So many Italies:
Statistical Evidence on Regional Cohesion

by

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Summary

We study regional dynamics of output in Italy on a sample period spanning from 1970 to 1992 using dynamic principal components analysis and coherency analysis. We find the presence of a basic common economic structure but also the presence of sharp heterogeneity both at low and high frequencies of the growth cycles. There is no evidence for convergence even for clubs of regions, not even for the most integrated group of regions included in the Centre-North-East. We find statistical evidence consistent with the view that the dualism between East and West is at least as important as the dualism between North and South. Finally, the geographical proximity seems to be the major element to shape the common dynamics of per capita real output.

Key words: dynamic principal components method, coherency and correlation analysis, long and short run growth cycles, co-movements, convergence.

JEL classification numbers: C14, O50

1. Introduction*

The analysis of the factors determining different growth rates across Italian regions has been a major theme for many years. Recently, this debate has been put again on the forefront of the economic research for two basic reasons: the first one is the apparently increasing gap between northern and southern economic performances with its implications on the allocation of the fiscal burden across regions and corollaries on the political equilibria of the nation. The second one is mainly theoretical and is related to the increasing attention paid by economists to growth and convergence across states and regions. Simultaneously to this theoretical debate many researchers have been involved in the empirical work trying to asses the factual predictions of alternative classes of models on the data using both cross section and time series analysis[1]. In Italy, most of the empirical studies, following Barro and Sala-i-Martin (1991), use the cross section approach.[2] A partial list of papers dealing with this issue includes Mauro and Podrecca (1994), Paci and Pigliaru (1995), Acconcia (1995). In all these paper the evidence provided by Barro and Sala-i-Martin (1991), reinforced by Sala-i-Martin (1994), about convergence of European regions is questioned.

A partial exception to the studies using cross section is the paper by Cellini and Scorcu (1995) that presents both cross section and time series evidence. Using pairwise

* We thanks Mario Forni for kindly providing the program to estimate dynamic principal components.

[1] A far from exhaustive list of prominent papers employing cross section regression is: Barro (1991), Barro and Sala-i-Martin (1991, 1992), Mankiw, Romer and Weil (1992), Sala-i-Martin (1994). Papers concerning time series approach to test for convergence are Bernard and Durlauf (1995), Carlino and Mills (1993), Cogley (1990), Pagano (1993). See Canova and Marcet (1995), Caselli et al. (1995), Quah (1993) for a critique about the traditional cross section approach.

[2] Typically, the convergence issue is tested analysing the pattern of income or productivity growth in a cross sectional unit (region or country) over the sample period. The time average growth rates are aggregated over the sample and a cross section regression is performed with one observation for unit. The right hand side variable of the regression is given by the beginning of period stock variable (e.g. initial level of income or productivity) often augmented by other explanatory variables (for example, average investment rate, indexes of educational attainment): a negative initial level coefficient is interpreted as convergence). This property corresponds to the concept of β-convergence, "... a poor economy tends to growth faster than a rich one, so that the poor country tends to catch up with the rich one in terms of the level of per capita income or product", (Barro and Sala-i- Martin 1995, p.383).

cointegration, they show that "stochastic local convergence is more convincing than stochastic global convergence even for regions within one country". In particular, they find that regions of the North-West and South have no common dynamics in the long run, while the reverse occurs for the often cited "third emerging group" of the North East and Adriatic regions, even if none of the long run restrictions for convergence are satisfied.

The aim of this paper is to perform the analysis of the dynamics and comovements of the regional per capita output both in the long run and in the short run. To this aim we use some statistical procedures in the context of the unit root random field, taking into account the information available for all the period and all the cross sectional units. However, we also test for stochastic convergence according to the definition proposed by Bernard and Durlauf (1995) and common dynamics across regional real outputs. Let us stress at this point that, except for the tests about the predictions of growth models about convergence across regions, our analysis is theoretically blind and mainly descriptive of the (dis-) similarity in regional output dynamics.

We use a dynamic principal component analysis to count up the number of common components to the economic fluctuations allowing to check for long run co-movements and convergence using large cross-section of regions simultaneously over a long time period as well as to check for co-movements across outputs at the cycle frequencies. Moreover, we study covariation of components at zero frequency (trends) across regions and of annual growth rates using coherency analysis[3].

Differently from the cross section approach, we allow for more efficient use of the time dimension of the data and do not force the region specific effects to be the same, in other words we test for the same steady state for each region, but we do not impose this condition in the estimation. With respect to most of the papers using time series we

[3] This approach is used by D'Amato and Pistoresi (1996a, 1996b) to study common dynamics of European real output and common OECD growth cycles.

focus both on the long run dynamics (convergence and common trends) and on the short and medium run comovements across regions (common short-medium growth cycles). This is mainly performed by employing non-parametric techniques. To the best of our knowledge this is the first attempt performed on regional Italian data[4].

The plan of the paper is as follows: section 2 contains a definition of stochastic convergence. Section 3 contains a description of the non parametric methods used. Section 4 presents the empirical results. Section 5 concludes.

2. Stochastic convergence

In this section, we present the stochastic notion of stochastic convergence proposed by Bernard and Durlauf (1995). This notion is based on the premise that each output series contains a stochastic trend. A series contains a stochastic trend if it is non stationary in levels, even after removing a linear trend, but is stationary in first differences (that is, the series is an I(1) process). The interactions of stochastic trends across countries or regions can be formalised into a general definitions of common trends and convergence as follows

Common trend in multivariate output (necessary condition for convergence). *Regions p= 1,...,n contain a single common trend if the long term forecast of output are proportional at a fixed time t, let* $y_t = \left[y_{1,t}, \ldots, y_{p,t} \right]$,

$$\lim_{k \to \infty} E\left(y_{1,t+k} - \alpha'_p \, y_{p,t+k} / I_t\right) = 0 \qquad (1)$$

Convergence in multivariate output. *Regions p= 1, ..., n converge if the long-term forecast of output for all regions are equal at a fixed time t:*

$$\lim_{k \to \infty} E\left(y_{1,t+k} - y_{p,t+k} / I_t\right) = 0, \quad \forall p \neq 1 \qquad (2)$$

where I_t is the information set available in t.

[4] Papers somewhat related to our approach are: Cogley (1990), Bernard and Durlauf (1995).

To clarify the convergence condition, let us assume that output of the region i and j can be represented in the following MA representation:

$$\Delta y_t = A(L)\varepsilon_t$$

where Δy_t is the (2x1) vector of outputs and A(L) is (2x2) polinomial matrix and ε_t is a (2x1) vector of white noises. Let us suppose that the two outputs contain a common stochastic trend, hence the MA representation above can be reparameterised as the Stock-Watson common trend representation as follow

$$\Delta y_t = \begin{pmatrix} 1 \\ \alpha \end{pmatrix} \varepsilon_t + (1-L)\tilde{A}(L)\varepsilon_t$$

On the right and side of the equation, the first term represents the two stochastic trends that are similar excepting for the proportionality factor α. The second part $(1-L)\tilde{A}(L)\varepsilon_t$ represents the cyclical components of the multivariate output process. This common trend representation describes condition (1) above. To satisfy the sufficient condition for convergence stated by condition (2), that is the restriction for identical common stochastic trend, we need $\alpha = 1$.

Intuitively, the necessary condition for (stochastic) convergence in (logged) real per capita outputs, towards a unique steady-state equilibrium, requires that a permanent shock to one region is related to a permanent shock to other regions, in other words it requires a single stochastic trend (or unit root) in outputs. The presence of one common trend in multivariate output *not necessarily implies* convergence since this outcome imposes relatively weak restrictions on output movements. In a context of optimal growth models, this only requires the existence of some links between regional production functions, so that the permanent shocks *partially* migrate, instead convergence would require that permanent (technological) shocks *fully* migrate from one region to another in the long run. In other words, convergence requires that each region of the group under examination has *identical* long run trends, while the presence of common trends allow for *proportionality* of the stochastic elements (in our bivariate example, the proportionality factor is α). Obviously, under the null of *n* common

stochastic trends, the innovations do not exhibit linear transmission mechanism in the long run and the source of fluctuations is idiosyncratic at regional level and not transferred from one region to another.

The definition of stochastic convergence has testable implications from the cointegration and common trends literature and can be tested using parametric and/or non parametric multivariate techniques. A parametric procedure, extensively used, is the Johansen cointegration procedure (Johansen 1991) to check the number of cointegrating vectors in multivariate output, while the non-parametric counterpart is the spectral-based procedure proposed by Phillips and Ouliaris (1988) to check the number of common trends[5].

The dynamic principal component analysis proposed in this paper differs from the method proposed by Phillips Ouliaris in that the analysis is performed over all the frequencies and not only at zero frequency. Hence, the method used here is the appropriate one to study not only the convergence issue, but also long run (at low-frequency) and short-medium run co-movements (at the frequency traditionally associated to business cycles[6]) across outputs. In other words, it permits to establish, by simultaneous estimation, the importance of the common shocks within large cross-section of regional per capita output on the whole frequency domain.

3. Non parametric methods for the analysis of convergence and comovements

In this section we introduce two non parametric methods to check for co-movements and convergence in regional outputs. The first one is a dynamic principal component

[5] Forni and Reichlin (1995) develop a method to analyse large cross section with non trivial time dimension, in particular to estimate and identify a factor analytic model.

[6] For a definition of the frequencies associated to the business cycles see section 3.1 when we presents the relation between principal component analysis and comovements.

analysis[7] performed to identify the number of common shocks in outputs and their contribution at each frequency in terms of explained total variance of output vector. This permits to obtain evidence for long run and short run co-movements for regions *within* a given area and to test for the "necessary" condition for convergence (one common trend). The second one is the analysis of coherency matrix and correlation matrix to check whether zero-frequency growth cycles (i.e. trends) are similar *across* regions or are idiosyncratic. Both methods are useful to establish the degree of short run co-movements and long run co-movements.

3.1 Dynamic principal components method. Let Y_t denote the $(n \times 1)$ vector of individual output levels (log real per capita GDP for n regions). Let us assume that the individual elements of the output vector are integrated of order one and, for exposition simplicity, let us omit the drifts. It is then natural to write a multivariate Wold representation of outputs as

$$\Delta Y_t = B(L)\zeta_t \qquad (3)$$

where B(L) is a $(n \times n)$ polynomial matrix and ζ_t is an $(n \times 1)$ vector of white noises. The spectral density of ΔY_t is

$$f_{\Delta Y}(e^{-i\omega}) = B(e^{-i\omega})\sum_{\zeta} B(e^{i\omega})^T, \qquad (4)$$

where ϖ indicates the frequency , $\sum_{\zeta}$ the variance-covariance matrix of innovations and "T" indicates a transpose. The rank of the spectral density matrix is smallest equal to the dimension of ζ_t. Test of the number of common shocks requires to compute the number of principal components of $f_{\Delta Y}(e^{-i\omega})$, that explain most of the variance of ΔY_t at each frequency. We can ask how many principal components explain at least the 95% of total variance of ΔY. If p components are sufficient we conclude that there are p common elements in the vector of regional outputs.

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[7] See Brillinger (1981) and Phillips and Ouliaris (1988). For application of principal components methods involving the analysis at zero frequency, see Bernard and Durlauf (1995) and at any frequencies see Forni and Reichlin (1995).

It is possible to decompose $f_{\Delta Y}(e^{-i\varpi})$ in the following way:

$$f_{\Delta Y}(\omega) = P(\omega)D(\omega)\overline{P(\omega)}^{T}, \qquad (5)$$

where $D(\varpi)$ is a diagonal matrix with *r* non-zero elements on the principal diagonal (the eigenvalues): $\lambda_1(\omega).....\lambda_p(\omega)]$ and $\text{rank}D(\omega) = \text{rank}f(\omega)$. Ordering the eigenvalues from the largest to the smaller it is possible to compute the variance ratio between the variance of the *p* principal components and the variance of all the components (*n*). Let us indicate this variance ratio as follows

$$\Phi_p(\omega) = \sum_{1}^{p}\lambda_i(\omega) \Big/ \sum_{1}^{n}\lambda_i(\omega) \quad p = 1, ..., n \qquad (6)$$

In other words, we will estimate $\Phi_p(\omega)$ for p = 1, .., 20 (twenty Italian regions) by estimating the spectral density matrix of regional output series, calculating the eigenvalues at different frequencies, cumulating and dividing by the sum. We will also estimate the average variance ratio given by the mean of the cumulated eigenvalues over frequencies divided by the mean of the sum. Let us indicate this ratio as follows

$$\overline{\Phi}_p = \int_0^{\pi}\sum_{1}^{p}\lambda_i(\omega)d\omega \Big/ \int_0^{\pi}\sum_{1}^{n}\lambda_i(\omega)\,d\omega, \qquad p = 1, ..., n. \qquad (7)$$

Dynamic principal component analysis and convergence. At zero frequency, the number of principal components necessary to explain most of the total variance is equal to the rank of the spectral density matrix at zero frequency. It gives indication for the number of common permanent components or common stochastic trends in regional output. If idiosyncratic long run growth elements dominate for each region, then we would expect to find *n* common permanent parts (or equivalently *n* common trends) for *n* regions. This means that each region converges to its own steady state. If regional percapita output converge, we expect to find the necessary condition for convergence

satisfied, that is one common permanent component (or equivalently one common trend, that is $\Phi_1(0) \geq 0.95$) that explains most of the total variance of ΔY_t.

Dynamic principal component analysis and comovements. A similar argument as above holds for each frequency on the whole frequency domain and more generally we refer to this analysis as co-movements analysis[8]. Hence, the number of principal components at each frequency considered in the analysis enables us to determine the degree of co-movements across the series in the long run, in the medium and in the short run. The fewer the number of components is necessary to explain most of the total variance of the output vector, more linked are the series, that is higher is the degree of co-movement. For example, series more linked by medium-short run comovements should exhibit a peak at frequency of the business cycle in the first dynamic principal component (in $\Phi_1(\omega)$ with $\omega > 1.26$).

3.2 Correlation and coherency between regional outputs. Let us introduce now two other indexes to analyse whether zero-frequency components of growth (i.e. trends, also defined long run growth cycles, for example, in Cogley 1990[9]) are more highly correlated across economies than annual changes in output (short run growth cycles). This issue can be addressed by comparing the correlation matrix of output growth $C = [\rho_{ij}]$, where ρ_{ij} is the correlation index between output growth rate in region i and output growth rate in region j, with the coherency matrix $H(\omega) = [h_{ij}(\omega)$ evaluated at $\omega = 0$. Coherency is the frequency domain analogue to correlation and it is defined as

[8] Notice that with annual data frequencies close to 3.14 correspond to 2-years growth cycles (period), frequencies close to zero, for example, at 0,63 correspond to 10-years growth cycles. Any frequency close to zero and at zero will be considered associated to long run growth cycles. We define short-medium growth cycles (business cycle) those corresponding to frequencies from 1.26 to 3.14.

[9] We will denote the components of the series evaluated at zero frequency either as long run growth cycles or trends within the series. Sometimes long run growth cycles are also used to denote growth cycles evaluated at frequencies close to zero (low frequencies), we will follow this terminology letting the context to clarify the difference.

4.1 Volatility of the regional output series

In order to analyse comovements across regional output we need to test for the presence of a permanent component in each of the regional output series.

Table 1 presents the estimates of a non parametric measure of persistence due to Cochrane (1988)[10]. The results reported suggest that in all the cases we can accept the hypothesis that the variables contain a random walk component (spectral density function at zero frequency is different from zero), that is all the series are difference stationary and not trend stationary. However, comparing the variability of first differences of outputs at different frequencies, we can see that in all the cases most of the output variability is mainly due to the variability in the short-medium-frequency components, corresponding to short-medium term growth cycles (2-5 years cycles, see the notes in Table 1)[11]. The shape of these spectra shows a peak at a frequency different from zero and traditionally associated to business cycles[12]. On the basis of this finding we argue that the analysis of short-medium run comovements is at least as important as the analysis of long run comovements.

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[10] The persistence measures tell us how much a shock changes the forecast of a variable in the long run. If this change is zero (persistence is zero), the innovations are viewed only to have effects during the short run and when the shock has passed, the economy returns to its natural (deterministic) path of growth. For this to happen, it is necessary that the permanent component (trend) evolves deterministically. Nevertheless, when output has a stochastic trend, innovations are expected to persist into the indefinite future (persistence different from zero). Hence, the persistence measure of innovations enables us to establish if outputs contains a stochastic or deterministic trend, that is if the series contains a unit root or not. The non parametric measure of persistence due to Cochrane (1988) is given by the spectral density evaluated at zero frequency (power spectrum in zero of the series. For the equivalence of the frequency domain and temporal domain analysis of non stationary data see, for example, Priestley (1981).

[11] Generally, the contribution of low-frequency component (long run growth cycle, 10 and more years growth cycles) in national output is found to be very large with respect to short-medium-frequency components. The national economies have high density function at zero frequency, see for example Cogley (1990).

[12] The estimated spectrum with a peak at cyclical frequency for the Italian output is also found in Ribba (1996) on a different data set on a sample spanning over the same period 1970-90. This is consistent with the interpretation given by De Long and Summers (1988) according to the existence of high variability at cyclical frequencies is an indicator of ineffectiveness of countercyclical policies.

$$h_{ij}(\omega) = \frac{f_{ij}(\omega)}{\left[f_{ii}(\omega) f_{jj}(\omega) \right]^{1/2}}$$

where f_{ij} is the *ij*-th element of the spectral density matrix evaluated at frequency ω.

The diagonal elements of the spectral density matrix are the power spectra and the off-diagonal elements are the cross-spectra. These latter evaluated at zero frequency are proportional to the covariance between long term growth cycles in each pair of regions. Under the hypothesis that output is characterised by a random walk component (trend) plus a stationary component (cycle), the cross-spectra at zero frequency are proportional to the covariance between the random walk innovations (permanent shocks) suggesting the link between long run growth cycle (or trends).

For example, if long run growth cycles (at zero frequency) are idiosyncratic but business cycles have a common component, then one might expect annual growth to be more highly correlated across economies than long run growth cycles, that is $\rho_{ij} > h_{ij}(0)$. Viceversa, if the path of long run growth are common to many regions, while short run growth cycles are largely region specific, then one might expect low-frequency components of growth to be more correlated than annual growth, that is $\rho_{ij} < h_{ij}(0)$.

4. Empirical results

The annual data used here are logs of per capita real GDP of the twenty Italian regions and cover the period 1970-1992. These data are taken from Istat (1995) and Svimez (1994). This data set has been extensively used, for example, by Acconcia (1995), Cellini and Scorcu (1995), Pigliaru and Paci (1995) and partially by Mauro and Podrecca (1994) to analyse the issue of convergence in Italy.

Table 1 Spectral density function evaluated at different frequencies (Bartlett window estimates, window size =5) and unit root tests.

Region	$f(0)$	$f(0.63)$	$f(1.26)$	$f(2.51)$	$f(3.14)$
PIE	0.42	0.67	1.07	1.20	1.07
	(0.23)	(0.26)	(0.42)	(0.47)	(0.56)
VDA	0.42	0.85	1.47	0.81	0.74
	(0.23)	(0.33)	(0.57)	(0.31)	(0.40)
LOM	0.57	0.79	1.19	1.02	0.76
	(0.31)	(0.31)	(0.46)	(0.39)	(0.42)
TRE	0.55	0.78	1.23	0.98	0.58
	(0.30)	(0.30)	(0.48)	(0.38)	(0.32)
VEN	0.44	0.70	1.02	1.25	0.74
	(0.24)	(0.27)	(1.25)	(0.48)	(0.41)
FRI	0.72	1.20	1.37	0.76	0.52
	(0.39)	(0.47)	(0.53)	(0.29)	(0.28)
LIG	0.37	0.65	1.00	1.30	1.28
	(0.20)	(0.25)	(0.39)	(0.51)	(0.71)
EMI	1.05	1.15	1.24	0.73	0.51
	(0.58)	(0.45)	(0.48)	(0.28)	(0.28)
TOS	0.57	0.80	0.84	1.37	0.40
	(0.31)	(0.31)	(0.33)	(0.53)	(0.18)
UMB	0.88	0.76	0.87	1.77	0.63
	(0.49)	(0.29)	(0.34)	(0.45)	(0.35)
MAR	1.39	1.29	1.18	0.62	0.39
	(0.76)	(0.50)	(0.46)	(0.24)	(0.22)
LAZ	0.42	0.55	1.04	1.24	0.87
	(0.25)	(0.21)	(0.40)	(0.48)	(0.48)
ABR	0.79	1.16	0.98	1.11	0.92
	(0.43)	(0.45)	(0.38)	(0.43)	(0.50)
MOL	0.81	1.15	1.43	0.65	0.81
	(0.45)	(0.45)	(0.55)	(0.26)	(0.45)
CAM	0.35	0.57	0.71	1.61	0.88
	(0.19)	(0.22)	(0.27)	(0.62)	(0.49)
PUG	0.54	0.71	0.97	1.25	0.88
	(0.29)	(0.27)	(0.37)	(0.48)	(0.48)
BAS	0.52	0.85	1.50	0.73	0.74
	(0.29)	(0.33)	(0.58)	(0.28)	(0.41)
CAL	0.32	0.32	0.70	1.63	2.61
	(0.39)	(0.12)	(0.27)	(0.63)	(1.43)
SIC	0.72	0.97	1.26	0.87	0.61
	(0.39)	(0.37)	(0.49)	(0.34)	(0.33)
SAR	0.44	0.75	0.87	1.39	1.13
	(0.24)	(0.29)	(0.34)	(0.84)	(0.62)

Note: Spectral density function of first differences of log output at different frequencies. $f(0)$ is the spectral density at zero frequency and corresponds to a period (period = $2\pi/\varpi$) equal to "infinity"; $f(0.63)$ corresponds to a period equal to 10 years, $f(1.26)$ to a period equal to 5 years, $f(2.51)$ to a period equal to 2.5 years and $f(3.14)$ to a period equal to 2 years. Asymptotic standard errors (Bartlett lag-window) in parentheses. Window size equal to $\sqrt{n}$, where n are the observations. On the estimation of the spectrum, see Priestley (1981).

We can synthesise the previous univariate analysis as follows: regional output variability is mainly due to short-medium term growth cycles, in other terms Italian regions have less volatile long run growth cycles. That is even if per capita outputs are difference stationary (including a random walk component), they are not purely random walk since the cyclical component indicated by the spectrum at intermediate frequency is not negligible[13].

4.2 Co-movements across regions estimated by coherencies and correlations

Having identified the presence of long run stochastic components in the series, let us now move to analyse the covariation among them. However, since we also found important short run volatility in the series, we use correlations across annual growth rates to compare short run dynamics. More precisely, the aim of the following analysis is to check whether low-frequency growth cycles (zero-frequency cycles, that is first difference of the trends) are either similar or idiosyncratic across regions and how they compare to correlation across regional annual growth. To achieve this aim we compare coherencies in zero, $h_{ij}(0)$, and correlations, ρ_{ij} (Tables 2 and 3).

Table 2 shows the results for the regions of Italian economy aggregated according to large macro-areas: North-East (NE includes Trentino, Veneto, Friuli), North-West (NW includes Valle d'Aosta, Piemonte, Lombardia, Liguria), Centre-East (CE includes Emilia Romagna, Umbria, Marche), Centre-West (includes Lazio, Toscana), South-East (SE includes Abruzzi, Molise, Puglia), South-West (SW includes Campania, Calabria, Basilicata, Sicilia, Sardegna).

The highest measure of coherency and correlation is relative to CE and NE, which we may consider the most integrated regional economies. NE comoves more, both in the

[13] We also performed parametric Dickey-Fuller tests which support the results obtained by using the measure of persistence. The results are available on request.

long run ($h(0)$= 0.93) and in the short run (ρ = 0.88), with CE than with any other macroarea. A similar pattern, though less strong in magnitude, applies for the relations between NW and CW. However, these latter macroareas share with NE more important short run comovements (ρ = 0.87) with respect to long run ones ($h(0)$ = 0.77). As for the southern regions the data show that: SE is well integrated to CE and NE in the long run ($h(0)$ = 0.81 and 0.82, respectively and remarkably higher than any other coherency). This holds true also in the short run but the differences with respect to the correlation with other areas is less sharp. Finally, the SW exhibits the lowest measure of comovements with the other macro areas, both in the long run and in the short run. As before this area turns out to be mostly related to SE than with any other area. This evidence is consistent with the view put forward by different authors that the dualism between North and South is at least as important as the dualism between West and East of Italy.

Table 2 Correlations of long run growth $h_{ij}(0)$ and correlations of annual growth ρ_{ij} *across* macro areas

	NE	**NW**	**CE**	**CW**	**SE**	**SW**
NE	1	0,70	0,93	0.85	0.82	0.53
NW	0.86	1	0,50	0.77	0.61	0.45
CE	0.88	0.82	1	0.70	0.81	0.63
CW	0.77	0.87	0.72	1	0.70	0.42
SE	0.70	0.62	0.68	0.62	1	0.75
SW	0.56	0.47	0.49	0.47	0.76	1

Notes: The values above the diagonal are coherencies, $h_{ij}(0)$, which are equal to correlations of long run growth cycles (trends) across regions when evaluated at zero-frequency. The values below the diagonal are correlation of annual growth across regions (short run dynamics), ρ_{ij}.

Legend: NE (North-East) includes Trentino, Veneto, Friuli; NW (North-West) includes Valle d'Aosta, Piemonte, Lombardia, Liguria; CE (Centre-East) includes Emilia Romagna, Umbria, Marche; CW (Centre-West) includes Lazio, Toscana; SE (South-East) includes Abruzzi, Molise, Puglia; SW (South -West) includes Campania, Calabria, Basilicata, Sicilia, Sardegna.

The general outcome is that of a basically common economic structure such that different regions share, to some degree, both long run and short run dynamics at least in sign (notice that, at this level of aggregation, we never find inverse relationships between cycles and or trends across macroareas). However, we also find deep heterogeneity both in the long run and in the short run dynamics across different regional areas, with regional proximity playing a major role in shaping the common reply that each regional economy may exhibit to both a permanent and transitory shocks.

In order to verify the robustness of the estimates above and take confidence about the selected aggregation of macro-areas, we move now to show the sign and magnitude of covariations estimated by the completely disaggregated table for coherencies and correlations across the twenty regions (see Table 3).

The first result is the clear evidence of a group of regions that share higher than average degree of covariations across long run growth cycles as well as correlations across annual growth rates. These regions belong to the macro areas defined as Centre-North-East. Even at this level of disaggregation it is confirmed that *geographical proximity plays a major role in shaping the common dynamic features of the per-capita GNP.* For example, Lombardia is mostly related to Piemonte both in the long run ($h(0) = 0.88$) and in the short run ($\rho = 0.91$). Emilia is mostly related to Marche and Veneto in the long run ($h(0) = 0.97$ and $h(0) = 0.93$, respectively) and in the short run ($\rho = 0.91$ and $\rho = 0.9$, respectively). In general, these measures decrease, the higher the distance between two given regions.

Particularly remarkable is the strong long run relation emerging across Toscana and the regions in the Centre-North-East. Some regions in the South of Italy have relevant degree of both long run and short run degree of correlation; these may be roughly

indicated as the regions in the South East. Lazio, Basilicata and Sardegna exhibit some negative sign indicating a lower degree of economic integration in the long run with the rest of nation. The overall picture emerging from this disaggregated analysis confirms the results obtained above by using more aggregated areas. The measure of cohesion across regions and macro areas computed so far may also allow the identification of homogeneous macroareas. To this aim we need a measure of cohesion *within* areas wich will be considered in the next section.

Table 3 Correlations and coherencies																				
	PIE	VDA	LOM	TRE	VEN	FRI	LIG	EMI	TOS	UMB	MAR	LAZ	ABR	MOL	CAM	PUG	BAS	CAL	SIC	SAR
PIE	1	0.57	0.88	0.46	0.71	0.77	0.45	0.51	0.39	0.29	0.4	0.56	0.36	0.63	0.43	0.67	0.17	0.15	0.13	0.068
VDA	0.79	1	0.36	0.18	0.38	0.38	0.49	0.24	0.3	0.21	0.18	0.31	0.43	0.14	0.24	0.45	0.47	0.44	0.36	0.1
LOM	0.91	0 ,79	1	0.67	0.85	0.87	0.39	0.7	0.63	0.49	0.56	0.34	0.42	0.7	0.61	0.61	-0.03	0.3	0.066	-0.09
TRE	0.76	0.56	0.69	1	0.89	0.82	0.4	0.91	0.89	0.88	0.87	-0.08	0.7	0.74	0.72	0.58	0.29	0.48	0.52	-0.08
VEN	0.85	0.72	0.86	0.88	1	0.94	0.59	0.93	0.82	0.83	0.85	0.052	0.64	0.77	0.76	0.71	0.33	0.48	0.44	0.031
FRI	0.85	0.7	0.86	0.83	0.9	1	0.55	0.89	0.78	0.76	0.82	0.15	0.72	0.83	0.76	0.83	0.34	0.45	0.49	0.099
LIG	0.8	0.72	0.75	0.75	0.85	0.78	1	0.44	0.36	0.5	0.38	0.32	0.42	0.28	0.56	0.51	0.56	0.29	0.47	0.52
EMI	0.82	0.71	0.85	0.83	0.91	0.89	0.75	1	0.88	0.9	0.97	-0.19	0.73	0.82	0.74	0.69	0.4	0.54	0.59	0.006
TOS	0.69	0.72	0.79	0.6	0.79	0.73	0.77	0.75	1	0.88	0.85	-0.23	0.79	0.71	0.77	0.56	0.23	0.64	0.59	-0.17
UMB	0.68	0.59	0.73	0.71	0.72	0.75	0.61	0.78	0.63	1	0.9	-0.24	0.74	0.6	0.73	0.61	0.42	0.62	0.65	0.029
MAR	0 ,70	0.66	0.75	0.67	0.76	0.84	0.58	0.9	0.69	0.78	1	-0.25	0.75	0.8	0.67	0.67	0.48	0.57	0.66	0.07
LAZ	0.71	0.6	0.61	0.49	0.55	0.61	0.6	0.42	0.48	0.41	0.43	1	-0.19	-0.03	-0.16	0.16	-0.05	-0.25	-0.2	0.28
ABR	0.49	0.51	0.5	0.57	0.58	0.66	0.63	0.52	0.68	0.58	0.52	0.39	1	0.69	0.81	0.82	0.62	0.65	0.81	0.23
MOL	0.34	0.53	0.55	0.56	0.61	0.71	0.62	0.64	0.51	0.49	0.61	0.26	0.6	1	0.65	0.76	0.37	0.3	0.45	0.15
CAM	0.42	0 ,37	0.51	0.63	0.65	0.6	0.66	0.52	0.66	0.54	0.37	0.17	0.79	0.5	1	0.7	0.37	0.62	0.52	0.25
PUG	0.56	0.35	0.47	0.5	0.48	0.63	0.5	0.5	0.4	0.62	0.53	0.49	0.71	0.65	0.49	1	0.6	0.46	0.65	0.41
BAS	0.25	0.32	0.12	0.55	0.39	0.44	0.46	0.38	0.11	0.25	0.37	0.22	0.51	0.52	0.41	0.46	1	0.4	0.77	0.64
CAL	0.17	0.41	0.32	0.13	0.24	0.27	0.16	0.28	0.36	0.41	0.47	0.08	0.42	0.1	0.42	0.36	0.22	1	0.58	0.015
SIC	0.24	0.11	0.22	0.31	0.27	0.34	0.38	0.31	0.42	0.2	0.38	0.41	0.58	0.32	0.26	0.58	0.44	0.27	1	0.33
SAR	0.26	0.17	0.18	0.35	0.3	0.27	0.48	0.15	0.26	0.19	0.13	0.4	0.62	0.33	0.63	0.57	0.53	0.26	0.48	1
Note The values below the diagonal are the correlations of annual output growth across countries.																				
The values above the diagonal are coherencies at zero frequency which are equal to the correlations of long term cycles across countries																				

4.3 Dynamic principal component analysis

The presence of economic linkages *across* regions and macro-areas implied by the results obtained in the previuos section can be matched by the analysis of economic cohesion *within* each area by considering the covariation among growth cycles (on the whole frequency domain) exihibited by regions included in each group.

As far as long run growth cycles we take the view that, while it is true that few number of common trends indicates the constraints imposed on the movements of the series in the long run, it is also the case that an interesting information may be recovered by establishing the amount of total variance of output vector that can be ascribed to the first common trend. Furthermore, this analysis can be replicated at higher frequencies. Even in this case a few number of common components at a given frequency can be taken as evidence for the importance of interregional linkages across short - medium growth cycles with a period correspondent to that frequency. To this aim we report now the dynamic principal component analysis by plotting $\overline{\Phi}_p$ as defined by equation (7) and $\Phi_p(\omega)$ as defined by equation (6).

4.3.1 Average comovements $\overline{\Phi}_p$. Figure.1 shows the variance of $\Delta y_{n,t}$ explained by the p principal components with p = 1, ..., n, where n represents the number of regions included in the macroareas and t the time index. As stated above, $\overline{\Phi}_p$ represents the average weight (with respect to the whole frequency domain) in terms of explained variance due to each dynamic principal component (i.e. by a mixture of transitory and permanent shocks).

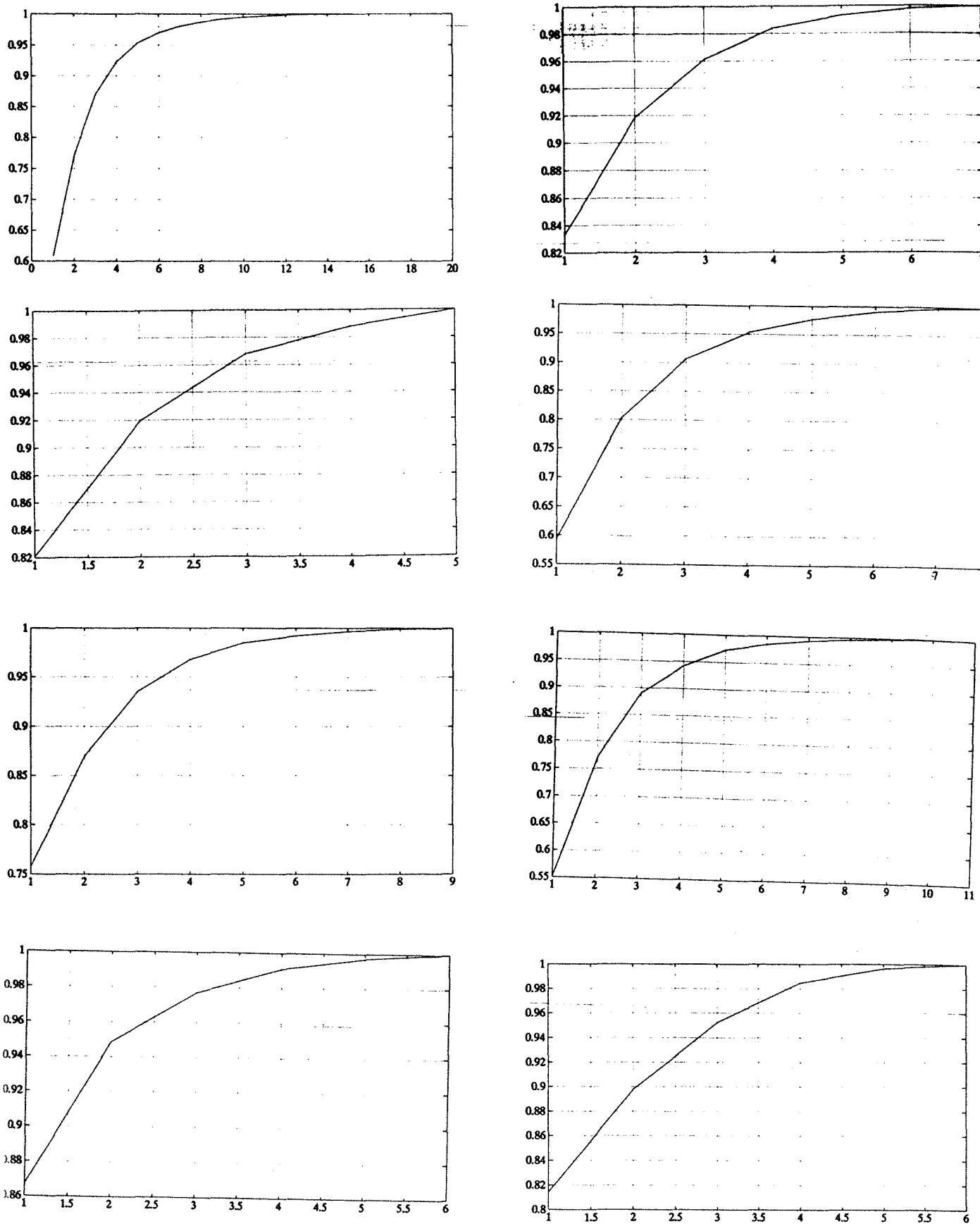

Figure 1 Explained variance by *p* dynamic principal components $\overline{\Phi}_p$ with p= 1,...,20, for different cases. $\overline{\Phi}_n$ = , when p = n. Starting from the first plot on the upper left corner, estimates are referred to the following macroareas: Italy, North, Centre, South, Eastern Italy, Western Italy, Center-North-Est, Center-North-West.

We focus on $\bar{\Phi}_1$, that is the averaged first principal component, the one explaining most of the total variance in $\Delta y_{n,t}$. The point estimate of the variance explained by the first dynamic principal component over the whole frequency domain represents the degree of homogeneity in output dynamics both in the short and in the long run.

Table 4 Point estimate of the average variance of $\Delta y_{n,t}$ explained by the first dynamic principal component on the whole frequency domain, $\bar{\Phi}_1$.

Italy	60%	North	83%	CNE	87%	NE	92%
East	76%	Centre	82%	CNW	81%	NW	85%
West	55%	South	60%	CN	80%	SE	80%
						SW	61%

Legend: East = CNE + SE, West = CNW + SW, North = NE+ NW, Centre = CE + CW, CN = Centre + North, CNE = NE + CE, CNW = NW + CW and see the legend in Table 2.

The evidence summarised in Table 4 supports the picture drawn on the basis of coherency-correlation analysis: the dynamics of percapita output in Italian economy is driven to a certain extent (60%) by common shocks indicating the presence of a basic common economic structure. However the degree of heterogeneity within each of the macro areas considered is still evident. Once again the most integrated area is represented by NE, followed by CNE and NW. Also notice that the South is as well (or as bad) integrated in a common economic structure as Italy as a whole. However, SE exhibits a higher degree of economic homogeneity than the SW.

4.3.2 Dynamic principal components at different frequencies: $\Phi_p(\omega)$. The results above can be further qualified by analysing the shape of dynamic principal components at each frequency. Figures 2 reports the ratios $\Phi_1(\omega),\Phi_2(\omega),...,\Phi_n(\omega)=1$, where n

indicates, as usual, the number of regions considered in the various cases. The spectra have been estimated using Bartlett's window with window-size ($\sqrt{n}$) equal to 5. One main feature of these plots are the number of dynamic principal components sufficient to explain 95% of the variance of $\Delta y_{n,t}$.

Evaluating $\Phi_1(0),\Phi_2(0),\ldots,\Phi_n(0)=1$, we get an indication of the number of common trends that are present in the aggregate macro-area. This is useful to test for the necessary condition for convergence that requires the presence of just one common trend across the n region in the macro area. The second feature on which we will focus our attention is the first principal component, $\Phi_1(\omega)$, since it is the one explaining most of the variance of $\Delta y_{n,t}$ and hence the most importasnt measure of the degree of comovement.

Table 5 reports the estimate of the percentage of the variance of $\Delta y_{n,t}$ explained by the first dynamic principal component evaluated at zero frequency, $\Phi_1(0)$ (see also Figure 2).

Table 5 Point estimate of the variance of $\Delta y_{n,t}$ explained $\Phi_1(0)$ (evidence for the existence of one common trend)

Italy 65%	North 69%	NE 92%	NW 65%
East 84%	Centre 91%	NE+EMI 93%	CNW 59%
West 49%	South 61%	CNE 91%	

Notes: see the legend in Table 4 and 2.

The results suggest that Italy as a whole has a significant long run component which is common across regions, indicating a certain degree of homogeneity though the necessary condition for convergence is clearly violated.

Furthermore it is also clear that the most serious candidate for satisfying the necessary condition for convergence (one common trend) is the macroarea labelled NE

including Emilia. Another area exhibiting a high level of homogeneity is the Centre. As far as North as a whole its degree of long run homogeneity is only slightly higher than Italy as a whole. The South as a whole turns out to be less homogeneous as Italy as a whole.

We move now to further analyse the dynamic principal components over the whole frequency domain, $\Phi_1(\omega),\Phi_2(\omega),...,\Phi_n(\omega) = 1$, as plotted in Figure 2A and 2B.

Italy. Figure 2A shows the dynamic principal components estimated for the twenty Italian regions in the first plot on the upper left corner.

The first statistical result is that we need at least (point estimation) 5 principal components to give account for 95% of the variance at zero frequency ($\Phi_5(0) > 0.95$). This implies at least 5 common trends and hence no convergence according to the definition by Bernard and Durlauf (1995).

The second result is that the $\Phi_1(\omega)$ (the most important in terms of explained variance) does not exhibit a peak at $\omega = 0$. As a results, common components at the medium-long run cycle frequencies are more important than common long run components.

The third result is that the sum of the first four dynamic principal components, $\Phi_4(\omega)$, is rather steady at each frequency so that the (low) degree of integration (high number of common components) across regional economies is similar at the long run as well as at the short run frequency. This result matches what we obtained in the previous paragraph by analysing coherencies and correlations: though the structure of common cycles and trend differs across macro areas (heterogeneity), an high coherency was generally matched by a high correlation and viceversa.

Taking the disaggregation for North, Centre and South separately it can be noticed that the North exhibits the higher degree of homogeneity at the high frequencies, $\Phi_1(\omega)$

has a clear peak around $\omega = 2.3$, whereas the Centre as a whole exhibits a strong common component at $\omega = 0$. As for South $\Phi_1(\omega)$ is much less important than $\Phi_1(\omega)$ referred to Centre and North. This indicates even lower degree of integration of southern regions (see also Table 4).

Following the same methodology, let us now perform the statistical analysis of different macroareas aggregated according to an ideal separating curve following the meridians rather than the parallels.

Eastern Italy From Figure 1 we had that 95% of the total variance is explained by the first 3-4 principal components, $\overline{\Phi}_3, \overline{\Phi}_4$ and $\overline{\Phi}_1$ explains 75% of the total variance of the series. Now, if we decompose the contribution of each principal component across frequencies (Figure2A) we can notice that the first two principal components explain the 90% of the variance at zero frequency $(\Phi_2(0) > 0.9)$ and the first three the 95% $(\Phi_3(0) > 0.95)$. This result implies a reduced number of common trends across the 9 regions aggregated under this issue. The sum of the first three components, $\Phi_3(\omega)$, is rather steady across the frequencies indicating that long run comovements are similar in weight as the short ones.

Western Italy Compared to the results obtained in the case of Eastern Italy, the results for this area are strikingly different: we need more than 4 components to explain the 95% of the total variance in the process of per capita output, $\overline{\Phi}_4 > 0.95$, (1-2 more than in the previous case), see Figure1. Decomposing the contribution of each principal component across frequencies, see Figure 2A, we find that the first four exhibit a similar shape at each frequency indicating a high level of heterogeneity both in the long and in the short run.

We move now to a more disaggregated unit of analysis for each of the macro-regions. Figure 2B shows the relevant plot for this disaggregated areas: CN, NE+EMI, NE, NW, CNE, CNW. From this plots we can argue that the most integrated area is the Centre-North-East which we now discuss.

Centre-North-East Figure 1 showed that only 2 dynamic principal components are enough to give account for the 95% per cent of the overall variance variables, $\Phi_2 > 0.95$. This is a good indication that the regions included in this economy are well integrated. By inspecting the, by now familiar, decomposition of the contribution of each principal component at each frequency, we can confirms the previous indication: $\Phi_1(0) > 0.90$ and $\Phi_2(0) > 0.95$ (see Figure 2B). This is the strongest evidence for a small number of common trends, at most two. Furthermore, the fact that the first principal component, explaining 90% of the overall variance has a peak at zero means that the degree of integration of the economies considered in this group seems to rest on long run properties of their per capita output dynamics.[14]

[14] We consider CNE area as the only serious candidate for testing the necessary and sufficient condition for convergence, i.e. the existence of an identical common stochastic trend (see section 2). If these regional output series have a common persistent component (trend), the output deviations from a selected benchmark region must all have zero-persistent components. How to choose the benchmark region. Asymptotically this choice should not matter, but in small samples it will be important. We choose Emilia Romagna as the reference region due to its prominence in this macroarea: it has the higher output level both at the beginning and at the end of the period. Testing for convergence has been implemented via dynamic principal component analysis on a vector of relative output (Emilia Romagna as benchmark) and rejected. Not reported. Results are available on request.

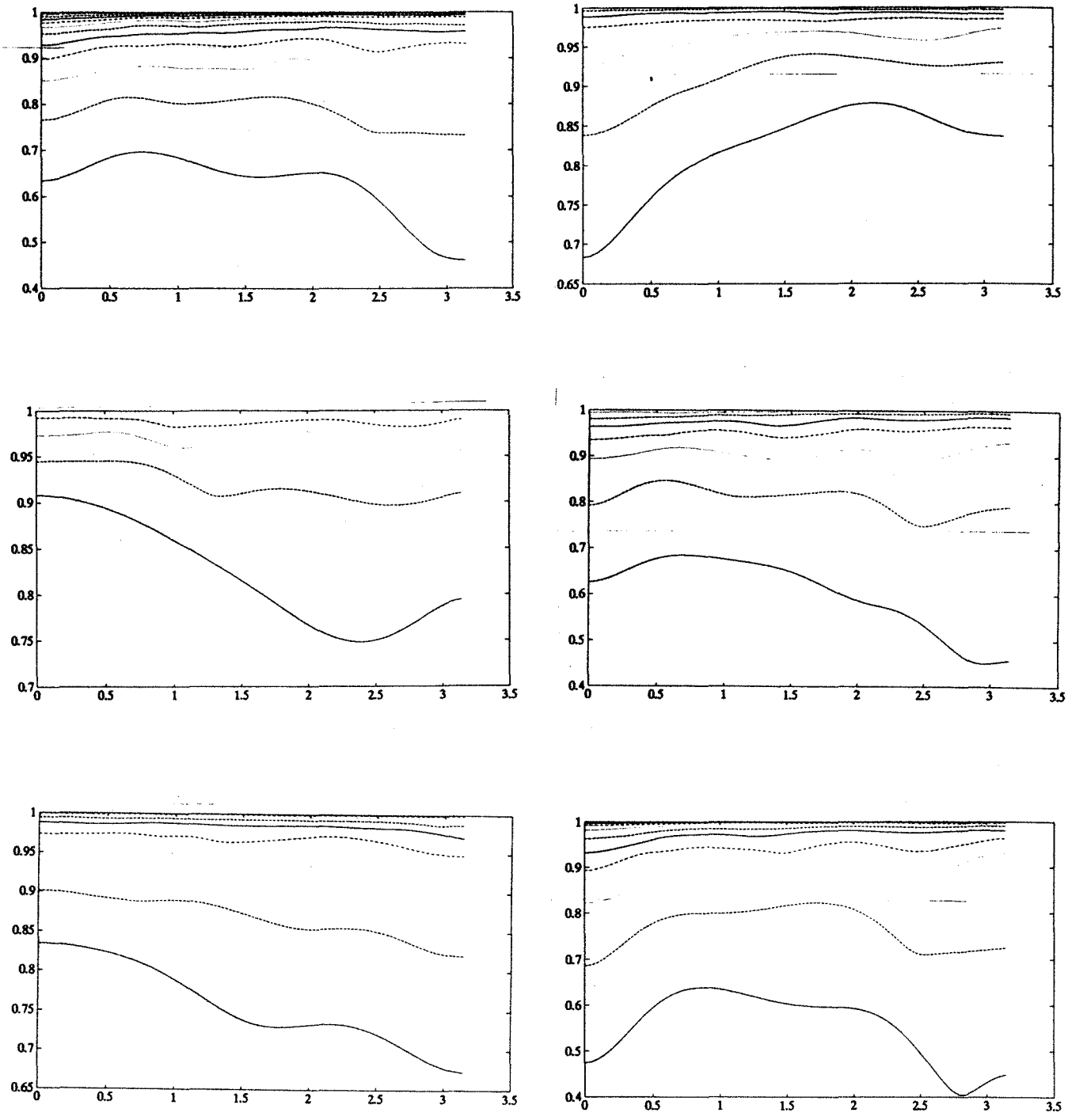

Figure2A Explained variance by p dynamic principal components $\Phi_p(\omega)$ for different cases and $\Phi_n(\omega) = 1$ when n = p. Starting form the first plot on the upper left corner of the figure we find the following aggregates: Italy, North, Centre, South, Eastern Italy, Western Italy.

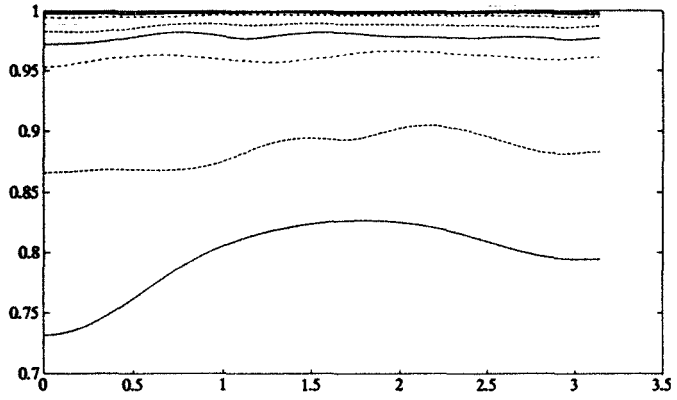
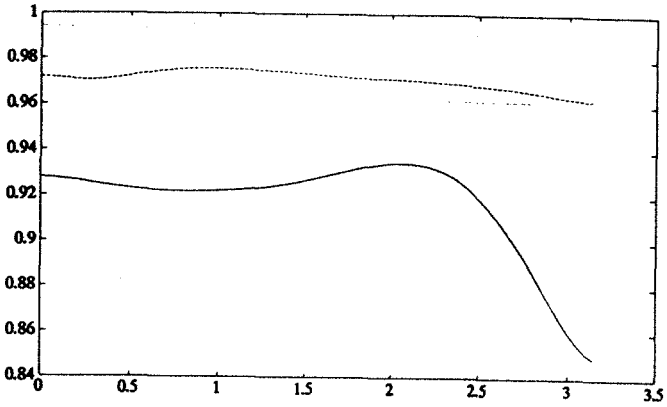
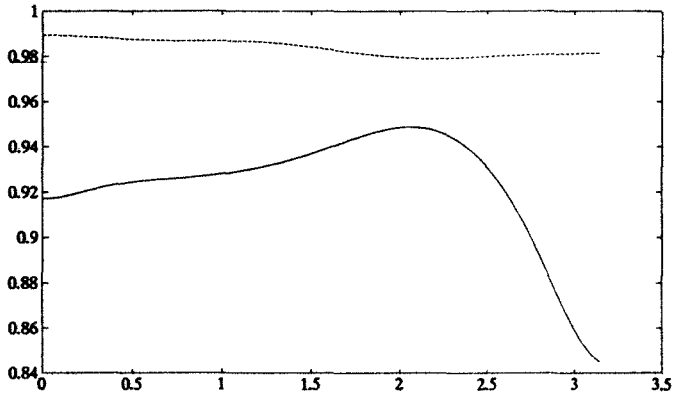
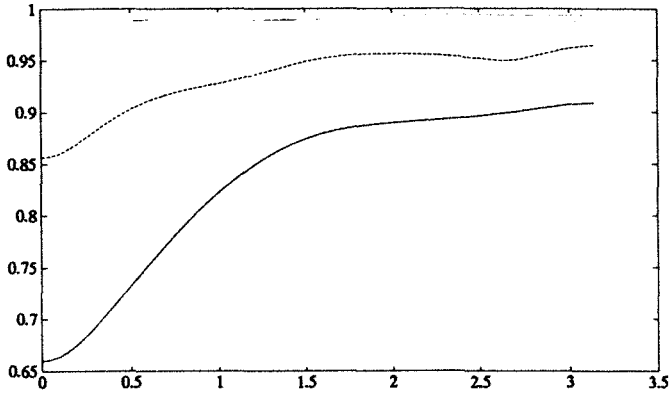
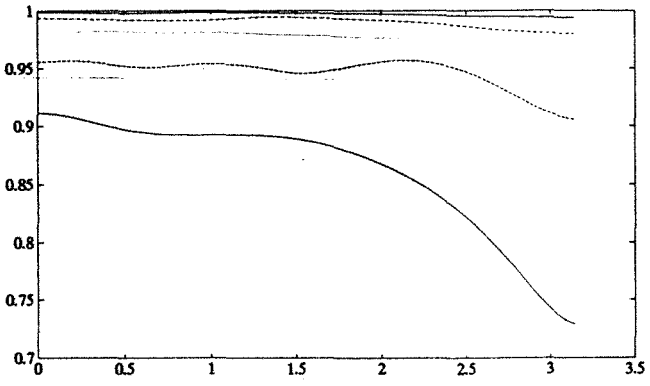
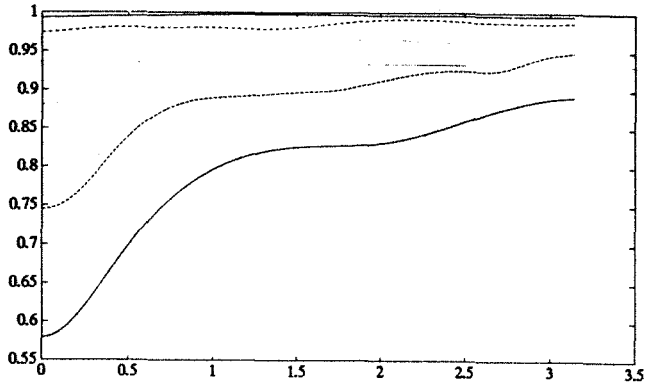

Figure2B Explained variance by p dynamic principal components $\Phi_p(\omega)$ for different cases and $\Phi_n(\omega) = 1$ when n = p. Starting form the first plot on the upper left corner of the figure we find the following aggregates: CN, NE+EMI, NE, NW, CNE, CNW.

5. Conclusions

Previous analysis, mainly dealing with the convergence issue, have reported mixed evidence about the rejections of the hypothesis of different definitions of convergence across italian regions and for different sub-periods, (see Cellini and Scorcu, 1994, Mauro and Podrecca 1994, Paci and Pigliaru, 1995, Acconcia, 1995). In this paper, by testing the Bernard and Durlauf (1995) definition of stochastic convergence, we reject this hypothesis for Italy as a whole and for different macroareas. However, the main focus of the paper is more general: we study long run and short run co-movements across regional output from a time series perspective, using different non parametric methods.

Homogeneity across region and macroareas has been analysed computing coherency (at zero frequency) across units as a measure of long run comovements and correlation between annual per capita output growth as a measure of short run comovements.

At the most disaggregated level, coherencies and correlations across regions indicate that the measures of both long run and short run output comovements are not homogeneous across regions. Some extreme examples are: Piemonte is significantly related to Lombardia in the long run, but not at all with regions like Calabria, Sicilia, Sardegna. Veneto is strongly related in the long run to Friuli, Emilia, Lombardia and other regions in the Centre-North. The regions in the South are mostly related to confining units, and the average measure of long run comovements is lower than in the case of northern regions. Lazio, Basilicata and Sardegna exhibit some negative sign of the covariaton across long run growth cycles indicating the presence of strong idiosyncratic growth path.

These results led us to investigate the degree of integration across different macro areas. Coherency at zero frequency and correlations indicate that North-East is more integrated to Centre-East, South-East and Centre-West than to North-West and South-

West. North-West is mostly related to Centre-West. South-West is mainly related to South-East but exhibits the lowest measure of comovement with any other macroarea.

The degree of *homogeneity within each macro-area* has been analysed by using dynamic principal components. From this analysis we can conclude that one common components explains 60% of the total variance (as an average on the whole frequency domain) of italian regions, indicating the existence of a common basic economics structure within Italy as a whole. However a certain degree of heterogeneity within sub aggregates is still evident. The most homogeneous area turns out to be Noth-East, followed by Centre-North-East, North-West, South-East and South-West (this latter exhibiting the lowest degree of integration).

The analysis of the degree of cohesion *within* macro areas has been further developed by considering the dynamic principal components at different frequencies. This allows us to discriminate between long run and short run degree of cohesion. As far as long run, from this analysis we can conclude that one common permanent shock explains 65% of the total variance (at zero frequency) of Italian regions, indicating the existence of a common basic economics long run structure within Italy as a whole. This measure is even higher than 65% for North-East and Centre-North-East. Regions within South turn out again to have the lowest measure of long run cohesion though South Eastern regions when aggregated to Centre-North-East do not reduce dramatically the measure of the cohesion of the whole group. In summary, the East-West line is at least as important as the North-South line in describing the degree of cohesion in the long run (one common permanent shock explains 84% of the total variance, at zero frequency, of regional outputs included in the group labelled Eastern Italy; this measure drops to 49% when the group of western regions is considered).

As far as the short run, the analysis indicates that Italy as a whole has a similar degree of cohesion as in the long run. Regions within North have a high degree of homogeneity at high frequency (a peak in the first common component is found at a

frequency correspondent to cycles of about 3 years). Regions in the South have as low degree of cohesion as in the long run (the importance of the first common component is the lowest at any frequency). Compared to Eastern regions, Western regions as a group exhibit a higher level of heterogeneity in the short run dynamics as it was the case for the long run.

Though we are aware of the exploratory nature of this analysis we can sinthesise the general results as follows: there is not any evidence for convergence even for clubs of regions, in particular for the most integrated group of regions belonging to Centre-North-East, but the economic growth in this macroarea cannot be reduced exclusively to idiosyncratic region-specific factors, a relatively small set of common components interact with regional economic characteristics to determine growth rates and the feature of *long run dynamics* prevent output levels from diverging by too much. The important feature showed by the data seems to be the role of geographical proximity in shaping the common dynamics of per capita real outputs.

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