show that its transitional dynamics has no problem of omitted variables, if a measure of the real exchange rate is available like the relative prices of the Penn World Table. Moreover, with GDP per capita a role for human capital in growth regressions appears, without the problem associated with the presence of the initial level of technology.

3.1 The model

First we want to point out that openness here means access to international capital markets and that we are not analyzing trade effects on growth and convergence.

The Solow model predicts a finite speed of convergence for a closed economy. But a small open economy with the same characteristics would have an infinite speed of convergence. With perfect international capital mobility, the remuneration of capital in a small open economy must be equal to the international interest rate and capital flows would eliminate any difference in remunerations instantaneously[14].

A two sectors endogenous growth model for a closed economy presents also a finite speed of convergence[15]. Notwithstanding the open economy growth model does not have a finite speed of convergence: the international interest rate ties down the marginal productivity of capital, determining also the equilibrium relative price. The stabilizing mechanism provided by the relative price is eliminated by the restriction given by the international interest rate[16]. Then the economy would jump immediately to the steady state. We would like to point out that this situation happens because we are using only two

[14] For a discussion on convergence of open economies see Barro and Sala-i-Martin (1995), chapter 3, and Obstfeld and Rogoff (1996), chapter 7.

[15] See Ortigueira and Santos (1997).

[16] This stabilizing mechanism depends on the production of the consumption good being more intensive in physical capital than the production of human capital. See Bond, Wang and Yip (1996).

factors of production. By having two accumulable factors and labor, it would lead to an open economy with finite speed of convergence.

We develop an open economy model where physical capital and consumption will be the tradable goods and human capital will be the nontradable. We will not have the problem of instantaneous adjustment, because we introduce adjustment costs in the accumulation of physical capital. Surprisingly, we will see that an economy with incomplete specialization in production has a speed of convergence that does not depend on the adjustment costs. And the speed of convergence does not depend on the parameter of preferences in this open economy with adjustment costs.

The planning problem is

$$\max_{C,v,u,K,H,q,D} \int_0^{+\infty} \frac{C^{1-\sigma}-1}{1-\sigma} e^{-\rho t} dt \tag{4}$$

subject to

$$\dot{D} = r^* D + A\,(vK)^{\alpha}\,(uH)^{1-\alpha} - C - I^T \left(1 + \frac{h}{2}\frac{I^T}{K}\right) \tag{5}$$

$$\dot{K} = I^T \tag{6}$$

$$\dot{H} = B\,[(1-v)\,K]^{\beta}\,[(1-u)\,H]^{1-\beta} \tag{7}$$

with D_0, K_0 and H_0 given.

In this model C represents consumption, ρ is the subjective discount rate, $\sigma > 0$ is the inverse of the intertemporal elasticity of substitution[17], K is physical capital, H is human capital, $v(0 < v < 1)$ is the fraction of physical capital and $u(0 < u < 1)$ is the fraction of human capital in the consumption sector, $\alpha(0 < \alpha < 1)$ is the share of physical capital in the consumption sector, and $\beta(0 < \beta < 1)$ is the share of human capital in the human capital sector. A and B represent the level of technology in the consumption and the human capital sectors, respectively. Let D represent net foreign bonds accumulated by the economy and r^* be the international interest rate. The parameter h is the sensitivity of the adjustment costs to the ratio investment to physical capital and I^T is the investment in physical capital.

[17] With $\sigma = 1$, the utility function becomes equal to $U(C) = \log C$.

The Hamiltonian for this problem is given by

$$J = U(C)e^{-\rho t} + \eta e^{-\rho t}\left[r^* D + A\left(vK\right)^{\alpha}\left(uH\right)^{1-\alpha} - C - I^T\left(1 + \frac{h}{2}\frac{I^T}{K}\right)\right] + \\ + \eta q e^{-\rho t} I^T + \mu e^{-\rho t}\left\{B\left[\left(1-v\right)K\right]^{\beta}\left[\left(1-u\right)H\right]^{1-\beta}\right\}$$

where $U(C)$ represents the utility function. η, ηq and μ are the costate variables for net foreign bonds, installed physical capital and human capital, respectively.

We obtain the following first order conditions:

$$C^{-\sigma} = \eta \tag{8}$$

$$\alpha A(vK)^{\alpha-1}(uH)^{1-\alpha} = \frac{\mu}{\eta}\beta B\left[\left(1-v\right)K\right]^{\beta-1}\left[\left(1-u\right)H\right]^{1-\beta} = r^K \tag{9}$$

$$\left(1-\alpha\right)A\left(vK\right)^{\alpha}\left(uH\right)^{-\alpha} = \frac{\mu}{\eta}\left(1-\beta\right)B\left[\left(1-v\right)K\right]^{\beta}\left[\left(1-u\right)H\right]^{-\beta} = r^H \tag{10}$$

$$q = 1 + h\frac{I^T}{K} \tag{11}$$

$$\dot{\eta} = \eta\left(\rho - r^*\right) \tag{12}$$

$$\dot{\mu} = \mu\left(\rho - \frac{\eta}{\mu}r^H\right) \tag{13}$$

$$\dot{q} = r^* q - r^K - \frac{h}{2}\left(\frac{I^T}{K}\right)^2. \tag{14}$$

The transversality conditions are

$$\lim_{t\to+\infty} \eta q e^{-\rho t} K = 0 \tag{15}$$

$$\lim_{t\to+\infty} \mu e^{-\rho t} H = 0 \tag{16}$$

$$\lim_{t\to+\infty} \eta e^{-\rho t} D = 0. \tag{17}$$

Equation (11) can be specified as

$$\frac{q-1}{h} = \frac{I^T}{K} = \frac{\dot{K}}{K}. \tag{18}$$

Let $P = \frac{\mu}{\eta}$, giving the relative price of human capital in terms of goods. In this open economy P is also the relative price of tradables over nontradables, that is a real exchange rate.

We also use the following notation: $d = \frac{D}{K}$, $k = \frac{K}{H}$, $c = \frac{C}{K}$, $y^K = \frac{A(vK)^{\alpha}(uH)^{1-\alpha}}{K}$ and $y^H = \frac{B[(1-v)K]^{\beta}[(1-u)H]^{1-\beta}}{H}$. Notice that with equations (9) and (10) we can represent r^K and r^H as a function of the relative price P. It follows that $r^K = \alpha A\phi^{\alpha-1}P^{\frac{\alpha-1}{\alpha-\beta}}$ and $r^H = (1-\alpha)\,A\phi^{\alpha}P^{\frac{\alpha}{\alpha-\beta}}$, where $\phi = \left[\frac{B}{A}\left(\frac{\beta}{\alpha}\right)^{\beta}\left(\frac{1-\alpha}{1-\beta}\right)^{\beta-1}\right]^{\frac{1}{\alpha-\beta}}$.

The dynamic system of this open economy is given by the following equations:

$$\frac{\dot{c}}{c} = \frac{1}{\sigma}\left(r^* - \rho\right) - \frac{q-1}{h} \tag{19}$$

$$\dot{d} = \left(r^* - \frac{q-1}{h}\right)d + y^K - c - \frac{q-1}{h}\left(1 + \frac{h}{2}\frac{q-1}{h}\right) \tag{20}$$

$$\frac{\dot{k}}{k} = \frac{q-1}{h} - y^H \tag{21}$$

$$\dot{q} = r^*q - r^K - \frac{h}{2}\left(\frac{q-1}{h}\right)^2 \tag{22}$$

$$\frac{\dot{P}}{P} = r^* - \frac{r^H}{P} \tag{23}$$

and taking into account the transversality conditions for D, K and H.

The steady state value of the relative price is given by equation (23). Then, we obtain q^* with (22). k^* is determined by equation (21). From the flow budget constraint, equation (5), and taking into account a no-Ponzi-game condition, we can obtain the intertemporal budget constraint:

$$\int_0^{+\infty} Ce^{-rt} = \int_0^{+\infty}\left[A\,(vK)^{\alpha}\,(uH)^{1-\alpha} - I^T\left(1 + \frac{h}{2}\frac{I^T}{K}\right)\right]e^{-rt} + D_0$$

where $C_t = C_0 e^{\frac{1}{\sigma}(r^*-\rho)t}$. d^* and c^* depend on the initial conditions.

It is possible to have $q^* = 1$ with a formulation of adjustment costs like: $I^T\left[1 + m\left(\frac{I^T}{K}\right)\right]$, where $m\left(\frac{I^T}{K}\right) = \frac{\frac{h}{2}\left(\frac{I^T}{K} - a\right)}{\frac{I^T}{K}}$ and $a = g = \frac{1}{\sigma}\left(r^* - \rho\right)$ is here the steady state growth rate[18]. With $q^* = 1$, we have $\left(r^K\right)^* = r^*$. We are assuming that the rest of the world is in the steady state.

3.1.1 Transitional dynamics and the speed of convergence

We linearize the system and consider the equations of k, q and P. The linearized system of these three equations is given by

$$\begin{bmatrix} \dot{k} \\ \dot{q} \\ \dot{P} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ 0 & a_{22} & a_{23} \\ 0 & 0 & a_{33} \end{bmatrix} * \begin{bmatrix} k - k^* \\ q - q^* \\ P - P^* \end{bmatrix}$$

where a_{ij} represents the partial derivative of the equation i with respect to the argument j, at the steady state values.

We consider the case where the share of physical capital in the tradable sector is greater than in the nontradable sector: $\alpha > \beta$. As the differential equation of the relative price is stable in this case, this condition leads to the stability and the dynamics of transition of the real exchange rate. Then:

$$a_{11} = -\frac{\partial y^H}{\partial k} k^* > 0;\ a_{22} = r^* - g \text{ and } a_{33} = -\frac{\beta}{\alpha - \beta} r^* < 0.$$

By a_{11}, we can see that an increase in the physical capital-nontradable capital ratio, k, leads to a decrease in the output of the nontradable sector, the sector that uses intensively nontradable capital ($\alpha > \beta$) and the first expression is positive. This is related to the Rybczynski theorem. By a_{33}, we can see that an increase in the nontradable relative price, P, leads to an increase in the remuneration of the nontradable capital, the factor used intensively in the nontradable sector and the later expression is negative. This is related to the Stolper-Samuelson theorem. It follows that the relative price has a stabilizing effect and the capital ratio a destabilizing role, in the transition dynamics of the economy.

The speed of convergence of this open economy[19], λ, is determined with

---

[18] This formulation of adjustment costs has been adopted by King and Rebelo (1993) and Ortigueira and Santos (1997). They follow the empirical work of Summers (1981). This author assumes that $m\left(\frac{I^T}{K}\right) = 0$, if $\frac{I^T}{K} < a$ (with $a > 0$).

[19] Turnovsky (1996) studies the dynamics of a similar model, but the author is interested in the effects of shocks to the parameters and not in the speed of convergence of such a model.

the differential equation of the relative price and, given the negative eigenvalue a_{33}, is equal to

$$\lambda = \frac{\beta}{\alpha - \beta} r^{*}. \tag{24}$$

We want to point out that the speed of convergence in the open economy model does not depend on the adjustment costs. This result applies since the economy is incompletely specialized.

In the Ramsey open economy one-sector model, the transitional dynamics of external debt depends on physical capital, around the steady state, and the initial level of physical capital determines the steady state level of external debt. In our model, we have the same kind of transitional dynamics for d. A linearized version of equation (20) depends on d and k:

$$\dot{d} = (r^{*} - g)(d - d^{*}) + \Lambda (k - k^{*})$$

where[20]

$$\Lambda = y_P^K \Pi + y_k^K + \left(\frac{1}{-\lambda} \frac{c^{*}}{h} - \frac{b^{*} + q^{*}}{h} \right) \Gamma$$

and

$$\Gamma = \frac{-(\lambda + a_{11})}{\frac{k^{*}}{h} - \frac{a_{13}}{a_{23}} (r^{*} + \lambda)} \quad \text{and} \quad \Pi = \frac{-(r^{*} + \lambda)}{a_{23}} \Gamma.$$

Observing the transversality condition, the solution of this differential equation leads to

$$(d - d^{*}) = \frac{\Lambda}{-\lambda - (r^{*} - g)} (k_0 - k^{*}) e^{-\lambda t}.$$

Notice that by knowing d^{*} with $t = 0$ and given k_0 , one obtains c^{*} with equation (20).

3.2 Equations for convergence analysis

Taking into account the linearized version of the equation (23), which gives the dynamics of the real exchange rate, one can show that the transitional dynamics of the real exchange is given by the following equation:

$$P_{t+T} - P^{*} = (P_t - P^{*}) e^{-\lambda T}.$$

[20] Notice that y^K and y^H depend on P and k.

Using logs we have:

$$\frac{1}{T}\log\left(\frac{P_{t+T}}{P_t}\right) = \left(\frac{1-e^{-\lambda T}}{T}\right)\log\left(P^*\right) - \\ - \left(\frac{1-e^{-\lambda T}}{T}\right)\log\left(P_t\right). \quad (25)$$

In this equation there isn't any term that could be unobservable like the initial level of technology. The bias associated with omitted variables in regressions using the GDP per capita and based in the exogenous growth model is not present when using the real exchange rate[21].

Without the problem of an omitted variable that appears using the GDP, it seems interesting to analyze the speed of convergence with the real exchange rate. We would like to point out that in the model presented above, the speed of convergence of the real exchange rate and GDP is the same: all variables depending on the same negative eigenvalue have the same speed of convergence. Differently from most studies on convergence, we are using an endogenous growth model. The variables used to analyze the steady state are the ratio GDP over physical capital, $\frac{Y}{K}$ or the ratio GDP over nontradable capital $\frac{Y}{H}$, where Y represents all production $Y^T + PY^{NT}$. Y^T means output of tradables, PY^{NT} represents the output of nontradables in units of tradables, K is physical capital and H is nontradable capital proxied by human capital. Let $\tilde{y} = \frac{Y}{H}$. The dynamics of this variable, like the real exchange rate, is given by the following equation:

$$\tilde{y}_{t+T} - \tilde{y}^* = \left(\tilde{y}_t - \tilde{y}^*\right)e^{-\lambda T},$$

and we obtain:

$$\frac{1}{T}\log\left(\frac{\tilde{y}_{t+T}}{\tilde{y}_t}\right) = \left(\frac{1-e^{-\lambda T}}{T}\right)\log\left(\tilde{y}^*\right) - \left(\frac{1-e^{-\lambda T}}{T}\right)\log\left(\tilde{y}_t\right).$$

Notice that y represents the GDP per capita, equal to GDP under the assumption of population constant and equal to one. Having $\log\tilde{y} = \log y -$

[21]For the conditional convergence, one can criticize the way of taking into account the steady state level of GDP. These criticisms can also apply when using the real exchange rate. We will return to this issue in the empirical analysis.

$\log H$, the equation of the dynamics of the GDP per capita is given by:

$$\frac{1}{T}\log\left(\frac{y_{t+T}}{y_t}\right) = \left(\frac{1-e^{-\lambda T}}{T}\right)\log\left(\tilde{y}^*\right) - \left(\frac{1-e^{-\lambda T}}{T}\right)\log\left(y_t\right) + \\ + \left(\frac{1-e^{-\lambda T}}{T}\right)\log\left(H_t\right) + \frac{1}{T}\log\left(\frac{H_{t+T}}{H_t}\right). \tag{26}$$

Instead of the level of technology that appears with the Solow model, in this equation there appears the log of the initial value of human capital, $\log(H_t)$, and its average growth rate, $\frac{1}{T}\log\left(\frac{H_{t+T}}{H_t}\right)$. Notwithstanding, in the augmented Solow model of Mankiw et al. (1992) the steady state level of human capital per unit of effective labor may also appear determining $\hat{y}^*$.

It is important to point out that Islam (1995) and Hall and Jones (1999) have shown a correlation between human capital and an estimated level of technology. One can say that cross-section studies controlling for human capital are in a certain way also controlling for the initial level of technology, if one has in mind the Solow model. In these studies the bias of an omitted variable will be less important. With our model, we can make a comparison between the speeds of convergence of GDP and of the real exchange rate, knowing that with this last variable there is no problem of an omitted variable. In fact, one would find the same speed of convergence using these two variables in a cross-section of countries.

4 Comparing speeds of convergence of the real exchange rate and of GDP

4.1 Variables

In this Section we test equations (25) and (26). The variables we need for estimating these equations are: the real exchange rate, GDP per capita, human capital and a proxy for the steady state of real exchange rate and GDP per capita over human capital.

Following the Penn World Table (PWT) version 6.1[22], our data set has 115 countries for which there are estimates of price level for 1996. Those

[22] For a description of the Penn World Table (version 5), see Summers and Heston (1991). The data of Penn World Table (version 6.1) are available at: http://pwt.econ.upenn.edu/

are benchmark countries. The number of countries are reduced in some specification because of the availability of other variables. Tables 1 and 2 present, respectively, Descriptive Statistics and Correlation Matrix of the variables.

[Table 1 and Table 2 to insert here]

4.1.1 Real exchange rate

Following our model, the real exchange rate is given by the relative price of nontradables over tradables, P. An increase of this relative price means an appreciation of the real exchange rate. For the empirical study, we will have the prices of the country over the prices of a reference country, where the prices are expressed in the same unit.

Assume P^i represents the price level of country i and P^{US} represents the price level of the USA, the country used as reference. We are also assuming that all goods have the same weight in the price level of both countries. The nominal exchange rate is given by e^i. Then, the real exchange rate is represented by $P = \frac{P^i}{P^{US} * e^i}$.

Price indexes of consumption and the GDP deflator are used to obtain the growth rate of the real exchange rate. Notice that the weights given to different goods in the different countries are not the same. Moreover, given that these price indexes have a base year as reference, there is another problem: one can not have the level of the real exchange rate for the base year.

The only available measures of the real exchange rate giving the possibility of calculating its initial level are the Purchasing Power Parities (PPP) of the PWT. We can have two measures of the real exchange: one based on the price level of GDP and the other based on consumption. Our measure will be the price level of GDP.

The price level measures result from the "International Comparison of Prices Program" of the PWT. These measures are based on the same group of goods and they are weighted by the real fraction of income spent on each group of goods. We would like to point out that the comparison of price levels in different countries are available for some "benchmark" years (1970, 1975, 1980, 1985, and 1996) and the number of countries participating is increasing. For example, 61 countries in 1980 and 115 countries in 1996. For other years and countries, the price levels are obtained with fitted values, based on regressions of price levels regressions on benchmark countries.

This database is also used to calculate the GDP in PPP. These values of GDP per capita appear in most studies on convergence. That is, the quality of the measures of the real exchange rate is comparable to that of the GDP.

4.1.2 GDP per capita

Following the literature on growth empirics, we use the real GDP per capita in Purchasing Power Parity (1995 international prices), Laspeyres index. This variable (named here GDP) also comes from the PWT version 6.1.

4.1.3 Human capital

Human capital (H) is the nontradable capital in our model. Our proxy is the average years of secondary schooling of the total population aged 15 or over (S). This variable comes from the updated Barro-Lee data set[23].

4.1.4 Proxies for the equilibrium level of the real exchange rate and of GDP

For conditional convergence, one needs proxies for the equilibrium level of the real exchange rate and GDP per capita over human capital. We will use one proxy for both variables, given they are determined by the same system and depend on the same parameters. Moreover, using the same proxy gives a more accurate comparison of the regressions based on GDP and the real exchange rate.

For the real exchange rate, one could also use the end of period GDP per capita, following the idea associated with the Balassa-Samuelson effect that these variables are correlated[24].

We take as a proxy for the steady state of these variables, the index of the quality of institutions (GADP) used by Hall and Jones (1999). This index

[23] See Barro (2001). The data are available at Center for International Development, Harvard University: http://www.cid.harvard.edu/ciddata/

[24] See Balassa (1964) and Samuelson (1964). For a presentation of this effect, see Rogoff (1996).

provides an assessment of risk to international investors. It constitutes an average of five categories for the years 1986-1995. These categories are the following:

(i) law and order;

(ii) bureaucratic quality;

(iii) corruption;

(iv) risk of expropriation;

(v) and government repudiation of contracts.

The index is measured on a scale from zero to one and its value increases with the quality of institutions of the country.

The importance of institutions in determining income has been also analyzed by Acemoglu, Johnson and Robinson (2001). Both studies use instrumental variables to assess the potential problem of endogenous variables. We choose the instruments used by Hall and Jones (1999), because they are available for more countries than in the work of Acemoglu et al. (2001). The instruments used are the fraction of population speaking English at birth (ENGFRAC), the fraction of population speaking a Western European language at birth (EURFRAC) and the distance from the equator (LATITUDE). We also use as an instrument a variable created by Jeffrey Sachs and coauthors, the share of a country's population in temperate ecozones (KGPTEMP). This variable is based on Koppen-Geiger ecozone classification system[25]. KGPTEMP is used in the place of LATITUDE, following Sachs.

4.2 Conditional convergence of the real exchange rate and of GDP

4.2.1 Period of 1960-1996

We will analyze cross-country convergence regressions over the period of 1960-1996. Results will be presented for the real exchange rate and for the GDP per capita. These regressions are based on equations (25) and (26), respectively.

Table 3 presents the regressions for conditional convergence, where the proxy for the steady state (of real exchange rate and GDP per capita) is

[25] The data are available at Center for International Development, Harvard University: http://www.cid.harvard.edu/ciddata/

given by an index of the quality of institutions (GADP). This index was presented above. With the same proxy for the steady state, the regressions of convergence for the two variables are more comparable.

[Table 3 to insert here]

Regression (i) gives the results for conditional convergence using the real exchange rate, following equation (25). Both coefficients have the right sign and are significative. Having a negative sign for the initial level of the real exchange rate means there is a process of convergence, a conditional convergence.

Regression (iii) presents the results for conditional convergence of GDP per capita. We would like to point out that this specification goes with equation (26), that is, one needs to include not only the log of initial level of human capital but also its growth rate. We are assuming that the average years of secondary schooling is a proxy for human capital. Regression (ii) shows the difference in the coefficient associated with the speed of convergence, when the term on the growth rate of human capital is not included in the specification.

The coefficients associated with the speed of convergence in regressions (i) and (iii) are similar, supporting the intuition of our model[26]. For example, the speed of convergence associated with the initial level of GDP per capita in regression (iii) is around 3.5% per year[27].

These values go with the results of the speed of convergence in cross-section studies, with values of 2-3%. The specifications presented above do not have the problem of omitted variables associated with the initial level of technology in exogenous growth models. Then, values for the speed of convergence around 10% found by Caselli et al. (1996) with panel data appear too high. One can say, in conclusion, that the speed of convergence seems to be closer to the values found in cross-section studies than in panel data.

[26]The results in the regressions with the real exchange rate do not change if we reduce the number of countries for taking into account the availability of data of human capital. Only the coefficient for unconditional convergence is smaller than the one presented in Table 5. Our conclusions do not change.

[27]The expression of the speed of convergence appears in equation (26). The coefficient of the initial level of GDP per capita is given by $\frac{(1-e^{-\lambda T})}{T}$, where λ represents the speed of convergence and T represents the number of years.

4.2.2 Instrumental variables

The results presented above provide evidence for speeds of conditional convergence supporting the values found in cross-country regressions. We used the quality of institutions as a proxy for the steady state values of real exchange rate and GDP per capita. This variable can be seen as a fundamental determinant of steady state values. Nevertheless, there may be a problem of endogeneity: for example, countries with high income can also have better institutions. A solution is to find instrumental variables that may proxy for exogenous variations in institutions. Hall and Jones (1999) and Acemoglu et al. (2001) look for such types of instruments. Because of availability, we will use the instruments of Hall and Jones (1999), the fraction of population speaking English at birth (ENGFRAC), the fraction of population speaking a Western European language at birth (EURFRAC) and the distance from the equator (LATITUDE). In some regressions, instead of LATITUDE, we will use a variable proposed by Jeffrey Sachs and referred to above as the share of a country's population in temperate ecozones (KGPTEMP).

There is a debate on the fundamental determinants of income. Acemoglu et al. (2001) show that when considering also geographic variables, institutions remain as the only important fundamental determinant. Rodrik, Subramanian and Trebbi (2002) consider not only institutions and geography, but also openness. Institutions remain as the only important variable. We take these studies into account to consider only the quality of institutions.

Table 4 presents the regressions of conditional convergence with instruments for the quality of institutions. These are two-stage least squares regressions. Columns (i) and (ii) present the results for the real exchange rate and the GDP per capita, respectively, using as instruments ENGFRAC, EURFRAC and LATITUDE. The coefficients are in line with those presented in Table 3. A test for the exogeneity of instruments is proposed and we cannot reject the null hypothesis (exogeneity of instruments). The test is given by nR^2, where n is the number of observations and R^2 results from the regression of the residuals of the second stage regression on the instruments and exogenous variables. The test for the null hypothesis (exogeneity of instruments) has a distribution $\chi^2(n)$. There are two degrees of freedom with three instruments and one endogenous variable. The 5 percent point critical value of $\chi^2(2)$ is 5.991. Notwithstanding, one needs to have present the limits of power associated with these tests. Columns (iii) and (iv) give the results when using as instruments ENGFRAC, EURFRAC and KGPTEMP. We cannot reject the null hypothesis (exogeneity of instruments), after changing the instruments. The coefficient associated with the speed of convergence in the regression of real exchange rate increases to -0.024. It would imply a speed of convergence of 5.5%, higher than expected but still lower than the 10% found in panel studies.

[Table 4 to insert here]

Taking into account the endogeneity of institutions, the results continue to support the previous conclusions. The speed of convergence goes with the values found in cross-country regressions of convergence.

4.3 Unconditional convergence of the real exchange rate and GDP

Using the initial level of the real exchange rate as the only independent variable, that is without taking into account its steady state level, means we are testing unconditional convergence. This results from equation (25). On the other hand, unconditional convergence of GDP per capita following equation (26) leads to control also for the log of initial level of human capital and its growth rate. Table 5 presents these regressions.

[Table 5 to insert here]

Regression (i) is for the unconditional convergence of the real exchange rate. The coefficient of its log initial level is negative and significative. Regression (iii) corresponds to the specification of unconditional convergence of GDP per capita, following equation (26). We also present regression (ii) to show the effect of not including the growth rate of human capital. The coefficient associated with the initial level of GDP per capita in regression (iii) is again similar to that associated with the initial level of real exchange rate in equation (i). The corresponding speed of convergence is equal to 1.84% per year.

Although one needs to be careful with these results, given the nature of the data, there is no evidence for divergence. Taking into account the model, we have evidence for unconditional convergence using one or another of the variables.

4.4 The role of human capital in growth regressions

In this subsection, we discuss the role of human capital in convergence, based on our model.

Our regressions of convergence with GDP follow equation (26), where the role of human capital is well specified. The convergence equation relates growth rate to log initial level of GDP over human capital. As we specify the regressions with GDP per capita, one needs to take into account that a higher level of human capital leads to a smaller GDP over human capital. Having both variables in logs, their coefficients are equal but with opposite signs. Note also that by taking into account the same issue, one would expect to find a coefficient equal to one for the growth rate of human capital.

The coefficients of log initial GDP and log initial human capital (proxied by log average years of secondary schooling) are in general similar and significative, as predicted. These results apply both to conditional and unconditional convergence, as is confirmed in Tables 3 to 5. For the annual average growth rate of human capital one would expect a coefficient equal to one. The values found are about 0.5 and significative in both types of convergence.

By using an open economy endogenous growth model, we presented a possible role for log initial level and growth rate of human capital in transitional dynamics.

5 Conclusion

We have argued that it is important to consider the transitional dynamics of economies, instead of only concentrating on steady state issues. Comparing with the literature, the values for the speed of convergence found in panel studies with fixed effects are too high.

Our results are based on a new perspective, where we compare the speeds of convergence of the real exchange rate and GDP, in a model without the problem of an omitted variable associated with the level of technology. We observed a process of convergence of the real exchange rate, conditionally and unconditionally, and we also presented a role for human capital in growth regressions.

References

Acemoglu, D., Johnson, S. and Robinson, J. (2001), 'The colonial origins of comparative development: An empirical investigation', *American Economic Review* **91**, 1369–1401.

Balassa, B. (1964), 'The purchasing power parity doctrine: A reappraisal', *Journal of Political Economy* **72**, 584–596.

Barro, R. (1997), *Determinants of Economic Growth*, Cambridge MA: MIT Press.

Barro, R. (2001), 'Human capital and growth', *American Economic Review Papers and Proceedings* **91**, 12–17.

Barro, R. and Sala-i-Martin, X. (1995), *Economic Growth*, New York: McGraw-Hill.

Benhabib, J. and Spiegel, M. (1994), 'The role of human capital in economic development: Evidence from aggregate cross-country data', *Journal of Monetary Economics* **34**, 143–173.

Bils, M. and Klenow, P. (2000), 'Does schooling cause growth?', *American Economic Review* **90**, 1160–1183.

Bond, E., Wang, P. and Yip, C. (1996), 'A general two-sector model of endogenous growth with human and physical capital: Balanced growth and transitional dynamics', *Journal of Economic Theory* **68**, 149–173.

Caselli, F., Esquivel, G. and Lefort, F. (1996), 'Reopening the convergence debate: A new look at cross-country growth empirics.', *Journal of Economic Growth* **1**, 363–389.

Durlauf, S. and Quah, D. (1999), The new empirics of economic growth, *in* J. Taylor and M. Woodford, eds, 'Handbook of Macroeconomics', Amesterdam: North Holland, chapter 4, pp. 231–304.

Hall, R. and Jones, C. (1999), 'Why do some countries produce so much more output per worker than others?', *Quartely Journal of Economics* **114**, 83–116.

Islam, N. (1995), 'Growth empirics: A panel data approach', *Quartely Journal of Economics* **110**, 1127–1170.

King, R. and Rebelo, S. (1993), 'Transitional dynamics and economic growth in the neoclassical model', *American Economic Review* **83**, 908–931.

Krueger, A. and Lindahl, M. (2001), 'Education for growth: Why and for whom?', *Journal of Economic Literature* **39**, 1101–1136.

Lucas, R. (1988), 'On the mechanics of economic development', *Journal of Monetary Economics* **22**, 3–42.

Mankiw, N. G., Romer, D. and Weil, D. (1992), 'A contribution to the empirics of economic growth', *Quartely Journal of Economics* **107**, 407–437.

Nelson, R. and Phelps, E. (1966), 'Investment in humans, technological diffusion, and economic growth', *American Economic Review* **56**, 69–75.

Obstfeld, M. and Rogoff, K. (1996), *Foundations of International Macroeconomics*, Cambridge MA: MIT Press.

Ortigueira, S. and Santos, M. (1997), 'On the speed of convergence in endogenous growth models', *American Economic Review* **87**, 383–399.

Rodrik, D., Subramanian, A. and Trebbi, F. (2002), Institutions rule: The primacy of institutions over geography and integration in economic development. NBER WP 9305.

Rogoff, K. (1996), 'The purchasing power parity puzzles', *Journal of Economic Literature* **34**, 647–668.

Romer, P. M. (1990), 'Endogenous technological change', *Journal of Political Economy* **98**(5), S71–S102.

Samuelson, P. (1964), 'Theoretical notes on trade problems', *Review of Economics and Statistics* **46**, 145–154.

Summers, L. (1981), 'Taxation and corporate investment: A q-theory approach', *Brookings Papers on Economic Activity* **1**(1), 67–127.

Summers, R. and Heston, A. (1991), 'The penn world table (mark 5): An expanded set of international comparisons, 1950-1988', *Quartely Journal of Economics* **106**, 327–368.

Temple, J. (1999), 'The new growth evidence', *Journal of Economic Literature* **37**, 112–156.

Turnovsky, S. (1996), 'Endogenous growth in a dependent economy with traded and nontraded capital', *Review of International Economics* **4**, 300–321.

Table 1: Descriptive Statistics, 1960-1996.

	Mean	Standard Dev.	Minimum	Maximum
DP_{6096}	0.0026	0.014	-0.0428	0.0353
$LogP_{60}$	3.847	0.414	2.735	4.739
$DGDP_{6096}$	0.019	0.0186	-0.032	0.066
$LogGDP_{60}$	7.81	0.87	5.95	9.43
$LogS_{60}$	-1.002	1.38	-6.907	1.284
DS_{6095}	0.036	0.027	-0.021	0.19
GADP	0.625	0.208	0.225	0.988

Number of observations: 86.

Table 2: Correlation Matrix, 1960-1996.

	DP_{6096}	$LogP_{60}$	$DGDP_{6096}$	$LogGDP_{60}$	$LogS_{60}$	DS_{6095}
DP_{6096}	1					
$LogP_{60}$	-0.25	1				
$DGDP_{6096}$	0.377	0.243	1			
$LogGDP_{60}$	0.507	0.427	0.18	1		
$LogS_{60}$	0.441	0.35	0.438	0.74	1	
DS_{6095}	-0.282	-0.017	-0.073	-0.382	-0.747	1
GADP	0.605	0.415	0.539	0.729	0.645	-0.302

Number of observations: 86.

Table 3: Conditional convergence of GDP per capita and the real exchange rate (P), 1960-1996.

	(i) DP_{6096}	(ii) $DGDP_{6096}$	(iii) $DGDP_{6096}$
Constant	0.045 (5.741)	0.109 (4.458)	0.139 (7.716)
$LogP_{60}$	-0.02026 (-9.027)		
$LogGDP_{60}$		-0.0161 (-4.672)	-0.0199 (-7.484)
$LogS_{60}$		0.0066 (3.978)	0.0165 (9.03)
DS_{6095}			0.466 (7.204)
GADP	0.0564 (12.975)	0.0685 (6.506)	0.0567 (6.149)
$\overline{R}^2$	0.576	0.469	0.645
N. Obs.	110	88	86

OLS regressions with robust standard errors. t statistics are in parentheses. Dependent variable: average growth rate of real exchange rate (DP) and average growth rate of GDP per capita (DGDP). S represents average years of secondary schooling of total population aged 15 or over, DS its average growth rate and GADP is an index of the quality of institutions.

Table 4: Conditional convergence of GDP per capita and the real exchange rate (P), 1960-1996. Instrumental variables for the quality of institutions.

	(i) DP_{6096}	(ii) $DGDP_{6096}$	(iii) DP_{6096}	(iv) $DGDP_{6096}$
Constant	0.0464 (5.536)	0.133 (6.928)	0.051 (5.687)	0.129 (7.277)
$LogP_{60}$	−0.0225 (−8.469)		−0.024 (−9.185)	
$LogGDP_{60}$		−0.0174 (−5.347)		−0.0189 (−6.862)
$LogS_{60}$		0.0181 (7.821)		0.0151 (7.742)
DS_{6095}		0.504 (7.075)		0.441 (6.805)
GADP	0.0685 (7.969)	0.0342 (1.9)	0.0714 (11.8)	0.0583 (4.741)
N. Obs.	110	86	102	81
Test of Instruments	5.085	1.387	5.636	4.128

2SLS regressions with robust standard errors. t statistics are in parentheses. Dependent variable: average growth rate of real exchange rate (DP) and average growth rate of GDP per capita (DGDP). S represents average years of secondary schooling of total population aged 15 or over, DS its average growth rate and GADP is an index of the quality of institutions. Instrumental variables for GADP: the fraction of population speaking English at birth (ENGFRAC), the fraction of population speaking a Western European language at birth (EURFRAC) and the distance from the equator (LATITUDE) in regressions (i) and (ii), and ENGFRAC, EURFRAC and the share of a country's population in temperate ecozones (KGPTEMP) in regressions (iii) and (iv). The test is given by nR^2, where n is the number of observations and R^2 results from the regression of the residuals of the second stage regression on the instruments and exogenous variables. The test for the null hypothesis (exogeneity of instruments) has a distribution $\chi^2(n)$. The 5 percent point critical value of $\chi^2(2)$ is 5.991.

Table 5: Unconditional convergence of GDP per capita and the real exchange rate (P), 1960-1996.

	(i) DP_{6096}	(ii) $DGDP_{6096}$	(iii) $DGDP_{6096}$
Constant	0.0534 (3.638)	0.78 (2.835)	0.124 (5.767)
$LogP_{60}$	-0.0134 (-3.458)		
$LogGDP_{60}$		-0.0066 (-2.036)	-0.0134 (-5.162)
$LogS_{60}$		0.0088 (3.515)	0.02 (8.28)
DS_{6095}			0.56 (7.426)
$\overline{R}^2$	0.147	0.209	0.473
N. Obs.	112	89	87

OLS regressions with robust standard errors. t statistics are in parentheses. Dependent variable: average growth rate of real exchange rate (DP) and average growth rate of GDP per capita (DGDP). S represents average years of secondary schooling of total population aged 15 or over and DS its average growth rate.