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Economics Working Paper 79

Cross-Sectional Regressions and the Empirics of Economic Growth*

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Revised, May 1994

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Keywords: Economic Growth, Endogenous Growth, Technological Change.

Journal of Economic Literature classification: O40, O41.

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* Paper presented at the European Economic Association Meetings in Helsinki. I apologize to all those researchers who, having contributed to the empirical growth literature during the last ten years, were not mentioned in this paper. The space limitations imposed upon me prevented a long reference list. I would like to thank Robert Barro, Devi Bhattacharyya, Michelle Connolly, Jinill Kim, Endarrera Aquestagent and Etsuro Shioji.

Abstract

This paper provides a short survey of the recent empirical growth literature based on cross-sectional analysis. Unlike some other analysts, I argue that this literature has uncovered interesting findings that should direct the theoretical research in the future.

The 1980s and 1990s saw a startling revival in the intellectual interest on the problem of economic growth. Perhaps the principal difference between this new literature and the neoclassical literature of the 1960s is the importance that empirical studies have had this time around: like Paul Romer's pioneering paper (Romer [1986]), most of the new literature has paid close attention to data and to the real world experiences of countries worldwide.

The empirical growth literature has evolved along three different lines: cross-sectional studies, time-series studies and case studies. In this paper I will try to recapitulate and think about the lessons we can draw from a decade of empirical work in the area of economic growth. Due to the limited space imposed by the editors, I will narrow my analysis to cross-sections, by far the most fertile of the three lines of research.

I will first discuss the cross-country evidence, which is divided between the early convergence results and the Barro-regressions and its criticisms. Then I will discuss the regional cross-sectional evidence and its lessons for the theory of economic growth.

(1) The Convergence Hypothesis: Early Results.

One of the most crucial empirical questions discussed by growth researchers has been the convergence hypothesis. This is because, as pointed out by the early proponents of the endogenous growth approach, the neoclassical assumption of diminishing returns to capital implies that the rate of return is negatively related to the stock of capital so that, *other things being equal*, countries with low amounts of capital are predicted to grow faster. This negative relation between the growth rate and the initial level of income is what we call the *convergence hypothesis*.[1] Romer's paper already cited cross-sectional evidence showing that this negative relation between growth and the initial level of income could not be found in a sample of industrialized and developing countries for the period 1950 to 1970.

Most of the early endogenous growth papers used the Summers and Heston [1988] data set (which includes over 100 countries) to show that, between 1950 and 1985, poor countries did not systematically grow faster than rich ones (in fact, the point estimate of a univariate regression of growth on the initial level of income was positive). This was taken as evidence against the neoclassical model and in favor of alternative theories that stress the absence of diminishing returns: theories of endogenous growth.

Even the long-run evidence presented by Baumol [1986] in favor of convergence was quickly downplayed by Romer [1986] and DeLong [1988] on the grounds of ex-post sample selection bias: by working with Maddison's data set of nations which were industrialized ex post (that is, by 1979), those nations that did not converge were excluded from the sample so convergence in Baumol's study was all but guaranteed. As soon as the data set was expanded to include countries that appeared rich ex ante (that is, by 1870)[2] the evidence for convergence quickly disappeared.

(2) Barro Regressions and the Determinants of Economic Growth.

However, knowing that the neoclassical model failed to account for the observed evidence was not enough since there were many possible alternative

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[1]This concept was labeled β-convergence by Barro and Sala-i-Martin [1992] to distinguish it from σ-convergence, which was defined as the reduction of cross sectional dispersion over time. The relevance of the two concepts is discussed in section 5.

[2]Note that this sample would include countries like Spain, Argentina or Ireland and exclude countries that have been successes ex post, like Japan.

theories of endogenous growth: one could construct models that stress R&D, learning by doing, education, publicly-induced distortions, public spending, financial development, etcetera. In order to search for good theories, however, growth economists were interested in the ultimate forces behind the long-run growth rate of the economy. Perhaps more importantly, they were trying to find out what (if any) policy actions could be taken to affect the long-run performance of the economy. Empirical studies were the only way to answer these important questions.

In 1991, Robert Barro expanded the Summers and Heston [1988] data set to estimate cross-sectional equations of the form:

$$\gamma_{it,t-T} = \alpha + \beta \cdot y_{it-T} + \delta \cdot X_{it-T} + \epsilon_{it}, \tag{1}$$

where $\gamma_{it,t-T}$ is the growth rate of per capita GDP between times t-T and t, y_{it-T} is the level of per capita GDP at time t-T, and X_{it-T} is a vector of explanatory variables such as primary and secondary school enrollments, number of political assassinations, investment rates, and measures of distortions in capital markets. The number of countries in a typical regression was close to 100.

Barro's initial interpretation of regression (1) was that the variables X_i were the determinants of long-run economic growth while the initial level of income was a proxy for some 'relative income variable' that would capture the different levels of technological progress. Four lessons emerged from Barro's study: first, *education* was an important determinant of the growth rate of the economy. Second, the *investment rate* was strongly positively correlated with growth (although the causation of this relation was far from clear). Third, coefficient of the *initial level of income* was significantly negative once other variables were held constant. And finally, *different* *measures of political instability and market distortions* also seemed to matter in varying degrees.

Following this initial study, the empirical literature blossomed with an enormous number of new results using the Barro approach. Since then, over 50 variables have been found to be correlated with growth in at least one regression.

(3) The Levine-Renelt Critique.

I am not going to cite all the relevant papers here (the reference list alone would eat up the imposed ten page limit). I will simply mention that in 1992, Levine and Renelt attempted to access the robustness of all the variables used in the literature. Using Leamer's extreme-bound test, they concluded that most of the findings were "fragile to small alterations in the conditioning set".

The extreme-bounds analysis can be described as follows. Consider a linear cross-sectional regression of the form

$$\gamma_{it,t-T} = \beta_x \cdot X_{it-T} + \beta_m \cdot M_{it-T} + \beta_z \cdot z_{it-T} + \epsilon_{it}, \tag{2}$$

where $\gamma_{it,t-T}$ is again the growth rate, X is a set of base variables always included in the regression, M is the policy variable of interest, and Z is the set of up to three additional variables. The extreme bounds test involves changing the Z variables until one finds a set of Z's for which the coefficient β_m changes sign or becomes insignificant. When this happens, the variable M is labeled 'fragile', otherwise it is 'robust'.

Using this method, Levine and Renelt found that most variables used in the empirical literature were fragile (when the sample for 1960 to 1989 was used, they found only two exceptions: the *investment share* and the *initial level of income*). Some economists interpreted this result to suggest that one should not pay much attention to cross-sectional growth analyses, on the basis that any variable can be made to look significant if looked at hard enough.[3]

My reading of the Levine and Renelt critique is, however, quite different. First, I would think that the *point estimates* of β_m follow some kind of distribution as the set of additional explanatory variables are changed. It is very unlikely that this distribution has only a positive or a negative domain. Hence, if one keeps trying combinations of explanatory variables, one is destined to find a set that will change the sign on the coefficient. As a result, there will always be some combination that will make the variable appear fragile. The implication is that the extreme bounds test seems to me too strong.

Second, and perhaps more importantly, Levine and Renelt always find some group of *policy variables* that matter. The problem is that since policies are so highly correlated with each other, the data cannot always tell them apart. For example, countries with high inflation rates tend also to have very distorted trade regimes and repressed financial sectors. They are also countries that tend to be politically and socially unstable. None of the variables is a perfect measure of the phenomenon that matters: a government in disarray affects the nation's growth performance adversely. Hence, if we use any one of policy variables as explanatory variables in a cross-country growth regression, we will probably find that some of them tend to matter. Depending on the sample and the exact choice of explanatory variables the data is likely to pick one variable or another because they all are close

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[3]Naturally, the same criticism may be applied to any branch of empirical analysis.

(albeit imperfect) indicators of the same phenomenon.

Hence, the main message from the Levine and Renelt study is not that nothing matters, but that policy matters. The data, however, cannot really tell exactly which policy is bad.

(4) Convergence Revisited: A Speed of Two Per Cent Per Year.

The empirical literature of the 1990s revisited the convergence hypothesis. Barro and Sala-i-Martin [1992], and Mankiw, Romer and Weil [1992] disputed the claim made by early endogenous growth researchers that the neoclassical model predicted that poor countries would grow faster than rich ones. The model's prediction was, instead, that the growth rate of an economy would be inversely related to the distance from its steady state. Only if all economies were to converge to the same terminal point would poor countries grow faster than rich ones. But if one accepts that countries differ in the levels of technology, attitudes towards saving, tax rates, etc, then one must also accept that these countries will approach different steady states. The growth rate of an economy is predicted to be inversely related to the distance from its steady state. The concept of convergence conditional on the steady state is known as '*conditional convergence*'.

In order to test the hypothesis of conditional convergence, the data sets had to be conditioned on the steady-state. Researchers found two ways to deal with the conditioning problem. The first was to find sets of economies for which one could plausibly argue that the different units would end up in the same steady state. In this case, one would find evidence of unconditional convergence. With this in mind, Barro and Sala-i-Martin turned to different regional data sets (a summary of these papers can be found in Barro and Sala-i-Martin [1994]). They argued that, because they shared the same legal system and similar technologies and similar types of people populated them, regions within a country[4] were more likely to converge to the same steady state. They analyzed per capita personal income of the states of the United States between 1880 and 1990 and they found that the states tend to converge at a speed slightly above *two percent per year*. They also studied income for 47 Japanese prefectures between 1930 and 1990 and traced a similar speed of convergence. They analyzed the regions of France, Germany, Italy, the UK, the Netherlands, Belgium, and Spain and again find that they converge at a speed of *two percent per year*.

Going back to cross-country evidence, Dowrick and Nguyen [1989] found evidence of convergence in productivity across OECD economies between 1950 and 1985.[5]

The second way to study conditional convergence is to hold the steady state constant empirically, that is, to introduce proxies for the target position towards which the different economies are approaching. Along these lines, one could interpret the X_{it-T} variables in the original Barro equation (1) as proxies for the steady state. Since, as pointed out earlier, Barro found that the coefficient on initial income became negative and significant when these variables were held constant, the conclusion was that the neoclassical model was consistent with the cross-sectional data. Moreover,

[4]The factor mobility problem becomes more important when one deals with regions within a country. Cohen [1992] and Barro, Mankiw and Sala-i-Martin [1992] show that as long as a fraction of the capital stock that an economy can use as collateral in interregional borrowing and lending is less than unity, the quantitative and qualitative implications of the neoclassical models still apply.

[5]OECD countries appear to be a more homogenous set of countries (in terms of technologies and attitudes towards saving and investment etc) than the representative economies of the large Summers and Heston data set. Hence, it is more likely that OECD countries converge to the same steady state.

the coefficient found implied a speed of convergence of about *two percent per year*. Mankiw, Romer and Weil [1992] interpreted the same finding within the Solow framework with a constant saving rate (recall that in the Solow model, the saving rate and the rate of population growth determine the steady-state level of income.)

I should mention at this point that a speed of convergence of two percent per year is particularly *low*. This, in turn, means that transitions are long and, therefore, empirically important. For example, a speed of two percent per year means that half the distance between an economy and its steady state will vanish in 35 years and 75 percent of the distance will vanish in 70 years. As a comparison, the neoclassical model with a capital share of 30 percent predicts a speed of convergence of six percent per year (which implies a half life about than 11 years). Hence, the speed found empirically is low. This has two important implications. First, if one wants to believe that the neoclassical model is generating all these data sets, then one has to accept a capital share much higher than 30 percent. In other words, one has to interpret capital in a broad sense so as to include human and perhaps other forms of capital, along the lines described by the endogenous growth literature.

The second implication is that the policies of these models will tend to have long-lasting effects (although they will surely not affect the steady-state growth rate). The main lesson is that, given that endogenous growth models are, in general, much easier to solve than neoclassical models, I would think that the former are probably acceptable as long as we understand that the effects of policies will last for 'only' a few hundred years, not forever.

(5) Two Concepts of Convergence.

The concept of convergence I have used in this paper is that economies with lower levels of per capita income tend to grow faster in per capita terms (this is what I referred to as β-convergence in section 1). This behavior is often confused with an alternative meaning of convergence, which is that the dispersion of real per capita income across groups of economies tends to fall over time. It can be shown that, even if absolute β-convergence holds, dispersion of per capita income does not necessarily tend to decline over time (see Barro and Sala-i-Martin [1992] and Quah [1993].) Some people have argued that the concept of β-convergence is irrelevant and the only thing of interest is whether economies are closer together as time goes by (Quah [1993] makes this point forcefully in the context of Galton's fallacy).

I believe that both concepts of convergence are interesting. Let me illustrate why β-convergence is interesting with an example where σ-convergence is eliminated by construction. Consider the ordinal rankings of the NBA teams over time. The dispersion of rankings is constant by definition. Sports analysts and NBA owners are most interested in questions such as 'how quickly the great teams revert to mediocrity' , 'how long do dynasties last in basketball'(that is, how long did it take for the great Boston Celtics and the Los Angeles Lakers of the 1980s to become average teams?) or 'how quickly mediocre teams become great teams' (how long did it take to create the Chicago Bulls of the 1990s?) One could even be interested in 'what kind of policies the NBA could introduce to transform bad teams into great teams in as little time as possible' (for instance, we could ask whether the introduction of the draft accelerated the convergence process).

But note that all these interesting questions refer to the concept of β-convergence, not σ-convergence. In fact, reducing the cross sectional variance would probably not make any sense.

Similar questions can be asked about economies. For example, it is interesting to know whether poor countries are predicted to grow faster than rich ones. It is also interesting to know how fast the average poor country becomes rich and how fast the average rich country becomes poor, independently of whether the aggregate cross sectional variance is falling or rising. For instance, if we knew that poor countries will become rich in very few years, then we would not even care about whether the variance is large or small as long as we knew that poor countries would escape poverty in little time. Similarly (and unfortunately), the analysis summarized above suggests that poor countries will be poor for a long time. Given this, knowing whether the overall world dispersion falls or not is of secondary importance. Hence, I was pressed to say which of the two concepts of convergence I find more interesting, I would probably choose β-convergence.

(6) So what did we learn?

Let me devote the least few lines to summarize what I think are the main lessons from cross-sectional empirical analysis:

(a) There is ample evidence of conditional β-convergence. Moreover, using a variety of data sets, researchers have found that the speed of convergence is remarkably similar across data sets: two percent per year. The lessons from this finding are that transitions are important and quite slow. There is no evidence of absolute β or σ convergence for the large sample of countries over the short run (1960-85) or the long run (1870-1990).

(b) In most empirical studies, one of the variables that seems to be

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