The Convergence Hypothesis After 10 Years

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Abstract

The convergence hypothesis has been at the forefront of empirical growth research for over a decade. This paper provides a critical overview of this literature. I argue that statistical tests for convergence have failed to address the notion of convergence in an economically interesting sense. I propose some new directions for empirical research that, by focusing more explicitly on cross-country heterogeneity in the growth process, have the potential to provide a better understanding of convergence as an economic phenomenon.

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1. Introduction

Few issues in empirical growth economics have received as much attention as the question of whether countries exhibit convergence. Convergence has been studied for over 10 years now in literally hundreds of studies. This work is part of the graduate curricula of many doctoral programs in economics. This interest may be explained on two levels. First, the large contemporary differences in per capita incomes across countries have enormous welfare implications. As studies such as Bourguignon and Morrisson (2002) and Firebaugh (1999) have argued, differences in per capita income across countries play a critical role in explaining levels of poverty and inequality across the world's population. Hence, to the extent that convergence occurs, it suggests that, at least over long time horizons, world inequality will diminish. At the same time, the convergence hypothesis is of importance within the context of scholarly debates over the nature of the economic growth process. Income convergence across countries is widely interpreted as a test of the Solow (1956) neoclassical growth model as opposed to the endogenous growth model pioneered by Lucas (1988) and Romer (1986); specifically, convergence tests have been used to evaluate the presence or absence of increasing returns to scale in the growth process. As such, the convergence hypothesis has important implications for modern macroeconomic theory.

In this paper, I provide a discussion of the state of the convergence hypothesis. My argument will largely be critical in that my view is that the empirical growth literature has failed to develop a coherent approach to assessing convergence as an economic phenomenon. As such, my arguments are part of a broader literature that has challenged conventional growth econometrics; examples include Brock and Durlauf (2001), Durlauf (2000), and Temple (2000). At the same time, I also believe that there are a number of fruitful directions in which the empirical literature can move in order to place convergence on a firmer empirical grounding.

Section 2 of this paper provides economic and statistical definitions of convergence and describes the conventional strategy for evaluating the convergence hypothesis. Section 3 provides two general critiques of convergence tests. Section 4 provides suggestions for future work.

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2. Defining convergence

i. convergence as an economic phenomenon

Why are economists interested in convergence? The essential reason concerns the role of initial conditions in explaining long run outcomes. The basic thought experiment underlying convergence studies is straightforward. Suppose that one observes two countries with identical preferences and technologies but with different initial human and physical capital stocks: convergence means that asymptotically, the growth rates in these economies will be identical. Barro (1997, pg. 2) describes the underlying economics of convergence as follows:

The convergence property derives in the neoclassical model from the diminishing returns to capital. Economies that have less relative capital per worker (relative to their long run capital per worker) tend to have higher rates of return and higher growth rates.

Similarly, Malinvaud (1998, p. 776) describes convergence as:

...countries or regions starting from very different levels of output per capita, evolving in stable environments and having access to the same technology should experience convergence: the dispersion of their output per capita should diminish; poor countries should grow faster than rich ones."

As such, the economic notion of convergence is closely related to the question of whether the growth process for an economy with specified preferences and technology exhibits multiple steady states, or in a stochastic context, multiple invariant measures. Formally, if $g_{i,t}$ denotes the growth in country *i* at time *t*, $S_{i,t}$ denotes the levels of human and physical capital, **q** denotes technology, **r** denotes preferences, and **m**(·) is a probability measure, then convergence can be thought of as the condition

$$\lim_{k \to \infty} \mathbf{m} \Big(g_{i,t+k} \Big| S_{i,t}, \mathbf{q}, \mathbf{r} \Big) \text{ does not depend on } S_{i,t}$$
(1)

To see how this general idea may be linked up with standard growth models, one may proceed as follows. For simplicity, assume that the population is fixed at 1, technical change is not occurring, depreciation of the capital stock is 100% after 1 period, and the savings rate is constant. This allows for a simple specification of the capital accumulation process: the capital stock k_t for a given country evolves according to

$$k_{t+1} = sf(k_t) \tag{2}$$

where, following standard conventions, s is a fixed savings rate and f is the aggregate production function. One can use this model to distinguish competing growth theories: the Solow perspective on growth assumes that f(k) is concave whereas the Romer/Lucas perspective assumes that f(k) is convex. The two models are portrayed in Figure 1. As is well known, in the Solow model, k_t converges to the same limit



regardless of whether one starts at the lower initial capital stock k_{low} or the higher initial capital stock k_{high} that are pictured, whereas for the Romer-Lucas model, the initial difference between the higher and lower capital stocks grows over time.

ii. convergence as a statistical phenomenon

The economic definition of convergence provided by eq. (1) is not, of course, directly amenable to statistical analysis. How has the economic idea of convergence been converted into a well defined statistical hypothesis? The primary basis for empirical convergence studies has been cross country growth regressions; Barro (1991), Barro and Sala-i-Martin (1992) and Mankiw, Romer, and Weil (1992) are the seminal studies in this regard, although Kormendi and Meguire (1985) is an underappreciated antecedent.² A canonical form for such regressions, is

$$g_i = y_{i,0} \boldsymbol{b} + X_i \boldsymbol{d} + Z_i \boldsymbol{g} + \boldsymbol{e}_i$$
(3)

where g_i is real per capita growth of country *i* across some fixed time interval, $y_{i,0}$ is the initial per capita income, X_i is a set of additional regressors suggested by the Solow growth model (population growth, technological change, physical and human capital savings rates transformed in ways implied by the model), Z_i is a set of additional control variables suggested by new growth theories, and e_i is an error. The distinction between X_i and Z_i is important in understanding the empirical literature. While the same X_i variables usually appear in different empirical studies, choices concerning which Z_i variables to include vary greatly. From the perspective of the economic definition, one

² I focus on cross-section versus panel studies of convergence, cf. Islam (1995) for a nice example. While panel studies constitute an important addition to the convergence literature, the criticisms I make of convergence tests apply when they are conducted using panel data as well.

can identify different roles for the controls used in (2). Variables such as initial income and population growth (as specified in the Solow model) affect growth because of their implications for transition dynamics towards a steady state. Variables such as saving rates reflect preferences and also affect short run dynamics. Other variables, in particular those one finds in Z_i , are usually interpreted as capturing differences in aggregate production functions across economies and as such proxy for growth theories that move beyond the Solow framework.

Following Barro (1991), Barro and Sala-i-Martin (1992) and Mankiw, Romer, and Weil (1992), the economic notion of convergence is replaced in cross-country regressions studies with a particular statistical notion of conditional convergence. Eq. (3) exhibits conditional **b** convergence if b < 0. Why is this definition interesting? Conditional **b** -convergence means that if one observes two economies with identical X_i and Z_i values, the country with lower initial income will grow faster than the country with higher initial income. This requirement is similar to the economic notion of convergence I have defined above. Notice that for the models described in Figure 1, there is a one to one mapping from the capital stock to output; hence the Figure illustrates how for the Solow model higher income countries grow more slowly than poorer ones, whereas the opposite happens for Romer/Lucas.

While \boldsymbol{b} convergence is not the only statistical measure of convergence that has been developed, it is the dominant measure and so I will focus on it in the subsequent discussion.³

³ There are two other definitions of convergence that are worth noting. In s – convergence, studied for example in Barro and Sala-i-Martin (1992), a set of countries are said to converge if the cross-section standard deviation of their growth rates is decreasing over time. This approach seems to have fallen out of favor, possibly due to Quah's (1993) demonstration that this definition suffered from Galton's fallacy of conflating a shrinking variance. A second approach, due originally to Bernard and Durlauf (1995), is based on time series methods and in essence equates convergence with the absence of deterministic or stochastic trends in the per capita output levels across

How strong is the evidence in support of convergence? It is difficult to answer this question based upon a survey of the empirical growth literature because of variations in the choice of which variables to include in Z_i . Because of disagreements over which growth determinants should be included in (3), it is difficult to compare findings across growth studies. However, recent work in the growth literature has suggested a way of dealing with this problem. Brock and Durlauf (2001). Doppelhofer, Miller, and Sala-i-Martin (2000), and Fernandez, Ley, and Steel (2001) employ Bayesian model averaging techniques⁴ to develop growth parameter estimates that account for uncertainty in the variable choice for growth regressions. Intuitively, these techniques compute an estimate of a model parameter from a set of regressions that weights each model-specific estimate by the posterior probability (the probability given one's prior beliefs and the available data) that the model is the "true" one. This approach has the critical advantage that it places greater weight on models that appear likely given the data (i.e. models that fit well) versus those that do not.

Doppelhofer, Miller and Sala-i-Martin (2000) and Fernandez, Ley and Steel (2001), applying Bayesian model averaging techniques to linear cross-country growth regressions, each find that the posterior distribution of \boldsymbol{b} computed across alternative specifications assigns essentially all probability mass to the negative half interval. As such, this constitutes the strongest support yet adduced for the convergence hypothesis.⁵

countries. This approach, however, is really only appropriate for analyzing data from economies whose output processes may be described by an invariant measure and so it does not commend itself to the simultaneous study of developed and developing economies; see Bernard and Durlauf (1996) for more discussion.

⁴ Wasserman (2001) provides a good introduction to model averaging.

⁵ In earlier work, Levine and Renelt (1992) also found evidence of a negative regression coefficient for initial income across growth regressions using the extreme bounds analysis methods developed by Edward Leamer. This evidence is based on a much narrower set of control variables than studied in the model averaging contexts. Sala-i-Martin (1997) also studies \boldsymbol{b} estimates across models and concludes that evidence of convergence is robust. However, the robustness criterion is ad hoc and does not appear to

3. Interpretation problems with convergence tests

While the recent studies of Dopplehoffer, Miller, and Sala-i-Martin (2000) and Fernandez, Ley and Steel (2001) provide strong evidence for the statistical definition of convergence, it is unclear how much evidence these and other studies have provided for the economic definition. My basic contention is that the empirical literature on \boldsymbol{b} - convergence has failed to provide compelling evidence in support of the economic definition and therefore has provided relatively little evidence in support of convergence in the economic sense. I make this argument for two basic reasons.

i. Null versus alternative hypotheses

The first problem with the convergence literature is a general failure to develop tests of the convergence hypothesis that discriminate between convergent economic models and a rich enough set of non-converging alternatives. While b < 0 is an implication of the Solow growth model and so is an implication of the baseline convergent growth model in the literature, this does not mean that b < 0 is inconsistent with economically interesting non-converging alternatives. One such example is the model of threshold externalities and growth developed by Azariadis and Drazen (1990). In this model, there is a discontinuity in the aggregate production function for aggregate economies. This discontinuity means that the steady state behavior of a given economy depends on whether its initial capital stock is above or below this threshold; specifically, this model may exhibit two distinct steady states. (Of course, there can be any number of such thresholds.) An important feature of the Azariadis-Drazen model is that data generated by economies that are described by it can exhibit statistical convergence even when multiple steady states are present.

have any decision-theoretic interpretation. For these reasons I focus on the studies by Doppelhofer, Miller, and Sala-i-Martin (2000) and Fernandez, Ley, and Steel (2001).

To see why this is so, I follow an argument in Bernard and Durlauf (1996) based on a simplified growth model. Suppose that for every country in the sample, X_i and Z_i are identical. Suppose as well that there is no technical change or population growth. Following the standard arguments for deriving a cross-country regression specification, the growth regression implied by the Azariadis-Drazen assumption on the aggregate production function is

$$g_{i} = c + (y_{i,0} - y_{l(i)}^{*})\boldsymbol{b} + \boldsymbol{e}_{i}$$
(4)

where l(i) denotes the steady state with which country *i* is associated and $y_{l(i)}^*$ denotes that steady state; all countries associated with the same steady state thus have the same $y_{l(i)}^*$ value.

The threshold externality model clearly does not exhibit economic convergence as defined above so long as there are at least two steady states. However, data generated by a cross-section of countries exhibiting multiple steady states may exhibit statistical convergence. To see this, notice that for this stylized case, the cross-country growth regression may be written as

$$g_i = c + y_{i,0} \boldsymbol{b} + \boldsymbol{e}_i \tag{5}$$

Since the data under study are generated by (4), this standard regression is misspecified. What happens when (5) is estimated when (4) is the data generating process? Using population moments, the estimated convergence parameter \boldsymbol{b}_{ols} will equal

$$\boldsymbol{b}_{ols} = \boldsymbol{b} \frac{(\operatorname{cov}((y_{i,0} - y_{l(i)}^{*}), y_{i,0})))}{\operatorname{var}(y_{i,0})} = \boldsymbol{b} (1 - \frac{\operatorname{cov}(y_{l(i)}^{*}, y_{i,0})}{\operatorname{var}(y_{i,0})})$$
(6)

From the perspective of tests of the convergence hypothesis, the feature of (4) is that one cannot determine the sign of \boldsymbol{b}_{ols} a priori as it depends on $(1 - \frac{\text{cov}(y_{l(i)}^*, y_{i,0})}{\text{var}(y_{i,0})})$, which is a

function of the covariance between the initial and steady states incomes of the countries in the sample. It is easy to see that it is possible for \boldsymbol{b}_{ols} to be negative even when the sample includes countries associated with different steady states. Roughly speaking, one would expect $\boldsymbol{b}_{ols} < 0$ if low income countries tend to initially be below their steady states whereas high income countries tend to start above their steady states. While I do not claim this is necessarily the case empirically, the example does illustrate how statistical convergence (defined as $\boldsymbol{b} < 0$) may be consistent with economic nonconvergence. Interestingly, it is even possible for the estimated convergence parameter \boldsymbol{b}_{ols} to be smaller (and hence imply more rapid convergence) than the actual parameter \boldsymbol{b} in (4).



This basic argument is illustrated in Figure 2. In this figure, the Azaridias-Drazen model is embedded in the capital accumulation equation (2) under the assumption that the aggregate production function is described by

$$f(k_t) = f_1(k_t) \text{ if } k_t < k_T$$

$$f(k_t) = f_2(k_t) \text{ if } k_t \ge k_T$$
(7)

As the Figure indicates, an economy starting with the low initial capital stock will experience positive growth whereas an economy starting with the high initial capital stock will experience negative growth, yet the two economies will not converge as they are associated with distinct steady states.

The inability of the standard convergence test to discriminate between data generated by the Solow growth model versus the Azariadis-Drazen model is an example of a more general shortcoming of the empirical growth literature: the failure of this literature to systematically deal with nonlinearities in the growth process. From the perspective of growth economics, a key nonlinearity is the dependence of the parameters of the growth process on the levels of initial income, human capital, and physical capital; the Azariadis-Drazen model is an example of such a nonlinearity. There exist a number of studies that have established the presence of nonlinearities in the growth process; examples include Durlauf and Johnson (1995) and Durlauf, Kourtellos and Minkin (2001). Durlauf and Johnson (1995) is particularly germane as it finds the presence of growth regimes that are consistent with the multiple steady states of the type suggested theoretically by Azariadis and Drazen.

Another perspective on the limitations of linear growth models as mechanisms for understanding convergence is due to Bernard and Durlauf (1996). This paper argues that it is important to distinguish between definitions of convergence that focus on the long run equality of the distribution of growth rates across economies and definitions of convergence that focus on "catching up", i.e. the diminution of some difference between economies across a fixed time period. The latter property is all that a finding of b < 0 implies when one compares models such as Solow and Azariadis-Drazen.

ii. Conceptual ambiguity between economic and statistical convergence

A first problem in my judgment is that empirical growth studies tend to conflate economic and statistical definitions of convergence. Specifically, many of the variables that are routinely included in growth regressions render interpretations of the convergence parameter problematic from the perspective of eq. (1).

It has become standard practice in growth regressions to include additional growth controls such as a dummy variable for Latin America, a dummy variable for sub-Saharan Africa, the percentage of the population that is Confucian, the percentage of the population that is Muslim, etc. Interestingly, Fernandez, Ley and Steel find that the sub-Saharan African, Confucian and Muslim variables are among the 6 growth determinants with the largest probabilities of importance among the 41 variables they studied. These types of variables, of course, do not have a clear causal interpretation, although one often sees stories associated with their inclusion. More important, many of the variables that are routinely included in growth regressions render conclusions about convergence problematic from an economic perspective.

One reason for this is that variables that are regional dummies (such as sub-Saharan Africa) or are proxies for various cultural differences (such as religious affiliation) themselves constitute factors that suggest that convergence is not occurring in the economic sense. If the economic logic of convergence is that initial capital stocks do not matter for long run economic performance, in the sense described by eq. (1), then the presence of such controls is clearly antithetical to this idea. Unless one wants to argue that such factors themselves evolve and converge over time (which is inconsistent with the way they are entered in these regressions), their presence in a growth regression is capturing something that is producing persistent (and perhaps permanent) growth differences that is not related to capital stocks.

Can the presence of such factors be interpreted as consistent with convergence? Users of cross-country growth regressions who wish to interpret them as describing neoclassical growth dynamics typically argue that Z_i captures level differences in production functions across economies. However, this is merely an assertion; the

presence of such factors can just as easily be interpreted as occurring due to differences in long run growth rates.

Further, the presence of control variables of this type renders it hard to interpret **b** estimates. To see this, suppose that there exist convergence clubs, in the sense that there exist subsets of countries such that convergence holds within a subset, but not across subsets. The multiple steady states of the Azariadis-Drazen model are an example of this, but one can construct other models where this holds. Suppose that there is some relationship between geographic and cultural variables and the particular steady states with which a country is associated. Then it is entirely possible that the inclusion of these variables is necessary in order to produce $\mathbf{b}_{ols} < 0$, as they in essence eliminate the misspecification associated with estimating (2) when (3) is the correct process. Recall that in the discussion of eq. (4), it is entirely possible for \mathbf{b}_{ols} to be positive.

This criticism also undermines one of the main reasons that have been given in support of using panels rather than cross-sections to study convergence. Islam (1995) for example, advocates the use of panel data methods for growth regressions specifically in order to eliminate country-level fixed effects in growth. But as argued in Durlauf and Quah (1999), eliminating these fixed effects eliminates important information about the growth process. In the context of convergence, it in essence eliminates factors that may well represent important evidence of nonconvergence as there is no reason to think these fixed effects represent transient phenomena.

Advocates of the study of b -convergence might argue that this objection is not germane to the question of the usefulness of b in identifying the presence of increasing versus decreasing returns to scale in aggregate production and hence its informativeness in understanding convergence. However, this argument loses weight given the interpretation difficulties concerning b raised in Section 3.i.

4. Suggestions for future research

If my argument that the empirical growth literature has failed to develop a coherent perspective on the convergence hypothesis is correct, what are appropriate directions for new research? My general view is that there has been far too little attention paid to the question of heterogeneity in the growth experiences of different countries. One way to interpret both of my critiques of tests for convergence is that standard analyses fail to adequately deal with heterogeneity in the growth process. Nonlinear growth models can be approximated, for a wide range of cases, as piecewise linear processes. Similarly, the role of factors such as geography or culture suggests that a common economic model is inadequate for describing the growth experiences across very diverse economies. Such a belief is similar to that expressed in Solow (1994, pg. 51)

"A particular style of empirical work...rests on international cross-section regressions with the average growth rates of different countries as the dependence variable and various politico-economic factors on the right hand side...I had better admit I do find this a confidence-building project. It seems altogether too vulnerable to bias from omitted variables, to reverse causation, and above all to the recurrent suspicion that the experiences of very different national economies are not to be explained as they represented different "points" on some well-defined surface."

More generally, the use of growth regressions such as (3) to interpret causal growth relationships requires strong homogeneity assumptions. For example, it is necessary to believe that the coefficients in the regression are constant across economies. Second, following an argument in Brock and Durlauf (2001), it is necessary to believe that, modulo variance differences, the residuals in (2) are indistinguishable given a researcher's prior information about the countries with which the residuals are associated. A formal way to state this is that regression errors should exhibit a certain conditional exchangeability condition. Intuitively, one needs to believe that there is no prior reason why the residuals for one subgroup of countries should have a different mean than for some other subgroup. This is generally hard to justify.

My judgment on future empirical growth research is that less attention should be paid to making ad hoc adjustment to linear growth models in order to better fit the full cross-section of economies and that far greater effort should be made to the identification of subgroups of economies that can plausibly be described as obeying a common linear model. Operationally, this means that a primary goal of empirical work in growth should be the identification of sets of countries which appear to obey a common growth model. Once such groupings are achieved, a natural second step is the analysis of the factors that explain why a particular country is part of a particular grouping. This sort of approach will avoid the artificial idea that a negative relationship between initial income and growth, conditional on allowing persistent differences, is an appropriate way to think about convergence. Put differently, I believe this sort of strategy will facilitate a better understanding of convergence as an economic phenomenon as opposed to a statistical artifact.

The identification of subgroups of countries that obey a common growth model corresponds to the longstanding idea that there may be convergence clubs for aggregate economies. (A difference is that it is not necessarily the case that countries within a group must exhibit statistical convergence.) As very well described in Galor (1997), there are good theoretical reasons why convergence clubs should characterize cross-country data. Part of the importance of the Azariadis-Drazen model is its rigorous description of an environment in which convergence clubs can arise. An example of an interesting recent theoretical model that produces convergence clubs is Howitt and Mayer-Foulkes (2002). Empirical evidence for convergence clubs has been developed using a range of methodologies; examples include Canova (1999), Desdoigts (1999), Durlauf and Johnson (1995) and Kourtellos (2000).

Such a refocusing will require the introduction of new statistical techniques into growth econometrics. The studies I have cited as providing evidence of convergence clubs use far more sophisticated tools than linear regression analysis. Canova, for example, employed Bayesian methods to identify a mixture distribution for the predictive density of per capita output. Durlauf and Johnson employ a clustering procedure known as regression tree analysis to identify subgroups of countries obeying a similar model. Desdoigts and Kourtellos employ projection pursuit methods that employ a search procedure to accommodate nonlinearities. To be fair, these tools have not been subjected to the same critical evaluation as have linear growth regressions, so it may well prove that some of the claims in these studies will prove to be overstatements. Similarly, the important research program on distribution dynamics that has been initiated by Quah (1996a,b,1997) has enormous promise in placing heterogeneity of growth experiences at the center of empirical growth research. This work is complementary to the search for clusters of countries as its focus is in the shape of the cross-section income distribution. What unites all this work is the view that much of growth econometrics should consist of the identification of patterns that unite groups of observations, rather than the estimation of parametric models. As such, the philosophy of statistics that underlies the approach I am advocating is very much that of pattern recognition.

An explicit focus on heterogeneity can also yield new insights into established results in the empirical growth literature. For example, consider efforts to understand the reasons for the poor growth performance in sub-Saharan Africa. In a well known study, Easterly and Levine (1997) have argued that an important source for this poor performance is the extremely high degree of ethnic heterogeneity in sub-Saharan Africa; specifically, they find that a measure of ethnic heterogeneity appended to a regression such as (3) produces a negative and statistically significant coefficient. Brock and Durlauf (2001) reanalyzed the Easterly and Levine model allowing for model uncertainty and general coefficient heterogeneity in the growth process for sub-Saharan Africa versus the rest of the world. This reanalysis confirmed the importance of the ethnic heterogeneity variable for sub-Saharan Africa, but additionally found that the variable was far less important in explaining growth in the rest of the world. This illustrated that in order to understand how ethnic heterogeneity matters for sub-Saharan Africa, one needs to understand why it does not appear to be important elsewhere.

The evidence that ethnic heterogeneity plays a different role in sub-Saharan Africa than the rest of the world also illustrates how heterogeneity in social and political structures is something more than an additional variable to add to a linear growth model. The implication of qualitative studies such as Landes (1998) is that historical experiences influence long run economic behavior in a far deeper sense than is accounted for in conventional growth studies. I believe that a pattern recognition perspective on cross-country growth behavior can help move growth analyses in a direction that is more

sensitive to the contingencies of history as they pertain to long run economic development.

In conclusion, it is important to acknowledge that the empirical convergence literature has made an important contribution to the identification of stylized facts concerning the growth process. If, as I have argued, it has failed to measure an economically interesting concept and has failed to properly address statistical issues such identification, this presumably reflects the relative youth of the empirical literature. I therefore am confident that future empirical research on economic growth will itself exhibit the dynamic increasing returns that have been a feature of many research programs in social science.

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