Regional convergence in Italy: time series approaches

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1. Introduction

The hypothesis of economic convergence, emerged first from the neoclassical growth theory models in the '50s, has been widely debated in recent decades. Both theoretical and empirical literature contributed greatly to refine the concept of this economic phenomenon. The initial notion of β-convergence has been usually used to analyse both an absolute and a conditional definition of convergence where the first states that economies with the same starting economic conditions (saving rates, population growth, technology level,…), diminishing returns and lower capital endowments grow faster than richer economies, while the second hypothesises different steady states due to differences in initial economic conditions. Recent studies (Battisti M, Di Vaio G., 2008 among others) show that the analysis of absolute β-convergence is appropriate only for testing the *within*-country convergence because regional economies share the same governmental policies, the same property rights and so on.

Another field of economists (Quah 1993, Friedman, 1994), instead, suggests that convergence should be rather analysed through the dynamics of income level and/or growth rate dispersion across economies, namely the σ-convergence.

Besides, since Baumol (1986), it has been widely hypothesised that convergence may hold rather within groups of economies showing similar characteristics (Azariadis and Drazen, 1990). This evidence is referred to as the "convergence club" hypothesis which implies that a set of economies may converge to each other, in the sense that in the long run they tend towards a common steady state position, but there is no convergence across different sets.

Finally, the idea that income convergence is the result of a technological catch-up process gave rise to a concept of total factor productivity (TFP) convergence.

The above concepts of convergence were initially all investigated through cross-section (Barro, 1991, Mankiw *et al*., 1992, *i.e.*) and subsequently with time series (Bernard and Durlauf, 1995; Vogelsang and Tomljanovich 2002, Galvao and Gomes, 2007) and panel (Islam, 1995; Evans, 1998; Bianchi and Menegatti., 2007, *i.e.*) methods. Particularly, two time series notions of convergence follow: a deterministic and a stochastic one. According to these concepts the deviation of an economy's income from a reference economy or the sample average, could present a deterministic or a stochastic trend, respectively, when testing for unit root hypothesis.

As it regards regional convergence, the analysis is complicated because of the economies' instabilities and cyclical fluctuactions (Quah, 1992; Eckey H.F., Turck M., 2007). Durlauf *et al*. (2005) pointed out that advanced economies may be better investigated using time series methodologies which use all the information rather than only the first and last values, emphasizing the convergence dynamics.

Following their suggestion, in this work we apply time series approaches to examine Italian regional convergence.

Previous empirical analyses showed contrasting results: Cellini and Scorcu (1995), among others, could not confirm the presence of a stable process of convergence across Italian regions; D'Amato and Pistoresi (1997) rejected the presence of a clear dualistic structure for the Italian economy; Arbia *et al*. (2005) confirm the presence of a structural break in the growth path of Italian provinces at the beginning of the seventies and a stronger convergence process in the first period (1950-1970).

Given past empirical literature results, this paper deepens the investigation of the gap between Italian regions (20 regions at NUTS2 level) and Italy as a whole during the period 1980-2007. Particularly, the work is aimed to verify the presence of an "actual" convergence process, that is the simultaneous presence of a stochastic and a β convergence, which, as far as we know, has not yet been implemented for the Italian regions. The analysis starts with unit root tests (Augmented Dickey-Fuller and Kwiatkowski-Phillips-Schmidt-Shin tests) in order to verify whether regional income deviation from the Italian average may convergence stochastically (De Siano, D'Uva, 2006, 2008). Results shows the absence of a stochastic convergence for most of the Italian regions. However, the possibility that regions do not share a unique pattern during the observed period suggests to go beyond the unit root results, modifying the model in order to allow for an exogenous instantaneous break in the series (1992 as break year[1]) as in the Additive Outlier model (AO).

Since Carlino and Mills (1993) argue that both β-convergence and stochastic convergence are necessary for actual convergence we also tested the β-convergence hypothesis considering the presence of a break both known (1992) and unknown (endogenously estimated from the data). Joint analysis of the AO model, for the stochastic convergence, and the trend break model, for the β-convergence, shows that most of the regions does not converge in an "actual" way before and after the break in both known and unknown trend break date models.

The paper is structured as follows: section 2 describes the methodology; section 3 discusses the econometric results and section 4 concludes. The appendix shows tables containing the econometric results.

2. Methodology

The first part of the econometric analysis aims to test stochastic convergence for Italian regions. This notion of convergence means that if the logarithm of a region's per

[1] We considered 1992 as a break year in the regressions since in this year Italy abandoned the European Monetary System and the Italian currency began to follow a flexible exchange rate regime with considerable effects on competitiveness and hence on international trade. Besides, in this year the extraordinary subsidies to the Southern Italian regions were suspended.

capita income relative to the whole country average does not contain a unit root, the region stochastically converges. The model we used (Ben-David, 1994; Qing Li, 1999) is the following:

$$y_{i,t} = \alpha_i + \beta_i t + \varphi y_{i,t-1} + \varepsilon_{i,t} \qquad (1)$$

where $y_{i,t}$ is the log of region *i* per capita income in year t, *t* is a time trend and ε is a white noise zero mean error. Summing the equation 1 for all regions and dividing the outcome by the number of regions, we obtain:

$$\overline{y}_t = \overline{\alpha} + \overline{\beta} t + \varphi \overline{y}_{t-1} + \varepsilon_t \qquad (2)$$

where $\overline{y}_t$ is the Italian overall average per capita income in year *t*.

Subtracting equation *2* from *1* we have:

$$RI_{i,t} = A + Bt + \varphi RI_{i,t-1} + \varepsilon_t \qquad (3)$$

where $RI_{i,t}$ is the logarithm of region *i* per capita income relative to the Italian average at time *t* ($y_{i,t}$ - $\overline{y}_t$).

For each region we apply the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979) using the ADF regression of equation 3:

$$\Delta RI_t = \mu + \beta t + \alpha RI_{t-1} + \sum_{j=1}^{k} c_j \Delta RI_{t-j} + \varepsilon_t \qquad (4)$$

Finally, considering the low power of the ADF test in the case of short time series, we also ran the Kwiatkowski-Phillips-Schmidt-Shin (1992) test (KPSS) for trend stationarity[2].

The eventuality that a region shows different patterns during the observed period suggests the opportunity of further analysis since a one-time change in the deterministic path could be mistaken for a persistent stochastic shock (Perron, 1989; Campbell and Perron, 1991). Therefore we modified the model by introducing an instantaneous

[2] The null hypothesis of the KPSS test is the trend stationarity against the unit root alternative

exogenous trend break, using an additive outlier model (AO) which enables a change in the slope while keeping the two paths joined at the time of break, that is 1992.

The AO model is estimated in two steps. First we run the following equation:

$$RI_t = \mu + \beta t + \theta DU_t + \gamma DT_t + \rho_t \qquad (5)$$

where ρ is the residual, DU_t=1 if t >T_B, and 0 otherwise, DT_t= t -T_B if t >T_B, and 0 otherwise.

In the second step we test the hypothesis that α=0 in the following regression:

$$\Delta\rho_t = \sum_{i=0}^{k} \omega_i D(T_B)_{t-i} + \alpha\rho_{t-1} + \sum_{j=1}^{k} c_j \Delta\rho_{t-j} + \varepsilon_t \qquad (6)$$

where $D(T_B)_{t-i}$=1 if t=T_B-i+1, and 0 otherwise. The dummy variables ensure that the t-statistics on α in eq. 6 is invariant to the value of *k*. We estimate the exogenous trend break model considering 1992 as the break year. We apply the procedure *k*=*k*(*t*-stat) (Campbell and Perron, 1991; Ng and Perron, 1995). Starting with an upper bound k_{max}=8 (Perron, 1989) on *k*, if the last included lag is significant we choose *k*= k_{max}=8, if not we reduce *k* by 1 until the last lag becomes significant. If no lags are significant, we set *k*=0.The asymptotical critical values are reported by Perron (1989).

In order to also test the presence of a β-convergence process we followed an approach recently proposed by Vogelsang and Tomljanovich (2002).Generally, investigation of *β*-convergence consists of testing hypotheses on the parameters of a deterministic relative per capita income trend function. Let y_t be the logarithm of the ratio of regional per capita income to the average at country level. The y_t trend function will be as follows:

$$y_t = \mu + \beta t + u_t \qquad (7)$$

where *t* indicates the trend and u_t zero mean random errors serially correlated. Given this expression, *μ* represents the initial level of *y* while *β* is its growth rate. For the misspecification and interpretation problems deriving from the presence of serial correlation both in data and error terms Vogelsang and Tomljanovich (2002) proposed modified statistics to perform significance tests on μ and β coefficients derived by simple OLS regressions. Two regressions are estimated. The first is given by:

$$y_t = \mu_1 DU_{1t} + \beta_1 DT_{1t} + \mu_2 DU_{2t} + \beta_2 DT_{2t} + u_t \qquad (8)$$

where $DU_{1t} = 1$ if $t \leq T_b$ and 0 otherwise, $DU_{2t} = 1$ if $t > T_b$ and 0 otherwise, $DT_{1t} = t$ if $t \leq T_b$ and 0 otherwise, $DT_{2t} = t - T_b$ if $t > T_b$ and 0 otherwise, with T_b as the break year which could generate a change in the parameters of the trend function. Then, since the choice of break points based on prior observation of the data may cause pre-testing problems we will consider the break both known (equal to 1992) and unknown. In the latter case it will be estimated endogenously from the data.

Parameters μ_1 and μ_2 indicate whether relative income of a region, respectively before and after the break, is either below ($\mu_i < 0$) or above ($\mu_i > 0$) the average country level while β_1 and β_2 are growth rates during the two periods.

The second regression is as follows:

$$z_t = \mu_1 SDU_{1t} + \beta_1 SDT_{1t} + \mu_2 SDU_{2t} + \beta_2 SDT_{2t} + S_t \qquad (9)$$

where, using partial sums, $z_t = \sum_{j=1}^{t} y_j$, $SDU_{it} = \sum_{j=1}^{t} DU_{ij}$, with i=1,2 and $SDT_{it} = \sum_{j=1}^{t} DT_{ij}$,with i=1,2.

For the convergence hypothesis all the parameters μ_i and β_i should be statistically significant and have signs consistent with convergence, that is $\beta_i < 0$ when $\mu_i > 0$ or the contrary. In testing these hypotheses Vogelsang (1997) provides modifications of the t_y and t_z[3] statistics computed by the standard OLS regressions in order to gain more robustness for results in the presence of serial correlation in the data and errors I(0) or

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[3] t_y and t_z are the t statistics for testing $\mu_i = 0$ and $\beta_i = 0$ in regressions (8) and (9).

I(1). For the y_t regression the appropriate modified t-statistics are simply $T^{-1/2}\ t_y$ where T is the sample size. For the z_t regression the appropriate modified t-statistics are defined as $t\text{-}PS_t = T^{-1/2}\ t_z exp(-bJ_T)$, where b is a constant and J_T is a statistic proposed by Park and Choi (1988) and Park (1990) for testing the null hypothesis that trend function errors (eq. 7) have an autoregressive unit root[4]. $J_T = (RSS_y — RSS_j)/ RSS_j$ where RSS_y is the OLS residual sum of squares from regression (8) and RSS_j is the residual sum of squares from the following regression[5]

$$y_t = \mu_1 DU_{1t} + \beta_1 DT_{1t} + \mu_2 DU_{2t} + \beta_2 DT_{2t} + \sum_{i=2}^{9} c_i t^i + \mu_t \qquad (10)$$

The $t\text{-}PS_t$ statistic contains the parameter b whose choice depends on the significance level, in the sense that it is given such that the asymptotic critical value of the statistics is the same when the errors are stationary (I(0)) and when they have a unit root (I(1)). A value of zero will be given if errors are known to be I(0). In this case, therefore, no J_T correction will be necessary.

Asymptotic distributions for the modified statistics depend on the break date used in the regressions and, in particular, whether the break date is assumed known or unknown. When unknown, the break date can be identified from the data, estimating regression (8) for break dates in the range T_b*, T_b* + 1,..., T - T_b*, with T_b* = λT where λ indicates the amount of trimming. For each regression, T^{-1} is multiplied by the Wald statistic for testing the no break hypothesis, that is $\mu_1 = \mu_2$ joined to $\beta_1 = \beta_2$. The endogenous break date is that corresponding to the largest normalized Wald statistic. Although this procedure avoids some data-mining problems related to an *a priori* choice, giving fewer statistically significant point estimates, it potentially damps the results in favour of β–convergence.

[4] Critical values for both the modified statistics are tabulated by Vogelsang (1997).
[5] Vogelsang (1998) recommended that the polynomial order should be 9 because for greater orders the increase in power of the $t\text{-}PS_t$ test is paltry

3. Empirical results

This section presents the results of the econometric models described above. Sample data consist of the GDP per inhabitant (ISTAT database) for all Italian regions during the period 1980-2007.

The combined analysis of ADF and KPSS tests run on the entire sample period shows the absence of a stochastic convergence for most of the Italian regions. Only Calabria and Tuscany strongly converge while Piemonte, Friuli Venezia Giulia, Lazio, Abruzzo and Sardinia weakly convergence (table 1). This outcome suggests that whenever a shock to relative regional per capita income occurs it has permanent effects for the majority of the sample.

The results of the stochastic convergence analysis in presence of an exogenous trend break in the series carried through the AO model are presented in table 2. On the whole, they evidence the presence of a unit root process. Among the regions only Tuscany, Umbria, Molise, Puglia and Basilicata converge stochastically when a break in 1992 is assumed.

Finally, in order to verify the presence of actual convergence we proceed to estimate also the β-convergence following a time series approach. Results are shown in tables 3-6. Tables 3-5 show the estimated coefficients together with the modified *t*-statistics (in parentheses) of y_t regression (equation 8), z_t regression (equation 9) without J_T correction and with J_T correction, respectively for both known and unknown trend break date models. In particular, in table 5 the t-PS_T statistic, computed by applying J_T correction, is presented both for 10% and 5% (the first and second, respectively). Besides, the tables report the modified *t*-statistic's critical values at 10% and 5% in the last two rows and the estimated break date for the unknown trend break date model in the last column.

Table 6 summarizes the results of tables 3, 4 and 5. As β-convergence requires $\mu>0$ and $\beta<0$ or $\mu<0$ and $\beta>0$, we use the letter *C* to indicate the point estimates (μ and β) compatible with β convergence statistically significant at least at the 10% level; *c* signifies point estimates compatible with β-convergence but with only one coefficient statistically significant at least at the 10% level; *D* and d mark the presence of a divergence process with both or only one coefficient statistically significant, respectively; finally, E is a sign of very small and statistically insignificant point estimates denoting that β-convergence has already occurred.

The first outcome is that even if the trend break date is estimated endogenously the selected year is very close to the exogenous one (1992).

Secondly, all the estimates of μ_1 , except of Friuli Venezia Giulia and Marche, are statistically different from zero both in the known and unknown trend break date models, meaning that initial per capita incomes were different with respect to the Italian average for all of them.

Econometric results relative to the known trend break date model show a different behaviour of the Italian regions before and after the break. Before 1992 only Valle D'Aosta, Trentino Alto-Adige Liguria, Emilia-Romagna, Toscana, Abruzzo, Lazio, Molise, Puglia, show a convergence process. Valle d'Aosta, Trentino Alto Adige, Emilia Romagna, Tuscany, Molise, Puglia and Calabria show evidence of β-convergence also in the second period. Finally, Friuli-Venezia Giulia and Umbria diverge both before and after the break.

The unknown break date model confirms the outcome of the known one, except for the behaviour of Puglia that diverge before the break.

Whatever break is chosen (known or unknown) results are more pronounced when the z_t model without J_t correction is used to estimate the β-convergence.

Joint analysis of the AO model for the stochastic convergence and the trend break model for the β-convergence shows that only Tuscany, Molise and Puglia may converge in an "actual" way in both periods while Basilicata converges only in the post break period.

4. Concluding remarks

This paper investigates the evolution of the gap between Italian regions and Italy as a whole during the period 1980-2007. In particular, we tested for the presence of the stochastic and the β convergence hypotheses using different time series approaches. Stochastic convergence was studied initially for the whole sample period using the traditional ADF and KPSS tests. Then, since regions may not share a unique pattern during the observed period, we modified the model allowing for an exogenous instantaneous break in the series (1992). Unit root results without a break show the absence of a stochastic convergence for most of the Italian regions. When including a break only Tuscany, Umbria, Molise, Puglia and Basilicata converge stochastically.

The β-convergence hypothesis has been analyzed considering a trend break in the series. Since the choice of break points based on prior observation of the data may cause pre-testing problems we considered the break both known (1992) and unknown (endogenously estimated from the data). Results of the known trend break date model evidence the absence of an "actual" convergence process for most of the Italian regions before and after the break both in the known and unknown break date models. Whatever break is chosen (known or unknown) results are more pronounced when the z_t model without J_t correction is used to estimate the β-convergence.

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Table 1. *ADF and KPSS tests results*

Regions	ADF statistics	KPSS statistics *l=4*	Regions	ADF Statistics	KPSS statistics *l=4*
Piemonte	-2.081	0.104	Marche	-2.153	0.138***
Valle D'Aosta	-3.048	0.158**	Lazio	-2.436	0.118
Lombardy	-1.120	0.143***	Campania	-1.262	0.137***
Trentino Alto-Adige	-2.158	0.155**	Abruzzo	-2.417	0.077
Veneto	-1.242	0.146**	Molise	-3.641*	0.153**
Friuli Venezia Giulia	-2.429	0.090	Puglia	-2.627	0.146***
Liguria	-1.680	0.137***	Basilicata	-2.451	0.139***
Emilia Romagna	-1.901	0.142***	Calabria	-3.973*	0.072
Tuscany	-4.371**	0.107	Sicily	-1.149	0.149**
Umbria	-2.905	0.192**	Sardinia	-2.183	0.093

*and ** denote statistical significance using unit root critical values at the 5% (-3.592) and 1% (-4.362) while ***, ** and * denote statistical significance using KPSS stationary critical values at the 10% level (0.119), 5% level (0.146) and 1% level (0.216), respectively.

Table 2. *AO model results*

Regions	α	$t_α$	k	Regions	α	$t_α$	k
Piemonte	-1.134	-3.81	3	Marche	-0.689	-3.73	0
Valle D'Aosta	-0.609	-3.52	0	Lazio	-0.893	-3.18	3
Lombardy	-0.494	-3.85	1	Campania	-0.709	-3.65	1
Trentino Alto-Adige	-0.423	-1.63	2	Abruzzo	-0.753	-3.83	0
Veneto	-0.856	-3.33	3	Molise	-0.615*	-3.97	0
Friuli Venezia Giulia	-0.664	-3.52	1	Puglia	-1.474*	-4.23	3
Liguria	-1.788	-3.60	4	Basilicata	-0.850*	-4.14	1
Emilia Romagna	-1.107	-3.62	3	Calabria	-0.738	-2.51	1
Tuscany	-1.284***	-6.69	0	Sicily	-0.668	-3.42	0
Umbria	-1.199***	-5.03	3	Sardinia	-0.719	-3.59	1

*, ** and *** denote statistical significance using critical values at the 10% (-3.96). 5% (-4.24) and 1% (-4.90) respectively.

Table 3. *Results for β-convergence: y_t regression estimation*

Yt	**Known**	**break**	**date**	**T_b=1992**	**Unknown**	**break**	**date**		
Region	**μ_1**	**β_1**	**μ_2**	**β_2**	**μ_1**	**β_1**	**μ_2**	**β_2**	**T_b**
Piemonte	0.154**	0.001	0.169**	-0.0010	0.146**	0.003	0.167**	-0.0009	1990
	(5.011)	(0.406)	(5.943)	(-0.444)	(5.297)	(0.839)	(7.706)	(-0.463)	
Valle	0.493**	-0.003	0.397**	-0.009*	0.497**	-0.004	0.379**	-0.009	1993
d'Aosta	(8.710)	(-0.529)	(7.600)	(-1.720)	(9.277)	(-0.727)	(7.086)	(-1.443)	
Lombardy	0.202**	0.008**	0.304**	-0.004	0.194**	0.009**	0.306**	-0.003*	1990
	(6.327)	(1.997)	(1.997)	(-1.392)	(6.293)	(2.143)	(12.616)	(-1.638)	
Trentino	0.112**	-0.002*	0.106**	-0.0004	0.112**	-0.002	0.106**	-0.0004	1992
Alto-Adige	(3.397)	(-0.686)	(3.505)	(-0.145)	(3.397)	(-0.686)	(3.505)	(-0.145)	
Veneto	0.099**	0.003*	0.176**	-0.001	0.088**	0.004*	0.190**	-0.003	1994
	(2.464)	(0.808)	(5.225)	(-0.323)	(3.853)	(1.630)	(7.702)	(-0.988)	
Friuli	0.008	0.005*	0.116*	0.004	0.004	0.006	0.137*	0.003	1994
Venezia Giulia	(0.151)	(0.840)	(2.281)	(0.829)	(0.098)	(1.230)	(2.636)	(0.495)	
Liguria	0.109**	-0.0015	0.057*	0.004	0.114**	-0.002	0.061	0.004	1994
	(3.207)	(-0.364)	(1.833)	(1.156)	(3.520)	(-0.668)	(1.753)	(1.028)	
Emilia	0.216**	-0.0008	0.249**	-0.0005	0.214**	-0.0003	0.257**	-0.001	1993
	(5.140)	(-0.160)	(6.412)	(-0.124)	(5.797)	(-0.081)	(6.975)	(-0.326)	
Tuscany	0.326**	-0.0001	0.317**	-0.002	0.327**	-0.0001	0.303**	-0.001	1994
	(11.070)	(-0.028)	(11.641)	(-0.961)	(13.374)	(-0.06)	(11.467)	(-0.597)	
Umbria	-0.115**	-0.001	-0.107**	-0.002	-0.096**	-0.006*	-0.115**	-0.0007	1988
	(-2,699)	(-0,306)	(-2,708)	(-0,437)	(-2,147)	(-0,811)	(-3,929)	(-0,291)	
Abruzzo	-0.141 **	0.003**	-0.117**	-0.0023	-0.141**	0.003	-0.117**	-0.002	1992
	(-5,036)	(0,958)	(-4,545)	(-0,820)	(-5,036)	(0,958)	(-4,545)	(-0,820)	
Basilicata	-0.396**	-0.0033	-0.380**	0.007	-0.403**	-0.002	-0.365**	0.007	1993
	(-5,131)	(-0,3462)	(-5,322)	(0,983)	(-5,256)	(-0,219)	(-4,753)	(0,771)	
Campania	-0.327**	-0.0056*	-0.440**	0.002	-0.325**	-0.005**	-0.452**	0.004	1994
	(-6,408)	(-0,883)	(-9,351)	(0,457)	(-8,196)	(-1,364)	(-10,524)	(0,784)	
Lazio	-0.031**	0.006*	0.007	0.0007	-0.056**	0.012**	0.019	-0.0002	1987
	(-0,595)	(0,883)	(0,159)	(0,146)	(-0,892)	(0,999)	(0,518)	(-0,075)	
Marche	0.0007	-0.003	0.010	0.001	-0.001	-0.002	0.023	0.0007	1993
	(0.018)	(-0.574)	(0.274)	(0.455)	(-0.054)	(-0.66)	(0.744)	(0.192)	
Molise	-0.253**	0.002	-0.248**	0.004	-0.254**	0.001	-0.248**	0.009	1998
	(-5,021)	(0,244)	(-5,322)	(0,894)	(-7,333)	(0,552)	(-4,713)	(1,007)	
Puglia	-0.373**	0.0001	-0.407**	0.002	-0.370**	-0.0006	-0.414**	0.003	1994
	(-10,088)	(-0,002)	(-11,908)	(0,595)	(-11,961)	(-0,197)	(-12,358)	(0,833)	
Calabria	-0.509**	0.0001	-0.504**	0.003	-0.518**	0.001	-0.464**	0.007	1998
	(-9,510)	(0,019)	(-10,205)	(1,312)	(-12,076)	(0,486)	(-7,108)	(0,675)	
Sicily	-0.269**	-0.005*	-0.046**	0.003	-0.265**	-0.006**	-0.420**	0.006	1994
	(-4,588)	(-0,739)	(-7,414)	(0,593)	(-7,215)	(-1,518)	(-10,562)	(1,300)	
Sardinia	-0.191**	-0.005**	-0.261**	0.0006	-0.198**	-0.004**	-0.275**	0.002	1994
	(-4,553)	(-1,043)	(-6,739)	(0,146)	(-5,428)	(-1,013)	(-6,956)	(0,474)	
I(0) 10% cv	**±0.389**	**±0.676**	**±1.820**	**±1.560**	**±0.671**	**±1.47**	**±2.370**	**±1.480**	
I(0) 5% cv	**±0.504**	**±0.887**	**±2.390**	**±2.040**	**±0.875**	**±2.000**	**±3.000**	**±2.010**	

Table 4. *Results for β-convergence: z_t regression estimation without J_T correction*

Zt b=0	**Known break date T_b=1992**				**Unknown break date**				
Region	**μ_1**	**β_1**	**μ_2**	**β_2**	**μ_1**	**β_1**	**μ_2**	**β_2**	**T_b**
Piemonte	0.152**	0.001**	0.168**	-0.001	0.147**	0.003*	0.169**	-0.001*	1990
	(13.553)	(1.056)	(11.221)	(-0.617)	(13.327)	(1.506)	(17.133)	(-0.937)	
Valle	0.487**	-0.002*	0.387**	-0.009**	0.492**	-0.003	0.369**	-0.008	1993
d'Aosta	(24.197)	(-0.703)	(14.438)	(-2.699)	(24.720)	(-1.130)	(11.478)	(-1.876)	
Lombardy	0.201**	0.008**	0.305**	-0.004**	0.197**	0.008**	0.310**	-0.004**	1990
	(17.159)	(4.201)	(19.589)	(-2.282)	(13.544)	(3.190)	(23.743)	(-2.800)	
Trentino	0.115**	-0.003**	0.109**	-0.0005	0.115**	-0.003**	0.109**	-0.0005	1992
Alto-Adige	(11.185)	(-2.039)	(7.969)	(-0.298)	(11.176)	(-2.039)	(7.969)	(-0.298)	
Veneto	0.093**	0.003**	0.182**	-0.001	0.089**	0.003**	0.195**	-0.003**	1994
	(7.109)	(1.383)	(10.473)	(-0.778)	(18.743)	(5.416)	(20.916)	(-2.742)	
Friuli	0.008	0.005*	0.125**	0.003*	0.002	0.006**	0.139**	0.002	1994
Venezia	(0.468)	(1.729)	(4.904)	(1.092)	(0.153)	(2.592)	(4.021)	(0.538)	
Giulia									
Liguria	0.109**	-0.001**	0.055**	0.004**	0.112**	-0.002**	0.058**	0.005**	1994
	(11.983)	(-1.016)	(4.575)	(2.827)	(14.827)	(-1.954)	(3.913)	(2.362)	
Emilia	0.219**	-0.001*	0.256**	-0.001**	0.215**	-0.0007	0.264**	-0.002	1993
Romagna	(24.197)	(-0.703)	(14.438)	(-2.698)	(17.792)	(-0.415)	(13.517)	(-0.789)	
Tuscany	0.325**	-0.0001	0.316**	-0.002**	0.326**	-0.0001	0.303**	-0.002**	1994
	(44.403)	(0.109)	(32.404)	(-2.379)	(80.771)	(-0.170)	(38.442)	(-1.791)	
Umbria	-0.111 **	-0.002**	-0.003**	-0.003*	-0.089**	-0.008**	-0.111**	-0.0009	1988
	(-7,312)	(-0,998)	(-4,948)	(-0,990)	(-4,847)	(-1,986)	(-10,36)	(-0,871)	
Abruzzo	-0.139**	0.003**	-0.117**	-0.002**	-0.139**	0.003**	-0.117**	-0.002**	1992
	(-17,643)	(2,311)	(-11,184)	(-1,612)	(-17,64)	(2,311)	(-11,18)	(-1,612)	
Basilicata	-0.389**	-0.004**	-0.370**	0.007**	-0.394**	-0.004**	-0.349**	0.005**	1993
	(-16,791)	(-1,293)	(-12,015)	(1,814)	(-20,23)	(-1,228)	(-11,11)	(0,058)	
Campania	-0.328**	-0.005**	-0.451**	0.003**	-0.323**	-0.006**	-0.457**	0.005**	1994
	(-20,144)	(-1,899)	(-20,824)	(1,346)	(-27,64)	(-3,532)	(-20,00)	(1,603)	
Lazio	-0.037**	0.007**	-0.003	0.001	-0.059**	0.013**	0.021**	-0.0007	1987
	(-1,916)	(2,228)	(-0,123)	(0,512)	(-1,283)	(1,183)	(1,035)	(-0,364)	
Marche	0.005	-0.004**	0.021*	0.0009	0.001	-0.032**	0.033**	-0.0003	1993
	(0.438)	(-1.897)	(1.211)	(0.445)	(0.217)	(-2.515)	(2.532)	(-0.181)	
Molise	-0.255**	0.002	-0.245**	0.004**	-0.255**	0.002**	-0.246**	0.009*	1998
	(-13,465)	(0,584)	(-9,699)	(1,221)	(-30,10)	(1,703)	(-6,633)	(1,160)	
Puglia	-0.376**	0.0004	-0.410**	0.002**	-0.371**	-0.0005	-0.415**	0.004**	1994
	(-36,528)	(0,242)	(-29,971)	(1,485)	(-44,54)	(-0,401)	(-25,49)	(1,597)	
Calabria	-0.509**	0.0003	-0.509**	0.007**	-0.517**	0.001**	-0.458**	0.007*	1998
	(-39,390)	(0,147)	(-29,578)	(3,500)	(-59,378)	(1,510)	(-12,061)	(0,926)	
Sicily	-0.271**	-0.004**	-0.409**	0.004**	-0.266*	-0.005**	-0.425**	0.007	1994
	(-13,548)	(-1,408)	(-15,332)	(1,211)	(-37,77)	(-5,611)	(-30,83)	(0,151)	
Sardinia	-0.191**	-0.005**	-0.266**	0.001	-0.194**	-0.004**	-0.269**	0.002	1994
	(-14,756)	(-2,512)	(-15,457)	(0,542)	(-18,59)	(-3,164)	(-13,22)	(0,650)	
I(0)10%cv	**±0.854**	**±0.683**	**±1.030**	**±0.908**	**±1.570**	**±1.330**	**±1.140**	**±0.936**	
I(0) 5% cv	**±1.120**	**±0.883**	**±1.350**	**±1.200**	**±2.190**	**±1.760**	**±1.500**	**±1.270**	

Table 5. *Results for β-convergence: z_t regression estimation with J_T correction*

Zt b≠0	**Known break Date T_b=1992**				**Unknown break date**				
Region	**μ_1**	**β_1**	**μ_2**	**β_2**	**μ_1**	**β_1**	**μ_2**	**β_2**	**T_b**
Piemonte	0.152**	0.001	0.168**	-0.001	0.147**	0.003	0.169	-0.001	1990
	(2.870)	(0.055)	(2.376)	(-0.032)	(4.123)	(0.077)	(0.291)	(-0.051)	
	(2.114)	(0.018)	(1.750)	(-0.010)	(3.378)	(0.022)	(0.069)	(-0.016)	
Valle d'Aosta	0.487**	-0.002	0.387**	-0.009	0.492**	-0.003	0.369	-0.008	1993
	(0.082)	(0.0002)	(0.094)	(-0.0001)	(4.023)	(-0.011)	(0.021)	(-0.021)	
	(0.029)	(0.0003)	(0.033)	(-0.0002)	(2.956)	(-0.001)	(0.002)	(-0.003)	
Lombardy	0.201	0.008	0.305	-0.004	0.197	0.008	0.310	-0.004	1990
	(7.772)	(4.975)	(13.742)	(-2.262)	(1.446)	(0.011)	(0.01)	(-0.01)	
	(7.772)	(7.772)	(7.772)	(7.772)	(0.989)	(0.001)	(0.0006)	(-0.001)	
Trentino	0.115**	-0.003	0.109**	-0.0005	0.115*	-0.003	0.109	-0.0005	1992
Alto-Adige	(3.461)	(-0.220)	(2.466)	(-0.032)	(2.417)	(-0.042)	(0.039)	(-0.006)	
	(2.747)	(-0.095)	(1.957)	(-0.014)	(1.863)	(-0.008)	(0.005)	(-0.001)	
Veneto	0.093*	0.003	0.182*	-0.001	0.089**	0.003	0.195*	-0.003	1994
	(0.967)	(0.031)	(1.424)	(-0.017)	(9.405)	(0.947)	(1.909)	(-0.498)	
	(0.652)	(0.007)	(0.961)	(-0.004)	(8.366)	(0.457)	(0.819)	(-0.256)	
Friuli	0.008	0.005	0.125	0.003	0.002	0.006	0.139	0.002	1994
Venezia Giulia	(0.065)	(0.041)	(0.683)	(0.025)	(0.021)	(0.018)	(0.004)	(0.004)	
	(0.044)	(0.010)	(0.463)	(0.006)	(0.015)	(0.002)	(0.0004)	(0.0006)	
Liguria	0.109**	-0.001	0.055**	0.004**	0.112**	-0.002	0.058*	0.005*	1994
	(9.392)	(-0.640)	(3.586)	(1.781)	(10.461)	(-0.809)	(1.166)	(0.997)	
	(8.952)	(-0.538)	(3.418)	(1.498)	(9.859)	(-0.559)	(0.7602)	(0.713)	
Emilia Romagna	0.219**	-0.001	0.256**	-0.001	0.215**	-0.0007	0.264	-0.002	1993
	(3.986)	(-0.022)	(2.378)	(-0.088)	(4.828)	(-0.015)	(0.146)	(-0.031)	
	(2.794)	(-0.0064)	(1.667)	(-0.024)	(3.869)	(-0.003)	(0.029)	(-0.008)	
Tuscany	0.325	-0.0001	0.316**	-0.002**	0.326**	-0.0001	0.303**	-0.002*	1994
	(35.329)	(0.071)	(25.782)	(-1.542)	(71.833)	(-0.126)	(25.586)	(-1.340)	
	(33.773)	(0.060)	(24.647)	(-1.311)	(70.417)	(-0.111)	(22.158)	(-1.197)	
Umbria	-0.111 **	-0.002**	-0.003**	-0.003*	-0.089**	-0.008**	-0.111**	-0.0009**	1988
	(-4,182)	(-0,346)	(-2,830)	(-0,343)	(-2,569)	(-2,662)	(-5,493)	(-1,167)	
	(-3,746)	(-0,346)	(-2,535)	(-0,231)	(-3,005)	(-3,774)	(-6,426)	(1,655)	
	-0.139**	0.003**	-0.117**	0.0002	-0.139**	0.003	-0.117**	-0.002**	
Abruzzo	(-7,79)	(0,491)	(-4,943)	(-0,343)	(-6,07)	(0,156)	(-0,276)	(-0,116	1992
	(-6,639)	(0,275)	(-4,208)	(-0,192)	(-5,07)	(0,051)	(-0,075)	(-0,041))	
	-0.389**	-0.004**	-0.370**	0.007**	-0.394**	-0.004	-0.349**	0.005	
Basilicata	(-13,487)	(-0,853)	(-9,651)	(1,197)	(-14,387)	(-0,519)	(-3,402)	(0,025)	1993
	(-12,917)	(-0,730)	(-9,243)	(1,025)	(-13,577)	(-0,362)	(-2,239))	(0,018)	
	-0.328**	-0.005**	-0.451**	0.003**	-0.323**	-0.006	-0.457	0.005	
Campania	(-3,441)	(-0,067)	(-3,557)	(0,047)	(-9,628)	(-0,245)	(-0,514)	(0,118	1994
	(-2,429)	(-0,019)	(-2,511)	(0,013)	(-8,049)	(-0,081)	(-0,141)	(0,043)	
	-0.037**	0.007**	-0.003	0.001	-0.059	0.013	0.021	-0.0007	
Lazio	(-0,615)	(0,258)	(-0,039)	(0,059	(-0,146)	(0,005)	(0,001)	(-0,002)	1987
	(-0,491)	(0,115)	(-0,031)	(0,026)	(-0,101)	(0,000)	(0,000)	(0,0002)	

	0.005	-0.004	0.021	0.0009	0.001	-0.032	0.033	-0.0003	
Marche	(0.076)	(-0.069)	(0.211)	(0.016)	(0.056)	(-0.084)	(0.023)	(-0.006)	1993
	(0.054)	(-0.020)	(0.149)	(0.004)	(0.045)	(-0.02)	(0.004)	(-0.001)	
	-0.255**	0.002	-0.245**	0.004**	-0.255**	0.002	-0.246	0.009	
Molise	(-4,914)	(0,086)	(-3,540)	(0,180)	(-7,195)	(0,046)	(-0,046)	(0,034)	1998
	(-4,029)	(0,042)	(-2,902)	(0,088)	(-5,643)	(0,010)	(-0,008)	(0,009)	
	-0.376**	0.0004	-0.410**	0.002**	-0.371**	-0.0005	-0.415**	0.004	
Puglia	(-19,386)	(0.073)	(-15,905)	(0,447)	(-25,819)	(-0,101)	(-3,839)	(0,415)	1994
	(-17,110)	(0,046)	(-14,039)	(0,285)	(-23,535)	(-0,057)	(-1,967)	(0,245)	
	-0.509**	0.0003	-0.509**	0.007**	-0.517**	0.001*	-0.458**	0.007	
Calabria	(-32,330)	(0,101)	(-24,277)	(2,407)	(-49,591)	(0,958)	(-6,454)	(0,593)	1998
	(-31,096)	(0,088)	(-23,350)	(2,092)	(-48,097)	(0,792)	(-5,17)	(0,499)	
	-0.271**	-0.004**	-0.409**	0.004**	-0.266**	-0.005**	-0.425**	0.007	
Sicily	(-4,877)	(-0,203)	(-5,520)	(0,174)	(-30,741)	(-3,333)	(-15,079)	(0,091)	1994
	(-3,988)	(-0,098)	(-4,513)	(0,085)	(-29,684)	(-2,681)	(-11,711)	(0.074)	
	-0.191**	-0.005**	-0.266**	0.001	-0.194**	-0.004	-0.269*	0.002	
Sardinia	(-7,974)	(-0,782)	(-8,353)	(0,169)	(-9,987)	(-0,657)	(-1,529)	(0,140)	1994
	(-7,064)	(-0,505)	(-7,399)	(0,109)	(-8,986)	(-0,341)	(-0,713)	(0,077)	
I(0) 10% cv	**±0.854**	**±0.683**	**±1.030**	**±0.908**	**±1.570**	**±1.330**	**±1.140**	**±0.936**	
I(0) 5% cv	**±1.120**	**±0.883**	**±1.350**	**±1.200**	**±2.190**	**±1.760**	**±1.500**	**±1.270**	

Table 6. *Summary of β-convergence econometric results*

	$T^{-1/2}t_y$: robust to I(1) errors				$t\text{-}Ps_T$:I(0) errors assumed				$t\text{-}Ps_T$: robust to I(1) errors			
	T_b=1992		T_b unknown		T_b=1992		T_b unknown		T_b=1992		T_b unknown	
Region	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break
Piemonte	d	c	d	c	D	c	D	C	d	c	d	E
Valle d'Aosta	c	C	c	c	C	C	c	c	c	c	c	E
Lombardy	D	c	D	c	D	C	D	C	E	E	E	E
Trentino Alto-Adige	C	c	c	c	C	c	C	c	c	c	c	E
Veneto	D	c	D	c	D	c	D	C	D	c	d	c
Friuli Venezia Giulia	d	d	E	d	d	D	d	d	E	E	E	E
Liguria	c	d	c	E	C	D	C	D	c	D	c	D
Emilia Romagna	c	c	c	c	C	C	c	c	c	c	c	E
Tuscany	c	c	c	c	c	C	c	C	E	C	c	C
Umbria	d	d	D	d	D	D	D	d	D	D	D	D
Abruzzo	C	d	c	d	C	D	C	D	C	d	c	D
Basilicata	d	c	d	c	D	C	D	C	D	C	d	c
Campania	D	c	D	c	D	C	D	C	D	C	D	E
Lazio	C	E	C	E	C	E	C	c	C	E	E	E
Marche	E	E	E	E	c	d	c	c	E	E	E	E
Molise	c	c	c	c	c	C	C	C	c	C	c	E
Puglia	c	c	d	c	c	C	d	C	c	C	d	c
Calabria	c	c	c	c	c	C	C	C	c	C	C	c
Sicily	d	c	D	c	D	C	D	c	D	C	D	c
Sardinia	D	c	D	c	D	c	D	c	D	c	d	c

C for point estimates compatible with β convergence and both coefficients statistically significant at least at the 10% level;
c for point estimates compatible with β convergence but with only one coefficient statistically significant at least at the 10% level;
D for divergence evidence with both coefficients statistically significant at least at the 10% level;
d for divergence and only one coefficient statistically significant at least at the 10% level;
E for very small and statistically insignificant point estimates. indicating that a β-convergence already occurred.