Banco Central de Chile
Documentos de Trabajo

Central Bank of Chile
Working Papers

N° 176

Agosto 2002

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Documentos de Trabajo del Banco Central de Chile
Working Papers of the Central Bank of Chile
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Documento de Trabajo
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IS THERE ENOUGH EVIDENCE AGAINST ABSOLUTE CONVERGENCE?

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Resumen
Este artículo analiza si es que los métodos econométricos usualmente aplicados para evaluar convergencia absoluta han sido justos con esta hipótesis. Muestro que los tests tradicionales de convergencia absoluta y condicional no son consistentes with incluso el modelo más simple que presenta convergencia. Además, afirmaciones de divergencia sobre la base de bimodalidades en la distribución del PIB per capita pueden ser consistentes con modelos en los cuales ni divergencia ni bimodalidades (*twin peaks*) están presentes en el largo plazo.

Abstract
This paper analyzes whether or not the econometric methods usually applied to test for absolute convergence have provided this hypothesis a fair. I show that traditional (absolute and conditional) convergence tests are not consistent with even the simplest model that displays convergence. Furthermore, claims of divergence on the grounds of bimodalities in the distribution of GDP per capita can be made consistent with models in which neither divergence nor twin peaks are present in the long run.

I would like to thank William Easterly, Rodrigo Fuentes, Eduardo Morón, Klaus Schmidt-Hebbel, Raimundo Soto, and the participants of the Fifth International Conference of the Central Bank of Chile for helpful comments and suggestions. Francisco Gallego provided able research assistance. The usual disclaimer applies.
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1 Introduction

Few subjects in applied economic research have been studied as extensively as the convergence hypothesis advanced by Solow (1956) and documented by Baumol (1986).[1] In simple terms, the hypothesis states that poor countries or regions tend to grow faster than rich ones. In its strongest version (known as absolute convergence), an implication of this hypothesis is that, in the long run, countries or regions should not only grow at the same rate, but also reach the same income per capita.[2] This hypothesis has been tested using different methodologies and data sets and appears to be strongly rejected by the data. In view of these results, several modifications of the absolute convergence hypothesis have been advanced and tested. However, they usually lack both theoretical foundations and econometric rigor and discipline.

This paper analyzes whether or not the econometric methods usually applied to test for absolute convergence have provided this hypothesis a "fair" chance. The paper is organized as follows: Section 2 presents a brief review of some of the tests for convergence advanced in the empirical literature and documents their shortcomings. Section 3 develops a simple theoretical model that implies absolute convergence. Section 4 discusses how likely would it be for time series generated from the model to accommodate the results of the tests described on Section 2. Finally, Section 5 draws some conclusions.

[1] An admittedly incomplete list of representative studies of this line of research is Aghion and Howitt (1997), Barro (1991), Barro and Sala-i-Martin (1992), Mankiw et al (1992), Durlauf and Johnson (1995), Jones (1995), and Kocherlakota and Yi (1996,1997).

[2] This interpretation has been challenged by Bernard and Durlauf (1996).

2 The Empirical Literature

The first stylized fact that appears uncontroversial is that whatever the type of data set used (a cross section of countries or panel data), the data strongly reject absolute convergence (Barro and Sala-i-Martin, 1995). The simplest test that can be devised to verify this claim using cross-sectional observations takes the form

$$g_i = \zeta + \vartheta \ln y_{i,0} + \varepsilon_i, \tag{1}$$

where $y_{i,t}$ is GDP per capita in period t for country i, and g_i is the average growth rate of GDP per capita in country i; that is:

$$g_i = \frac{1}{T} \sum_{t=1}^{T} \Delta \ln y_{i,t} = \frac{1}{T} \left(\ln y_{i,T} - \ln y_{i,0} \right).$$

When pooled data are used, tests for absolute convergence usually take the form

$$\Delta \ln y_{i,t} = \zeta + \vartheta \ln y_{i,t-1} + \varepsilon_{i,t}. \tag{2}$$

In both cases absolute convergence is said to be favored by the data if the estimate of ϑ is negative and statistically different from zero. If the null hypothesis ($\vartheta = 0$) is rejected, we would conclude that not only do poor countries grow faster than rich countries, but also that they all converge to the same level of GDP per capita.

As Table 1 and Figure 1 show, the convergence hypothesis is strongly rejected by the data.[3] In fact, if these results are taken seriously, the evidence appears to favor divergence instead of convergence. That is, the countries that grew faster were those that had a higher initial GDP per capita.

	Cross-section	Pooled Data
$\widehat{\vartheta}$	0.0047	0.0048
	(0.0014)	(0.0010)
Adjusted R^2	0.051	0.007
No. of countries	116	85
No. of observations	116	3,219

Table 1: Tests for absolute convergence. Standard errors consistent with heteroskedasticity are in parentheses.

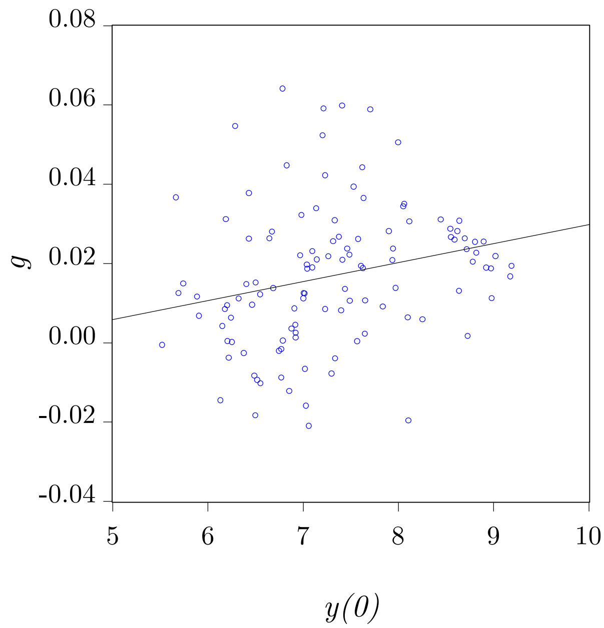

Figure 1: Growth rate from 1960 to 1998 versus 1960 GDP per capita

[3]All tests using panel data were conducted using the latest version of the Penn World Tables data set described in Summers and Heston (1991), with data for most variables ranging from 1960 to 1998. Cross-section regressions were conducted using the data set described in Doppelhofer et al (2000).

As the null hypothesis being tested in both cases is that ϑ is equal to zero versus the alternative that it is negative, equation (2) makes explicit that a test for absolute convergence is essentially a test for a unit root on y. As abundantly documented elsewhere, these tests not only have nonstandard asymptotic properties, but also lack power. In fact, if a traditional (augmented Dickey-Fuller) unit-root test on $\ln y$ were performed for each country, none would reject the null at standard significance levels. Moreover, the first-order autocorrelation coefficient of $\ln y$ for each country ranges from 0.610 to 0.999, with an average value of 0.947. These results suggest that, even if a unit root were not present, $\ln y$ is extremely persistent, and initial conditions would take a long time to dissipate.

In light of the above results, Barro (1991) considered a modification of equation (1) in which, even when convergence is still understood as the situation where poor countries grow faster than rich countries (unconditionally), their growth rate may be influenced by other factors that may prevent convergence in levels of GDP per capita. Tests for conditional convergence using cross-sectional observations usually take the form

$$g_i = \zeta + \vartheta \ln y_{i,0} + \varphi' x_i + \varepsilon_i, \tag{3}$$

where x is a vector of k variables that may influence growth. Given that the x variables are different for each country, even if ϑ were negative, incomes might never converge.

Table 2 presents the results of cross-sectional and panel regressions that include

	Cross-section	Panel Data
$\widehat{\vartheta}$	-0.0154	-0.0456
	(0.0028)	(0.0062)
Adjusted R^2	0.811	0.181
No. of countries	79	85
No. of observations	79	2,552

Table 2: Tests for conditional convergence. Standard errors consistent with heteroskedasticity are in parentheses.

some of the usual candidates for specifications such as equation (3).[4] As noted by Durlauf (2001), serious problems plague this strategy. First, as economic theory is usually silent with respect to the set of x variables to be included, empirical studies have often abused in terms of the potential candidates used; Durlauf and Quah (1999) report that, as of 1998, over 90 different variables had appeared in the literature, despite the fact that no more than 120 countries are available for analysis in the standard data sets. Second, important biases in the results may be due to the endogeneity of most of the control variables used (Cho, 1996). Third, the estimated coefficients of the convergence parameter (ϑ) are rather small, suggesting that, even after controlling for the x variables, $\ln y$ continues to be extremely persistent. Fourth, as a corollary of the previous observation, initial conditions may play a crucial role in the results. Fifth, the robustness of results in terms of the potential determinants

[4] The model that uses cross-sectional observations includes the following x variables (signs on the coefficients associated with the variables are in parentheses): life expectancy in 1960 (+), equipment investment (+), years of open economy (+), a "rule of law" index (+), a dummy variable for Sub-Saharan African countries (-), and the fraction of people that profess the Muslim (+), Confucian (+), and Protestant (-) religions. The model that uses panel data was estimated using fixed effects and the following x variables: investment-to-GDP ratio (+), growth rate of the population (-), ratio of exports plus imports to GDP (+), ratio of liquid liabilities to GDP (-), inflation rate (-), and ratio of government consumption to GDP (-).

of long-run growth is subject to debate (see, for example, Levine and Renelt, 1992; Sala-i-Martin, 1997; and Doppelhofer et al, 2000). Finally, several of the variables included in the x vector are fixed effects that cannot be modified; if these variables were actually long-run determinants of growth, convergence would never be achieved (even with $\vartheta < 0$).[5]

Durlauf and Johnson (1995) suggest that cross-sectional growth behavior may be determined by initial conditions. They explore this hypothesis using a regression tree methodology, which turns out to be a special case of a threshold regression (Hansen, 2000). The basic idea is that the level of GDP per capita on which each country converges depends on some initial condition (such as initial GDP per capita) and that, depending on this characteristic, some countries converge on one level and others on another. A common specification used to test this hypothesis considers a modification of equation (1) that takes the form

$$g_i = \begin{cases} \zeta_1 + \vartheta_1 y_{i,0} + \varepsilon_i & \text{if } y_{i,0} < \varkappa \\ \zeta_2 + \vartheta_2 y_{i,0} + \varepsilon_i & \text{if } y_{i,0} \geq \varkappa \end{cases}, \tag{4}$$

where $\varkappa$ is a threshold that determines whether or not country i belongs to the first or the second "club". In this case convergence would not be achieved if the whole sample is taken into consideration, but it would be achieved among members of each

[5] A curious example of such a variable is "absolute latitude", which measures how far a country is from the Equator. When statistically significant, its coefficient is usually positive, implying that one way to enhance growth would be for a country to move its population toward the North or the South Pole.

group.

If equation (4) were the actual data-generating-process (DGP), results such as those in Table 1 could be easily motivated, given that if two regimes are present, with each regime converging to a different state and at a different rate, estimations based on a single regime might produce a nonsignificant estimate for the convergence parameter. On the other hand, eqaution (4) states that if the threshold variable (in this case, initial GDP per capita) is correlated with some of the x variables included in equation (3), results such as those reported in Table 2 are likely to be encountered, even if the x variables are not (necessarily) determinants of long-run growth. However, equation (4) has an unequivocal implication in terms of the distribution of GDP per capita across countries: if the parameters that characterize each regime are different, a threshold process should be consistent with a bimodal distribution for $\ln y$.

Quah (1993,1997) noticed that relative GDP per capita (defined as the ratio of the GDP per capita of country i with respect to average world GDP per capita, represented here by $\widetilde{Y}_{i,t}$) displays such bimodality. He conjectured that if clubs of convergence were present, even if the unconditional distribution of initial GDP per capita were unimodal, the existence of such clubs would imply that countries would not converge to a degenerate distribution in the long run (as absolute convergence would seem to imply), but that one group may converge to one level of GDP per capita and another group to another, in which case twin peaks would arise.

Figure 2 presents kernel estimators of the unconditional density of relative GDP per capita in 1960 and 1995. Consistent with Quah's claim, twin peaks are present in 1995; however, a bimodal distribution also appears to be present in 1960. If Quah were right, rich countries would converge to one distribution, while initially poor countries would never be able to catch up and would converge to a distribution with a permanently lower GDP per capita. On the other hand, Figure 3 presents surface and contour plots of the (log of) relative GDP per capita, which shows that a bimodal joint density does indeed appear to be consistent with the data. However, given that the initial distribution is also bimodal, it is difficult to assess whether or not the bimodal distribution of 1995 is due to the presence of twin peaks or to the persistence of the GDP per capita level.

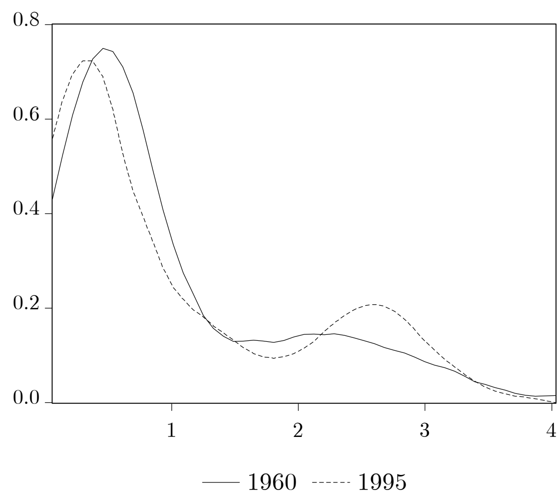

Figure 2: Densities of relative GDP per capita

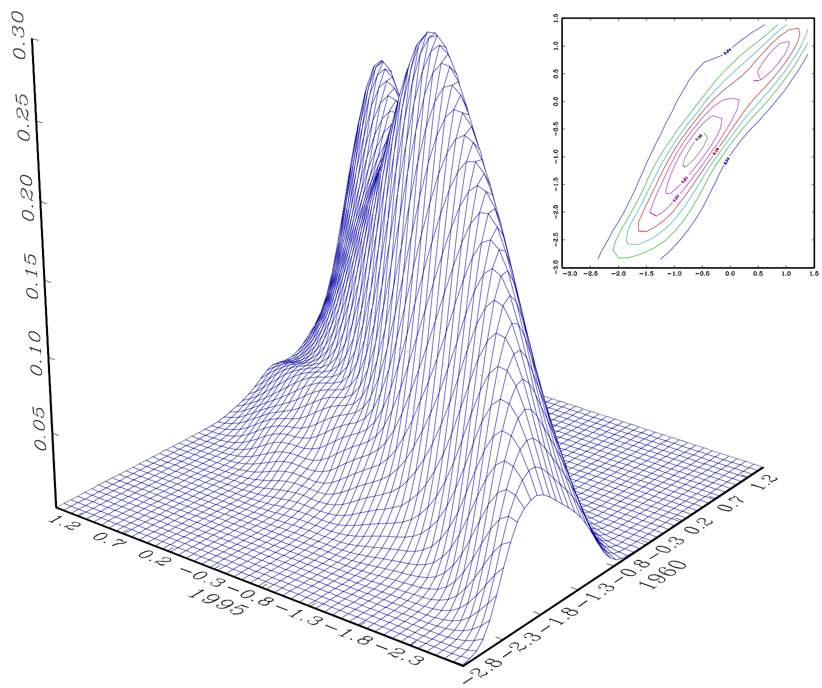

Figure 3: Surface and contour plots of (log of) relative GDP per capita

3 A Model with Absolute Convergence

This section presents a simple exogenous growth model in which absolute convergence holds, and asks whether or not the tests for convergence presented in the previous section would be robust. That is, if time-series realizations were generated using a model in which convergence holds, would tests for convergence find convergence? Simply put, the models that we will discuss imply that

- countries should converge to a stationary distribution,
- countries with initially lower GDP should grow faster, and
- twin peaks should not be present in the long run.

To clarify concepts, I next present the type of model to be used, describe its properties and the DGP that $\ln y$ would obey, and ask whether the tests discussed in the previous section are really tests for convergence.

The model considers a representative, infinitely lived household that maximizes

$$\mathcal{U}_0 = \mathcal{E}_0 \sum_{t=0}^{\infty} \beta^t L_t \ln c_t,$$

where $0 < \beta < 1$ is the subjective discount factor, c_t $(=C_t/L_t)$ is consumption per capita,[6] and $\mathcal{E}_t$ is the expectations operator conditional on information available for period t. There is no utility from leisure, and the labor force is equal to L_t.Utility is

[6]Lower case letters denote per capita values, upper case totals, and a hat above a variable denotes that the value is per unit of effective labor.

maximized with respect to consumption per capita and the capital stock per capita, k_{t+1}, subject to the budget constraint:

$$K_{t+1} + C_t = e^{z_t} K_t^{\alpha} \left[(1+\lambda)^t L_t \right]^{1-\alpha} + (1-\delta) K_t,$$

where α is the compensation of capital as a share of GDP. In this economy technological progress is labor-augmenting and occurs at the constant rate λ. Note that production is affected by a stationary productivity shock z_t. It is straightforward to show that capital and consumption per unit of effective labor, $\widehat{k}_t$ and $\widehat{c}_t$, are stationary.[7] In fact, one can transform the above economy to a stationary economy and obtain exactly the same solutions for $\widehat{k}_t$ and $\widehat{c}_t$. Such an economy can be characterized by the following maximization problem:

$$\max_{\left\{\widehat{k}_{t+1}, \widehat{c}_t\right\}} \mathcal{E}_0 \sum_{t=0}^{\infty} \left[\beta (1+\lambda)^{1-\gamma} \right]^t L_t \ln \widehat{c}_t, \tag{5}$$

subject to

$$\left(1+\eta_{t+1}\right)(1+\lambda) \widehat{k}_{t+1} + \widehat{c}_t = e^{z_t} \widehat{k}_t^{\alpha} + (1-\delta) \widehat{k}_t, \tag{6}$$

where η_t is the rate of population growth for period t.

Given that this model will be used to compare the dynamics of different economies, following den Haan (1995), I include a simple channel to induce correlation between each economy's income. Specifically, I obtain correlated incomes by assuming that

[7] $\widehat{k}_t = k_t / (1+\lambda)^t$ and $\widehat{c}_t = c_t / (1+\lambda)^t$.

the law of motion of technology shocks in country i can be written as

$$z_{i,t} = \rho z_{i,t-1} + \varepsilon_{i,t}, \quad \varepsilon_{i,t} = (1-\phi)\, v_t + \phi w_{i,t}, \tag{7}$$

where v_t and $w_{i,t}$ are independent $\mathcal{N}(0, \sigma_i^2)$ random variables (for $i = v, w$). If ϕ is equal to zero, all countries face the same aggregate shock; if ϕ is equal to one, each country faces only an idiosyncratic shock.

In order for the model to be fully characterized, a stance regarding the rate of population growth has to be taken. Here I consider the case in which fertility is exogenous and has the following law of motion:

$$\ln\left(1+\eta_{i,t}\right) = \overline{\eta}\,(1-\tau) + \tau \ln\left(1+\eta_{i,t-1}\right) + n_{i,t}, \tag{8}$$

where $n_{i,t}$ is an independent $\mathcal{N}(0, \sigma_n^2)$ random variable.

Once values for the preference and technology parameters are chosen, this dynamic programming problem can be solved using numerical methods to generate artificial realizations of the variables of interest. Here, I am interested in generating realizations of GDP per capita for several samples of "countries" and applying the convergence tests discussed in Section 2. As shown below, this model implies convergence (in a sense to be defined below). The goal is to evaluate how likely it is for the tests to conclude otherwise, even though the main feature of this model is that countries converge.

4 Convergence Tests and the Model

To understand whether the tests discussed in Section 2 are useful in testing for convergence, I tailor the model to instances in which a closed-form expression for the DGP of the log of GDP per capita is available. I argue that this simplification imposes a very rigid structure on the theoretical model and makes it harder for its realizations to present the features considered signs of rejection of the absolute convergence hypothesis.

If $\delta = 1$ an analytical expression for the capital stock policy function is available and is expressed as

$$\ln \widehat{k}_{t+1} = \ln(\alpha\beta) - \ln(1+\lambda) + \ln \widehat{y}_t, \tag{9}$$

where $\widehat{y}_t = e^{z_t} \widehat{k}_t^{\alpha}$ is GDP per unit of effective labor.

Because $\ln \widehat{y}_t$ can be expressed as

$$\ln \widehat{y}_t = z_t + \alpha \ln \widehat{k}_t, \tag{10}$$

we can replace equations (7) and (9) in equation (10) to obtain a simple expression for $\widehat{y}_t$:

$$\ln \widehat{y}_{i,t} = A + (\alpha + \rho) \ln \widehat{y}_{i,t-1} - \alpha\rho \ln \widehat{y}_{i,t-2} + \varepsilon_{i,t}, \tag{11}$$

where $A = \alpha(1-\rho)[\ln(\alpha\beta) - \ln(1+\lambda)]$. Recalling that $\widehat{y}_{i,t}(1+\lambda)^t = y_{i,t}$, one can use equation (11) to obtain a compact representation of the DGP of GDP per capita as follows:

$$\ln y_{i,t} = B + Dt + (\alpha + \rho) \ln y_{i,t-1} - \alpha\rho \ln y_{i,t-2} + \varepsilon_{i,t}, \tag{12}$$

where B and D are constants.[8]

Four features of equation (12) are worth mentioning: First, as is typical of exogenous growth models, GDP per capita is trend stationary.[9] Second, given that the technology shock follows an AR(1) process, $\ln y$ follows an AR(2) process.[10] Third, even without exogenous growth ($\lambda = 0$), an AR(1) process for $\ln y$ such as equation (2) is consistent with rquation (12) only if white-noise technology shocks ($\rho = 0$) are present. Finally, this model suggests that convergence on growth rates and GDP levels should eventually be achieved. The type of convergence on GDP levels would depend on the characteristics of the aggregate and idiosyncratic shocks that are present in equation (7). In particular, if the only source of variation in technology shocks is the aggregate shock ($\phi = 0$), all countries should eventually converge on the same GDP per capita, independent of their initial conditions and independent of the persistence of z. On the other hand, if at least part of the variation in technology shocks is due to the idiosyncratic component ($\phi > 0$), GDP per capita would converge to a nondegenerate distribution that does not display a mass point. That is, $\ln y$ would converge to a normal distribution with positive variance, in which case the probability

[8] More precisely, $B = \alpha (1 - \rho) \ln (\alpha\beta) + \rho (1 - \alpha) \ln (1 + \lambda)$ and $D = (1 - \alpha)(1 - \rho) \ln (1 + \lambda)$.

[9] In fact, a case for divergence can only be made when $\ln y$ has a unit root. For that to be the case, either $\rho = 1$ (a unit root in the technology shock) or $\alpha = 1$ (a model of endogenous growth of the AK type) is needed.

[10] In general, if the productive shocks follow an AR(j) process, $\ln y$ follows an AR($j + 1$) process.

of observing identical levels of y would be zero.

Next, I focus on the implications of different parameterizations of equation (12) for the convergence tests discussed in Section 2.

4.1 Independently and Identically Distributed Shocks

The only instance in which an absolute convergence test such as equation (2) is correctly specified is when the technology shocks are independently and identically distributed (i.i.d.), given that in that case equation (12) reduces to

$$\ln y_{i,t} = \alpha \ln (\alpha\beta) + (1-\alpha)\ln(1+\lambda)\,t + \alpha \ln y_{i,t-1} + \varepsilon_{i,t}. \tag{13}$$

Thus, independent of the initial distribution of GDP per capita and population growth rates, $\widehat{\vartheta}$ in equation (2) will consistently estimate the coefficient $\alpha - 1$, and convergence should occur.[11]

Figure 4 presents the empirical distribution of $\widehat{\vartheta}$, computed from artificial samples of countries. Each sample consists of 100 countries, and the initial GDP per capita is obtained from bootstrapping realizations of GDP per capita in 1960. Based on these initial conditions, values of $\ln y_{i,t}$ are simulated from equation (13) for a 36-year period. Finally, for each sample an estimate for ϑ was obtained by running a regression like equation (1).[12] Obviously, the probability of obtaining estimates of

[11] That is, $\widehat{\vartheta}$ should be negative and statistically different from zero, provided that $0 < \alpha < 1$. Of course, equation (2) should also include a deterministic trend.

[12] The parameter values for this model were set as follows: $\alpha = 0.35$, $\beta = 0.96$, $\lambda = 0$, $\phi = 1$, and

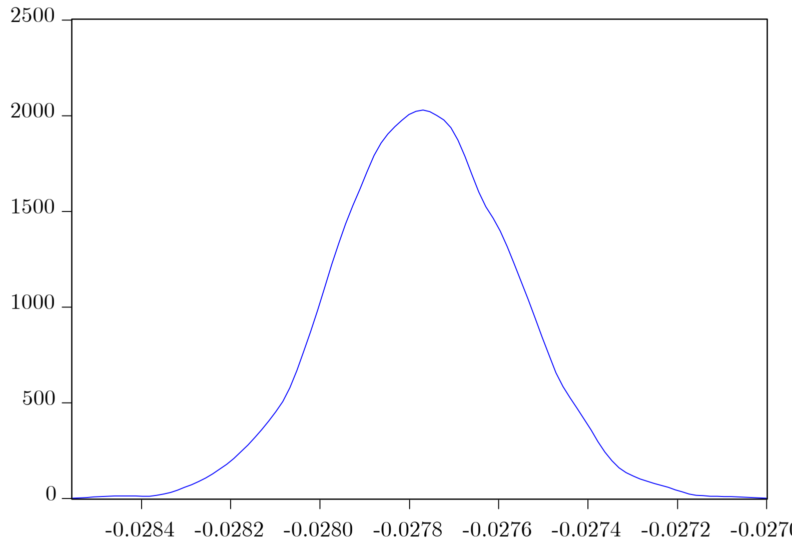

Figure 4: Distribution of $\widehat{\vartheta}$ from absolute convergence tests with i.i.d. shocks. Estimates obtained from 2,000 artificial samples for 100 countries.

$\widehat{\vartheta}$ consistent with the results from Section 2 is zero because even if the distribution of GDP per capita in 1960 is considered as the initial condition, i.i.d. shocks with realistic figures for α are unable to produce enough persistence in $\ln y$.

Furthermore, the precise nature of absolute convergence will be dictated by ϕ. If $\phi = 0$, in the long run countries would converge (in probability) to the same GDP per capita, whereas if some shocks are idiosyncratic, in the long run, GDP per capita converges to a nondegenerate distribution.

Figures 5 and 6 reveal another characteristic of i.i.d. productivity shocks: even when they begin with a bimodal distribution for initial GDP per capita, as y is not persistent enough, the bimodality quickly disappears. In fact, after 36 years, GDP

$\sigma_w^2 = 0.05^2$.

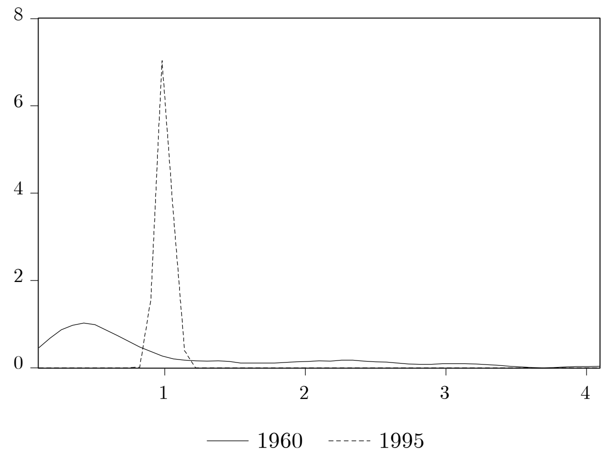

Figure 5: Densities of relative GDP per capita with i.i.d. shocks. Empirical densities for an artificial realization of 100 countries.

per capita would not feature twin peaks. Thus, i.i.d. shocks are inconsistent with the evidence reported on Section 2.

4.2 Persistent Shocks

Once we abandon the unrealistic setup of i.i.d. technology shocks, we can obtain significant persistence for $\ln y$ by choosing a value of ρ close to one. Persistence of technology shocks is routinely invoked in the Real Business Cycles literature and is broadly consistent with key stylized facts of modern economies. Once persistence in $\ln y$ is obtained, without having to resort to unrealistic values of α, the conclusions we reach regarding i.i.d. shocks change radically.

Remember that the law of motion of the univariate representation for $\ln y_{i,t}$ is

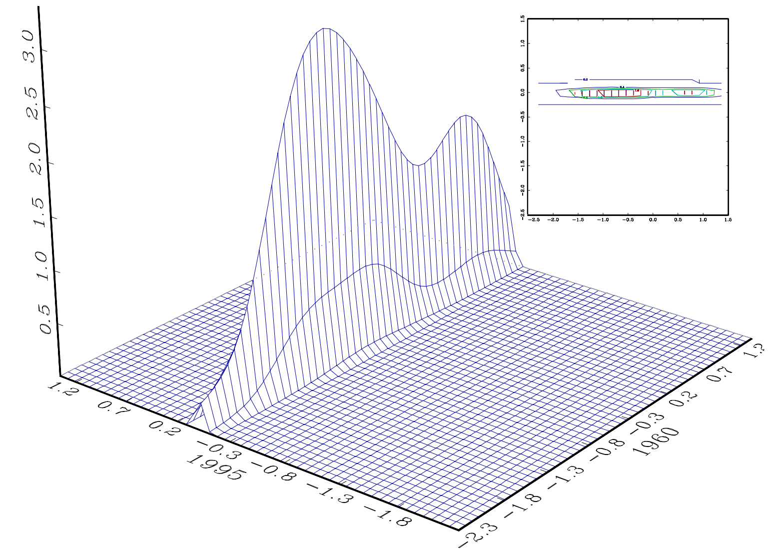

Figure 6: Surface and contour plots of (log of) relative GDP per capita for i.i.d. shocks. Results for an artificial realization of 100 countries.

expressed by equation (12); that is,

$$\ln y_{i,t} = B + Dt + (\alpha + \rho) \ln y_{i,t-1} - \alpha\rho \ln y_{i,t-2} + \varepsilon_{i,t}.$$

One immediately notices that convergence tests such as equation (2) are misspecified. Furthermore, as demonstrated by den Haan (1995), the estimated value of ϑ in equation (1) will be inconsistent and biased toward zero. That is, even if the model implied convergence, the estimated value of ϑ would be biased toward the rejection of this hypothesis. Furthermore, if pooled observations were used in equation (2), we would find that

$$\widehat{\vartheta} \xrightarrow{p} \psi - 1 = -\frac{(1-\alpha)(1-\rho)}{1+\alpha\rho},$$

where $\psi = (\alpha + \rho) / (1 + \alpha\rho)$ is the first-order autocorrelation of $\ln y$. This implies that the more persistent the technology shocks, the closer the probability limit of $\widehat{\vartheta}$ will be to zero.

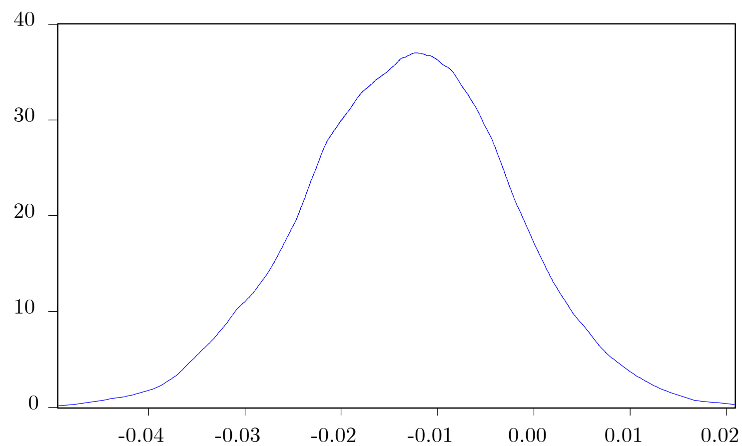

Figure 7: Absolute convergence tests with AR(1) shocks: empirical distribution of the $\widehat{\vartheta}$ coefficients obtained with 2,000 artificial samples for 100 countries.

Figure 7 presents an exercise similar to that reported in Figure 4 for the i.i.d. case. Here we consider exactly the same parameterization, but now we set $\rho = 0.97$. The difference is that, even when the model implies convergence, the results of estimating equation (1) by bootstrapping the initial distribution of $\ln y$ that was observed in 1960 presents a nonnegligible probability (11 percent) that the estimated coefficient would indeed be positive (implying divergence).

Furthermore, as Figure 8 reveals, persistent technology shocks can replicate a bimodal joint distribution of the initial (log of) GDP per capita (consistent with the one observed in 1960) and the figures that would be obtained 35 years later. As

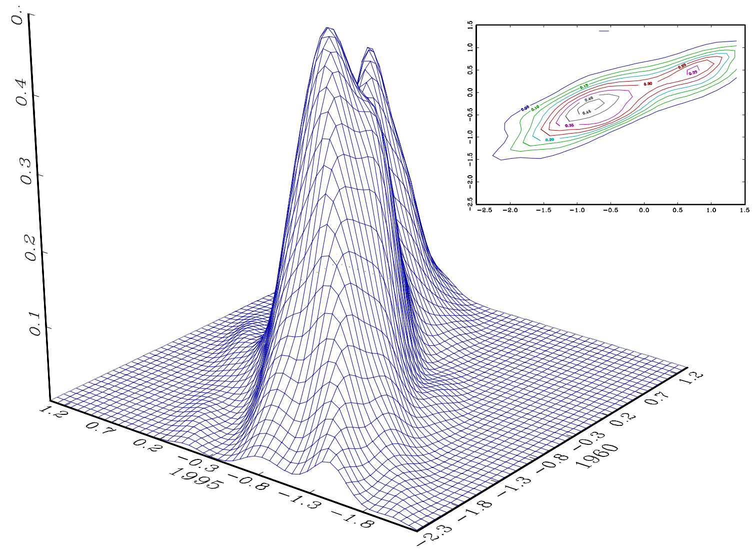

Figure 8: Surface and contour plots of (log of) relative GDP per capita for AR(1) shocks. Results for an artificial realization of 100 countries.

initial conditions do not dissipate as fast as in the i.i.d. case, an initially bimodal distribution would persist even over long periods. Thus bimodality in the short run is not inconsistent with a model that displays convergence in the long run.

In summary, persistent technology shocks can be broadly consistent with the evidence reported in Section 2, in the sense that, whatever the initial conditions of the distribution of GDP per capita, they will fade slowly. In particular, this simple model, which displays convergence to a unimodal distribution in the long run, will be consistent with twin peaks in the distribution of GDP per capita, even over relatively prolonged horizons.

4.3 The Model and Conditional Convergence

Once persistent shocks are allowed, even the simplest of the exogenous growth models can display several of the features that are considered evidence of divergence or club convergence. Thus, given an initially bimodal distribution of (the log of) GDP per capita, persistence by itself could generate an illusion of bimodality for prolonged periods.

However, the models just described are not consistent with evidence of conditional convergence. This is so because a few lags added to an equation like equation (2) would become sufficient statistics for $\ln y$, and no other variable in the econometrician's information set should be informative. Nevertheless, the results of conditional convergence (statistically significant x variables) can be found when a misspecified law of motion for $\ln y$ is considered. In particular, if some x variables are correlated with the initial distribution of y, models that do not include as many lags of the variable as necessary can easily be found to be significant.

Furthermore, the models just discussed are among the simplest that can be generated from our theoretical model. In particular, models in which population growth rates can be determinants of $\ln y$; in such a case (such as the ones described in Chumacero, 2002), its exclusion from growth regressions could generate results consistent with conditional convergence, provided that technology shocks and population growth are persistent and that the x variables chosen correlate with initial conditions. In fact, as stressed in Section 2, most of the "robust" x variables that are included in growth regressions are both persistent and strongly correlated with initial conditions.

Of course, if the economy is better characterized using parameters that do not allow for an analytical solution for the law of motion of $\ln y$, equations (1) and (2) can at best be viewed as linear approximations. The more nonlinear the model, the more inaccurate this approximation will be, and any nonlinear terms omitted may be approximated by any x variable that is correlated with the initial conditions.

5 Concluding Remarks

This paper takes issue with the interpretation of cross-country growth models that contend that the convergence hypothesis is strongly rejected by the data. It shows that even the simplest exogenous growth model that displays absolute convergence in the long run can present several features that are argued to be evidence against convergence.

In particular, if persistent and moderately volatile productivity shocks are allowed, exogenous growth models can display features such as bimodality and asymmetries in the unconditional distribution of relative GDP per capita. Furthermore, there is a nonnegligible probability that misspecified econometric models will reject absolute convergence even when it is present.

Nevertheless, persistence of technology shocks is not enough to generate these results. In this case persistence implies that initial conditions will eventually dissipate, and if bimodality were present in a given period, it would not dissipate for long periods.

Furthermore, simple (and realistic) variations of the models presented, which ultimately imply convergence, can be made consistent with conditional convergence results, provided that the "determinants of growth" chosen are correlated with initial conditions and that the models being tested are misspecified (with an incorrect law of motion of GDP per capita or omission of nonlinearities).

It is only fair to mention that this paper does not explain the initial bimodality that appears to be present in the data. It may well be the case that apparently relevant policy variables in conditional convergence regressions have something to do with this. In line with McGrattan and Schmitz (1999), distortionary policies may be behind this, but this model implies that, if distortions are at fault, convergence to an ergodic distribution of GDP per capita should be achieved if these policies also converge.

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