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GROWTH OF THE PERUVIAN ECONOMY AND CONVERGENCE IN THE REGIONS OF PERU: 1970-2010

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PONTIFICIA **UNIVERSIDAD CATÓLICA** DEL PERÚ

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Abstract

The Peruvian economy has been growing sustainably during the last 15 years. Verifying whether the Departments (or Regions) have achieved a process of convergence, be it towards a single stationary state or its own stationary state, would be equivalent to verifying a process of inclusion in the said process of growth. Basic characteristics of the national Census allow us to state that a great number of the Departments that still do not reach certain minimum criteria of subsistence are therefore in a clear process of exclusion. From this perspective, we think that the concept of convergence can give us some light over the situation. If convergence exists, it is probable that the said convergence is realized towards poverty or exclusion. In this document, different statistical tests are applied to verify the existence of stochastic and deterministic convergence, as well as a recent methodology for identifying the so-called clubs of convergence. The results of the application of the tests of unit root without structural break indicate the inexistence of stochastic convergence. However, when incorporating the presence of endogenous break the results get reversed for all the Departments with the exception of Huancavelica. The application of a statistic for structural break robust to the presence of errors of type I(0) and I(1) allow us to estimate the departamental rates of growth before and after the break. The results suggest that the majority of the Departments have accelerated their rates of growth after the breaking point. Some Departments show the inexistence of structural change and even a few cases show a deceleration of their rates of growth. On the other hand, evidence has been found about the formation of clubs of convergence that are robust to different order settings proposed by the methodology that was utilized. According to that methodology, the Departments of Apurimac and Huancavelica are not part of any club of convergence, which means that they are disconnected to the rest of the country.

Keywords: Convergence, Inclusion, Clubs of Convergence, per capita GDP

Classification: JEL: C22, O40, R00

Resumen

La economía peruana ha crecido sosteniblemente durante los últimos 15 años. Verificar si los departamentos (o regiones) han logrado un proceso de convergencia, ya sea hacia un único estado estacionario o su propio estado estacionario, sería equivalente a la verificación de un proceso de inclusión en dicho proceso de crecimiento. Características básicas del censo nacional nos permiten afirmar que un gran número de los departamentos que aún no llegan a ciertos criterios mínimos de subsistencia son, por tanto, en un claro proceso de exclusión. Desde esta perspectiva, consideramos que el concepto de convergencia nos puede dar un poco de luz sobre la situación. Si existe convergencia, es probable que dicha convergencia se realiza hacia la pobreza o la exclusión. En este documento, diferentes pruebas estadísticas se aplican para verificar la existencia de convergencia estocástica y determinística, así como una metodología reciente para la identificación de los denominados clubes de convergencia. Los resultados de la aplicación de las pruebas de raíz unitaria sin cambio estructural indican la inexistencia de convergencia estocástica. Sin embargo, al incorporar la presencia de ruptura endógena los resultados se invierten para todos los departamentos, con excepción de Huancavelica. La aplicación de un estadístico de quiebre estructural robusto a la presencia de errores de tipo I(0) e I(1) nos permite estimar las tasas departamentales de crecimiento antes y después del punto de quiebre identificado endógenamente. Los resultados sugieren que la mayoría de los Departamentos han acelerado sus tasas de crecimiento luego del punto de ruptura. Algunos departamentos muestran la inexistencia de cambios estructurales e incluso algunos casos muestran una desaceleración de sus tasas de crecimiento. Por otro lado, se ha encontrado evidencia acerca de la formación de clubes de convergencia que son robustos a diferentes tipos de ordenamiento sugeridos en la metodología . De acuerdo con esta metodología, los departamentos de Apurímac y Huancavelica no forman parte de ningún club de la convergencia, lo que significa que no están conectadas con el resto del país.

Palabras Claves: Convergencia, Inclusión, Clubes de Convergencia, PBI per cápita.

Clasificación JEL: C22, O40, R00

Growth of the Peruvian Economy and Convergence in the Regions of Peru: 1970-2010*

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1. Introduction

The probability that economies with lower per capita GDP exhibit higher rates of growth than the economies with higher per capita GDP and in that way that all the economies follow a unique path of growth or a unique stationary state, has been subject to theoretical and methodological discussion since the nineties. Romer (2006) maintains that there are at least three reasons why this phenomenon is reasonable. The first comes from the neoclassical model of growth. The second reason originates from the inverse relationship that exists between the rate of return on capital and the abundance of that factor, which as a consequence generates incentives for a flow of capital from the economies with high levels of capital per worker to economies with low levels of capital per worker. Finally, the third reason is that the diffusion of technology would eliminate a big part of the differences in incomes (per capita GDP) between economies (Kuznets, 1955).

The lack of robust empirical evidence for absolute β-convergence would suggest lack of support. On the contrary Barro and Sala-i-Martin (1991, 1992) propose extensions to the neoclassical model in such a way that economies would converge conditioned not to the distance that separates their per capita incomes from a unique stationary state, but to the distance that separates them from their own stationary state. In that manner, the conditional β-convergence transforms itself into a more plausible theoretical option, where only those economies with similar initial conditions tend to a

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common stationary state in the long term. A consequence of that is the possibility that a group of economies converge in a conditioned manner but not in absolute terms.

Theoretically, the differences between the stationary states of the economies are related to their capacity to absorb and adapt technologies, as well as with the macroeconomic environment and the policies of investment of each country. Sala-i-Martin (1996) argues that the differences in the speeds of convergence cannot be attributed only to the difference in technology levels, but also to factors such as geographic location, industrial development, labor market characteristics, and government policies.

Notwithstanding, the rejection of the hypothesis of absolute β-convergence between different countries does not imply a rejection of the absolute β-convergence between regions inside the same country. Moreover, it would be more probable that the regions inside the same country converge in an absolute manner towards the same path of growth due to the possible greater homogeneity that exists between them, and not only because they share the same government, rather also because they possess the same access to technologies (hence, the same potential level of factor productivity). However, the analysis of the absolute β-convergence between regions inside the same country could be invalid due to very small or inexistent barriers to the movement of factors between regions that violate the assumption of a closed economy of the neoclassical theory. Barro and Sala-i-Martin (2004) point out, with respect to that, that the dynamic properties of the regions with movement of capital, can be similar to those of closed economies if only a fraction of the stock of capital is not tradable or cannot be used as collateral for interregional transactions.

In the last decades, Peru has gone through different phases of economic models applied to the Peruvian context. The economy had to keep up with the comings and goings of different economic models, from models that have closed the economy to foreign markets and trade to models of a liberalized economy, with a reduction of tariffs and free trade agreements. All those types of agreements and commercial economic models as well as development models have had an important impact in the regional economies or Departments.

In the last decade it seems possible to observe an important growth in the more disconnected Departments of the national economy, something which has prompted authors such as Webb (2013) to point out that there exists from long time, a connection between the rural economies and the urban economies. All those changes could be configuring a process of convergence between the departmental economies towards a unique path of growth of per capita GDP, also called stationary state. These phenomena revive the concept of economic convergence, and in this article an analysis is made of the departamental convergence using modern methodologies to investigate the presence of stochastic convergence, deterministic convergence, and the presence of clubs of convergence inside the country.

A demonstration of the presence of convergence and the presence of clubs of convergence is important as it allows evidence to emerge regarding the existence of macroregions of development inside the country, which have an important potential as hubs of development once their economic strengths are identified. Notwithstanding this last point, it is important to mention that these macroregions get constituted due to the existence of interrelations that not only affect per capita GDP, but variables such as inequality, education levels, state of health, among others.

In that sense, the article sets against the possibility of stochastic convergence using contrasts of unit root without structural break and of unit root with endogenous structural break. In a second phase, a structural break test robust to I(0) or I(1) errors is applied that allow us to observe the existence of convergence between Departments. In a third phase, a search is done to identify clubs of convergence between the Departments of Peru using a methodology suggested by Phillips and Sul (2007).

The article is divided in the following sections: Section 2 shows the stylized facts, Section 3 makes a brief revision of the literature, Section 4 presents the theoretical framework, Section 5 presents the empirical evidence and in Section 6 the final conclusions of this work are presented.

2. Stylized Facts

In the last 40 years, the growth of real national per capita GDP has shown a clear irregular behavior (Figure 1). During the decade of the seventies, per capita GDP suffered five years of decrease and five years of increase, ending with growth superior to 5% by 1979. During the eighties, per capita GDP suffered a contraction of more than 10% by 1983, and the same happened between the years 1987-1989. With the unilateral liberalization of trade and the economy, per capita GDP recovered in an important way although with instability. It is starting from year 2001 that per capita GDP presents growth of more than 3% up until year 2010, with a sole decrease in year 2009 due to the international financial crisis.

On the other hand, Figure 2 shows the existing relationship between the natural logarithm of per capita GDP in year 2010 against the mean rate of growth between years 1970 and 2010 for each Department. A negative relationship is shown between both variables, giving evidence of a possible convergence between the Departments of the country. That is to say, there is a possibility that the departamental economies show a pattern of convergence towards a unique path of national growth where the poorer Departments (lower per capita GDP) reach the richer Departments (higher per capita GDP).

Nonetheless, we can observe that the Departments of Moquegua, Arequipa, Apurimac, Huánuco and Lima lie very far from the tendency, something which can indicate an economic performance disconnected from the rest of the country, which in turn weakens the evidence of convergence towards a single stationary state for the country. Figure 2 shows also that Madre de Dios, Tacna, Huánuco, Tumbes and Piura - Departments that began with higher levels of income (Madre de Dios and Tacna) and moderately high incomes (Huánuco, Tumbes and Piura) - had the worst economic performance when considering that their average growth rates were not positive in forty years.

On the other hand, Figure 3 shows a distribution of the natural logarithm of per capita GDP of the Departments of Peru for years 1970, 1990 and 2010, in order to be able to observe the changes that the country has been going through in those time frames. It can be observed that in the year 1970 the shown inequality in the distribution of income was big, having not only a distribution with the least average (i.e. the national average per capita GDP was the lowest) but also the width of the distribution was the highest, something which indicates a great dispersion between the per capita GDP's of the Departments in the sample. That situation did not change much in the year 1990, where the distribution shifts to the right, something which indicates growth in the national average, and the breadth of the distribution decreases little, indicating some advance in the inequality of domestic per capita GDP between the Departments. Already for the year 2010 the change is notorious, the inequality has decreased strongly (i.e. a higher national average of per capita GDP).

All the growth observed both in the national economies as well as in the subnational (departamental) economies has been reflected in their respective social and developmental indicators. In that sense, the main limiting factor in the analysis within the Departments from 1970 to year 2010 is the available data for each Department regarding their economic and social performance. The only evidence available in that respect is the National Census of 1972, which will be used as initial evidence of the economic and social situation in education and access to basic services. Additionally, statistical data from the *Compendio Estadístico Nacional* for 2010 will be used.

Table 1 shows the advance that the Departments have achieved in some socioeconomic indicators that will be used as indicators of development. Panel A shows the advance in educational terms, represented by the evolution of the rate of illiteracy for each Department for year 1972 (year of the National Census) and for year 2010 (extracted from the *Compendio Estadístico Nacional* published by Instituto Nacional de Estadística e Informática-INEI). Panel B shows the advance in living conditions by the type of dwelling inhabited, where B1 represents the percentage of Independent dwellings in the Departments, B2 refers to a Flat in a Building, B3 represents dwellings in a "Quinta" or Neighborhood with Divided Property, and finally B4 represents the percentage of Humble Dwellings. Panel C shows the living conditions in access to water through the percentage of dwellings with access to water by type of access, C1 refers to dwellings with access to water through public connections inside the dwelling or building, C2 refers to access to water through pipes, C3 refers to access through wells, and C4 refers to access through a water wagon. Finally, Panel D shows the expenditure capacity of the households through the percentage of households that do not possess any household appliances for the years 1972 and 2010, respectively.

Panel A shows that the illiteracy rate fell in average to 81% since 1972 and up until 2010 in the whole country. Also, in all of the Departments of the country there has been an important advance in the fight against illiteracy, with a reduction in the rates of illiteracy of more than 65% in all cases. Madre de Dios is the Department that reduced the rate of illiteracy the most, from 42% of the population to 5% in year 2010, representing thus a reduction in the rate of illiteracy of 89%, from the year 1972 to year 2010. Huánuco, on the other hand, has been the Department that has made the least progress with respect to illiteracy, reducing the rate of illiteracy from 59% to 19% for the year 2010, which represents an advance of 69% in the reduction of illiteracy.

Panel B shows that in 1972 there was much heterogeneity in the type of dwellings inhabited by the families in the Departments; however, in the majority of the Departments more than 50% of the dwellings corresponded to own dwellings. The national average was 65.2%, followed by 18.8% of dwellings that corresponded to humble dwellings. In the year 2007 (Census 2007) the national average of dwellings that corresponded to own homes increased to 87.1%, while the percentage of dwellings that corresponded to humble dwellings decreased to 6.0% with respect to year 1972.

According to Panel C, the percentage of dwellings that possessed connections to drinkable water inside the dwelling or the building at the national level was 20.8% for the year 1972, that percentage increased to 56.3% for the year 2007. Apurimac was the Department that had the lowest rates of connections to water inside the dwellings in 1972, with a rate of connected dwellings of 4.6%, while Lima possessed a rate of connection of 64%. For the year 2007, Lima was still the Department with the highest rate of connection, with 81% of the dwellings connected to water inside the dwelling or building, while Apurimac increased its rate to 52%, leaving the Department of Huancavelica in the last place with a rate of 30% (it started with 4.8% in 1972).

Panel D shows the proportion of dwellings that did not possess any type of domestic appliances: for year 1972, 46.4% of the dwellings did not possess domestic appliances in average at the national level; Apurimac was the Department with the highest proportion of dwellings without domestic appliances with 70%, while Lima possessed a proportion of 20%. For the year 2007, the national average of dwellings without domestic appliances reached a proportion of 18.9%; Huancavelica was the Department with more dwellings without domestic appliances with a proportion of 35%, while Lima reached a proportion of 7%.

In that way, with the help of the panels previously shown, it can be observed that poverty has multiple manifestations, particularly with low rates of connections to drinkable water, something which increases the sanitary problems of the most vulnerable sectors of the population. A further manifestation of the poverty situation presents itself through the lack of possession of domestic appliances, something which reflects the weak spending capacity of the poorest and the impossibility for them to acquire durable goods; that is to say, the poor work in order to live day by day, with a low capacity for savings.

The low rates of own dwellings and the high illiteracy rates are other forms in which poverty manifests itself. The high illiteracy rates reflect the low level of education that the poorest receive, something which will in the future determine the capacities that they possess to escape poverty, and thus illiteracy contributes to the vicious circle of poverty.

However, in all the cases, an important advance in the fight against poverty can be observed, with improved rates; it is worth mentioning that there exist high rates of heterogeneity in the forms that poverty displays itself between the Departments, and also that that heterogeneity decreased in an important manner for year 2007, showing the advance of the fight against poverty in all of the Departments and even though much of them showed little advance in several indicators or forms of poverty.

An important question that emerges from the stylized facts is whether a process of convergence between these Departments has been possible, be it towards higher poverty notwithstanding the national growth or towards better conditions that go hand in hand with the national growth experienced. In other terms, the question can be formulated as follows: is it so that these Departments or Regions have been included or excluded from the process of national growth? It is probable that many Departments or Regions have converged to different equilibria, distant from the national equilibrium, in which case we could talk of clear and definitive exclusion. It is also possible that an arrangement in groups or clubs of Departments with similar characteristics can be found and that they have grown with different rates and that they belong to different degrees of inclusion or exclusion.

3. Review of the Literature

In its majority, the literature has opted for a classic approach. Barro and Sala-i-Martin (1991, 2004) and Sala-i-Martin (1996) for the case of the United States find evidence of absolute convergence between its States for the period 1880 – 2000, a phenomenon which even prevails for sub-periods of ten years. The authors show that the speed of convergence increases when the stationary states remain conditioned by geographical location and when the productive structure by sector is considered to control for asymmetric shocks between the states.

Sala-i-Martin (1996) finds evidence of β-convergence for the period 1950-1990 between five countries of the OECD (Germany, France, United Kingdom, Italy and Spain) and also between those countries. The convergence that he finds is the conditional and the unconditional, and he finds rates of convergence of between 1% (Italy) and 3% (United Kingdom).

On the other hand, Barro and Sala-i-Martin (2004) analyze the 47 Japanese Prefectures and find evidence of β-convergence between 1930 and 1990; however, due to the presence of outliers and relevant structural breaks it was not possible to corroborate the robustness of the β-convergence in sub-periods. Other important references are: Barro (1991), Mankiw et al (1992), Lichtenberg (1994), Bernard and Durlauf (1995), De la Fuente (2003), Quah (1997) [1].

Nagaraj et al. (1998) find evidence of conditional convergence inside the regions of India for the period 1960-94, as well as convergence between the States that share similar financial characteristics, of infrastructure and of education. Further references for other countries are Siriopulus and Asterieu (1997), Mitchener and Mc. Lean (1999), Duncan and Fuentes (2005), Elias (1995).

For Latin America, Serra et al. (2006) do not find important evidence of regional convergence in the last 30 years. They find that the Argentinian regions do not converge, while the regions of Brazil, Colombia and Chile do converge in an absolute manner but with weakness in statistical terms, and thus arises the possibility of having "clubs of convergence" inside the regions of those countries. Cabrera-Castellano (2002) finds absolute β-convergence for the period 1970-1995 in Mexico. The authors find that the richer States at the beginning of the period did not converge between them, a phenomenon that does happen between the poorer States, something which suggests similarity between the economies.

For the Peruvian case, there are three studies that have analyzed the hypothesis of regional convergence using the neoclassical methodology. In first place, Gonzales de Olarte and Trelles (2004)[2], using panel data between 1970 and 1996, do not find evidence of convergence between the Departments, even though they show that the government's expenditures have effects that compensate the so-called stimulating and retardant forces. In second place, Serra et al. (2006) find evidence of unconditional convergence between 1970 and 2001, although at a slow rate of

[1] For a review, see De la Fuente (1997).

[2] For more details about the process of regionalization in Peru, see Gonzales de Olarte (1982).

approximately 1.4%. That velocity increases when eight groups of Departments are taken into account, something which indicates the existence of "clubs of convergence".

Finally, Delgado and Del Pozo (2011) find evidence of absolute convergence between 1979 and 2008 between the Peruvian Departments. However, when they make estimations for different sub-periods, it can be observed that the statistical significance of the economic convergence of per capita GDP strongly decreases. It is also shown that Moquegua is an important outlier, showing a disconnection between its economy and the rest of the country. It is additionally shown that if the Departments are conditioned through socioeconomic indicators, productive structures, levels of public expenditure, and dummy variables for geographical location, the hypothesis of conditional convergence gets strong support. They also deal with macroregions of development with the use of economic cycles, a first advance in the research on the existence of "clubs of convergence" between the Departments of Peru.

In the last years, a new current of theoretical and empirical work has utilized econometric tools of time series to analyze the existence of stochastic convergence and through that, the possibility of deterministic convergence as a second step.

Carlino and Mills (1993) show the existence of β-convergence in the regional per capita incomes in the States of the US for the period 1929-1990 using techniques of time series. They obtain evidence of persistent shocks in per capita incomes as it was not possible for them to reject the null hypothesis of unit root in the series. However, when they incorporate the possibility of a structural breaking point in 1946 they get results that are consistent with the existence of stochastic β-convergence accompanied by transitory shocks in per capita incomes. Loewy and Papell (1996) perform tests of unit root to the series of per capita income in eight regions of the United States and they incorporate the possibility of an unknown structural breaking point. Finally, they find evidence that is favorable to the presence of stochastic convergence in seven out of eight regions in North America.

Tomljanovich and Vogelsang (2002) argue, firstly, that the model of Carlino and Mills (1993) is wrongly specified if the errors do not follow an AR(2) process. Secondly, they argue that the assumption of a structural breaking point in 1946 in each region affects the power of the statistics utilized for determining the presence of stochastic convergence. The authors use econometric tests developed by Vogelsang (1998) to incorporate the possibility of an unknown breaking point and of robustness to the presence of errors of types I(0) and I(1). The statistic developed is asymptotically valid for serial correlation of the data, even in the presence of correlation of the type ARMA, and does not require the estimation of nuisance parameters; see Vogelsang (1997, 1998). Finally, they show evidence of β-convergence for the eight regions of the US between 1929 and 1990, even in the presence of serial correlation in the errors. They also mention that the evidence is strong when the breaking point is known and fixed in 1946.

Furthermore, Rodríguez (2006) analyses the presence of β-convergence or deterministic convergence in the ten Provinces of Canada for the period 1926-1999 after performing an analysis of stochastic convergence with a methodology of time series. The study allows unknown structural break and concludes that there exists sufficient evidence for the presence of β-convergence in the Provinces, as well as confirms that the role of the governmental transfers are not key for the finding of β-convergence but do accelerate the economic growth of the poorest Provinces.

From a different perspective, Phillips and Sul (2009) show evidence of the presence of β-convergence and clubs of convergence applying econometric tools developed by themselves (Phillips and Sul (2007)). The authors incorporate the possibility of heterogeneity in the patterns of growth as a consequence of technological disparities. The authors use three panels for their study, the first one uses 48 States of the US between 1929 and 1998; the second panel consists of 127 countries between 1950 and 2001; finally, the third panel includes 152 countries from 1970 until 2003 and 98 countries from 1960 to 2003. They do not find evidence of absolute convergence for the States of the US. For the case of the second and third panel, the authors find evidence of five clubs of convergence and one club of no convergence formed by 13 countries.

Recently, Hamit-Haggar (2012) finds evidence of the presence of β-convergence and clubs of convergence of per capita GDP, labor productivity, intensity of capital and growth in total factor productivity for the ten Canadian Provinces between 1981 and 2008. In the case of provincial per capita GDP, the study finds that there exist three clubs of convergence, two in the case of labor productivity, three in the case of the intensity of capital, and, finally, two in the case of total factor productivity.

In this way, the objective of this document is, in a first instance, to make an analysis of the presence of absolute β-convergence for the Departments of Peru using the methodologies of stochastic convergence and with the help of the statistics of unit root developed by the authors that we have already mentioned. We also apply a structural break test robust to I(0) or I(1) errors proposed by Perron and Yabu (2009a, 2009b). With the results obtained, we perform, in a final instance, an analysis of clubs of convergence using the methodology developed by Phillips and Sul (2007) and in the search for possible clubs of convergence of the Peruvian Departments towards different levels of stationary states.

4. Methodology

In this section we present the different statistics that are necessary to verify the hypothesis of stochastic convergence, deterministic convergence, and the identification of clubs of convergence. In a first instance, we present statistics of unit root without structural break such as the standard ADF (Said and Dickey, 1984), the ADF-GLS and PT-GLS (Elliott et al., 1996) and the MPT-GLS (Ng and Perron, 2001). In a second instance, we present the contrast of unit root with endogenous break suggested by Zivot and Andrews (1992)[3].

In order to analyze the presence of deterministic convergence we use Perron and Yabu (2009a), which is based on Perron and Yabu (2009b). They propose a statistic which test for structural change which is robust to the presence of errors I(0) or I(1)[4]. Finally, we apply the methodology proposed by Phillips and Sul (2007) for the analysis of the possible existence of clubs of convergence.

Let y_t be the logarithm of the ratio of per capita income of one Department with respect to the average per capita income of the country. Following Carlino and Mills (1993), we assume the existence of an invariant compensation in time of the differentials of the series with respect to their levels of equilibrium in the long run for each Department in relation to the national average. Under that assumption, y_t, possesses two parts; the differential equilibrium in the long run, y^e, and the deviations in the series with respect to the equilibrium in the long run, e_t (this occurs for each Department; however, we decided to omit the sub index *i* relative to each Department):

$$y_t = y^e + e_t \,. \qquad (1)$$

[3] We also applied the statistics suggested by Perron and Rodríguez (2003). The conclusions are similar. For lack of space, those results are available upon request.

[4] Previous references in this same sense are two statistics proposed by Vogelsang (1997, 1998). However, simulations of Perron and Yabu (2009a, 2009b) show that their statistic has good size and is more powerful. We applied both approaches but in order to save space we only present results of Perron and Yabu (2009a). Other results are available upon request; see also Delgado (2013).

On that respect, the deviation of the product in relation to its level of equilibrium is consistent with a functional form with intercept and deterministic tendency, as follows:

$$e_t = v_0 + \beta t + u_t, \quad (2)$$

where v_0 is the initial deviation from equilibrium and β is the deterministic rate of convergence. From equations (1) and (2), we obtain:

$$y_t = \mu + \beta t + u_t, \quad (3)$$

where $\mu = y^e + v_0$. The stochastic convergence requires that if a Department is above the initial level of equilibrium (roughly the initial level of per capita GDP) with respect to its long term value, i.e. $\mu > 0$, then the Department has to grow at a rate that is lower than the national average, i.e. $\beta < 0$. Similarly, if $\mu < 0$, then $\beta > 0$. In this way, the hypothesis of the presence of deterministic convergence can be corroborated.

With respect to the inference of the resulting parameters of the estimation, these cannot be interpreted in a direct way due to the fact that u_t is a random process serially correlated and could be an integrated process of order one, that is, I(1)[5]. More precisely, when u_t becomes a process I(0) the inference of β can be obtained from the estimation of the slope; and when u_t becomes a process I(1) that coefficient would be zero and the inference should be found from the estimation of the intercept in an autoregressive representation of y_t.

In this way, the statistics of unit root help to contrast the presence of stochastic convergence. If the stationarity of the series of the sample is corroborated, then the Departments converge to a unique stationary state (concept of absolute convergence). On the contrary, under the presence of unit root, the series converge towards a different stationary state, which would corroborate the presence of relative or conditional convergence. Nevertheless, it is necessary to take into account the possibility of structural breaks as part of the temporal behavior of the series. Thus, it becomes necessary to make tests of unit root under the context of series without structural break and with structural break.

[5] A process I(1) makes reference to a series that needs to be differentiated once to be transformed into a stationary series.

All the statistics, with the exception of the original Augmented Dickey-Fuller (Said and Dickey, 1984) are built using the suggestion made by Elliott et al. (1996), which is, using the GLS method to eliminate the deterministic components of the series under analysis. The ADF-GLS is based in the following equation:

$$\Delta\tilde{y}_t = \alpha_0\tilde{y}_{t-1} + \sum_{i=1}^{k} b_i\Delta\tilde{y}_{t-1} + e_t\,, \qquad (4)$$

where, $\tilde{y}_t = y_t - \hat{\psi}' z_t$, $H_0\colon \alpha_0 = 0$, z_t are the deterministic components, when there is no intercept and no trend $z_t = \{\phi\}$, intercept $z_t = \{1\}$, and intercept and trend $z_t = \{1, t\}$ and $\hat{\psi}'$are the GLS coefficients obtained from an OLS regression of $y_t^{\bar{\alpha}}$ versus $z_t^{\bar{\alpha}}$ where $y_t^{\bar{\alpha}} = (1-\bar{\alpha}L)y_t$ and $z_t^{\bar{\alpha}} = (1-\bar{\alpha}L)z_t$ for $t = 2, \dots, T$, $y_1^{\bar{\alpha}} = y_1$ y $z_1^{\bar{\alpha}} = z_1$. The asymptotic distribution is not standard and from that follows that we should use different critical values tabulated by Elliott et al. (1996). Those critical values depend on the nature of the deterministic components z_t.[6]

The following contrasts of unit root were suggested by Stock (1999) and analyzed by Ng and Perron (1996):[7]

$$MZ_\alpha = \frac{T^{-1}\tilde{y}_T^2 - s^2}{2T^{-2}\sum_{t=1}^{T}\tilde{y}_{t-1}^2}\,, \qquad (5)$$

$$MSB = \left[\frac{T^{-2}\sum_{t=1}^{T}\tilde{y}_{t-1}^2}{s^2}\right]^{1/2}, \qquad (6)$$

$$MZ_t = \frac{T^{-1}\tilde{y}_T^2 - s^2}{\left[4s^2T^{-2}\sum_{t=1}^{T}\tilde{y}_{t-1}^2\right]^{1/2}}\,, \qquad (7)$$

where s^2 is an autoregressive estimate of (2π times) the spectral density at the frequency zero and is defined by $s^2 = \frac{s_{ek}^2}{[1-\hat{b}(1)]^2}$, whose elements are obtained from equation (4). Finally, the statistic PT-GLS gets defined by:

$$P_T^{GLS} = \frac{S(\bar{\alpha}) - \bar{\alpha}S(1)}{s^2}\,, \qquad (8)$$

[6] The traditional or standard ADF is constructed in a similar way but in this case $\hat{\psi}'$ are the OLS coefficients obtained from a OLS regression of y_t versus x_t. The critical values were tabulated by Dickey and Fuller (1979) and Said and Dickey (1984).

[7] These statistics are modifications of other statistics; see Stock (1999), Ng and Perron (1996) for further details.

where $S(\bar{\alpha})$ and $S(1)$ are the Sums of the Squares of the Residuals of the GLS regressions with $\alpha = \bar{\alpha}$ and $\alpha = 1$, respectively.

On the other hand, with respect to the contrasts of unit root with structural break, the statistic of Zivot and Andrews (1992) is utilized. That contrast possesses as the null hypothesis an integrated series without structural break of the form $y_t = \mu + y_{t-1} + e_t$, where e_t can be of the form ARMA(p,q). The alternative hypothesis is represented by a stationary process with trend and structural break at an unknown point in time, where $\lambda = T_B/T$ is the parameter of location of the structural break. We choose a λ that minimizes the t-statistic of only one tail for the contrast of $\alpha^i = 1$, where a small t-statistic gets us to reject the null hypothesis, and where the supraindex "i" makes reference to models with break in the intercept, break in the trend and break in the intercept and the trend (i=1,2,3).

On the other hand, the contrast of Perron and Yabu (2009a) considers a structural change in the trend of a univariate series without the need to know the behavior of the error term; that is, if the noise is of type I(0) or I(1). Also, when the break is unknown the exponential function proposed possesses a statistic of limit distribution that is closely identical to errors of the type I(0) and I(1). Following Perron and Yabu (2009a), the structure of the model proposed by the authors is the following:

$$y_t = z'_t\psi + u_t, \qquad (9)$$

$$u_t = \alpha u_{t-1} + e_t, \qquad (10)$$

for t=1,…,T where $e_t \sim i.i.d.(0, \sigma^2)$, z_t is a vector of deterministic components, while ψ is a vector of unknown parameters. Additionally, $\alpha \in]-1,1]$, hence they allow for cases of first-order stationarity and integration in the error term. Regarding the presence of structural breaks, we have the following cases:

- Model I: structural change in the intercept. Hence $z_t = (1, DU_t, t)'$ and $\psi = (\mu_0, \mu_1, \beta_0)'$, where $DU_t = 1_{(t>T_B)}$. The alternative hypothesis is $\mu_1 = 0$.
- Model II: structural change in the trend. Hence $z_t = (1, t, DT_t)'$ and $\psi = (\mu_0, \beta_0, \beta_1)'$, where $DT_t = 1_{(t>T_B)}(t - T_B)$. The alternative hypothesis is $\beta_1 = 0$.

- Model III: structural change in the intercept and the trend. Hence $z_t = (1, DU_t, t, DT_t)'$ and $\psi = (\mu_0, \mu_1, \beta_0, \beta_1)'$. The alternative hypothesis is $\mu_1 = \beta_1 = 0$.

Taking into account that in practice α is unknown, the authors propose the estimation of Feasible Generalized Least Squares (FGLS) of ψ, applying the estimator of α:

$$\hat{\alpha} = \frac{\sum_{t=2}^{T} \hat{u}_t \hat{u}_{t-1}}{\sum_{t=2}^{T} \widehat{u^2}_t}, \qquad (11)$$

where $\hat{u}_t$ are the residuals of the estimation by OLS of y_t versus z_t. When $|\alpha| < 1$, the contrast of Wald obtained by the FGLS procedure still possesses a limit distribution $\chi^2(q)$.

Now, $\widehat{\Psi}$ is the estimator by FGLS of Ψ using $\hat{\alpha}$, that is, the estimator by OLS of the regression of $y_t^{\hat{\alpha}}$ versus $z_t^{\hat{\alpha}}$ where $y_t^{\hat{\alpha}} = (1 - \hat{\alpha}L)y_t$ and $z_t^{\hat{\alpha}} = (1 - \hat{\alpha}L)z_t$ for $t = 2, \dots, T$, $y_1^{\hat{\alpha}} = y_1$ and $z_1^{\hat{\alpha}} = z_1$. The residuals of the regression are symbolized by $\hat{e}_t$. The Wald statistic for the contrast of the null hypothesis of $R\Psi = \gamma$, is:

$$W_{FS}(\lambda) = \left[R\left(\widehat{\Psi} - \Psi\right)\right]'[s^2 R(Z'Z)R']^{-1}\left[R\left(\widehat{\Psi} - \Psi\right)\right], \qquad (12)$$

where $Z = z_t^{\hat{\alpha}}$ and $s^2 = T^{-1} \sum_{t=1}^{T} \hat{e}_t^2$, $\lambda = T_B/T$. It follows that if $|\alpha| < 1$, then $W_{FS}(\lambda) \overset{d}{\to} \chi^2(q)$. When the break is unknown, we use the following functional forms of the Wald statistic in order to take into account different possible structural breaks. That is, following Andrews (1993) and Andrews and Ploberger (1994) we have:

$$Mean - W_{FS} = T^{-1} \sum_{\Lambda} W_{FS}(\lambda'), \qquad (13)$$

$$Exp - W_{FS} = log\left[T^{-1} \sum_{\Lambda} exp\left(\frac{1}{2} W_{FS}(\lambda')\right)\right], \qquad (14)$$

$$sup - W_{FS} = \sup_{\Lambda} W_{FS}(\lambda'), \qquad (15)$$

where $\Lambda = \{\lambda'; \epsilon \leq \lambda' \leq 1 - \epsilon\}$, for some $\epsilon > 0$ denominated 'trimming'. The point T_B, hence λ', denote the structural break used to build a specific value of the Wald contrast. Based on simulations, Perron y Yabu (2009a) suggest the use of the statistic of equation (14), given that its critical values are very similar both to errors of type I(0) and I(1). However, with the aim of improving the performance of the statistic in finite samples, they make a corrected estimation of the unit root parameter based on Roy y Fuller (2001). Using this new estimator we apply a GLS transformation and we get an improved version of the Wald test, which will be denominated as W_{RQF} [8], and is defined as follows:

$$W_{RQF}(\lambda) = \left[R\left(\widetilde{\Psi} - \Psi\right)\right]'\left[\hat{h}_v R(Z'Z)R'\right]^{-1}\left[R\left(\widetilde{\Psi} - \Psi\right)\right], \qquad (16)$$

where $\widetilde{\Psi}$ is the FGLS estimator of Ψ using a corrected estimator of $\hat{\alpha}$, denominated $\tilde{\alpha}_{MS}$ and suggested by Roy and Fuller (2001), that is, the estimator by OLS of the following regression:

$$(1 - \tilde{\alpha}_{MS}L)y_t = (1 - \tilde{\alpha}_{MS}L)x'_t\Psi + (1 - \tilde{\alpha}_{MS}L)u_t, \qquad (17)$$

for $t = 2, \dots, T$, and where $y_1 = x'_1\Psi + u_1$.[9]

Finally we use a methodology developed by Phillips and Sul (2007) for the identification of clubs of convergence. That methodology allows us to incorporate the possibility of heterogeneity of cross section data of technical progress in a neoclassical growth model. In that respect, the growth model developed by Solow presupposes a homogeneous technological progress, therefore, in a cross section analysis, all the economies under study will experiment technological improvements at the same rate through time while they operate at different initial levels. Thus, it is interesting to incorporate heterogeneity in the rates of technological progress in the regions analyzed. Parente and Prescott (1993) incorporate the possibility of "Barriers of Adoption" in order to explain the heterogeneity of income in cross section data. Benhabib and Spiegel (1994) specified models where the possibility that technology depends on the level of the stock of human capital is incorporated.

Phillips and Sul (2009) incorporate heterogeneity that varies through time with the inclusion of a function of technological progress of the form $A_{it} = A_{i0}e^{X_{it}t}$, where the rate of growth of technological progress differs due to variable X_{it}, which changes between the departments and through time. Nevertheless, there is a chance of convergence at the same rate when t→∞ for all the departments or for a group of those that have a common trend inside of each group. Hence, under that technological heterogeneity, the individual transition path of the logarithm of per capita real income, $logy_{it}$, will depend on X_{it} of technological progress, and thus we have:

[8] Wald Robust Quasi Feasible GLS.

[9] For further details, see Perron and Yabu (2009a, 2009b).

$$logy_{it} = logy_i{}^* + logA_{i0} + [logy_{i0} - logy_i{}^*]e^{-\beta_{it}t} + X_{it}t, \qquad (18)$$

where log is the natural logarithm, $y_i{}^*$ is the stationary level of real per capita GDP, y_{i0} is the initial value of per capita GDP, X_{it} is the rate of growth of technical progress through time and β_{it} is the speed of convergence that changes through time. In this way, equation (18) can be written as follows:

$$logy_{it} = logy_i{}^* + logA_{i0} + [logy_{i0} - logy_i{}^*]e^{-\beta_{it}t} + X_{it}t = a_{it} + X_{it}t \ , \qquad (19)$$

where $a_{it} = logy_i{}^* + logA_{i0} + [logy_{i0} - logy_i{}^*]e^{-\beta_{it}t}$. Phillips and Sul (2007) modify in this way the equation and get the following form:

$$logy_{it} = \left(\frac{a_{it}+X_{it}t}{\mu_t}\right)\mu_t = \delta_{it}\mu_t, \qquad (20)$$

where δ_{it} measures explicitly the weight of the common trend μ_t that economy i experiments. In general, the coefficient of the idiosyncratic components, δ_{it}, captures the path of individual transition of an economy towards a path of growth of common stationary state determined by μ_t. During the period of transition, δ_{it} depends on the speed of convergence β_{it}, the rate of technical progress X_{it}, the initial technical base (A_{i0}) as well as on the levels of the stationary state ($y_i{}^*$) through the parameter a_{it}.

Phillips and Sul (2007) developed a contrast based on a regression of time series that includes a *test-t* of only one of the tails of the null hypothesis of convergence against the alternative that includes no convergence or convergence by subgroups. For the formulation of the null hypothesis of convergence in growth, they use a semi-parametric model for the transition coefficients that allows us to incorporate technological heterogeneity between individuals through time. If the null hypothesis is not rejected and $\delta_{it} = \delta_i$ for every i≠j, the model allows for periods of transition where $\delta_{it} \neq \delta_i$, therefore, it incorporates the possibility of transitional heterogeneity or even of transitional divergence through i. Therefore, the null hypothesis to be considered would be:

$$H_0: \quad \delta_{it} = \delta_i \text{ and } \alpha \geq 0. \qquad (21)$$

The alternative hypothesis in that regard would be represented by:

$$H_a: \{ \delta_i = \delta \text{ for every } i \text{ with } \alpha<0\} \text{ or } \{\delta_{it} \neq \delta_i \text{ for some } i, \text{ with } \alpha\geq 0, \text{ or } \alpha<0\}.$$

The alternative hypothesis includes divergence but also the possibility of having clubs of convergence. The model of regression *log-t* takes the following form:

$$log\left(\frac{H_1}{H_t}\right) - 2logL(t) = a + blogt + u_t, \quad \text{for } t=T_0,\ldots,T \qquad (22)$$

where $H_t = N^{-1}\sum_{i=1}^{N}(h_{it}-1)^2$, $h_{it} = \frac{logy_{it}}{N^{-1}\sum_{i=1}^{N} logy_{it}}$, L(t)=log(1+t). In the equation, the regression *log-t* is based on data of time series in which r% of the data is discarded. The second term on the left side of the equation, *-2logL(t)*, plays a role as a penalty function and improves the performance of the statistic in a particular way under the null hypothesis.

A detailed analysis of the agglomeration procedure was developed by Phillips and Sul (2007). This procedure can be summarized in the following four steps:

1. Ordering: Get the members in order under some criteria such as the averages of the data.
2. Group Formation: Find the members of the subgroups of the panel by estimating the regression *log-t* for k individuals with the highest per capita GDP with 2≤k≤N, and calculate the t-statistic under convergence. The members of the subgroup are elected based on the maximum t_k with t_k>-1.65.
3. Filter out the individuals for the formation of clubs: Add the new members of the k members elected in step 2 and contrast the performance of test *log-t*.
4. Stop rule: Estimate a regression *log-t* for the remaining members of the panel and observe if the criteria of convergence get fulfilled. That is to say, if the group with the remaining members satisfies the statistics of convergence, then those members form a second club of convergence. Otherwise, steps 1 to 3 get repeated in order to observe if the remaining members can be subdivided in other clubs of convergence. If no group can be formed in step 2, then those members present a divergent behavior.

5. Empirical Evidence

As a result of the contrasts of unit root, in all cases, except Puno and Tacna, it is not possible to reject the null hypothesis of unit root at 1% and 5%, respectively, suggesting that the shocks are not transitory and, as a consequence, that there is no presence of stochastic convergence or β-convergence. On the other hand, the presence of stationarity in the series suggests that those Departments present a convergent behavior towards their individual levels of stationary states (see Table 2).

Nevertheless, a visual analysis of the data suggests the possible presence of a structural break of the departamental per capita GDP. Then, a second analysis of the series of per capita GDP was done incorporating the possibility of a structural break unknown in mean, trend and in both of them. Table 3 shows the results of the statistic t_{α} when applying the contrast suggested by Zivot and Andrews (1992)[10]. The criterion for the election of lags is using BIC and the breaking point is chosen minimizing the value of the statistic as suggested by Zivot and Andrews (1992). When the null hypothesis that incorporates an intercept and trend cannot be rejected, a simpler model shall be used that incorporates a break in the trend and, finally, the possibility of a break in the intercept. In other words, it is assumed that the statistics lose power as the model used becomes more general. The results of the statistics by Zivot and Andrews (1992) lead us to reject the presence of unit root in all of the Departments with the exception of Huancavelica. That implies that with the exception of that Department, all the rest of the country presents stochastic β-convergence.

Table 4 presents the statistics by Perron and Yabu (2009a). It can be observed that the Departments that present a structural break that is significant at least at 10% are: Ancash, Apurimac, Arequipa, Ayacucho, Cajamarca, Cuzco, Huánuco, Ica, Lambayeque, Loreto, Lima, Moquegua, Piura, Puno, San Martin y Tumbes. For the Departments of Loreto and Moquegua the structural break presented itself before 1985, specifically in 1983, and it could have been a consequence of the El Niño Phenomenon that previously affected the country. Between 1989 and 1990, the Departments of Huánuco (1989), Lima (1989), Arequipa (1990), Ica (1990), and Puno (1990) had an important structural break that was a consequence of the severe economic crisis of the first administration of Alan García, which lead to big changes in the productive structures of the Departments. Between 1994 and 1995, Ayacucho (1994), Lambayeque (1994) and Cajamarca (1995), had structural breaks due to important structural reforms of the administration of Alberto Fujimori. In 1998, Tumbes suffered an important change in its pattern of economic growth as it was affected by the El Niño

[10] Zivot and Andrews (1992) use OLS in order to eliminate the deterministic components. However, we also applied GLS to eliminate the deterministic components as in Perron and Rodríguez (2003) and the results are similar. For lack of space, the results are available upon request.

Phenomenon, which caused big destruction in the country, and Tumbes was severely affected. Between years 2001 and 2002, Ancash (2001), Apurimac (2001), Piura (2001), San Martin (2001) and Cuzco (2002) suffered structural breaks in their paths of long term growth, something which had as a probable cause the changes brought about by the aggressive process of trade liberalization implemented by the government at that time and its effect on productive organizations.

Table 4 also shows information about the behavior of the rates of growth before and after the breaking point and we can observe the following. First, those Departments where the statistic W_{RQF} does not reject the null hypothesis means that there is no structural change, that is, there was no change that was statistically significant in the behavior of the rates of growth, in other words, it is possible to argue that in those cases the growth rates before and after the breaking point are equal. Those Departments are: Amazonas, Huancavelica, Junin, La Libertad, Madre de Dios, Pasco y Tacna. Second, in those Departments where the statistic W_{RQF} is statistically significant we can observe that in the majority of cases the rate of growth after the breaking point is positive and greater than the rate of growth before the breaking point. For instance, in the case of Ancash the statistic W_{RQF}=33.32 which is significant at 1% and it indicates that that Department has jumped from a rate of growth of -0.57% to 1.39%, and where the year 2001 is the breaking point. We could state that Ancash has entered a process of growth since 2001. Similar are the cases of Apurimac, Ayacucho, Cajamarca, Ica, Lambayeque, Lima, Puno and Tumbes. In the cases of Cuzco, Piura and an Martin, the increases in the rates of growth before and after the breaking point have been higher. Third, and in contrast to the previous cases, there are few cases in which the statistic W_{RQF} is statistically significant but where the rates of growth in those Departments have been opposite, and those are the cases of: Huánuco, but above all Loreto and Moquegua, where there was a slowing down of growth (Huánuco) or a strong decrease in the rate of growth (Loreto and Moquegua). Specially, Moquegua called our attention because its rate of growth goes down from 5.91% to 0.47%, 1983 being the breaking point.

Using as a reference the article by Phillips and Sul (2009) for the analysis of clubs of convergence, Table 5 shows the *log-t* for clubs of convergence of per capita GDP for the Departments of Peru in the period 1970-2010. The upper part of Table 5 shows the results of contrasting the hypothesis of absolute convergence and of clubs of convergence for the departamental per capita GDP. As can be inferred, the null hypothesis of absolute convergence can be rejected at 1% significance, showing a t-statistic of -83.994, less than the critical value at 1% of -2.345. From there we proceed to contrast the hypothesis to find possible clubs of convergence of per capita GDP using the algorithm suggested by Phillips and Sul (2007). In order to improve the robustness of the contrast, we performed five estimations to obtain clubs of convergence under different orderings of the data base according to the suggestions made by the authors. The first contrast was performed with a data base without any ordering. The second contrast was performed with a data base ordered from higher to lower per capita GDP according to the average of the whole time period, that is, from 1970 to 2010. The third contrast was performed under the ordering from higher to lower per capita GDP according to the average from 1994 to 2010. The fourth contrast was performed under a decreasing ordering of per capita GDP during the last ten years (2001 - 2010). Finally, the fifth contrast was performed under a decreasing ordering of per capita GDP during the last 5 years (2006 - 2010).

The test of clubs of convergence shows the existence of three clubs of convergence under the five orderings and that the members of those three clubs are the same Departments under these orderings, something which corroborates the robustness of the results. The first club of convergence is constituted by Ancash, Arequipa, Ayacucho, Cuzco, Ica, La Libertad, Lima, Madre de Dios, Moquegua, Pasco and Tacna. We can observe as well that, according to Figures 4a and 4b, the Departments that form the club of convergence are reducing the distances and getting closer to a unique stationary state within the club. The most evident case is Moquegua, which until 1983 shows high rates of growth, something which at first sight seems to lead the Department to a disconnection with the rest; however, after 1983 the trend gets reversed and the Department starts a process of convergence to a stationary state.

The second club is formed by: Amazonas, Cajamarca, Junin, Lambayeque, and Piura. Figure 5 shows the Departments that form the club converge to a unique stationary state. The most evident case is Piura, which starts with a relative per capita GDP that is above the club and starts to get closer to the stationary state at dynamic rates.

The third club is formed by: Huánuco, Loreto, Puno, San Martin, and Tumbes. Figure 6 shows the process and the dynamic of convergence of the Departments that form this club of convergence.

That Figure shows the case of Loreto, which until the end of the seventies possessed a dynamic of convergence, began the eighties with a process of transition and later on starts a dynamic of convergence towards the stationary state of the club of convergence.

Finally, the Departments of Apurimac and Huancavelica are not able to form a club of convergence between them, something which leads us to conclude that the evolution of their per capita GDP in time is divergent towards their own levels of stationary states (relative or conditional convergence).[11]

6. Conclusions

This document analyses the existence of absolute, deterministic convergence, as well as identifies clubs of convergence using information on the per capita GDP of the Departments of Peru. With that purpose in mind we used different econometric tools such as statistics of unit root with or without structural break, statistics of structural breaks that are robust to the level of persistence of the errors to identify breaks in the rates of growth of the Departments and regressions to identify the formation of clubs of convergence between the Departments of the country. This analysis allows us to observe those Departments that have benefitted from national growth, those that are at a standstill and also those that are disconnected from the process of national growth.

The results of applying the tests of unit root without structural break indicate the inexistence of stochastic convergence. However, when we incorporate the presence of endogenous breaks, the result gets reversed for all the Departments with the exception of Huancavelica. After applying a statistic of structural breaks that is robust to the presence of errors of type I(0) and I(1) allows us to estimate the departamental rates of growth before and after the break. The results suggest that the majority of the Departments have accelerated their rates of growth after the breaking point. Some Departments do not show the existence of structural change and some few cases show a deceleration of their rates of growth. On the other hand, we have found evidence of the formation of clubs of convergence that are robust to different orderings suggested by the methodology applied. According to that methodology, the Departments of Apurimac and Huancavelica do not

[11] We also identified clubs of convergence under the methodology previously detailed but using as inputs the Regions suggested by Gonzales de Olarte and Trelles (2004), and we obtained the same formation of clubs as in Table 5.

form part of any club of convergence, which is equivalent to saying that they are disconnected from the rest of the country.

Indeed, using as a reference the works of Phillips and Sul (2007, 2009), we abandon the assumption of homogeneity in the diffusion of technology and allow for the inclusion of particularities in it, that is to say, we allow for heterogeneity in the adoption of technology between the different Departments of Peru. Additionally, we introduce an analysis of possible clubs of convergence. In that way, in a first approximation, we reject the hypothesis of null absolute convergence, in correspondence to previous analyses with time series. In a second step, we find the existence of three clubs of convergence. The first club of convergence, Club 1, formed by 11 Departments, shows a stable dynamic of growth and initial levels of per capita GDP higher than the rest of clubs (see Table 5). The second club of convergence, Club 2, formed by 5 Departments, shows an average dynamic in its rates of growth of per capita GDP, as well as average initial incomes (see Table 5). Finally, Club 3, is formed by 5 Departments with low initial levels of per capita GDP and rates of growth that lack in dynamics (see Table 5). We also show that Huancavelica and Apurimac are Departments that do not belong to any club and have different dynamics than the rest of clubs and departamental economies, forming by themselves clubs that converge towards their own levels of stationary states. These findings were robust to the different orderings suggested by the methodology of Phillips and Sul (2007). We proposed five different orderings: no ordering, by the average of the whole sample, by the average since 1994, by the average since the last ten years and by the average of the last five years. In all cases, the results were the same and significant at 1%.

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Table 1. Socio-Economic Indicators 1972 - 2010 by Departments

Panel A: Departamental Illiteracy Rates

	Amz	Anc	Apu	Arq	Ayc	Caj	Cuz	Hcva	Hua	Ica	Jun	Lib	Lamb	Lim	Lor	MdD	Moq	Pas	Piu	Pun	Sma	Tac	Tum
1972	40	53	72	33	69	59	62	69	59	31	44	42	38	25	46	42	38	51	49	59	45	33	35
2010	10	11	16	5	15	15	13	18	19	5	7	8	8	3	6	5	5	7	9	12	7	4	4

Panel B: Percentage of Dwellings: by type of Dweelling

		Amz	Anc	Apu	Arq	Ayc	Caj	Cuz	Hcva	Hua	Ica	Jun	Lib	Lamb	Lim	Lor	MdD	Moq	Pas	Piu	Pun	Sma	Tac	Tum
1972	B1	68	80	80	70	60	16	59	70	79	85	78	85	84	52	48	21	75	9	84	62	71	74	90
	B2	0	0.4	0	1.1	0.1	0.1	0.6	0	0.2	1.7	0.8	0.5	0.9	12	0.2	0	3.1	0.2	0.5	0.2	0	7.5	0.3
	B3	1.2	2.8	2.2	14	4.7	1	13	2.2	4	8.2	13	4.8	4.7	21	2.1	2.7	5.3	5.8	0.6	5.1	0.9	11	1.9
	B4	19	11	18	11	34	27	28	27	17	2.8	7	8.1	9.5	0.3	47	74	10	0.3	12	32	26	5.7	6.2
2007	B1	85	95	92	89	87	93	83	91	87	84	84	94	93	79	79	78	86	84	96	82	84	82	95
	B2	0.3	0.6	0.4	2.9	0.4	0.8	1.9	0.1	1.3	1.4	2.1	2.7	3.1	14	0.4	0.6	3.9	1.3	0.9	0.4	0.3	4.6	1
	B3	3.1	0.9	2.6	2.9	2.1	2	7.1	2.5	2	2	4.8	1.9	2	4.5	2.9	12	0.7	4.8	0.4	2.4	4.1	1.2	2.9
	B4	11	1.9	4.8	3	9.5	3.5	6.8	6.5	9.5	2	8.7	1	1	0.3	17	7.7	3.3	9.3	1	14	11	4.7	0.3

Panel C: Percentage of Dwellings with access to water: by type of access

		Amz	Anc	Apu	Arq	Ayc	Caj	Cuz	Hcva	Hua	Ica	Jun	Lib	Lamb	Lim	Lor	MdD	Moq	Pas	Piu	Pun	Sma	Tac	Tum
1972	C1	8.2	9.8	4.6	40	7.8	6.9	17	4.8	9.9	37	24	25	32	64	14	12	28	17	20	5.6	8.8	58	23
	C2	11	14	8.4	11	13	5.1	12	11	5.3	27	23	16	15	8.7	4.6	4.2	13	38	17	6.4	5.1	11	40
	C3	18	6.2	1.2	6.2	2	13	5.1	3	4.7	14	7.1	7.8	15	3.7	16	6.7	2.3	3.7	4.7	43	12	3.6	5.8
	C4	1.3	11	0.1	5.2	0.2	0.1	0.1	0.1	0.1	8.7	0.1	8.1	1.2	16	0.3	0.7	14	0.1	4	0.1	0	2.4	11
2007	C1	41	69	52	74	51	56	61	30	34	73	59	63	64	81	34	62	70	35	58	37	51	71	68
	C2	1.6	2.8	2.3	5.8	4.1	2.4	3.3	4.1	3.6	3.6	1.7	1.9	5.4	3.9	3.4	4.4	6.4	4.2	5.1	2.6	1.7	15	4.9
	C3	10	6.3	2.8	2.8	3.6	16	3.1	5.4	9.2	7.3	4.4	13	18	2.5	21	14	0.9	5.2	5.8	32	11	3.5	2.1
	C4	0.1	0.5	0	5.8	0.9	0.1	0.2	0.1	0.8	5.4	0.2	2	1.8	8.5	2.3	0.7	0.7	0.5	4	0.9	0.2	2.4	4.3

Panel D: Percentage of Dwellings without any appliance

	Amz	Anc	Apu	Arq	Ayc	Caj	Cuz	Hcva	Hua	Ica	Jun	Lib	Lamb	Lim	Lor	MdD	Moq	Pas	Piu	Pun	Sma	Tac	Tum
1972	62	53	79	33	70	66	60	66	57	26	39	40	28	20	42	41	38	35	45	55	54	29	30
2007	26	19	29	10	29	18	13	35	28	13	18	14	12	7	35	18	11	16	17	26	17	11	12

Note 1: To reduce the size of the Table is set some abbreviations, which are: Amazonas (Amz), Ancash (Anc), Apurimac (Apu), Arequipa (Arq), Ayacucho (Ayac), Cajamarca (Caj), Cuzco (Cuz), Huancavelica (Hcva), Huanuco (Hua), Ica (Ica), Junín (Jun), La Libertad (Lib), Lambayeque (Lamb), Lima (Lim), Loreto (Lor), Mother of God (MoD), Moquegua (Moq), Pasco (Pas), Piura (Piu), Puno (Pun), San Martin (Sma), Tacna (Tac) and Tumbes (Tum).

Note 2: Due to the lack of statistical and departmental levels representative surveys for the range 1970-2010, we have decided to use as a basis comparable National Census of 1972 and 2007.

Source: INEI, National Census 1972 and 2007.

Table 2. Tests of Unit Root without Structural Break

Department	ADF		ADF-GLS		PT-GLS		MPT-GLS	
	Statistic	Lag	Statistic	Lag	Statistic	Lag	Statistic	Lag
Amazonas	-2.357	1	-2.2030	1	10.940	1	10.629	1
Ancash	-2.447	1	-1.7710	1	22.600	1	16.171	1
Apurímac	-2.248	1	-1.9260	1	15.550	1	13.353	1
Arequipa	-2.206	3	-1.6970	0	20.830	3	15.479	0
Ayacucho	-1.775	1	-1.6580	0	15.985	1	16.135	0
Cajamarca	-1.572	0	-1.6980	0	15.500	0	16.199	0
Cuzco	-2.060	0	-2.1840	0	10.788	0	11.296	0
Huancavelica	-0.623	5	-1.1930	0	186.380	5	23.831	0
Huánuco	-0.945	6	-0.8500	1	71.310	6	32.407	1
Ica	-1.568	3	-0.4680	4	136.450	3	32.848	4
Junín	-2.458	0	-2.4480	0	9.960	0	10.034	0
La Libertad	-1.966	3	-1.5990	2	20.200	3	14.855	2
Lambayeque	-1.676	1	-1.6170	1	17.910	1	17.981	1
Lima	-1.159	3	-1.6870	3	20.440	3	14.823	3
Loreto	-2.082	9	-1.4340	0	74.380	9	28.514	0
Madre de Dios	-2.476	0	-2.5350	0	9.000	0	9.390	0
Moquegua	-2.541	1	-1.9910	9	7.790	1	11.664	9
Pasco	-0.845	0	-1.4410	0	14.220	0	14.545	0
Piura	-1.809	3	-1.5040	3	18.850	3	15.578	3
Puno	-2.828	4	-2.2010	4	3.920	4	10.226	4
San Martin	-2.532	1	-1.9650	1	9.100	1	12.527	1
Tacna	-4.080	8	-1.2830	0	10.610	8	252.135	0
Tumbes	-2.090	1	-1.8870	1	16.340	1	15.159	1
C.Value at 10%	-3.190		-2.8900		6.770		6.670	
C.Value at 5%	-3.520		-3.1900		5.720		5.480	
C.Value at 1%	-4.210		-3.7700		4.220		4.030	

Lag length has been selected using MAIC of Ng and Perron (2001). Note: a, b and c mean significant at 1%, 5% and 10%, respectively.

Table 3. Test of Unit Root with Structural Break: Zivot-Andrews (1992)

Department	t_α	k	$\widehat{T}_B$	$\hat{\alpha}$	Deterministic Component
Amazonas	-4.398[a]	0	1994	0.360	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Ancash	-6.522[a]	0	2001	0.190	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Apurímac	-5.867[a]	2	2001	0.000	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Arequipa	-5.968[a]	2	1977	0.290	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Ayacucho	-5.314[a]	3	1977	0.430	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Cajamarca	-2.797[c]	3	1982	0.580	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Cuzco	-3.896[a]	0	2001	0.560	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Huancavelica	-2.401	4	2002	0.750	$z_t = \{1, 1(t \geq T_b)\}$
Huánuco	-6.023[a]	2	2001	-0.500	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Ica	-3.690[a]	0	1990	0.530	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Junín	-5.627[a]	0	1984	0.170	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
La Libertad	-6.014[a]	1	1977	0.440	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Lambayeque	-3.142[b]	2	1987	0.590	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Lima	-4.482[a]	1	1989	0.450	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Loreto	-11.007[a]	4	1978	0.230	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Madre de Dios	-4.556[a]	0	1977	0.460	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Moquegua	-8.070[a]	0	1977	0.140	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Pasco	-4.723[a]	0	2001	0.300	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Piura	-4.312[a]	0	1976	0.390	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Puno	-4.945[a]	0	1998	0.200	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
San Martin	-4.465[a]	4	1980	0.390	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Tacna	-7.972[a]	4	1977	-0.200	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$
Tumbes	-4.275[a]	0	1998	0.430	$z_t = \{1, 1(t \geq T_b), t, 1(t \geq T_b)(t - T_b)\}$

Note: a, b and c mean significant at 1%, 5% and 10%, respectively

Table 4. Test of Structural Change of Perron and Yabu (2009a)

Department	W_{RQF}	T_B	Growth Rates	
			Pre-T_B	Post-T_B
Amazonas	2.104	1991	0.92	1.34
Ancash	33.32[a]	2001	-0.57	1.39
Apurímac	4.133[b]	2001	-0.20	1.71
Arequipa	2.688[c]	1990	-0.03	1.51
Ayacucho	5.228[b]	1994	-0.46	1.43
Cajamarca	3.133[b]	1995	-0.12	1.29
Cuzco	4.133[b]	2002	0.32	3.64
Huancavelica	1.963	1989	-0.05	0.15
Huánuco	6.011[a]	1989	0.87	0.46
Ica	5.622[b]	1990	-0.64	1.62
Junín	1.999	1989	-0.18	0.97
La Libertad	2.345	1990	-0.20	1.53
Lambayeque	4.290[b]	1994	-0.23	0.42
Lima	3.718[b]	1989	-0.59	1.17
Loreto	5.692[a]	1983	4.96	-0.48
Madre de Dios	1.813	1989	-1.25	0.36
Moquegua	28.960[a]	1983	5.91	0.47
Pasco	2.146	1989	0.60	1.04
Piura	11.620[a]	2001	-0.55	2.13
Puno	6.504[a]	1990	0.02	1.29
San Martin	5.439[a]	2001	-0.14	2.33
Tacna	1.672	1990	-1.28	0.51
Tumbes	3.571[b]	1998	-0.26	0.95
Critical Value at 1%	5.25			
Critical Value at 5%	3.12			
Critical Value at 10%	2.48			

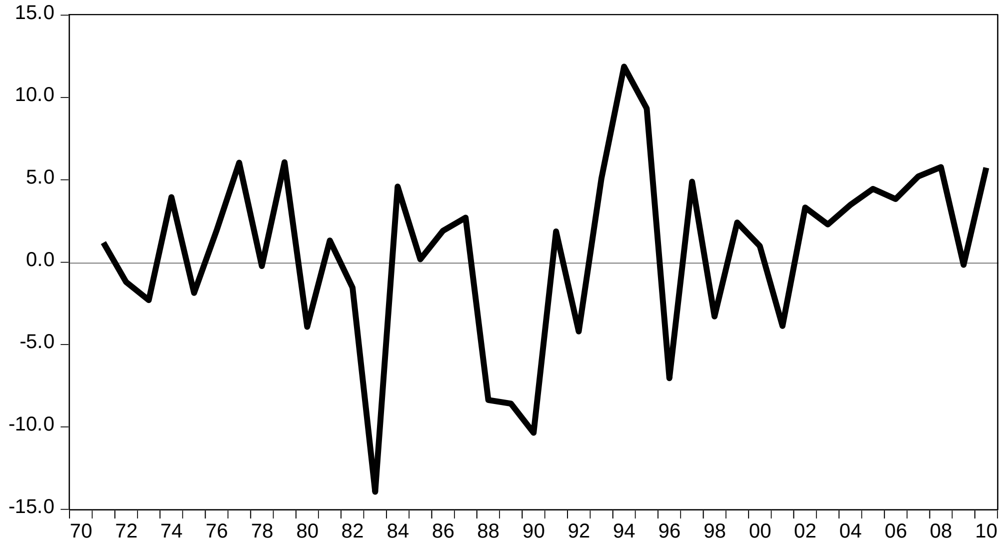
Note: a, b and c mean significant at 1%, 5% and 10%, respectively.

Table 5. Convergence clubs of per capita GDP

Types of Convergence	log-t	t-statistic
Test of Absolute Convergence	-0.538	-53.857
Test of Convergence at 1%		
First Club of Convergence	-0.033	-1.125
Ancash, Arequipa, Ayacucho, Cuzco, Ica, La Libertad, Lima, Madre de Dios, Moquegua, Pasco y Tacna		
Second Club of Convergence	0.680	7.211
Amazonas, Cajamarca, Junín, Lambayeque, y Piura		
Third Club of Convergence	1.440	36.030
Huánuco, Loreto, Puno, San Martín, y Tumbes		
Fourth Club of Convergence	-0.230	-3.684
Apurímac, y Huancavelica		

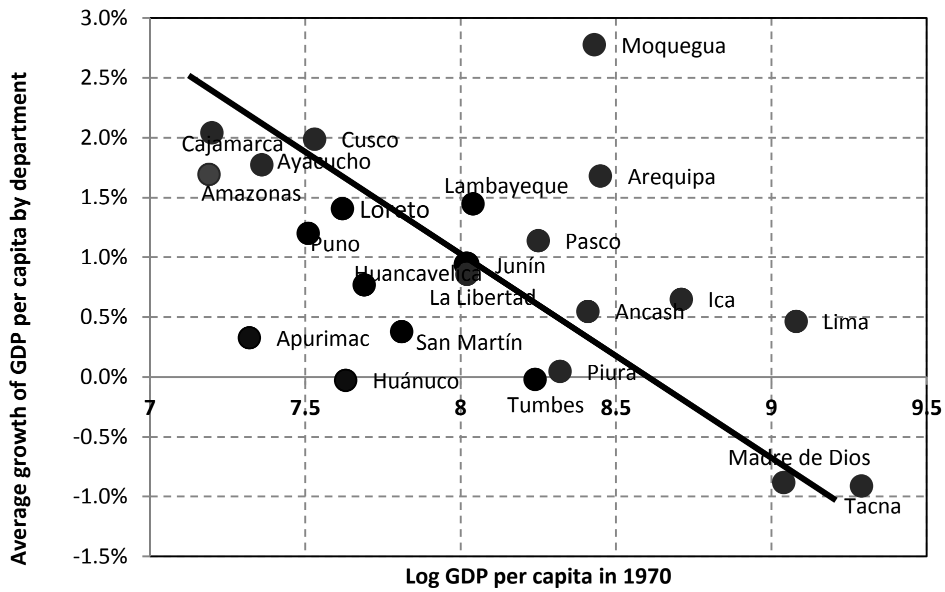
Note: Orders used are: (i) no order, (ii) average of the period from 1970 to 2010, (iii) average since 1994 to 2010, (iv) average of the last 10 years, from 2001 to 2010, and (v) average of the last five years, from 2006 to 2010.

Figure 1. Growth of GDP per capita (%) 1970-2010



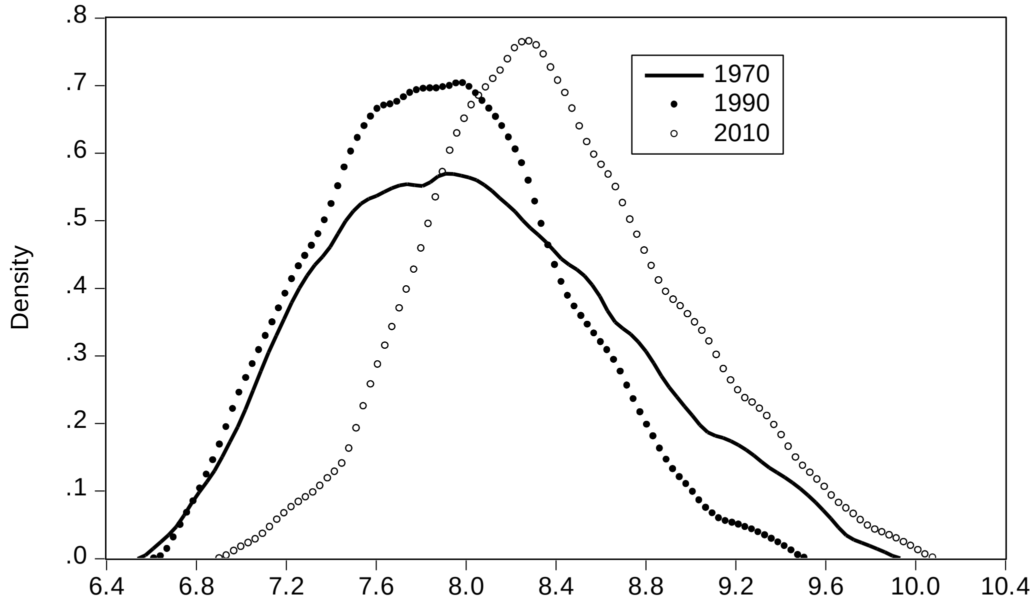
Source: INEI

Figure 2. Relationship between Initial GDP per capita and Average Growth by department



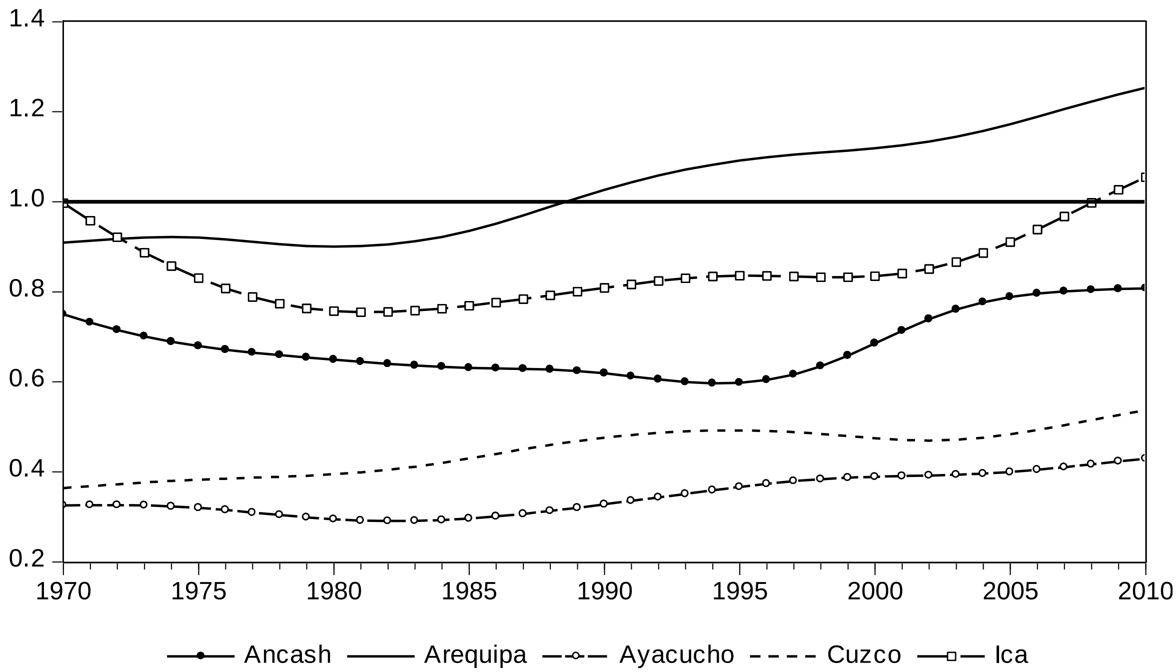
Source: INEI

Figure 3. Distribution of the natural logarithm of GDP per capita of the Departments of Peru for the years: 1970, 1990 and 2010



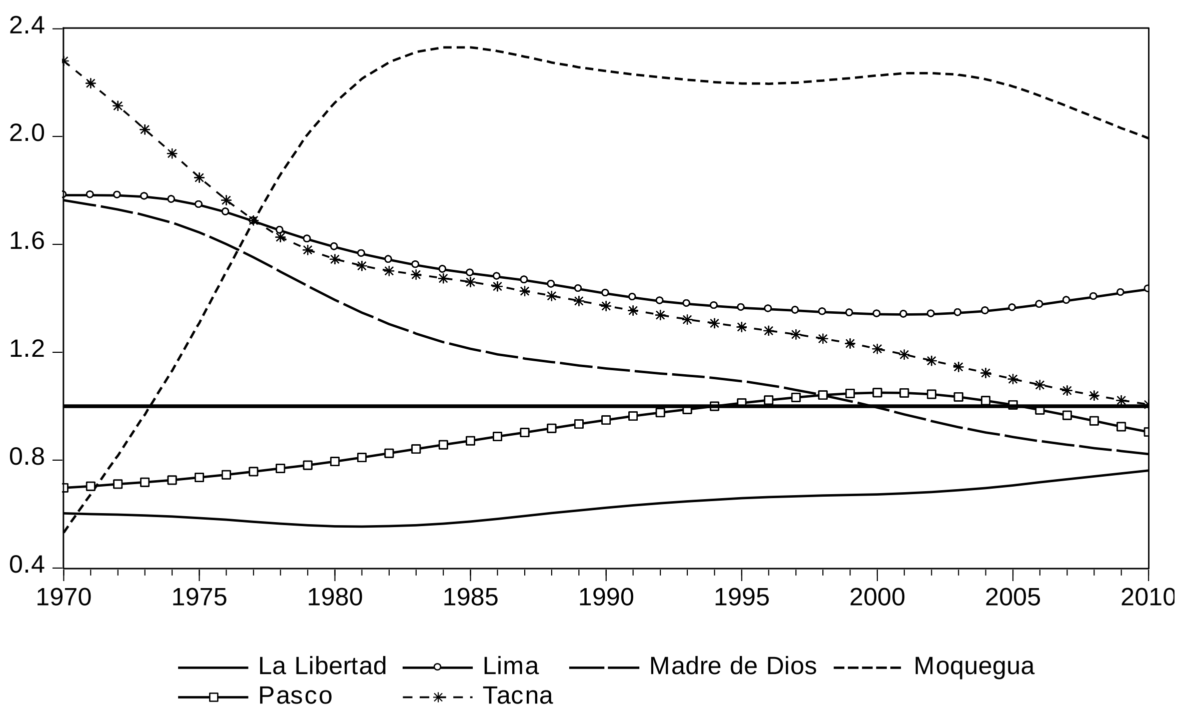
Source: INEI

Figure 4a. First Club of Convergence



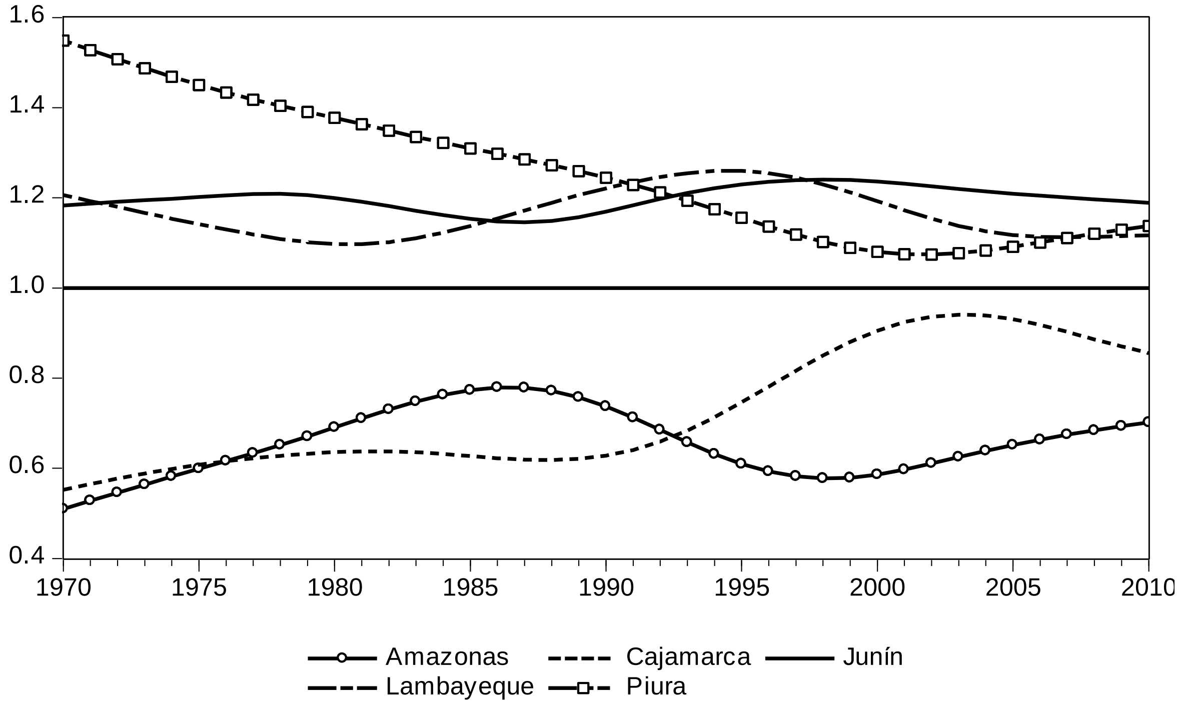
Source: INEI

Figure 4b (cont.). First Club of Convergence



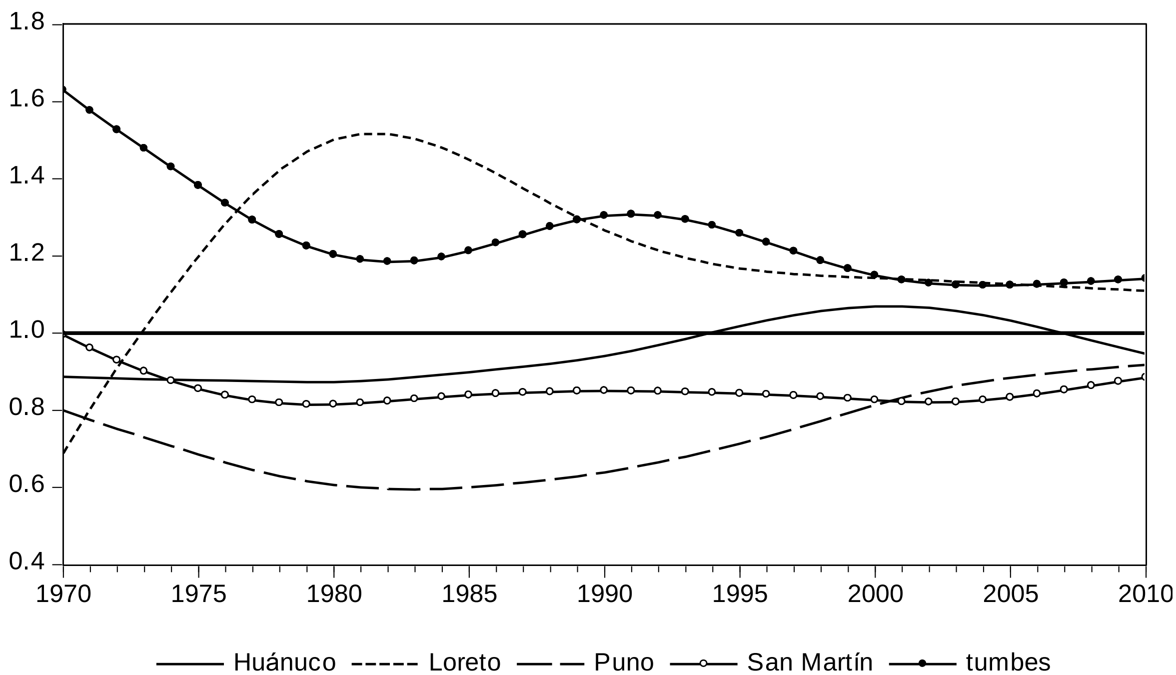
Source: INEI

Figure 5. Second Club of Convergence



Source: INEI

Figure 6. Third Club of Convergence



Source: INEI

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