10 de diciembre de 2002

CIDE

NÚMERO 238

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GROWTH CONVERGENCE?: EVIDENCE FROM MARKOV-SWITCHING MODELS USING PANEL DATA

Abstract

In this paper we model the rate of growth of per capita output as a Markov-switching process. We consider panel data sets of 48 USA states, 13 OECD countries, and a wider sample of 57 countries, all with observations for the last 4 decades. For each sample, we characterize each regime's first and second moments, the transition probabilities as well as the unconditional probabilities of being in each regime. We find that the USA states and 57-country samples are consistent with 3 growth regimes while the OECD sample is more consistent with a 2-growth regime model. We also find in general that low growth regimes exhibit high volatility but are not persistent while higher growth regimes are less volatile and more persistent. In all cases, the unconditional probability of a country or state being in a negative or quite low mean growth regime is positive but relatively small. In terms of convergence, our results imply heterogeneous growth processes as we identify significantly different growth regimes in the data, even in apparently homogeneous samples such as OECD countries and USA states.

Resumen

En este artículo modelamos a la tasa de crecimiento del producto por persona como un proceso de regímenes cambiantes de tipo Markov. Consideramos paneles de datos de 48 estados de EUA, 13 países de la OECD y una muestra más amplia de 57 países, con información para las últimas 4 décadas en todos los casos. Para cada caso, caracterizamos el primer y segundo momento, las probabilidades de transición así como la probabilidad incondicional de que ocurra cada régimen. Encontramos que los estados de EUA y la muestra de 57 países son consistentes con 3 regímenes de crecimiento, mientras que la OECD es consistente con 2 regímenes de crecimiento. Encontramos también que en general los regímenes de bajo crecimiento exhiben alta volatilidad pero no son persistentes, mientras que los regímenes de más alto crecimiento son menos volátiles y más persistentes. En todos los casos, la probabilidad incondicional de que un país o estado se encuentre en un régimen de crecimiento muy bajo o negativo es positiva aunque relativamente baja. En términos de convergencia, los resultados de este estudio sugieren procesos de crecimiento heterogéneos en la medida en que se identifican regímenes de crecimiento significativamente diferentes, incluso en muestras aparentemente homogéneas tales como los países de la OECD y los estados de EUA.

Introduction

In this paper we model per capita income growth of 3 panel data samples as two and three state Markov-switching processes. We attempt to characterize each regime's first and second moments as well as the conditional and unconditional probabilities of being in a given state. In this way we are able to make statements in terms of persistence and volatility of the different growth regimes consistent with the data.

Although the approach of this paper is simple, we consider it may have two relevant potential contributions. First, in relation to existing regime-switching models, this paper attempts to direction these methods to a panel data context opening thus an avenue for studying a number of more complicated and relevant issues that have already been addressed in the time series literature. Secondly, by modeling the growth rates as regime-switching processes we are offering an alternative to regression based convergence approaches, which may enable us to obtain more realistic characterizations of the growth processes, more consistent with heterogeneity across economies.

Quah (1993a, 1993b, 1996), after criticizing the conventional regression based approaches, has offered economic arguments for modeling the dynamics of the cross sectional distribution as a mean to address a number of meaningful questions concerning the possible existence of convergence clubs, divergence, etc.

Our approach is in the same spirit, although it has two significant differences. First, instead of per capita income levels we directly focus on growth rates, which is not a well-known process. Second, instead of modeling the entire cross-section empirical distribution evolving over time, we consider a parametric approach with a given mixture of distributions governing different states or regimes and with countries switching among them or remaining in a particular one over time.

Our findings seem quite revealing. In general, we find that low growth regimes are very volatile but not persistent. On the other hand, higher growth regimes are much less volatile and more persistent. In all cases, the unconditional probability of a country being in a negative or quite low mean growth regime is positive but relatively small. In terms of convergence, our results are consistent with heterogeneous growth processes as we identify significantly different growth regimes in the data, even in the apparently homogeneous samples of OECD countries and USA states.

The rest of the paper is organized as follows. Section 1 briefly summarizes some of the existing literature. Section 2 describes our proposed methodology. Section 3 reports the main empirical results, and, finally, Section 4 briefly concludes and proposes some avenues for future research.

1. The empirics of convergence

The research on convergence of per capita income among countries or regions has produced a large amount of studies.[1] Originally, most researchers have used cross-section regressions of the growth rate of per capita income, over some period, on the level of per capita income at the beginning of the period (or initial per capita income); conditional on a number of variables specific to each economy. Some examples are Barro (1991), Barro and Sala-i-Martin (1992) and Mankiw, Romer and Weil (1992), who usually have found that economies converge at rates of about 2%.

The cross-section approach, however, has been questioned in several aspects. First, this type of regressions is likely to produce invalid inferences on convergence rates. Specifically, Evans (1997) shows that even if the conditioning variables control 90% of the variance of the per capita output in the steady state, the probability limit of the estimator of the coefficient on initial level of per capita income is about half of its true value. Second, Levine and Renelt (1992) found that the cross-section regressions are not robust to the set of control variables used. Also, it has been pointed out that this approach does not consider the heterogeneity across economies (Evans, 1998, Grier and Tullock, 1989), and misleads the dynamics of output, since it uses averages of growth rates over long periods of time, implying that economies grow continuously and uniformly over time (Qua, 1993a, 1993b).

Several alternative methods have tried to deal with the aforementioned problems. Generally, they use dynamic panel data models with individual effects, formally derived from a partial adjustment mechanism between actual and steady state levels of per capita income. Some examples are Canova and Marcet (1995), Evans (1996, 1997, 1998), Evans and Karras (1993, 1996a, 1996b), and Islam (1995). Other relevant studies are those of Caselli, Esquivel and Lefort (1996), Cermeno (1999), Gaulier, Hurlin and Jean-Pierre (1999), Maddala and Wu (2000) and Nerlove (1998). In general, most of the previous authors find evidence of conditional convergence among groups of countries relatively homogeneous, such as the USA states, OECD countries or European regions. Only for the case of 15 European Union countries over the period 1960-1990, Gaulier, Hurlin and Jean-Pierre (1999) find that per capita income converges to the same steady state level (absolute convergence).

Contrary to what would be expected a priori, Islam (1995) presents evidence on conditional convergence in a wide and heterogeneous sample of countries. Islam's study can be considered as an extension of Mankiw, Romer and Weil (1992) to a panel context. Islam argues that the low convergence rates obtained

[1] In this paper we concentrate on a small number of representative papers. For a more extensive review, see De la Fuente (1997). For more critical reviews, see Evans (1998), Maddala (1999) and Quah (1996).

by Mankiw et.al. is due to the omission of country specific effects and finds, using minimum distance and LSDV estimators, higher convergence rates (between 4% and 5%). This study, though, has also been subject to several objections. As in Mankiw et.al. it is not possible to pool 98 different countries in a single sample (Grier and Tullock ,1989); neither in Islam (1995) is it possible to pool all the countries in a single panel (Grier, 1998). Morover, Lee, Pesaran and Smith (1998) and Maddala and Wu (2000), show that the homogeneity restrictions imposed a priori will bias the convergence estimates. On the other hand, Cermeno (1999) finds, using median unbiased estimators in panel, that even under the assumption of homogeneity, it is not possible to obtain convergence in samples of 100 and 57 countries, once the biases are eliminated.

On a different avenue of research, Durlauf and Johnson (1995) estimated cross-section regressions allowing for sub-sample heterogeneity and concluded in favor of the existence of possible different steady-state regimes for different groups of economies. Following Friedman's (1992) suggestion that researchers should focus on the time series properties of the cross-economy variance process of the logarithm of per capita output, Evans (1996) finds that growth rates of per capita outputs of 13 OECD countries seem to revert toward a common trend.

On the other hand, (Quah (1993a, 1993b, 1996) offered economic justification to study the worldwide cross-economy distribution and its evolution over time. One of the most striking findings of Quah's studies is that the entire cross sectional distribution of per capita income seems to have evolved towards a bi-modal distribution at the end of the sample period, which clearly challenges several regression based convergence results and is more consistent with cross national heterogeneity and a polarization process.

2. Econometric Methodology

2.1 Motivation

The approach of this paper is somehow similar to that in Qua's studies, although there are two notable differences. First, we model growth rates instead of per capita income levels. Second, instead of directly measuring the entire cross-sectional distribution at each point in time, we consider a parametric approach with a given mixture of distributions governing different states or regimes and with economies switching among them or remaining in a particular one over time.

Justification for this approach can be offered both at the theoretical and empirical levels. A number of theoretical results imply that economies grow at different rates unless it is assumed that they are equal in all aspects. For example, the so-called endogenous growth models, e.g. Romer (1986, 1990), Barro (1990), Rebelo (1991), imply permanent differences in growth rates across economies.[2]

Jones (1997) models explicitly the steady-state distribution of per capita income as a function of steady-state investment rates, accumulation of skills, population growth rates and relative total factor productivity levels. The main finding of Jones' calibration exercise is that the world income distribution will be characterized by additional divergence at the bottom and convergence and overtaking at the top; thus there is no reason to expect that current per capita output leaders maintain their position in the long run, which obviously implies substantial differences in growth rates. On the other hand, Quah (1996) points out that coalitions of economies with different convergence dynamics, depending upon initial conditions, form endogenously.

At the empirical level, the facts that not only the observed per capita GDP levels but also their growth rates varied considerably across countries over the past few decades are widely documented.[3]

2.2 A Panel Markov-Switching Model

We consider the following simple version of Hamilton's (1990, 1994) Markov-switching models adapted to a panel context.[4] Let g_{it} denote the rate of growth of per capita output of economy *i* at time *t*. Let s_{it} be an unobservable discrete random variable that represents the state or regime of the observable random variable g_{it}. We assume *S* states ($s_{it} = j$ with $j = 1,2,...,S$). Each state can be characterized by a specific probability density function, which generates the observed rate of growth of economy *i* at time *t*. Assuming that this density is normal, the distribution of g_{it} conditional on the process being governed by state $s_{it} = j$ will be:

$$f(g_{it} / s_{it} = j;\theta) = (2\pi\sigma_j^2)^{-\frac{1}{2}} * \exp\{-(g_{it} - \mu_j)^2 / 2\sigma_j^2, \quad j = 1,2,...,S \tag{1}$$

Where μ_j and σ_j^2 are state or regime-specific parameters. Let the unconditional probability that g_{it} is in state *j* be:

$$P(s_{it} = j;\theta) = \phi_j, \qquad j = 1,2,...,S \tag{2}$$

The vector $\theta = [\mu_1,\cdots,\mu_S,\sigma_1^2,\cdots,\sigma_S^2,\phi_1,\cdots,\phi_S]'$ includes all relevant parameters for this *S*-state Markov-switching model.

Using (1) and (2), the joint density of g_{it} and s_{it} can be expressed as:

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[2] Also there are several factors that may determine different growth patterns, such as political instability (Alesina, et.al., 1996), location of countries (Moreno and Trehan, 1997), government intervention (Lee, 1996), regional instability (Ades and Chua, 1997), social conflict (Benhabib and Rustichini, 1996) and the distribution of human capital (Galor and Tsiddon, 1997).

[3] See for example Barro and Sala-i-Martin (1995).

[4] For a detailed basic treatment of Markov-switching processes, see Bhat (1972).

$$p(g_{it}, s_{it} = j; \theta) = \phi_j * (2\pi\sigma_j^2)^{-\frac{1}{2}} * \exp\{-(g_{it} - \mu_j)^2 / 2\sigma_j^2, j = 1,2,...,S \quad (3)$$

Therefore, the unconditional distribution of g_{it} will be obtained by summing (3) over the S states or regimes. That is,

$$f(g_{it}, \theta) = \sum_{j=1}^{S} p(g_{it}, s_{it} = j; \theta), \quad (4)$$

which is the density that appropriately describes the observable variable g_{it}. Under the assumption that the random state variable, s_{it}, is independently distributed across economies and time periods the log likelihood function for all observations in the panel can be expressed as:

$$\ell(\theta) = \sum_{i=1}^{N} \sum_{t=1}^{T} \log f(g_{it}; \theta) \quad (5)$$

In this paper we will use numerical methods from the GAUSS OPTMUM module to obtain estimates of the parameter vector θ by maximizing (5) subject to the constraints that the unconditional probabilities be non negative and add up to unity. Specifically, we will model the rate of growth of per capita income as 2-state and 3-state Markov-switching processes and characterize the first and second moments of each state, the conditional probabilities as well as the unconditional probability of an economy being in a given state, namely a high growth state. After estimating the parameter vector θ, the unconditional probability that a given observed growth rate, g_{it}, has been generated by regime j can be computed as follows:

$$P(s_{it} = j / g_{it}; \theta) = \phi_j * f(g_{it} / s_{it} = j; \theta) / f(g_{it}; \theta), \quad (6)$$

which is the joint distribution (3) divided by the unconditional density (4).

It is important to notice that in terms of convergence this approach implies heterogeneous growth processes in a distributional sense unless the unconditional probability of being in a particular growth regime collapses to unity. However, even if this were the case it does not imply that economies grow at the same rate but that the growth process can be characterized by a single regime with a given mean growth rate.

3. Empirical Results

3.1. The Data

This study uses three panel data sets on per capita GDP. The first sample is taken from the Summers and Heston's (1993) Penn World Tables, mark 5.6. This sample (sample 1) includes annual information for 57 countries over the period 1950-1960. Sample 2 includes per capita real gross domestic product for 13 OECD countries during 1950-1989. The source for this data is Maddison (1996). Finally, sample 3 includes real per capita personal income for the 48 contiguous USA states over the period 1950-1991.[5] We have chosen to study the last four decades of income growth in order to be able to make more appropriate comparisons of the different growth experiences.

3.2 The 2-state regime switching model for per capita output growth

In the Table 1 we present maximum likelihood estimates of the two-state regime-switching model for the growth rates of per capita income. Several results are worth noting. First, for the 57-country sample the low growth regime has a negative annual mean growth rate although it is not statistically different from zero. For the OECD sample we have obtained a mean growth rate of 2.8 %, while for the USA states sample the mean growth rate of the low growth regime is about 1.0% per year. The high growth regime is characterized by mean growth rates of 2.1, 2.6 and 3.2 for samples 3, 1 and 2 respectively.

Second, the low growth regime appears to be quite volatile compared to the high growth regime. In fact, the ratio of variances of the low growth to the high growth regime is about 12, 4, and 9 for the samples 1, 2 and 3 respectively. It should be noticed that for both regimes the highest variances correspond to the 57-country sample while the OECD sample achieves the lowest variances. Third, the conditional probabilities of remaining in the low growth regime are not significantly different from zero in the three samples. On the other hand, the high growth regime is quite persistent particularly in samples 1 and 3 as the conditional probability of staying in this regime, p_{22}, is approximately 0.9 and it is statistically different from zero in both cases.

[5] Details on this data set can be found in Evans and Karras (1996a).

TABLE 1:
Maximum likelihood estimates of 2-state Markov-Switching model
for growth rates of per capita output

Model Coefficients	Sample 1: 57 countries (1950-1990)	Sample 2: 13 OECD's (1950-1989)	Sample 3: 48 USA states (1950-1991)
μ_1	-0.413 (0.12)	2.828 (0.00)	1.019 (0.00)
μ_2	2.621 (0.00)	3.149 (0.00)	2.046 (0.00)
σ_1^2	117.4 (0.00)	6.735 (0.00)	46.34 (0.00)
σ_2^2	10.7 (0.00)	1.930 (0.00)	5.257 (0.00)
p_{11}	0.20 (0.41)	0.60 (0.37)	0.19 (0.47)
p_{22}	0.87 (0.00)	0.28 (0.46)	0.90 (0.00)
ϕ_1	0.14 (0.00)	0.64 (0.00)	0.11 (0.00)
Log-likelihood	-6647.13	-1125.65	-4863.53

Numbers in parenthesis are p-values.

Fourth, the unconditional probability of an economy being in the low growth regime is relatively low (0.14 and 0.11 for samples 1 and 3 respectively). In the case of the OECD countries, however, it is more likely that a country is in the low than in the high growth regime. It should be remarked, though, that in this case the low growth regime has a mean growth rate of 2.8% per year.

3.3. The 3-state regime switching model for per capita output growth

Maximum likelihood estimates for this model are presented in Table 2. In this case we find that the lowest growth regime has negative mean growth rates for all samples, although for the OECD sample this value is not significantly different from zero. The other 2 regimes have positive means of 1.3% and 2.9% (sample 1), 1.6% and 2.5% (sample 3), and 3.1% and 7.0% (sample 2). In terms of variance we find that for sample 1 the negative growth regime has the highest variance (319.4) while for sample 3 the positive low regime has the highest variance (46.4). In the case of sample 2 (OECD), the variances of all three regimes are in the range of 2.2 to 3.4, which are quite low compared to the other samples.

TABLE 2:
Maximum likelihood estimates of 3-state Markov-switching model for growth rates of per capita output

Model Coefficients	Sample 1: 57 countries (1950-1990)	Sample 2: 13 OECD's (1950-1989)	Sample 3: 48 USA states (1950-1991)
μ_1	-2.120 (0.05)	-0.840 (0.15)	-1.628 (0.00)
μ_2	2.853 (0.00)	3.081 (0.00)	2.532 (0.00)
μ_3	1.348 (0.00)	6.957 (0.01)	1.590 (0.00)
σ_1^2	319.36 (0.00)	2.220 (0.01)	1.899 (0.00)
σ_2^2	6.961 (0.00)	3.077 (0.00)	3.368 (0.00)
σ_3^2	35.48 (0.00)	3.382 (0.14)	46.442 (0.00)
p_{11}	0.12 (0.44)	0.10 (0.14)	0.09 (0.48)
p_{12}	0.36 (0.18)	0.79 (0.48)	0.34 (0.48)
p_{21}	0.01 (0.43)	0.05 (0.46)	0.07 (0.44)
p_{22}	0.98 (0.00)	0.92 (0.43)	0.93 (0.15)
p_{32}	0.00 (0.36)	0.10 (0.12)	0.11 (0.46)
p_{33}	0.95 (0.00)	0.29 (0.39)	0.44 (0.42)
ϕ_1	0.03 (0.00)	0.08 (0.05)	0.12 (0.00)
ϕ_2	0.62 (0.00)	0.87 (0.00)	0.77 (0.00)
Log-likelihood	-6618.56	-1125.13	-4842.38

Numbers in parenthesis are p-values.

The estimates of the transition probabilities are not significant except for two coefficients in sample 1. Nonetheless, the probability of remaining in the negative mean growth regime is relatively small for the three samples (0.12, 0.10 and 0.09 respectively). For sample 1, the probability of remaining in the positive low and positive high mean growth regimes is quite high and statistically significant (0.95 and 0.98 respectively). For sample 2, the probability of remaining in the positive low growth regime is quite high (0.92) while the probability of remaining in the positive high growth regime is much lower (0.29). In the case of sample 3, the same previous probabilities take the values of 0.44 and 0.93 respectively.

Regarding unconditional probabilities, we find that being in the negative growth regime is not quite likely in all cases (0.03, 0.08 and 0.12 respectively). The probability of an economy being on the positive high growth regime at any time is 0.62 for sample 1, 0.77 for sample 3 and only 0.05 for sample 2. This result is not surprising since for sample 2 the positive high growth regime has a mean of 7.0% per year. On the other hand, the unconditional probability for an OECD country of being in the 3.1% mean growth regime (positive low) is 0.92.

4.2 Growth convergence?

Before discussing some implications of the previous results in terms of convergence it is necessary to determine which model is more appropriate for each sample. To discriminate between 2-regime and 3-regime models we carry out likelihood ratio tests (which will be distributed as $\chi^2_{(6)}$) and find that sample 1 (57 countries) and sample 3 (USA states) can be best described by 3-regime models while sample 2 (OECD) is best described by a 2-regime model.

In general we have characterized the mean, variance, conditional and unconditional probabilities for the different regimes and found statistically significant results except for the transition probabilities for samples 2 and 3. This evidence is largely consistent with heterogeneous growth processes despite we are considering quite homogeneous samples such as OECD countries and USA states.

Using the best model results we find that for the 57-country sample (sample 1), countries are mostly growing at mean growth rates of 2.9% (positive high) and 1.3% (positive low) with variances of 6.96 and 35.48 respectively. In the case of the USA states sample (sample 3) we find that states are mostly growing at 2.5% average growth rates (positive high) with a variance of 3.37. For the case of the OECD countries (sample 2) the main result is that countries are quite likely to be growing at a mean growth rate of 2.8% and less likely at a mean growth rate of 3.2%, with variances of 6.74 and 1.93 respectively. Thus, even though the growth process for the OECD countries implies fewer differences than in the USA sample and particularly much less differences than in the 57-country sample, in neither case the results imply a common growth rate process.

4. Summary and future research perspectives

This research has focused on characterizing the per capita output growth as Markov-switching processes. We have found that the 57-country and USA states samples can be characterized by 3 growth regimes while the OECD sample is best described by a 2-growth regime model. In general, we have found that the low growth regimes exhibit high volatility but are not persistent while the higher growth regimes are substantially less volatile and very persistent. In any case, the evidence is consistent with heterogeneous growth processes despite we are considering quite homogeneous samples such as OECD countries and USA states.

Future work will focus on such important issues as modeling the growth rates by time series processes or structural models, as suggested by economic theories, and considering time dependent volatility. Last but important, we can study to which extent the different factors suggested in the growth literature (i.e. human capital, physical capital investment, population growth, technological growth, factor mobility, among others) may determine the different growth regimes that generate the observed growth rates.

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