FUNDAÇÃO
GETULIO VARGAS
EPGE
Escola de Pós-Graduação
em Economia

Ensaios Econômicos

Escola de
Pós Graduação
em Economia
da Fundação
Getulio Vargas

Nº 510

ISSN 0104-8910

Output convergence in Mercosur: Multivariate time series evidence

Mariam Camarero
Renato G. Flôres Jr.
Cecílio Tamarit

Outubro de 2003

Output convergence in Mercosur: multivariate time series evidence [1]

Mariam Camarero
Jaume I University, Castelò

Renato G. Flôres Jr.
EPGE/Fundação Getulio Vargas, Rio de Janeiro

Cecilio Tamarit
University of Valencia, Valencia

(This version: August 2003)

[1]The authors gratefully acknowledge the financial support from the AECI, as well as from the CICYT project SEC2002-03651 and the *Generalitat Valenciana* projects GV2001-127 and 129. They are also indebted to Leonardo R. Souza, who wrote the Matlab programme to compute the Abuaf & Jorion and Flôres, Preumont & Szafarz tests, as well as to J. B. Breuer, R. McNown and M. Wallace for their Gauss procedure to compute Taylor & Sarno's and their own test. All opinions, omissions and mistakes are of our entire responsibility .

Abstract

The aim of this paper is to provide evidence on output convergence among the Mercosur countries and associates, using multivariate time-series tests. The methodology is based on a combination of tests and estimation procedures, both univariate and multivariate, applied to the differences in per capita real income. We use the definitions of time-series convergence proposed by Bernard & Durlauf and apply unit root and stationarity tests to the individual variables, as well as the multivariate unit root tests proposed by Abuaf & Jorion and Taylor & Sarno. In this same multivariate context, the Flôres, Preumont & Szafarz and Breuer, McNown & Wallace tests, which allow for the existence of correlations across the series without imposing a common speed of mean reversion, identify the countries that converge. Concerning the empirical results, there is evidence of long-run convergence or, at least, catching up, for the smaller countries, Bolivia, Paraguay, Peru and Uruguay, towards Brazil and, to some extent, Argentina. In contrast, the evidence on convergence for the larger countries is weaker, as they have followed different (or rather opposing) macroeconomic policy strategies. Thus the future of the whole area will critically depend on the ability of Brazil, Argentina and Chile to find some scope for more cooperative policy actions.

Key words: convergence, multivariate tests, unit roots, Mercosur, per capita income.

J.E.L. classification: F15, C22, C15.

1 Introduction.

The present research is related to the growing empirical literature on the role of economic integration in achieving convergence. These studies have usually focused on developed countries, and more precisely on OECD countries. However, convergence, that is, the tendency of per capita income of different economies to equalize over time, as predicted by Solow's (1956) neoclassical growth model, remains a question of vital importance in the whole globe.

Three main features of the paper should be pointed out. First, we present a careful synthesis of convergence concepts used until now. From this, it clearly stands out that the theme remains controversial, a unifying definition being still needed. Moreover, as applications deal with groups of countries, it is somewhat surprising that empirical tests resorting to a multivariate treatment of the problem are still scarcely used.

The second salient feature relates to the last point above. In fact, a way of reconciling the importance of the cross-sectional dimension for the assessment of convergence with the well established inference procedures from the time series literature can be found in the recently proposed multivariate unit root tests. Starting with the pooled test first used by Abuaf and Jorion (1990), multivariate tests have been derived that allow for different degrees of heterogeneity in the cross-sections, with the important property of exploiting the information in the covariances among the group of countries. Examples are the tests proposed by Flôres et al. (1996), Sarno and Taylor (1998) and Breuer et al. (1999).

We develop here an econometric methodology that comprises a range of techniques. The gist of our approach is the sequential application of the four mentioned multivariate tests. It is complemented by the use of Johansen's cointegration test and the detection of convergence clusters by the technique proposed by Hobijn and Franses (2000). As a result, a robust identification of convergence clubs is achieved.

Finally, this is a study on South American economies, notably Mercosur members and associates. The findings point out to the increasing leadership role of Brazil and to the singular position occupied by Argentina, a country that has not of late experienced a consistent spell of favorable economic conditions. There is also suggestive evidence that the creation of Mercosur helped the convergence process.

The paper is organized as follows. Section 2 surveys the several ways of defining and measuring convergence, as well as the notion of convergence itself. Section 3 briefly discusses the testing methods used in the paper, within the framework of our proposal. Section 4 contains a rather descriptive presentation of the data and the results of applying the traditional tests for

β- and $\sigma-$convergence. Section 5 presents the empirical results using the methodology proposed and, finally, section 6 concludes.

2 Convergence concepts: a synthesis.

The definition of convergence has been changing over time as a result of a feed-back process between theory and empirics[1]. The traditional definition of convergence is associated with Sala-i-Martin (1990) who first defined two concepts of convergence derived from the classical growth literature: *$\beta-$convergence* and *$\sigma-$convergence*. There is *$\beta-$convergence* if poor economies tend to grow faster than the rich ones. In this case, per capita incomes of countries converge to one another in the long-run, independently of their initial conditions. Let y_{it} be data on per capita income for a cross-section of economies, whereas their annualized rate of growth is defined as $\gamma_{i,t,t+T} \equiv \log(y_{i,t+T}/y_{i,t})/T$. If in the estimation of:

$$\gamma_{i,t,t+T} = \alpha - \beta \log(y_{i,t}) + \varepsilon_{i,t} \qquad (1)$$

we find that $\beta > 0$, then the data exhibit *absolute convergence*.

A group of economies is $\sigma-$converging if the dispersion of their real per capita GDP levels tends to decrease over time. Thus,

$$\sigma_{t+T} < \sigma_t \qquad (2)$$

where σ_t is the standard deviation of $\log(y_{i,t})$ across i.

Both concepts are related, so that a necessary condition for the existence of *$\sigma-$convergence* is the existence of *$\beta-$convergence*. Sala-i-Martin (1996) also argues that, as a natural process, the initially poor economies tend to grow faster than the rich ones, so that their GDP per capita levels become more similar over time. Thus, the existence of *$\beta-$convergence* tends to generate *$\sigma-$convergence*.

In the eighties, Baumol (1986), using Maddison's data-set, consisting of 13 rich countries starting in 1870, found cross-country convergence, specially after World War II. However, Romer (1986) and Delong (1988) challenged this hypothesis of cross-country convergence, based on the problem of ex-post sample selection bias: countries that were industrialized were selected

[1] For a survey on alternative concepts of convergence, see Baumol, Nelson and Wolff (1994).

ex-post and countries that did not converge were excluded from the sample. According to them, in the context of endogenous growth models, there is no tendency in the economies to converge over time, so that rejection of convergence would give empirical support to this approach.

In order to avoid these problems, a feasible solution was to use a data set that included a larger group of countries. Summers and Heston (1991) worked with 110 countries, though in a much shorter sample span, starting in 1960. The results were favorable to divergence: the standard deviation increased and the sign obtained in (1) was positive.

Notwithstanding, Barro (1991) and Mankiw, Romer, and Weil (1992) found that convergence can be achieved among economies that exhibit similar characteristics and when human capital variables such as education and savings rates are controlled for. The inclusion of these variables would give a more realistic picture than the one by the restrictive neoclassical model. In this case, the prediction of these models, according to Sala-i-Martin (1990, 1996), is that the growth rate of an economy is positively related to the distance that separates it from its own steady state. Per capita incomes of countries that are identical in their structural characteristics (such as preferences, technologies, rates of population growth, government policies) converge to one another in the long-run, independently of their initial conditions. This cross-section notion of convergence was called *conditional* $\beta-$*convergence* and has been tested using the following expression:

$$\gamma_{i,t,t+T} \equiv a - b\log(y_{i,t}) + \Psi X_{i,t} + \varepsilon_{i,t,t+T} \tag{3}$$

where $X_{i,t}$ is a vector of variables that control for the steady state of economy i, and $b = (1 - e^{-\beta T})/T$. If β is positive, once $X_{i,t}$ is held constant, the group of countries exhibits *conditional* $\beta-$*convergence*. The above mentioned authors obtained results that supported this version of convergence, finding a uniform rate of convergence equal to 2% a year.

Quah (1996b) argued that the conventional analyses miss a few key aspects. Notably, they do not allow for the distinction between economic progress (that causes growth successes or miracles, both in rich and poor countries) and the relative performance of rich and poor economies, that is, whether catching up among them occurs. The first process is called growth by Quah (1996b) and, the second one, convergence. As the traditional approach fails to distinguish between these two dimensions, theoretical and empirical statements made about one are often taken, inappropriately, to the other. The new empirical research in this area should model directly the dynamics of the cross-section distribution of countries. Thus, the *club convergence* *hypothesis* implies that per capita incomes of countries that are identical in their structural characteristics converge to one another in the long-run, provided they lie in the basin of attraction of the same steady-state equilibrium. He obtains evidence on persistence and stratification; on the formation of convergence clubs; and on the cross section distribution polarizing into *twin peaks* of rich and poor.

As noted also by Galor (1996), the domination in the empirical literature of the conditional convergence hypothesis may be partially attributed to insufficient familiarity with its theoretical non-robustness. Contrary to prevailing wisdom, the traditional neoclassical growth paradigm (when some heterogeneity across individuals is permitted) generates both the *conditional convergence* and the *club convergence hypotheses,* so that the two concepts are not opposed. Multiple steady-state equilibria and both club convergence and conditional convergence are viable hypotheses. Quah(1996a)'s view is that the relevant economic agent is not the individual country itself, but the quantile in an income distribution: he then looks at the collective destiny of a group of countries, not at their individual performance.

Another way of defining convergence is based on the long-run output movements in the context of time series techniques. Bernard and Durlauf (1995) define long-run convergence between countries i and j if the long-term forecasts at time t of the considered variable for both countries obey:

$$\lim_{k \to \infty} E(y_{i,t+k} - y_{j,t+k} \mid I_t) = 0 \tag{4}$$

where I_t stands for the information available at time t. This definition will be satisfied if $y_{i,t+k} - y_{j,t+k}$ is a zero mean stationary process. It implies that, for countries i and j to converge, the two series must be cointegrated with cointegrating vector $[1, -1]$. In addition, if the series are trend-stationary, the definition implies that the time trends for each country must be the same.

The definition in equation (4) can be extended to more than two countries, making for *multivariate convergence.* Thus, countries $i = 1, ..., n$ converge if the long-term forecasts of output at time t, for all countries, obey:

$$\lim_{k \to \infty} E(y_{1,t+k} - y_{i,t+k} \mid I_t) = 0 \qquad \forall i \geq 1 \tag{5}$$

Similarly, countries $i = 1, ..., n$ contain a single *common trend* if the long-term forecasts of output are proportional at a fixed time t.

In order to test for multivariate convergence, Bernard and Durlauf (1995) use the cointegration tests developed by Phillips and Ouliaris (1988) and Johansen (1988).

In spite of the main problem being that convergence is a gradual and on-going process, all these conditions have been extensively applied to study its existence.

Bernard and Durlauf (1995, 1996), Oxley and Greasley (1995) and Greasley and Oxley (1997) have also proposed different definitions or degrees of convergence, that allow for a more flexible interpretation of the concept, yielding an appropriate testing framework based on cointegration techniques. According to these authors, the definition of convergence given above would correspond to the concept of *long-run convergence*. However, it could be the case that both series are not equal in the long-term, but proportional. That is, they may still respond to the same long-run driving processes and face the same permanent shocks with different long-run weights or different magnitude across countries. In this case, the series would be cointegrated but the cointegrating vector would be $[1, \alpha]$ with $\alpha < 0$ and both series would show a *common trend*. Finally, if both series are cointegrated with vector $[1, -1]$, but the difference between the two series is a stochastic variable with a non-zero time trend, the deviation between the series is expected to decrease but not to disappear. This case is called *catching-up* by Bernard and Durlauf (1995, 1996) and Oxley and Greasley (1995).

The time series evidence has not, in general, been supportive of the convergence hypothesis. Quah (1990) and Ben-David (1994) did not find conclusive evidence of convergence among a large number of countries using the Summers-Heston (1988) data. Campbell and Mankiw (1989) and Bernard and Durlauf (1995) failed to find convergence among OECD countries. Reichlin (1999) argued that the notion of convergence derived from Quah's approach is closely related to that implied by cointegration. The difference is that while Quah cares about groups, in the cointegration framework one cares about individuals. Although Quah's methodology is more adequate to handle a large number of time series, an important problem may arise when it is not possible to find a normalization for which the model for the quantiles is stationary: in this case, the results are difficult to interpret.

Another limitation of Quah's work is that he does not clearly state the needed hypotheses. While his methodology is in an early stage of development, time series models are, in contrast, well developed and the assumptions needed to test for convergence are clearly stated. Reichlin (1999) proposes using the cointegration framework to detect convergence clubs by looking at cointegration clusters. Given a group of countries, one can find, for example, two separate subgroups, each one cointegrated within its own members, but the two not cointegrated amongst them. If one conditions each group with respect to its own mean, we get a set of stationary series, and each set is a convergence club. Thus, most of the empirical questions of cross-sectional distribution dynamics can also be answered within a time series framework for which we there exist well developed inference tools.

A definition weaker than Bernard and Durlauf (1995)'s postulates convergence if the log of relative output is trend stationary; it is called *stochastic convergence* and was proposed by Carlino and Mills (1993). This definition is however open to criticism, since the presence of a time trend allows for permanent per capita output differences. A stronger definition of convergence, which we shall call *deterministic convergence*, requires that the log of relative output is level stationary, while Bernard and Durlauf (1995)'s concept of time series convergence further requires the log of relative output to be level stationary with zero mean.

Finally, Loewy and Papell (1996) reexamine the whole issue by allowing endogenously determined break points and lag lengths. They are able to find evidence of stochastic convergence, giving support to Carlino and Mill's results and providing a benchmark case for convergence among similar economies.

3 Time series convergence: a methodological framework.

Following the discussion in section 2, the time series literature and, more specifically, the cointegration tests, offer a well developed framework for testing for convergence. Indeed, the definitions of convergence given above are closely linked to the concepts *of deterministic and stochastic cointegration,* Park (1992). Cointegration is a necessary, though not sufficient, condition for convergence of two non-stationary series. Only in this case the differences between the series will neither diverge nor have infinite variances. If the series under consideration are $I(1)$, it may be reasonable to define convergence in terms of the difference between them being of a lower integration order (Hall, Robertson and Wickens, 1992).

The concept of catching up is particularly appropriate for our context as, at least for emerging economies, convergence is an on-going process. Now, the problem is how to test for the different degrees of convergence. A possible empirical strategy could be to test for unit roots in the difference between two individual series. The joint rejection of a unit root and a deterministic trend (*deterministic cointegration*) would imply the existence of convergence. Conversely, if a deterministic trend is present, that would mean that there is *catching-up* (*stochastic cointegration*). The main problem related to the implementation of unit root tests to detect the presence of convergence is the possibility of structural discontinuities in the convergence process. In the empirical literature two methods have been implemented to solve this problem. First, testing for the possibility of structural breaks in the long-run relationships, as adopted by Carlino and Mills (1993), Loewy and Papell (1996) and Greasley and Oxley (1997). The second way of solving the problem involves using a time-varying- parameters technique as in Hall, Robertson and Wickens (1992), Haldane and Pradham (1992) and Loufir and Reichlin (1993).

However, the time series literature has recently benefited from new developments in the area of multivariate time series tests. Bernard and Durlauf (1995) also defined convergence in a multivariate setting, although they were aware of the additional difficulties of this type of analysis, mainly related to identification. Two strands have recently experienced an intense development: the panel unit root techniques and the multivariate unit roots tests. Levin et al. (2002) and Im, Pesaran and Shin (1999) proposed different versions of unit root tests in a panel setting, whereas Hadri (2000, 2001) built stationarity tests in panels. Although all these tests are being extensively used, their main drawback is the assumption (common to them all) of absence of correlation across the cross-sections of the panel. That is, the individual members of the panel (countries) are independent. This assumption cannot be maintained in the majority of the cases, specially when the countries are neighbours or are involved in an integration process. The multivariate unit root tests, in contrast, do not impose this assumption but rather incorporate the countries covariances in the estimation, by resorting to the more efficient SURE technique.

In this section we use the Johansen technique to test for Bernard and Durlauf (1995)'s definition of convergence and, then, try to identify clusters of countries using Hobijn and Franses (2000) method. In addition, we apply different versions of multivariate unit root tests that permit, first, to analyze if there is any evidence of convergence and, if this is the case, to identify which countries are effectively converging. A brief description of the methodology and tests follows.

3.1 Bernard & Durlauf 's multivariate convergence and common trends.

We shall concentrate on Johansen's tests using the series of output levels (Y_t), rather than that of deviations. From Bernard and Durlauf (1995)'s definition of convergence, for the individual output series to converge there must be $n-1$ cointegrating vectors, or one common trend. The set of vectors of the form (1,0,...,-1,0), where the first element is fixed and -1 successively occupies the $n-1$ possible positions, must form a basis of the cointegrating space. As a consequence, the series formed by the average of the n original series must define a common trend.

3.2 Hobijn & Franses 's asymptotically perfect and relative convergence.

The analytical techniques in the multivariate settings proposed by Bernard and Durlauf (1995) and Quah (1996a) are useful to assess whether the whole sample of countries exhibits convergence, but they do not allow for endogeneously identifying convergence clubs within a sample of countries. Hobijn and Franses (2000) propose an empirical procedure that permits to endogeneously cluster countries in groups of converging economies. In addition, this technique also provides information on the limiting behavior of the distribution of per capita income levels.

These authors complement Bernard and Durlauf (1995)'s definition of long-run convergence. They consider it to be very strong, what explains why it has been very difficult in the literature to find evidence of this type of convergence. Their definitions concentrate on the properties of the per capita income disparities and are not based on any assumptions about the common growth process that drives income levels in any country. In order to derive testable restrictions, they suppose that the log of per capita income disparities, $d_{(i,j),t} = y_{it} - y_{jt}$, can be represented as:

$$d_{(i,j),t} = \alpha_{(i,j)} + \beta_{(i,j)} t + \phi_{(i,j)} \sum_{k=1}^{t} \eta_{(i,j),k} + \varepsilon_{(i,j),t} \tag{6}$$

where $\alpha_{(i,j)}$ and $\beta_{(i,j)}$ are constant over time, $\phi_{(i,j)} \in \{0,1\}$, and $\eta_{(i,j),k}$ and $\varepsilon_{(i,j),t}$ are covariance stationary processes with mean zero and strictly positive variances. The conditions for convergence are the following:

- $y_{i,t}$ and $y_{j,t}$ *asymptotically perfectly converge* iff $d_{(i,t),t}$ is a zero mean stationary process, that is, if $\alpha_{(i,j)} = \beta_{(i,j)} = \phi_{(i,j)} = 0$.
- $y_{i,t}$ and $y_{j,t}$ *asymptotically relatively converge* iff $d_{(i,t),t}$ is a level stationary process with finite expectation, that is, if $\beta_{(i,j)} = \phi_{(i,j)} = 0$ and $\alpha_{(i,j)} \in (-\infty, \infty)$.

This framework provides two testable necessary and sufficient conditions for convergence. In addition, according to their Proposition 3, asymptotically relative convergence of per capita income levels will imply that per capita growth rates converge asymptotically perfectly.

In order to form the convergence clubs, Hobijn and Franses (2000) use a cluster algorithm based on the hierarchical farthest neighbour method proposed by Murtagh (1985). Use of this cluster algorithm is justified because it only clusters countries under very strong assumptions. Then, for each resulting club, it holds that for any pair of countries in the group the necessary and sufficient conditions for convergence are not rejected. This aims at minimizing the chance of clustering together countries that actually are not converging. For stopping the clustering process, they use a critical distance (or *measure),* that indicates to what degree one has evidence that two time series satisfy the necessary and sufficient conditions for convergence. Their measures are generalizations of the *KPSS* test for stationarity. Finally, since asymptotically perfect convergence implies asymptotically relative convergence, they first cluster the countries on the basis of zero mean stationarity, then those that converge in an asymptotically relative sense.

3.3 Multivariate unit root tests I: no identification of countries outside the club.

From the definition of multivariate convergence, two testing strategies can follow. The first was described in the previous subsection: in a cointegration framework, convergence among n countries would imply finding $n-1$ cointegrating relationships between the original output variables. The second is based on the output deviations from the benchmark country, that is, $(y_1 - y_p)$. The restriction imposed is equivalent to testing whether the two variables are cointegrated with a vector of the form $(1, -1)$.

The application of this second approach uses unit root or stationarity tests to determine the existence and the extent of convergence, be it *long-run*, *common trends* or *catching-up convergence*. Previous empirical studies, such as Oxley and Greasley (1995) and Greasley and Oxley (1997), applied univariate unit root tests, and not a multivariate testing of convergence. The multivariate tests in this subsection, if the null of non-convergence is rejected, are unable to identify which countries are responsible for the failure.

3.3.1 Abuaf & Jorion 's pooled unit root test.

Abuaf and Jorion (1990)'s test, AJ hereafter, was proposed in the context of the applied PPP literature. In our case, let's assume that the process of the deviations from the benchmark $dy_{it} = y_{1t} - y_{it}$[2] follows a simple first-order autoregressive process:

$$dy_{it} = \mu + \rho dy_{it-1} + u_{it} \tag{7}$$

where μ and ρ are constant and the error term u_{it} is a white noise.

The AJ test may be viewed as a multivariate version of the statistics proposed by Dickey and Fuller (1979) that improves on the power of the latter in two ways (see Flôres et al. (1996)):

1. The regressions are specified in levels and have more power than regressions in first differences against the alternative of a stable near random walk model. Thus, the alternative hypothesis is a first-order autoregression in levels, with $\rho < 1$.

2. The system of univariate autoregressions is estimated jointly by the seemingly unrelated regression (SURE) method. This, as known, is more efficient than estimating equation by equation using OLS, as it fully exploits the information in cross-equation correlations. In addition, the null is common to all the cross-sections: all values of ρ are unity.

We shall apply the AJ test to the system:

$$\begin{aligned} dy_{1t} &= \mu_1 + \rho dy_{1t-1} + u_{1t} \qquad t = 1, ..., T \\ &\dots \\ dy_{Nt} &= \mu_N + \rho dy_{Nt-1} + u_{Nt} \qquad t = 1, ..., T \end{aligned}$$

The null $\rho = 1$ implies a unit root for each and every member of the panel, or rather, in our context, no convergence. In contrast, rejection of the null can be taken as favorable to convergence.

The finite sample test statistic is unknown and has to be derived by simulation. In their original paper, Abuaf and Jorion presented the simulated critical values for a DGP with no intercept. In addition, they only considered marginally the possibility of allowing for higher orders of serial correlation.

[2] Note that y_{it} is written in logarithms.

3.3.2 Sarno & Taylor 's multivariate augmented Dickey-Fuller test (MADF)[3].

The MADF test can be considered a generalization of the AJ test, allowing for higher order serial correlation in the variables. As in the previous case, the sum of the autoregressive coefficients may vary across countries, under the alternative. Sarno and Taylor (1998)'s proposal considers a N-dimensional stochastic process defined by:

$$dy_{it} = \mu_i + \sum_{j=1}^{k} \rho_{ij} dy_{it-j} + u_{it} \tag{8}$$

for $i = 1, ..., N$, where N denotes the number of series in the panel. The disturbances $\mathbf{u}_t = (u_{1t}...u_{Nt})'$ are assumed to be independently, normally distributed, with zero means. In contrast to the standard ADF test, they estimate system (8) by the SURE method, taking into account the contemporaneous correlations among the disturbances. Their joint null is:

$$H_0 : \sum_{j=1}^{k} \rho_{ij} - 1 = 0, \qquad \forall i = 1, ..., N \tag{9}$$

and is tested by way of a Wald statistic.

The ρ coefficients are allowed to differ across the panel members and the test also permits heterogeneous lags.

Process (8) can be also be specified in differences:

$$\Delta dy_{it} = \mu_i + \rho_i dy_{it-1} + \sum_{j=1}^{ki} \delta_{ij} \Delta dy_{it-j} + u_{it} \qquad t = 1, ..., T; \quad i = 1, ..., N \tag{10}$$

when the $MADF$ test becomes a joint test of the null $\rho_1 = \rho_2 = ... = \rho_N = 0$.

3.4 Multivariate unit root tests II: identifying countries outside the club.

In both previous tests, rejection of the null means that not all the members of the panel contain a unit root. Breuer et al. (1999) point out that there

[3]A first application of the test appeared in 1997 as a CEPR Discussion Paper that was finally published as Taylor and Sarno (1999).

may be a mixture of $I(0)$ and $I(1)$ processes in the panel. However, as the tests are joint tests, rejection does not provide information about how many countries follow the null, being impossible to identify the stationary and non-stationary cross-sections. The two multivariate tests proposed here can, on the contrary, identify which variables contain a unit root and which do not. They complement the AJ and $MADF$ tests and should be applied in a second stage of the analysis.

3.4.1 Flôres, Preumont & Szafarz 's multivariate unit root testing strategy.

Flôres et al. (1995) developed a multivariate testing strategy, FPS hereafter, that also generalizes the AJ test. In Flôres et al. (1999), the strategy was applied to the PPP hypothesis.

They consider that the AJ test, by imposing the same autoregressive parameter ρ for all countries, does not allow to differentiate the order of integration across them. Moreover, even from an econometric point of view, it might not be necessary to impose a common ρ to benefit from panel data. Thus, they propose multivariate tests with different speeds of mean reversion in the autoregressive process:

$$dy_{it} = \mu_i + \rho_i dy_{it-1} + u_{it}, \qquad i = 1, ..., N \tag{11}$$

The strategy is based on sequentially using the AJ test and theirs. As rejection of the null by the AJ test indicates that at least some of the series may be stationary, they suggest to continue then with their test. Moreover, unit root tests for a particular series are more powerful if performed jointly with stationary series, because they help in weakening the influence of the non-stationary ones. For the two-variable case, for example, the authors found that the asymptotic distribution of ρ_1 under the null of unit root ($\rho_1 = 1$) does not depend on the value of the other coefficient, ρ_2, when the other series is stationary ($\rho_2 < 1$). In addition, in finite samples, the lower the ρ_2 the tighter the critical values. These findings seem to apply also in the higher dimensional cases.

The sequential testing strategy is described below, the Monte Carlo technique for performing it is outlined in the Appendix:

1. Under the first null hypothesis, the DGP is based on the autoregressive model with $\mu = 0$, $\rho_i = 1$, for the N countries. The AJ test is performed; if the null is not rejected the sequence stops, otherwise the first FPS test, which has the same null but allows for different autoregressive coefficients, is performed.

2. From the results of the first *FPS* test, define a set of countries I_l for which the null is rejected. These countries' series are from now on considered stationary.

3. In a third step, a new DGP is assumed for the null, in which the series $j \notin I_l$ have as slope parameters $\rho_j = 1$, while for $j \in I_l$ the slope coefficients are taken at their previous point estimates, $\rho_j = \hat{\rho}_j$. Then, the second *FPS* test is used to check whether any of the $j \notin I_l$ are stationary.

3.4.2 Breuer, McNown & Wallace 's multivariate test.

Breuer et al. (1999) also allow for heterogeneous serial correlation across the panel, contemporaneous correlation among the errors, and different autoregressive parameters for each panel member under the alternative. In contrast to the $MADF$ test, separate null and alternative hypotheses are tested for each panel member within a SURE framework.

Similarly to the other tests, the $SURADF$ test has nonstandard distributions and the critical values must be obtained by simulation. The simulation produces critical values for testing the null that $\rho_i = 0$, in an equation such as (10) for each individual country. The critical values, as in the *FPS* case, are specific to the estimated covariance matrix, the sample size and the number of panel members. The procedure allows identification of how many and which series contain a unit root.

4 The Mercosur countries and their associates: preliminary analysis.

The data sample used in this paper covers the 1960-1999 period and has been obtained from the World Bank. It consists of the logarithm of real GDP per capita in constant dollars (international prices, base year 1985) for Argentina, Bolivia, Brasil, Chile, Paraguay, Peru and Uruguay. The original source is Penn World Table 5.6. and the missing data are calculated from 1985 GDP per capita and GDP per capita growth rates (Global Development Finance and World Development Indicators).

Though economic integration between Argentina, Brazil and Uruguay started during the middle eighties, on a bilateral basis, Mercosur was formally created in 1991, after the Asunción Treaty was signed. Initially a free trade zone between Argentina, Brazil, Paraguay and Uruguay, Mercosur became an imperfect customs union in 1995. Indeed, on January 1st 1995, most tariff and many non-tariff barriers among the members had already been eliminated, and a common external tariff (CET) was set. Schedules for full implementation of the customs union had 2001 as its first target, but for Paraguay, that had to converge to the CET by 2006. Recent local crises have delayed these deadlines.

In 1996, Chile and Bolivia were incorporated as associated members, i.e., they negotiate bilaterally with Mercosur. These negotiations aim at their full participation at least in the free trade zone by 2006.

In Figure 1 we present the evolution of openness in Mercosur and associates during the last years. Openness, measured as the percentage of total trade over GDP, has in general increased during the whole period, although in the eighties ("the lost decade") it remained still for many countries and decreased in others. During the nineties, when a new wave of integration in the area progressively consolidated, evolution was more positive, specially in the smaller countries and Chile, which has a more export-oriented policy. The larger economies, Argentina and Brazil, also show a tendency to increase their openness, although the process is slower.

Insert Figure 1 by here

Figures 2 and 3 illustrate the two concepts of convergence traditionally tested in the literature[4]. As explained above, $\beta-$convergence would imply that poorer countries tend to grow faster than rich ones, so that a negative relation should be expected between the initial output levels and the rate of growth. Thus, in the case of convergence, a scatterplot of these two variables would show a negative slope. We find this pattern in Figure 2, where a negative relation emerges between the logarithm of the initial income per capita and its average growth rate during the period 1960-1999. The concept of $\sigma-$convergence implies that convergence exists when the dispersion of income per capita has progressively declined. In Figure 3 we show the results of dispersion for the whole Southern Cone area (darker pattern) and for the Mercosur countries (lighter line pattern). During the sixties and the seventies, a steady convergence process occurred in the area (Mercosur countries showing larger dispersion than the whole group) but this tendency was inverted at the beginning of the eighties. Since then, the dispersion in the whole area has increased again, returning to the values of the sixties. However, this has not been so acute in the Mercosur countries, where the integration process seems to have been able to partially offset the diverging trend.

[4] See Elías and Fuentes (2001) for a study on convergence between Chile and Argentina.

Insert Figures 2 and 3 by here

The results obtained from this simple version of the traditional analysis would cast serious doubts on the existence of convergence in the Southern Cone area. However, the increase in openness, the results of $\beta-$convergence and the better performance of $\sigma-$convergence in Mercosur are an indication of the importance that regional integration is having and may still have in the area and demand deeper attention from an empirical point of view.

5 Empirical results.

5.1 No benchmark country: Bernard & Durlauf 's and Hobijn & Franses 's approaches.

We estimated a VAR system formed by the seven countries considered, using Johansen's methodology. The final system specification had three lags and the constant unrestricted; the residuals passed normality and ARCH tests. However, some autocorrelation persists although it occurs at relatively high orders. According to the $\lambda-$ max and the trace tests (see Table 1a), one cannot reject the existence of five cointegration relationships at the 5% level, although at 10% even six long-run relations can be accepted. This implies that there are six cointegration relations and one common I(1) trend that drives the system. The space generated by the six vectors coincides with the one expected, described in section 3.1. As explained there, the average of the seven series must then define a common trend. In order to know the order of integration of this average, we applied the Kwiatkowski et al. (1992) stationarity test. The results presented in Table 1b show that stationarity can be rejected at 1% in the model with intercept and at 5% in the model with trend. Thus, the average of the output per capita in the Mercosur countries plus associates is a common trend that drives the whole system.

The main problem associated with the previous analysis is the identification of the convergence clubs. As at 5% there was an indication of only five cointegrating relations, a complementary analysis was carried out applying Hobijn and Franses (2000) methodology. Taking into account that the group is relatively small, we have selected $p_{\min}$=0.05, as recommended by the authors[5], with the bandwidth parameter l ranging from 1 to 6 to examine the robustness of the results. The clusters obtained are in Table 2. In all the

[5] However, the results did not change for $p_{\min} = 0.01$ and $p_{\min} = 0.10$.

combinations of $p_{\min}$ and l used, two clusters formed by Bolivia-Paraguay and Chile-Brazil appeared; also, Peru never formed a cluster with any other country. However, with $l = 6$ we also found a cluster between Argentina and Uruguay. From the definitions given in the methodological section, the hypothesis of asymptotic perfect convergence implies testing whether the difference defined in (6) is a zero-mean stationary process, whereas relative convergence implies stationarity around a non-zero mean. Although the first concept of convergence is stronger than the second one, in this case we have found that the same clusters converge in the two senses.

5.2 Univariate unit root and stationarity tests.

Previous to the application of the multivariate unit root tests, we applied the time series definitions discussed in section 3 to individual country pairs.

The first benchmark chosen was Brazil; the difference in per capita income between each country and Brazil was then computed. Table 3 presents the results of the unit root analysis using the Phillips and Perron (1990) tests. From the univariate tests, only in the cases of Argentina, at 10%, and Uruguay, at 5%, it is possible to reject the null of non-stationarity in a model with no deterministic term. Then, we applied the $KPSS$ stationarity tests, finding that stationarity around a trend cannot be rejected for Bolivia, Paraguay and Peru, whereas stationarity with non-zero mean cannot be rejected for Chile and Paraguay. When the benchmark country is Argentina, the null of non-stationarity (using the ADF test) can be rejected in the cases of Peru and Brazil. In addition, there is evidence of stationarity using the KPSS test only in the case of Uruguay, whereas when allowing for a trend, the hypothesis of convergence cannot be rejected in the cases of Paraguay and Peru.

All the above results are summarized in Table 4, that compares with Table 2. As explained above, the definitions of perfect and relative convergence proposed by Hobijn and Franses (2000) are tested using $KPSS$ equivalents. Perfect convergence implies that the difference between the two variables is a zero mean stationary variable, whereas in the case of relative convergence, the difference would be stationary around a non-zero mean. Consequently, the results from the univariate η_μ $KPSS$ tests should be similar to those obtained in the cluster analysis. This is the case: the results from the two analyses do not differ much, the pairs Argentina-Uruguay and Chile-Brazil converging in both. The cluster Bolivia-Paraguay has not been considered in the univariate tests.

5.3 Multivariate unit root tests I: no identification of countries outside the club.

In this stage we concentrate on groups of countries and select a "leader" to act as a benchmark, as in the univariate tests discussed above. In order to apply the Abuaf and Jorion (1990) test, we estimate by SUR a system for each of the country groups, imposing the same parameter ρ for all the series in the system.

Taking Brazil as the first benchmark country, in Table 5a, the estimated ρ takes a value of 0.9265 in the first club, formed by Mercosur and Bolivia, whereas the value is 0.9296 when we include Chile instead of Bolivia. The third group with Brazil as leader is formed with all the countries at stake, yielding an estimate of 0.9397.

Two groups have been analysed when the benchmark country is Argentina. The first includes the whole set of countries, whereas the other is Mercosur plus Bolivia. As in the case of Brazil, the estimates are very high: 0.9396 and 0.9253.

Using the residuals from each club, we simulated the critical values for the null of a unit value against the AR(1) alternative (with drift) of $\rho < 1$. We present in Table 5a the obtained critical values at 10%, 5% and 1% significance levels. All are below 0.9 in the two benchmark options, so that the null cannot be rejected.

The less restrictive possibility proposed by Sarno and Taylor (1998) and described in the previous section was then tried. Though allowing for differences in the autoregressive parameters, the $MADF$ test is also a joint test of the null $\rho_1 = \rho_2 = ... = \rho_N = 0$. Rejection of the null also implies that not all the members of the panel contain a unit root.

The results for nearly the same country groups are presented in Table 5b. As expected, the test is more flexible than the AJ one - i.e., less sensible to a few non-stationary components -; taking into account the variables-specific critical values, it is possible to reject the null, either at 5% or 1%, for all the groups but the second one (Argentina+Chile+Paraguay+Uruguay, with Brazil as benchmark). The most significant rejection, however, is for the second Argentinean group, not checked under the AJ.

The MADF produces then evidence in favour of, at least, partial convergence, and goes against the findings in the AJ test. Notwithstanding, given that it is hard to accept, at least at a first look, that the two last groups - when Argentina is the benchmark - make for a convergence club, the results might suggest that the $MADF$ test is overrejecting. This adds further support to proceed with the analysis, in order to obtain additional information on which countries might be converging.

5.4 Multivariate unit root tests II: identifying countries outside the club.

The Flôres et al. (1995) test allows for different autoregressive coefficients and, here, we have used the version including an intercept[6].

In order to apply the test, we first perform the unconstrained estimation of the system. Using the residuals under the null, we proceed to compute 1.000 simulations where some series are taken to be stationary.

The first row of Table 6 shows the results for the group of countries formed by Mercosur plus Bolivia, with Brazil as the benchmark country. In this case, the series for Paraguay and Uruguay were assumed stationary (they yielded the lowest estimated auto-regressive coefficients). The critical values obtained from the simulations for Argentina and Bolivia, leaving the two "stationary coefficients" fixed, do not allow the rejection of the unit root hypothesis in the first case, although for Bolivia the non-stationarity can be rejected at 5%.

In the second group, formed by Mercosur plus Chile, the Paraguay and Uruguay series were taken again as stationary. The results are more discouraging than before: it is not possible to reject the null of non-stationarity either for Argentina or Chile.

Finally, in the group including all the countries with Brazil as the benchmark, the only converging countries were Paraguay and Uruguay; the very two assumed as stationary, from the first estimation results.

A similar exercise was performed with Argentina as the leader. In the larger group, Bolivia, Paraguay and Peru converge, whereas for the case of Mercosur plus Bolivia, the converging countries are Bolivia, Brazil and Paraguay.

These results are partially confirmed by those obtained using the Breuer et al. (1999) test, shown in Table 7. In the cases in which Brazil is the benchmark the coincidences are nearly perfect; Argentina and Chile are always non-stationary, and the Mercosul+Chile group, which has produced identical results under the AJ and MADF tests, again yields the same conclusions. Peru, however, shows a somewhat striking deviant behaviour in the last group. In the first two groups of countries, Paraguay and Uruguay converge towards Brazil, whereas the other countries don't. The larger club (Mercosur plus Bolivia, Chile and Peru) does not change significantly the convergence outcome: Peru is also added to the countries converging with

[6] Flôres et al. (1995) show that the results still hold when an intercept is included in the estimation, whether or not it exists in the data generating process. The presence of the intercept will allow for stationarity around a non-zero mean, that is, a less restricted version of convergence.

Brazil.

Equivalent groups have also been defined in relation to Argentina. The coincidence, in the larger group, becomes weaker, though the deviant cases correspond to a 10% significance level. It is also worth noticing that, the last group, in spite of not being identical to the one for the FPS test, the convergence finding is maintained for the sub-cluster Argentina, Bolivia, Brazil and Paraguay, though weaker in the Argentina-Brazil pair. Evidences are in general less strong, even if some convergence is found between Argentina and all the countries, with the exception of Chile and Uruguay, in the larger group. The clearest rejection of non-convergence appears in relation to Bolivia. In a second step, we have excluded the non converging countries from the group and obtained more clear rejections, with the exception of Brazil (at 10%).

The comparison of the results obtained with the two benchmark countries indicates that, in general, the small countries (namely Bolivia, Paraguay, Peru and Uruguay) are converging towards the two larger countries (Argentina and Brazil), whereas the evidence of convergence between the two large economies is rather weak. Concerning Chile, it does not converge with any of the two large neighbours, confirming its relative isolation from the rest of the area, very likely due to the different macroeconomic and international trade policies it adopted.

Table 8 compares the results of the two tests applied in this section, for identifying the converging countries. The results for Argentina are identical: Argentina converges with Bolivia, Paraguay and Peru, and, in a somewhat weaker level, with Brazil. When Brazil acts as benchmark, the two tests support the existence of convergence with Paraguay and Uruguay. In addition, the *FPS* test suggests convergence with Bolivia, whereas the *SURADF* test identifies Peru as the third converging country.

6 Concluding remarks.

In this paper we have used a wide variety of tests, many of them complementary, in order to assess the degree of per capita income convergence in Mercosur and associate countries. As an introduction to the study, we have reviewed the time series literature on convergence and, thus, the main definitions of convergence that are commonly used in such analyses. Our approach combines the applicability of well-defined testable hypotheses from the time series literature with recent multivariate techniques that allow for cross-country effects. In this way, the paper also makes a comparison of the main multivariate unit root tests available nowadays.

In a first stage of the analysis, we did not impose any benchmark country.

Using the definitions of multicountry convergence proposed by Bernard and Durlauf (1995), we find that there are six cointegration relations between the seven countries considered or, equivalently, one common trend. This would imply convergence in Bernard and Durlauf's sense as we identify the average of the area as an I(1) variable representing the attractor or common trend of the group. Moreover, trying to find convergence clubs, we applied the clustering method by Hobijn and Franses (2000). The clusters obtained consist of three pairs: Argentina-Uruguay, Chile-Brazil and Bolivia-Paraguay.

The next stage implies using benchmark countries, Brazil and Argentina in our case. We applied first univariate unit root and stationarity tests and then, multivariate unit root tests. The KPSS stationarity tests support the country-pairs obtained using the clustering technique, although the results from the *ADF/PP* tests do not. In fact, their equivalent should be found in the multivariate *ADF* tests.

From a methodological point of view, the combined use of the univariate and multivariate SUR unit root tests implies a step forward in the study of per capita income convergence. Two possibilities are considered in the multivariate case. First, the tests proposed by Abuaf and Jorion (1990) and Taylor and Sarno (1998) impose the same alternative for all the countries, so that there is no precise identification of which are those outside the convergence club. Second, the Flôres et al. (1996) and Breuer et al. (1999) tests are applied to the individual countries separately and identify those that are converging. These two groups of tests are then complementary. Using the AJ and the MADF tests, we check jointly the null of non-convergence. Rejection of this null motivates the search for the countries that are converging, with the aid of the FPS and SURADF tests.

Although different in their formulation, the countries that catch-up according to the *FPS* and the *SURADF* tests are practically the same, which adds robustness to the analysis. In addition, if we compare the univariate results with the *SURADF* ones, they agree on the convergence found between Argentina-Brazil, Brazil-Uruguay and Argentina-Peru.

Summing up, the main conclusions that emerge from this paper are the following:

- Using (purely) multivariate techniques, it has not been possible to find a big cluster of converging countries. In particular, the Hobijn-Franses method just detected pairs of converging countries.

- If we consider separately the Mercosur members, its associates and Peru, the evidence suggests (as in the traditional sigma convergence) that the process of convergence has been stronger for those countries in Mercosur.

- Although partial, there is consistent evidence on convergence in the form of *catching-up* among the Mercosur members, as well as with the associate and neighbour countries.

- Due to the particular configuration of the area, there are two large countries that may be used as benchmark for the analysis, whereas the rest (with the possible exception of Chile) are small economies. The evidence found points to *catching-up* of the smaller economies towards the larger ones. There is weaker evidence of *catching-up* between Argentina and Brazil, as well as none between each of them and Chile.

- In spite of the more consistently favourable evidences of Argentina being the country towards which a larger number of smaller countries are slowly converging, it cannot be considered as the area-leader. In fact, its per capita income has been steadily decreasing for a long period of time. Thus, this evidence of catching-up seems to be just capturing the tendency of the smaller countries to grow. In contrast, Brazil, starting from a lower level of per capita income, looks like an attractor in the Southern Cone.

Appendix. The algorithm for performing the FPS test.

In the first step, under the null hypothesis called H_0, the data generating process is based on the autoregressive model with $\mu = 0$ and $\rho_i = 1, for$ all i, for a sample of size T and N countries. In each experiment, one generates jointly T times N error terms u_t from a multivariate normal distribution with mean zero and the historical covariance matrix. This matrix accounts for cross-correlation across the variables. By replicating 1000 times the experiment, one generates the sample distribution of the statistics for known autoregression coefficients. The empirical $p-$values are then obtained.

From the results of the first step, one defines a set of countries I_l for which the null is rejected. These countries' series are considered stationary.

In a third step, one simulates a model where the series $j \notin I_l$ have as slope parameters $\rho_j = 1$, while the slope coefficients are taken at their point estimate, $\rho_j = \hat{\rho}_{1j}$, for the series considered stationary, that is, $j \in I_l$, $j \neq i$. As in the previous step, $\mu = 0$. Then, one tests individually whether any of the $j \notin I_l$ are non-stationary.

References

[1] Abuaf, N. and P. Jorion (1990): "Purchasing Power Parity in the Long Run", *Journal of Finance,* vol. XLV, n. 1, 157-174.

[2] Barro, R.J. (1991): "Economic growth in a cross-section of countries", *Quarterly Journal of Economics,* vol. 106, 407-443.

[3] Baumol, W.J., R.R. Nelson and E.N. Wolff (1994): "Introduction: The Convergence of Productivity, Its Significance, and Its Varied Connotations", 1-19, in Baumol, W.J., R.R. Nelson and E.N. Wolff (eds.) *Convergence of Productivity. Cross-national studies and historical evidence,* Oxford University Press.

[4] Ben-David, D. (1994): "Convergence clubs and diverging economies", *CEPR Discussion Paper,* n. 922.

[5] Bernard, A.B. and S.N. Durlauf (1995): "Convergence in international output", *Journal of Applied Econometrics,* vol. 10, 97-108.

[6] Bernard, A.B. and S.N. Durlauf (1996): "Interpreting tests of the convergence hypothesis", *Journal of Econometrics,* vol. 71, 161-173.

[7] Breuer, J.B., R. McNown and M. Wallace (1999): "Series-specific Tests for a Unit Root in a Panel Setting with an Application to Real Exchange Rates", mimeo, University of South Carolina.

[8] Campbell, J.Y. and N.G. Mankiw (1989): "International evidence on the persistence of economic fluctuations", *Journal of Monetary Economics,* vol. 23, 319-333.

[9] Carlino, G.A. and L.O. Mills (1993): "Are U.S. regional incomes converging? A time series analysis", *Journal of Monetary Economics* 32: 335-346.

[10] DeLong, J.B. (1988): "Productivity growth, convergence, and welfare: Comment", *American Economic Review,* vol. 78, 1138-54.

[11] Elías, V. and R. Fuentes (2001): "Convergencia en el Cono Sur", en T. Mancha and D. Sotelsek (eds.), *Convergencia Económica e Integración. La experiencia en Europa y América Latina*, Ed. Pirámide. Madrid.

[12] Flôres, R., P.Y. Preumont and A. Szafarz (1995): "Multivariate Unit Root Tests", mimeo, Université Libre de Bruxelles.

[13] Flôres, R., P. Jorion, P.Y. Preumont and A. Szafarz (1999): "Multivariate unit root tests of the PPP hypothesis", *Journal of Empirical Finance,* vol. 6, 335-353.

[14] Galor, O. (1996): "Convergence? Inference from theoretical models", *The Economic Journal,* vol. 106, 1056-1069.

[15] Greasley, D. and Oxley, L. (1997): "Time-series based tests of the convergence hypothesis: Some positive results", *Economics Letters,* 56: 143-147.

[16] Haldane,A.G. and Pradhan,M. (1992): "Real Interest Parity, Dynamic Convergence and the European Monetary System", Working Paper Series No.1, Bank of England.

[17] Hall,S.G., Robertson,D. and Wickens,M. R. (1992): "Measuring Convergence of the EC Economies. Papers in Money, Macroeconomics and Finance", *Supplement Manchester School,* vol. LX: 99-111.

[18] Hobijn, B. and P.H. Franses (2000): "Asymptotically perfect and relative convergence of productivity", *Journal of Applied Econometrics,* vol. 15, n.1, 59-82.

[19] Im, K., M.H. Pesaran and Y. Shin (1995): "Testing for unit roots in heterogeneous panels", Department of Applied Economics, University of Cambridge.

[20] Johansen, S. (1988): "Statistical analysis of cointegration vectors", *Journal of Economic Dynamics and Control,* vol. 12, 231-54.

[21] Kwiatkowski, D., Phillips, P.C.B., Schmidt, P. and Shin, Y. (1992) Testing the null of stationary against the alternative of a unit root. Journal of Econometrics 54: 159-178.

[22] Levin, A., C. Lin and C. Chu (2002): "Unit root tests in panel data: Asymptotic and finite-sample properties", *Journal of Econometrics,* vol. 108, 1-24.

[23] Levy, E. and F. Sturzenegger (2000): "Is EMU a blueprint for Mercosur?", *Cuadernos de Economía,* vol. 34, n. 110, 63-99.

[24] Loewy, M.B. and D.H. Papell (1996): "Are U.S. regional incomes converging? Some further evidence", *Journal of Monetary Economics,* vol. 38, 587-598.

[25] Loufir,R. and Reichlin,L. (1993): "Convergences nominale et relle parmi les pays de la CE et de l'AELE", *Observations et Diagnostiques Economiques,* n. 43: 69-92.

[26] Mankiw, N.G., D. Romer and D.N. Weil (1992): "A contribution to the empirics of economic growht, *Quarterly Journal of Economics,* vol. 107, 407-437.

[27] Murtagh, F. (1985): *Multidimensional clustering algorithms,* Physica-Verlag, Heidelberg.

[28] Oxley, L. and Greasley, D. (1995): "A Time-Series Perspective on Convergence: Australia, UK and USA since 1870", *The Economic Record* 71: 259-270.

[29] Phillips, P.C.B. and S. Ouliaris (1988): "Testing for cointegration using principal components methods", *Journal of Economic Dynamics and Control,* vol. 12, 205-230.

[30] Perron, P. y T.J. Vogelsang (1992a): "Nonstationarity and level shifts with an application to purchasing power parity", *Journal of Business and Economic Statistics,* vol. 10, 301-320.

[31] Perron, P. y T.J. Vogelsang (1992b): "Testing for a unit root in a time series with a changing mean: Corrections and extensions", *Journal of Business and Economic Statistics,* vol. 10, 467-470.

[32] Quah, D. (1993): "Galton's fallacy and tests of the convergence hypothesis", *Scandinavian Journal of Economics,* vol. 95, n. 4, 427-443.

[33] Quah, D. (1994): "Exploiting cross-section variations for unit root inference in dynamic data", *Economics Letters* vol. 44, 9-19.

[34] Quah, D. (1996a): "Convergence empirics across countries with (some) capital mobility", *Journal of Economic Growth,* vol. 1, 95-124.

[35] Quah, D. (1996b): "Twin peaks: Growth and convergence in models of distribution dynamics", *The Economic Journal,* vol. 106, 1045-1055.

[36] Reichlin, L. (1999): "Discussion" to D. Quah, "Convergence as distribution dynamics (with or without growth)" in R. Baldwin, D. Cohen, A. Sapir and A. Venables, *Market integration, regionalism and the global economy*, CEPR, Cambridge, Cambridge University Press.

[37] Romer, P. (1990): "Endogenous technical change", *Journal of Political Economy* vol. 98, 71-102.

[38] Sala-i-Martín, X. (1990): "On growth and states", Ph.D. dissertation, Harvard University.

[39] Sala-i-Martín, X. (1996): "The classic approach approach to convergence analysis", *the Economic Journal,* vol. 106, 1019-1036.

[40] Sarno, L. and M. Taylor (1998): "Real exchange rates under the recent float: unequivocal evidence of mean reversion", *Economics Letters,* vol. 60, 131-137.

[41] Solow, R.M. (1956): "A contribution to the theory of economic growth", *Quarterly Journal of Economics,* vol. 70, 65-94.

[42] Summers, R. and A. Heston (1991): "Penn World Table (Mark 5): An expanded set of international comparisons, 1955-1988", *Quarterly Journal of Economics,* vol. 106, 327-368.

[43] Taylor, M. and L. Sarno (1998): "The behavior of real exchange rates during the post-Bretton Woods period", *Journal of International Economics* vol. 46, 281-312.

[44] Zivot, E. y D.W.K. Andrews (1992): "Further evidence on the Great Crash, the Oil-Price Shock, and the unit-root hypothesis", *Journal of Business and Economic Statistics,* vol. 10, 251-270.

A Tables.

Table 1
a) Cointegration tests for the seven countries system
(lgdpar, lgdpbo, lgdpbr, lgdpch, lgdppa, lgdppe, lgdpur)
1960-1999

Eigenvalue	$\lambda - \max$	Trace	$H_0 : r$	$p - r$	$\lambda - \max(5\%)$	Trace (5%)
0.8969	84.07*	262.66*	0	7	48.28	124.24
0.7919	58.09*	178.58*	1	6	39.37	94.15
0.7725	54.78*	120.50*	2	5	33.46	68.52
0.5839	32.45*	65.71*	3	4	27.07	47.21
0.3926	18.45	33.27*	4	3	20.97	29.68
0.3108	13.77	14.82	5	2	14.07	15.41
0.0278	1.04	1.04	6	1	3.76	3.76

b) KPSS stationarity test applied to the average of *(lgdpar, lgdpbo, lgdpbr, lgdpch, lgdppa, lgdppe, lgdpur)*

	η_μ	η_τ
	$l = 4$	
Average	0.777***	0.156**

Note: (**) and (***) denote rejection of stationarity at 5% and 1%, respectively.

Table 2
Results of Hobijn & Franses 's clustering algorithm

Asymptotically Perfect Convergence ($p_{\min} = 0.05, l = 6$)	*Asymptotically Relative Convergence* ($p_{\min} = 0.05, l = 6$)
Clusters:	Clusters:
1. Argentina-Uruguay	1. Argentina-Uruguay
2. Bolivia-Paraguay	2. Bolivia-Paraguay
3. Chile-Brazil	3. Chile-Brazil
4. Peru	4. Peru

Table 3

Phillips-Perron unit root tests and KPSS stationarity tests (l=4)

Series	$Z(t_{\tilde{\alpha}})$	$Z(t_{\alpha^*})$	$Z(t_{\hat{\alpha}})$	η_μ	η_τ
$dbrar_t$	-0.91	-1.36	-1.87*	0.75**	0.17*
$dbrbo_t$	-1.53	-1.04	0.65	0.76**	0.12
$dbrch_t$	-0.61	-1.28	-1.14	0.30	0.20*
$dbrpa_t$	-2.21	-1.93	0.26	0.43	0.10
$dbrpe_t$	-1.63	-0.90	-0.07	0.80**	0.13
$dbrur_t$	-0.81	-2.13	-2.30**	0.57*	0.21**
dbo_t	-2.67	-2.66	-0.84	0.50*	0.21**
dbr_t	-0.91	-1.36	-1.87*	0.75**	0.17*
dch_t	-1.35	-0.37	-1.06	0.52*	0.20*
dpa_t	-1.48	-1.35	-0.78	0.66*	0.12
dpe_t	-3.19*	-2.12	-0.07	0.54*	0.12
dur_t	-2.53	-1.53	-0.72	0.45	0.17*

Note: (a) ** and * denote rejection of the null hypothesis at 5% and 10% respectively. $Z(t_{\tilde{\alpha}})$ is the version of the test with trend and intercept, $Z(t_{\alpha^*})$ contains an intercept and $Z(t_{\hat{\alpha}})$ has no deterministic component.

(b) ** and * denote rejection of the null hypothesis of stationarity at 1 and 5% respectively.

Table 4

Convergence summary results from the univariate tests

	PP tests		*KPSS tests*	
Countries	With trend	With constant	With constant	With trend
Bra-Arg	—	Yes	—	—
Bra-Bol	—	—	—	Yes
Bra-Chi	—	—	Yes	—
Bra-Par	—	—	Yes	Yes
Bra-Pe	—	—	—	Yes
Bra-Ur	—	Yes	—	—
Arg-Bol	—	—	—	—
Arg-Bra	—	Yes	—	—
Arg-Chi	—	—	—	—
Arg-Par	—	—	—	Yes
Arg-Pe	Yes	—	—	Yes
Arg-Ur	—	—	Yes	—

Note: The word “Yes” indicates that there is evidence in favour of convergence between the pairs of countries (rnotice that the tests have different null hypotheses).

Table 5
Multivariate Unit Root Tests: Common Autoregressive Coefficient

a) Abuaf & Jorion's test

Benchmark	Club		10%.	5%	1%
Brazil	Arg, Bol, Par, Ur	0.9254	0.8456	0.8228	0.7764
Brazil	Arg, Ch, Par, Ur	0.9290	0.8463	0.8230	0.7729
Brazil	Arg, Bol, Ch,Par, Pe, Ur	0.9397	0.8590	0.8411	0.7984
Argentina	Bo, Br, Ch, Par, Pe, Ur	0.9396	0.8591	0.8415	0.8046
Argentina	Bo, Br, Par, Ur	0.9253	0.8447	0.8209	0.7692

b) Taylor & Sarno's MADF test

Benchmark	Club	$MADF$	1%	5%	10%
Brazil	Arg, Bol, Par, Ur	18.07**	21.06	16.07	13.45
Brazil	Arg, Ch, Par, Ur	16.48*	22.60	16.85	14.11
Brazil	Arg,Bo,Ch,Par,Pe,Ur	26.89**	28.22	23.11	19.98
Argentina	Bo, Br, Ch, Par, Pe, Ur	25.47**	24.95	20.49	17.88
Argentina	Bo,Br,Par,Pe	22.33***	12.11	8.58	7.11

Note: (*), (**) and (***) denote rejection of the hypothesis of no convergence (non-stationarity) at 10, 5 and 1%, respectively.

Table 6

Flôres, Preumont & Szafarz's unit root test

Benchmark	Club		10%	5%	1%
Brazil	Arg.	0.9403	0.8929	0.8493	0.7337
	Bol.	0.9615**	0.9736	0.9666	0.9514
	Par.	0.8209^f	—	—	—
	Ur.	0.8709^f	—	—	—
Brazil	Arg.	0.9630	0.7971	0.7480	0.6313
	Chile	0.9356	0.8151	0.7694	0.6629
	Par.	0.8597^f	—	—	—
	Ur.	0.8988^f	—	—	—
Brazil	Arg.	0.9398	0.8882	0.8433	0.7348
	Bol.	0.9742	0.9640	0.9515	0.9169
	Chile	0.9169	0.8395	0.7932	0.6888
	Par.	0.8092^f	—	—	—
	Peru	0.9561	0.9126	0.8778	0.7799
	Ur.	0.8649^f	—	—	—
Argentina	Bol.	0.7388^f	—	—	—
	Br.	0.9359	0.9291	0.8951	0.8122
	Chile	1.0187	0.8842	0.8430	0.7477
	Par.	0.9180***	0.9874	0.9841	0.9777
	Peru	0.8125^f	—	—	—
	Ur.	0.9681	0.8460	0.8031	0.7017
Argentina	Bol.	0.6999^f	—	—	—
	Br.	0.9111***	0.9628	0.9512	0.9221
	Par.	0.9016***	0.9874	0.9845	0.9789
	Ur.	0.9632	0.8394	0.7938	0.6825

Notes: i) (*), (**) and (***) denote rejection of the hypothesis of no convergence (non-stationarity) at 10, 5 and 1% respectively; ii) ^{f} denotes the coefficients which were kept fixed in the second stage of the test.

Table 7
Breuer, McNown & Wallace's SURADF test

Benchmark	Club	$SURADF$	10%	5%	1%
Brazil	Arg.	-1.5139	-2.6078	-2.9567	-3.5321
	Bol.	-1.1295	-2.6071	-2.8799	-3.3770
	Par.	-2.8620***	-1.4187	-1.7661	-2.5482
	Ur.	-3.8242***	-1.5639	-1.9694	-2.6121
Brazil	Arg.	-1.3347	-2.6483	-2.9613	-3.4259
	Chile	-2.1436	-2.6204	-3.0250	-3.6580
	Par.	-2.6093***	-1.4279	-1.8076	-2.5175
	Ur.	-3.5516***	-1.7079	-2.1718	-3.0107
Brazil	Arg.	-1.5426	-2.6388	-2.9446	-3.6944
	Bol.	-0.9288	-2.8399	-3.1177	-3.8831
	Chile	-2.4687	-2.8802	-3.1977	-3.6871
	Par.	-2.8731***	-1.4613	-1.8143	-2.6380
	Pe	-2.8627***	-1.4579	-1.8416	-2.7360
	Ur.	-3.9108***	-1.7357	-2.1138	-2.8014
Argentina	Bol.	-4.2116***	-1.4918	-2.0026	-2.5366
	Br.	-2.6852*	-2.4203	-2.7576	-3.3863
	Chile	-0.1101	-2.7289	-2.0587	-3.6127
	Par.	-1.9066*	-1.6024	-1.9827	-2.7592
	Per.	-1.6859*	-1.4960	-1.8334	-2.6286
	Ur.	-1.1353	-2.7873	-3.0745	-3.6038
Argentina	Bol.	-3.9095***	-1.2735	-1.6804	-2.4260
	Br.	-2.4402*	-2.2765	-2.6010	-3.1357
	Par.	-1.3310***	-0.7734	-0.9155	-1.1190
	Per.	-1.9250**	-1.2542	-1.5442	-2.1332

Note: (*), (**) and (***) denote rejection of the hypothesis of no convergence (non-stationarity) at 10, 5 and 1%, respectively.

Table 8

Summary convergence results from the multivariate tests
that identify the converging countries.
[A "Yes" means evidence in favour of convergence; in the fraction between brackets, the numerator is the number of favourable evidences found and, the denominator, the number of times this was tested. A "—" means that no convergence was found.]

Countries	*FPS test*	*SURADF test*
Bra-Arg	—	—
Bra-Bol	Yes (1/2)	—
Bra-Chi	—	—
Bra-Par	Yes (3/3)	Yes (3/3)
Bra-Pe	—	Yes (1/1)
Bra-Ur	Yes (3/3)	Yes (3/3)
Arg-Bol	Yes (2/2)	Yes (2/2)
Arg-Bra	Yes (1/2)	Yes (2/2)*
Arg-Chi	—	—
Arg-Par	Yes (2/2)	Yes (2/2)
Arg-Pe	Yes (1/1)	Yes (2/2)
Arg-Ur	—	—

Note: * one of the evidences was a borderline rejection, at 10%.

ENSAIOS ECONÔMICOS DA EPGE

462. POLÍTICA DE COTAS E INCLUSÃO TRABALHISTA DAS PESSOAS COM DEFICIÊNCIA - Marcelo Côrtes Neri; Alexandre Pinto de Carvalho; Hessia Guilhermo Costilla – Novembro de 2002 – 67 págs.

463. SELETIVIDADE E MEDIDAS DE QUALIDADE DA EDUCAÇÃO BRASILEIRA 1995-2001 - Marcelo Côrtes Neri; Alexandre Pinto de Carvalho – Novembro de 2002 – 331 págs.

464. BRAZILIAN MACROECONOMICS WITH A HUMAN FACE: METROPOLITAN CRISIS, POVERTY AND SOCIAL TARGETS – Marcelo Côrtes Neri – Novembro de 2002 – 61 págs.

465. POBREZA, ATIVOS E SAÚDE NO BRASIL - Marcelo Côrtes Neri; Wagner L. Soares – Dezembro de 2002 – 29 págs.

466. INFLAÇÃO E FLEXIBILIDADE SALARIAL - Marcelo Côrtes Neri; Maurício Pinheiro – Dezembro de 2002 – 16 págs.

467. DISTRIBUTIVE EFFECTTS OF BRAZILIAN STRUCTURAL REFORMS - Marcelo Côrtes Neri; José Márcio Camargo – Dezembro de 2002 – 38 págs.

468. O TEMPO DAS CRIANÇAS - Marcelo Côrtes Neri; Daniela Costa – Dezembro de 2002 – 14 págs.

469. EMPLOYMENT AND PRODUCTIVITY IN BRAZIL IN THE NINETIES - José Márcio Camargo; Marcelo Côrtes Neri; Maurício Cortez Reis – Dezembro de 2002 – 32 págs.

470. THE ALIASING EFFECT, THE FEJER KERNEL AND TEMPORALLY AGGREGATED LONG MEMORY PROCESSES - Leonardo R. Souza – Janeiro de 2003 – 32 págs.

471. CUSTO DE CICLO ECONÔMICO NO BRASIL EM UM MODELO COM RESTRIÇÃO A CRÉDITO - Bárbara Vasconcelos Boavista da Cunha; Pedro Cavalcanti Ferreira – Janeiro de 2003 – 21 págs.

472. THE COSTS OF EDUCATION, LONGEVITY AND THE POVERTY OF NATIONS - Pedro Cavalcanti Ferreira; Samuel de Abreu Pessoa – Janeiro de 2003 – 31 págs.

473. A GENERALIZATION OF JUDD'S METHOD OF OUT-STEADY-STATE COMPARISONS IN PERFECT FORESIGHT MODELS - Paulo Barelli; Samuel de Abreu Pessoa – Fevereiro de 2003 – 7 págs.

474. AS LEIS DA FALÊNCIA: UMA ABORDAGEM ECONÔMICA - Aloísio Pessoa de Araújo – Fevereiro de 2003 – 25 págs.

475. THE LONG-RUN ECONOMIC IMPACT OF AIDS - Pedro Cavalcanti G. Ferreira; Samuel de Abreu Pessoa – Fevereiro de 2003 – 30 págs.

476. A MONETARY MECHANISM FOR SHARING CAPITAL: DIAMOND AND DYBVIG MEET KIYOTAKI AND WRIGHT – Ricardo de O. Cavalcanti – Fevereiro de 2003 – 16 págs.

477. INADA CONDITIONS IMPLY THAT PRODUCTION FUNCTION MUST BE ASYMPTOTICALLY COBB-DOUGLAS - Paulo Barelli; Samuel de Abreu Pessoa – Março de 2003 – 4 págs.

478. TEMPORAL AGGREGATION AND BANDWIDTH SELECTION IN ESTIMATING LONG MEMORY - Leonardo R. Souza - Março de 2003 – 19 págs.

479. A NOTE ON COLE AND STOCKMAN - Paulo Barelli; Samuel de Abreu Pessoa – Abril de 2003 – 8 págs.

480. A HIPÓTESE DAS EXPECTATIVAS NA ESTRUTURA A TERMO DE JUROS NO BRASIL: UMA APLICAÇÃO DE MODELOS DE VALOR PRESENTE - Alexandre Maia Correia Lima; João Victor Issler – Maio de 2003 – 30 págs.

481. ON THE WELFARE COSTS OF BUSINESS CYCLES IN THE 20TH CENTURY - João Victor Issler; Afonso Arinos de Mello Franco; Osmani Teixeira de Carvalho Guillén – Maio de 2003 – 29 págs.

482. RETORNOS ANORMAIS E ESTRATÉGIAS CONTRÁRIAS - Marco Antonio Bonomo; Ivana Dall'Agnol – Junho de 2003 – 27 págs.

483. EVOLUÇÃO DA PRODUTIVIDADE TOTAL DOS FATORES NA ECONOMIA BRASILEIRA: UMA ANÁLISE COMPARATIVA - Victor Gomes; Samuel de Abreu Pessoa;Fernando A . Veloso – Junho de 2003 – 45 págs.

484. MIGRAÇÃO, SELEÇÃO E DIFERENÇAS REGIONAIS DE RENDA NO BRASIL - Enestor da Rosa dos Santos Junior; Naércio Menezes Filho; Pedro Cavalcanti Ferreira – Junho de 2003 – 23 págs.

485. THE RISK PREMIUM ON BRAZILIAN GOVERNMENT DEBT, 1996-2002 - André Soares Loureiro; Fernando de Holanda Barbosa - Junho de 2003 – 16 págs.

486. FORECASTING ELECTRICITY DEMAND USING GENERALIZED LONG MEMORY - Lacir Jorge Soares; Leonardo Rocha Souza – Junho de 2003 – 22 págs.

487. USING IRREGULARLY SPACED RETURNS TO ESTIMATE MULTI-FACTOR MODELS: APPLICATION TO BRAZILIAN EQUITY DATA - Álvaro Veiga; Leonardo Rocha Souza – Junho de 2003 – 26 págs.

488. BOUNDS FOR THE PROBABILITY DISTRIBUTION FUNCTION OF THE LINEAR ACD PROCESS – Marcelo Fernandes – Julho de 2003 – 10 págs.

489. CONVEX COMBINATIONS OF LONG MEMORY ESTIMATES FROM DIFFERENT SAMPLING RATES - Leonardo R. Souza; Jeremy Smith; Reinaldo C. Souza – Julho de 2003 – 20 págs.

490. IDADE, INCAPACIDADE E A INFLAÇÃO DO NÚMERO DE PESSOAS COM DEFICIÊNCIA - Marcelo Neri ; Wagner Soares – Julho de 2003 – 54 págs.

491. FORECASTING ELECTRICITY LOAD DEMAND: ANALYSIS OF THE 2001 RATIONING PERIOD IN BRAZIL - Leonardo Rocha Souza; Lacir Jorge Soares – Julho de 2003 – 27 págs.

492. THE MISSING LINK: USING THE NBER RECESSION INDICATOR TO CONSTRUCT COINCIDENT AND LEADING INDICES OF ECONOMIC ACTIVITY - JoãoVictor Issler; Farshid Vahid – Agosto de 2003 – 26 págs.

493. REAL EXCHANGE RATE MISALIGNMENTS - Maria Cristina T. Terra; Frederico Estrella Carneiro Valladares – Agosto de 2003 – 26 págs.

494. ELASTICITY OF SUBSTITUTION BETWEEN CAPITAL AND LABOR: A PANEL DATA APPROACH - Samuel de Abreu Pessoa ; Silvia Matos Pessoa; Rafael Rob – Agosto de 2003 – 30 págs.

495. A EXPERIÊNCIA DE CRESCIMENTO DAS ECONOMIAS DE MERCADO NOS ÚLTIMOS 40 ANOS – Samuel de Abreu Pessoa – Agosto de 2003 – 22 págs.

496. NORMALITY UNDER UNCERTAINTY – Carlos Eugênio E. da Costa – Setembro de 2003 – 08 págs.

497. RISK SHARING AND THE HOUSEHOLD COLLECTIVE MODEL - Carlos Eugênio E. da Costa – Setembro de 2003 – 15 págs.

498. REDISTRIBUTION WITH UNOBSERVED 'EX-ANTE' CHOICES - Carlos Eugênio E. da Costa – Setembro de 2003 – 30 págs.

499. OPTIMAL TAXATION WITH GRADUAL LEARNING OF TYPES - Carlos Eugênio E. da Costa – Setembro de 2003 – 26 págs.

500. AVALIANDO PESQUISADORES E DEPARTAMENTOS DE ECONOMIA NO BRASIL A PARTIR DE CITAÇÕES INTERNACIONAIS - João Victor Issler; Rachel Couto Ferreira – Setembro de 2003 – 29 págs.

501. A FAMILY OF AUTOREGRESSIVE CONDITIONAL DURATION MODELS - Marcelo Fernandes; Joachim Grammig – Setembro de 2003 – 37 págs.

502. NONPARAMETRIC SPECIFICATION TESTS FOR CONDITIONAL DURATION MODELS - Marcelo Fernandes; Joachim Grammig – Setembro de 2003 – 42 págs.

503. A NOTE ON CHAMBERS'S "LONG MEMORY AND AGGREGATION IN MACROECONOMIC TIME SERIES" – Leonardo Rocha Souza – Setembro de 2003 – 11págs.

504. ON CHOICE OF TECHNIQUE IN THE ROBINSON-SOLOW-SRINIVASAN MODEL - M. Ali Khan – Setembro de 2003 – 34 págs.

505. ENDOGENOUS TIME-DEPENDENT RULES AND THE COSTS OF DISINFLATION WITH IMPERFECT CREDIBILITY - Marco Bonomo; Carlos Viana de Carvalho – Outubro de 2003 – 27 págs.

506. CAPITAIS INTERNACIONAIS: COMPLEMENTARES OU SUBSTITUTOS? - Carlos Hamilton V. Araújo; Renato G. Flôres Jr. – Outubro de 2003 – 24 págs.

507. TESTING PRODUCTION FUNCTIONS USED IN EMPIRICAL GROWTH STUDIES - Pedro Cavalcanti Ferreira; João Victor Issler; Samuel de Abreu Pessoa – Outubro de 2003 – 8 págs.

508. SHOULD EDUCATIONAL POLICIES BE REGRESSIVE ? Daniel Gottlieb; Humberto Moreira – Outubro de 2003 – 25 págs.

509. TRADE AND CO-OPERATION IN THE EU-MERCOSUL FREE TRADE AGREEMENT - Renato G. Flôres Jr. – Outubro de 2003 – 33 págs.

510. OUTPUT CONVERGENCE IN MERCOSUR: MULTIVARIATE TIME SERIES EVIDENCE - Mariam Camarero; Renato G. Flôres Jr; Cecílio Tamarit – Outubro de 2003 – 36 págs.