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Co-movements in European real outputs

di

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Abstract: We study the issue of convergence and long run and short run co-movements across European countries in a time series perspective. To this aim we perform dynamic principal components analysis, cointegration analysis and correlation analysis across trends and across cycles of real outputs on a sample period spanning from 1960 to 1992. We reject the hypothesis of convergence, but find evidence for long run co-movements in real output more important than the business cycle ones for all the 16 European countries particularly when the smaller sample of the 6 original European Community countries is considered.

Key words: dynamic principal components method, Johansen cointegration procedure, Beveridge and Nelson decomposition, co-movements, convergence.
JEL classification numbers: C14, C32, O40, O57

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1. Introduction*

Since the influential work of Baumol (1986) the empirical debate on convergence has been placed at the forefront of economic research. A far from exhaustive list of prominent papers on the empirics of economic growth includes: Barro (1991), Barro and Sala-i-Martin (1991, 1992), Barro and Lee (1994a, 1994b), De Long (1988), Dowrick and Nguyen (1989), Levine and Renelt (1992), Mankiw, Romer and Weil (1992), Sala-i-Martin (1994)[1]. Typically, this literature analyses the pattern of income or productivity growth in a cross sectional unit (country, region) 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 (generally, time-averages flows: e.g. average investment rate, and beginning of period stocks: e.g. indexes of educational attainment): a negative initial level coefficient is interpreted as convergence. This outcome means that: "... a poor economy tends to grow 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. This property corresponds to our concept of β-convergence"[2] (Barro and Sala-i-Martin 1995, p. 383).

Recently this kind of analysis has been object of intensive critique on many sides. One of these is the expected endogeneity of the subset of explanatory

*We thank Mario Forni for useful suggestions and for kindly providing the program to estimate dynamic principal components.

[1]For recent references, see Barro and Grilli (1994) and Barro and Sala-i-Martin (1995).

[2]Absolute or conditional depending on the presence of explanatory variables other than the initial growth rates.

variables, when included (see, among others, Caselli et al. 1995); another one is the incorrect treatment of country-specific effects, that is of the differences in steady-states, representing, for example, differences in technology (see, for example, Canova and Marcet 1995, Caselli et al. 1995, Knight et. al 1993, Islam 1995). A third one is known as "Galton's fallacy critique" and has been put forward by Quah (1993), who argues that a negative cross-section regression coefficient on initial level is, in fact, consistent with the absence of convergence as defined above. In other words, the sign of the initial level coefficient says nothing about whether there is convergence or divergence. Finally, time series variations are ignored and this methodology fails to test the concept of convergence implicit in growth models (see Bernard and Durlauf 1994, Quah 1993, for further details).

In this paper we utilise some statistical procedures in a context of unit root random field that permit us to test for convergence across European real outputs taking into account the information available for all the period and all the cross sectional units avoiding some of the critiques above. We allow for more efficient use of the time dimension of the data and do not force the country specific effects to be the same, in other words we test for the same steady state for each country, but we do not impose this condition in the estimation. In particular, we utilise a notion of convergence entirely referred to the time series properties of these series rather than cross-section ones: abandoning the concept of β-convergence and according to the definition proposed by Bernard and Durlauf (1991, 1995), we define convergence for a group of economies to mean that each of them has identical long run trends, either stochastic or deterministic: if the process describing the technological progress contains a stochastic trend, then convergence implies that the permanent components in output are the same across economies.

One of the statistical procedures adopted here to test for this notion of convergence and common trends, is a dynamic principal component analysis. This method permits 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 countries simultaneously over a long time period as well as to check for co-movements across outputs at the cycle frequencies. For comparison, we use cointegration procedure, the counterpart of the common trends literature, proposed by Johansen (1991) that enables us to test directly the convergence hypothesis (for dimensionally not too large cross-section of countries). To provide further evidence about long run and short run co-movements, we also perform correlations across trends and correlations across cycles of the European outputs. To do this, we utilise the trend-cycle decomposition due to Beveridge and Nelson (1981).

Our analysis leads to two basic conclusions. First, we do not find convergence, but find strong evidence of a small number of common stochastic elements in European outputs, explaining most of total variance[3]. Moreover, the high weight of the first permanent common component (at zero frequency, explains at least 0.80 of total variance) prevents output levels to diverge too much in the long run. Second, at the business cycle frequencies, there is not evidence of important co-movements. This latter outcome is reinforced by the results of correlation analysis across trends and across cycles of the series.

Our work is related, among others, to papers by Bernard and Durlauf (1991, 1995), Campbell and Mankiw (1989), Cogley (1990), Quah (1990), who also explore convergence in a time series perspective. All these papers find persistence in output disparities of the OECD economies. In particular, Bernard and Durlauf (1991, 1995) and Cogley (1990) stress that the no-convergence result is a substantial outcome for many countries, but, as in our case, there is a strong

[3]The existence of more than one permanent component should merit to be theoretically modelled in order to perform identification of their sources. This requires a more adequate analysis with respect to the a-theoretical one performed in this paper. See, for example, Blanchard and Quah (1989), King et. al. (1991) and Forni and Reichlin (1995).

evidence of common stochastic elements in long run economic movements. Our analysis differs from these papers in some respects. We use a different data set and a different econometric technique: a dynamic principal component analysis over all the frequencies, which seems to be appropriate to study not only the convergence issue, but also long run and short run co-movements; since this method permits to establish the weight of the common shocks to the variables at different frequencies of the business cycle.

The plan of the paper is as follows. Section 2 contains the definition of convergence proposed by Bernard e Durlauf (1991, 1995) and the description of the econometric methods utilised. Section 3 presents the empirical results. Section 4 concludes.

2. Definition of convergence and econometric methods

Bernard and Durlauf (1991, 1995) introduce a definition of convergence entirely referred to the time series properties of outputs. According to these authors, 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 country is related to a permanent shock to other countries, in other words it requires the same stochastic trend (or unit root) in national outputs[4].

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[4]The formal definition of convergence in stochastic environments is provided in Bernard and Durlauf (1995) p. 99. According to these authors we report the definitions of common trends and convergence: **Common trends in multivariate output.** *Countries p= 1,...,n contain a single common trend if the long term forecast of output are proportional at a fixed time t, let* $\bar{y}_t = [y_{1,t}, \ldots, y_{p,t}]$,

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

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

A large class of real business cycle models[5], stochastic versions of the standard neo-classical growth model, interprets the presence of unit root in national output and a common unit root in international output movements as due to permanent technological shocks. In other words the stochastic trend (or common stochastic trend) in output (in international multivariate output) is representative of the random walk technology process. This will be referred to as the purely technological interpretation of unit root in output.

The presence of one common trend (n-1 cointegrating vectors) in multivariate output *not necessarily implies* convergence since this outcome imposes relatively weak restrictions on technology movements. In a context of optimal growth models, this only requires the existence of some links between national production functions, so that the permanent shocks *partially* migrate, instead convergence would require that permanent (technological) shocks *fully* migrate from one country to another. In other words, convergence requires that each country of the group under examination has *identical* long run trends, while common trends or cointegration allow for *proportionality* of the stochastic elements[6]. Obviously, under the null of n common stochastic trends (no-cointegration), the innovations do not exhibit linear transmission mechanism in the long run and the source of fluctuations is idiosyncratic at domestic level and not transferred from a country to another.

This analysis has been considered as a test for factual implication of the thesis, derived in the context of optimal growth models, that if all countries share technology and preferences, then output levels will converge over time. If this is

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

Both the definition have testable implications from the cointegration literature. For example, convergence in countries i and j requires a cointegration vector (1, -1), while common trends definition requires a cointegration vector (1, $-\alpha$) - we refer to this as the necessary condition for convergence.

[5] See, for example, King et. al. (1991).

[6] More formally, convergence among n economies requires (n-1) cointegrating vectors of the form (1, -1) and identical deterministic components.

not the case, idiosyncratic microeconomic factors are important to explain the growth. Hence, testing for the presence of just one common persistent part explaining most of the total variance of international output movements is equivalent to testing for the "necessary" condition for convergence and "purely" technological interpretation of unit root.

Now, we briefly introduce the three different methods to check for co-movements and convergence in European outputs. The first one is a dynamic principal component analysis[7] performed to identify the number of common shocks in European 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 across outputs and to test for the "necessary" condition for convergence (one common trend). The second one is the Johansen's cointegration procedure, that permits to test directly the hypothesis of convergence across outputs (necessary and sufficient condition), when the cross-sectional units are not too large. Finally, Beveridge and Nelson's trend-cycle decomposition of European output is also presented. The estimated permanent and transitory components (trend and cycle) of each series is used to analyse correlations among cycles of different economies in order to establish the degree of short run co-movements and compare them with the long run co-movements (correlations among trends).

2.1 Dynamic principal components method. Let Y_t denote the $(n \times 1)$ vector of individual output levels (log real per capita GDP for n economies). 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

[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 (1991, 1995) and at any frequencies see Forni and Reichlin (1995).

$$\Delta Y_t = B(L)\zeta_t \qquad (1)$$

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

$$f_{\Delta Y}(e^{-i\varpi}) = B(e^{-i\varpi})\sum\nolimits_{\zeta} B(e^{i\varpi})',$$

where ϖ indicates the frequency and $\sum_{\zeta}$ the variance-covariance matrix of innovations. 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 $f_{\Delta Y}(e^{-i\varpi})$, that explain the most of the variance of ΔY_t at each frequency. We can ask how many principal components explain at least the 0.95% of total variance of ΔY. If p components are sufficient we conclude that there are p common elements in the vector of international outputs.

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

$$f_{\Delta Y}(\varpi) = P(\varpi)D(\varpi)\overline{P(\varpi)}',$$

where $D(\varpi)$ is a diagonal matrix with r non-zero elements on the principal diagonal (the eigenvalues): $[\lambda_1(\varpi)\ldots\ldots\lambda_p(\varpi)]$ and $\text{rank}D(\varpi) = \text{rank}f(\varpi)$. 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):

$$\int_0^{\pi}\sum_1^{p}\lambda_i(\varpi)d\varpi \Big/ \int_0^{\pi}\sum_1^{n}\lambda_i(\varpi)d\varpi, \qquad p = 1, \ldots, n.$$

At *zero frequency*, the number of principal components (equal to the rank of the spectral density matrix at zero frequency) gives indication for the number of common permanent components or common stochastic trends in international output.

If idiosyncratic elements dominate for each country, then we would expect to find n common permanent parts (or equivalently n common trends) for n countries. This means that each country converges to its own steady state If countries converge, we expect to find the necessary condition for convergence respected, that is one common permanent component (or equivalently one common trend) that explains most of the total variance of ΔY_t.

2.2 Multivariate cointegration procedure. For Johansen tests for cointegration (Johansen 1991), we impose additional structure on the output series. Assume that representation (1) can be rewritten as the following vector autoregressive representation

$$\Gamma(L)\Delta Y_t = \Pi Y_{t-1} + \zeta_t \qquad (2)$$

where the Π matrix represents long run relations across output levels and the polynomial matrix $\Gamma(L)$ represents the short run impact of shocks on the system. Tests for cointegration concerns the rank, r, of the long run matrix Π. If $r = 0$, we have no-cointegration and n idiosyncratic trends in international output. If Π is a full rank matrix, that is $r = n$, we have n cointegrating vectors and no common trends, finally if Π is a reduced rank matrix, $r < n$ we have r cointegrating vectors and $(n\text{-}r)$ common trends. Convergence requires identical common long run trends in international output. Representation (2) under the hypothesis of $(n\text{-}1)$ cointegration vectors of the form (1, -1) implies both identical stochastic trend and identical deterministic component in international output that is convergence[8]. Hence, Johansen procedure permits to test directly necessary and sufficient condition for convergence.

[8]Cointegrating vectors can be thought of as representing constraints that an economic system imposes on the movements of the outputs in the long run within the n-dimensional space. More cointegrating vectors there are, the more stable is the system. In a system with no common trends, so it is stationary, the vector of outputs never wanders too far from its steady state equilibrium value. If there is one common trend and (n -1) cointegrating vectors, there are only (n -1) directions where the variance is finite and one in which it is infinite. In other words the system *converges* to a unique long run equilibrium. The fewer the number of cointegrating vectors, the less constrained is the long run relationship across outputs. If there are no cointegrating vectors, the outputs are free to wander anywhere, they are unbounded.

2.3 Trend-cycle decomposition. We introduce now the analysis performed by Beveridge and Nelson (1981) decomposition. Let y_t be an element of output vector Y_t and consider its univariate[9] Wold representation

$$\Delta y_t = b(L)\varepsilon_t \qquad (3)$$

We can rewrite representation (3) as follows

$$\Delta y_t = b(1)\varepsilon_t + \Delta\bar{b}(L)\varepsilon_t \qquad (4)$$

where $\bar{b}(L) = \dfrac{b(L) - b(1)}{(1-L)}$. Representation (4) is the univariate Beveridge and Nelson decomposition of a series in trend and cycle. In particular, $b(1)\varepsilon_t$ is the first difference in the trend component and $\Delta\bar{b}(L)\varepsilon_t$ is the first difference in the cyclical component. By integrating equation (4), we obtain

$$y_t = b(1)\sum_{s=0}^{\infty}\varepsilon_{t-s} + \bar{b}(L)\varepsilon_t \qquad (5)$$

where $b(1)\sum_{s=0}^{\infty}\varepsilon_{t-s}$ is an infinite sum of shocks plus a constant and represents the stochastic trend, while $\bar{b}(L)\varepsilon_t$ is a stationary moving average representing the cycle.

By fitting an ARMA(p, q) for Δy_t, we can derive the Wold representation, as in equation (3), and decompose the output growth in its permanent and cyclical components, as in equation (4). In order to analyse the links among European output fluctuations, we can compute the correlation coefficients across trends and across cycles of the series.

[9]Given the small number of observations, we prefer utilise univariate Beveridge and Nelson decomposition in spite of multivariate one.

3. Empirical results

The annual data used relate to log per capita real output (in US \$ at 1985 price levels) of 16 European economies, 1960-1992, and are taken from OECD Annual National Account: Main Aggregates[1]. Results (not reported) from Dickey-Fuller tests, with autoregressive corrections of order 0 through 4 in regressions with and without trend, suggest that the series of real outputs utilised in this paper are I(1) with drift in levels. In testing for co-movements and convergence, the analysis is performed for two groups of economies: all 16 European countries (16 EC) together and the original six European Community countries (6 ECC).

Starting with the case of 16 economies, Figure 1 reports the ratios: $\lambda_1(\varpi)\Big/\sum_1^{16}\lambda_i(\varpi)$, $\sum_1^{2}\lambda_i(\varpi)\Big/\sum_1^{16}\lambda_i(\varpi),\ldots\ldots,\sum_1^{16}\lambda_i(\varpi)\Big/\sum_1^{16}\lambda_i(\varpi)=1$ at each frequency ϖ where i represents the number of eigenvalues in decreasing order. The spectra have been estimated using Bartlett's window[2] with lag window size equal to ten. The variance of $\Delta Y_{16,t}$ explained by the first principal component at zero frequency, where it is possible to capture permanent components in the series, is nearly 0.85 of total variance. It suggests that there is one very important common shock which, in the context of an optimal growth model, can be interpreted as a technological shock. However, to capture at least 0.95 of total variance of $\Delta Y_{16,t}$ at zero frequency are necessary at least three components. This means that there are at least three common permanents shocks (or common stochastic trends) that explain the long run European output movements. This outcome suggests that the cointegration of groups of economies is more probable than cointegration two by

[1]The countries are: Austria (AUT), Belgium (BEL), Denmark (DNK), France (FRA), Western Germany (DEU), Greece (GRC), Ireland (IRL), Italy (ITA), Luxembourg (LUX), Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), United Kingdom (GBR).
[2]Bernard and Durlauf (1991,1995) use rectangular Daniel window.

two[3] (which is equivalent to testing the presence of just one common trend) and that the "necessary" condition to have global convergence in all the European sample (16 EC) does not hold. However, there are some economies that may be linked by common long run movements, suggesting the possibility to have convergence clubs. We move now to test this hypothesis[4].

Figures 2 summarises the dynamic principal components analysis for the sub-aggregate six original European Community countries[5]. In this case, two components at zero frequency are able to capture 0.95 of the total variance suggesting that there are at least two common trends, representing presumably a technological component and a non technological component in GDP. In particular, the first component (always at the zero frequency) is able to capture 0.85 of total variance of the 6 ECC outputs suggesting weak evidence about the interpretation of persistence (or unit root) in output as technology based and preventing outputs to diverge too much[6]. Relying on this evidence we will perform a direct test of convergence using Johansen tests for the 6 ECC group.

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[3]This result confirms the outcome of bivariate cointegration tests, that is considering economies two by two, that we also performed. There is little evidence of bivariate cointegration between all the countries. The results are available on request.

[4]In the text, we report only the results for the group of 6 ECC. The same analysis performed for other sub-aggregates does not reduce the number of principal component necessary to explain large part of total variance of output vector with respect to the group of 16 economies.

[5]BEL, FRA, DEU, ITA, LUX and NDL.

[6]When we add to the 6 ECC countries such as Ireland, Greece, Spain and Portugal the weight of the first permanent shock decrease suggesting more divergence both respect to the 6 ECC case and all 16 group.

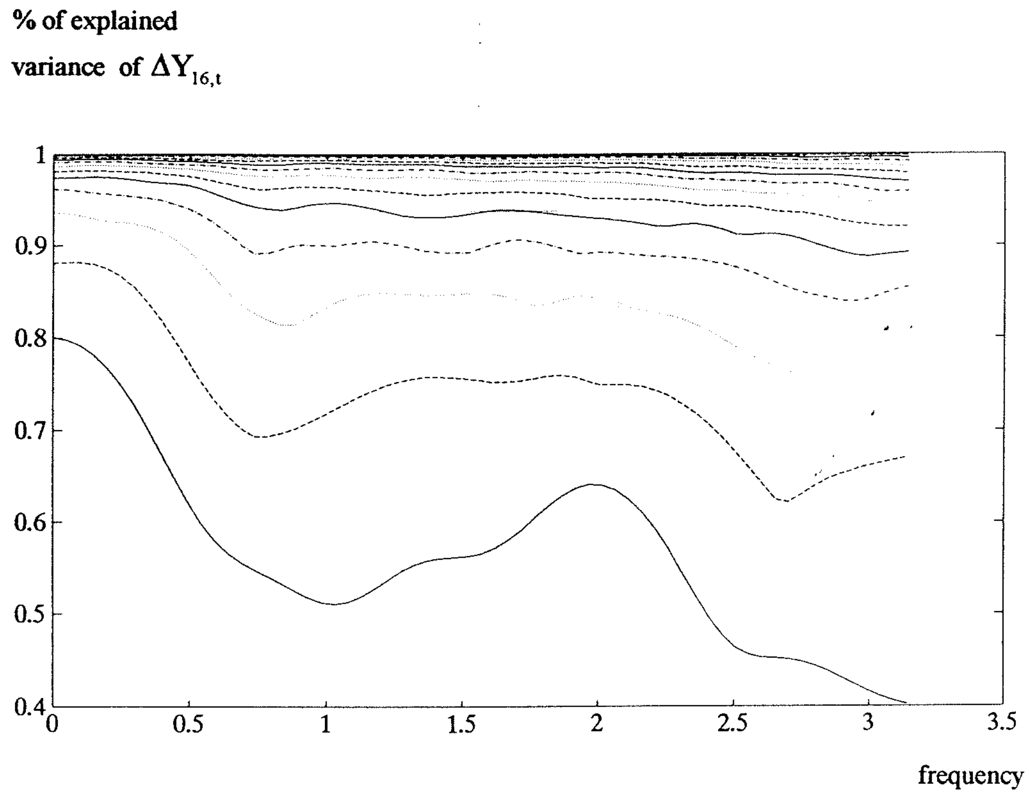

Figure1 Variance of $\Delta Y_{16,t}$ explained by 16 principal components at different frequencies

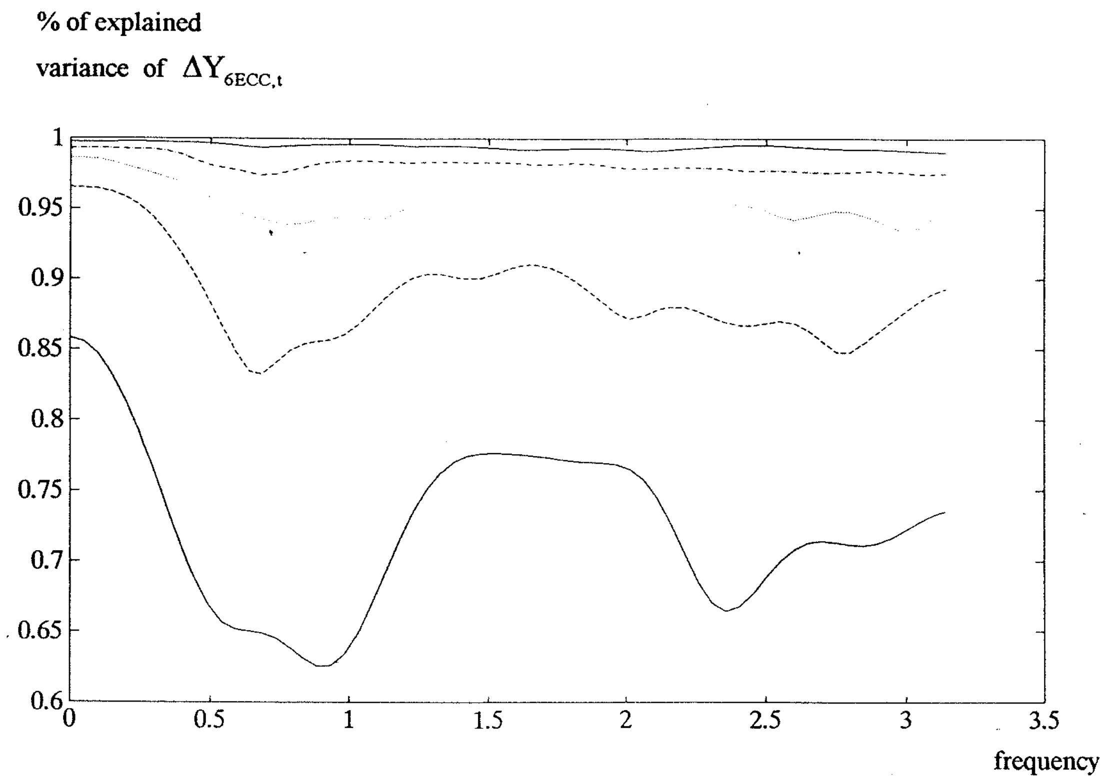

Figure 2 Variance of $\Delta Y_{6ECC,t}$ explained by 6 principal components at different frequencies

In Table 1, we present the results from the Johansen trace and maximum eigenvalue statistics on convergence and common trends for a dimensionally not too large cross-section of countries: the 6 ECC. The lag length of the models has been chosen using standard diagnostic testing procedure and information criterion tests[7]. Testing for convergence suggests that this hypothesis can not be accepted (see table 1, test for convergence), we turn to the test for the number of common trends. Maximum eigenvalue statistics enable us to reject the null hypothesis that there are four or more distinct trends, while trace statistics enables us to accept the presence of one or two, depending on the significance level, common trend in the 6 ECC group. These results match the previous outcomes derived by using dynamic principal component method, suggesting, however, higher level of economic integration across these economies.

[7]Diagnostic tests for autocorrelation, normality and heteroscedasticity and information criterion tests have been performed using PC-FIML program. For references and a discussion of these tests, see Doornick and Hendry (1994).

Table 1 Multivariate Tests for Cointegration or Common Stochastic Trends

	Six ECC		
Trends	Max Eig	Trace	Tests for Convergence
$\bar{>}5$	81.48	182.9	$\chi^2(5)$= 53.77*
>4	40.43	101.4	
>3	28.2*	61	
>2	19.29	32.7*	
>1	12	13.4#	
>0	1.44	1.44	

Notes: VAR lag length = 3; test for convergence distributed as a $\chi^2(n-1)$ where *n* is the number of countries;
* rejected at 5% critical value.
Max Eig: maximum eigenvalue test for cointegration = $T\ln(1-\lambda_{r+1})$.

Trace: trace test for cointegration = $T\sum_{r+1}^{p}\ln(1-\lambda_i)$. # rejected at 10% critical value.
Critical Values in Osterwald - Lenum (1992);

Let us now turn to the analysis of co-movements in European real outputs. Focusing on the first principal components in Figures 2 and 3, that track the *importance* of short run and long run co-movements, we see that there is a peak at zero frequency explaining most of the total variance (at least 0.80 percent) of the series. This outcome suggests that economies comove more in the long run than at the business cycle frequencies, that is there is substantial evidence for important idiosyncratic (transitory) shocks at country level. On the other hand, these economies face the same permanent shocks although with different long run weight (no convergence, but a small number of common trends).

Relying on this evidence, we perform now an analysis on long run and cyclical co-movements using correlations across trends and correlations across cycles of outputs, identified according to the Beveridge and Nelson decomposition (see, Tables 2 and 3)[8].

In Table 2, we report the *correlations across first differences of cyclical components* in European outputs. The pattern of contemporaneous correlations is not clear cut. The most striking result regards Germany and shows prevalence of negative correlations with the other European economies. Restricting attention to the 6 ECC countries, the cyclical component of German output turns out to be positively correlated only with Luxembourg. A similar patter is exhibited by Great Britain. These results seem to support the view stressing the costs and the difficulties implied by co-ordination of short run monetary and fiscal policies in Europe.

In Tables 3, we report *correlations across first differences of permanent components* (stochastic trends). The results show a quite different homogeneous pattern with positive and significant correlations. In particular, the group of the 6 ECC exhibits the highest correlations with 13 out of 15 coefficients larger than 0.55. Even in this case, Great Britain seems to have different growth pattern with respect to the rest of Europe.

In synthesis, correlations across trends (long run permanent component in outputs) are larger than correlations across cycles in almost all the cases, particularly for the group of the original six European Community country. This outcome matches the results obtained by applying a dynamic principal components method.

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[8]To obtain the Beveridge e Nelson representation given by equation (4) for all the series, we need to decide an optimal lag structure for the ARMA models of Δy_t. An AR(1) or AR(2) seem good representations for the European real outputs. We omit to present ARMA estimates, diagnostics of correct specification, but they are available on request.

Table 3 Correlations across first differences of the permanent component in European outputs

	AUT	BEL	DNK	FRA	DEU	ITA	LUX	NDL	ESP	CHE	GBR	GRC	IRL	NOR	PRT	SWE
AUT	1															
BEL	0,72	1														
DNK	0,44	0,48	1													
FRA	0,59	0,7	0,68	1												
DEU	0,56	0,58	0,63	0,58	1											
ITA	0,59	0,73	0,29	0,62	0,4	1										
LUX	0,43	0,7	0,5	0,62	0,56	0,48	1									
NDL	0,51	0,74	0,64	0,62	0,62	0,55	0,63	1								
ESP	0,39	0,42	0,29	0,39	0,25	0,43	0,54	0,18	1							
CHE	0,67	0,77	0,35	0,51	0,39	0,67	0,56	0,61	0,41	1						
GBR	0,17	0,21	0,35	0,44	0,4	0,2	0,24	0,25	0,22	0,12	1					
GRC	0,21	0,21	0,32	0,36	0,45	0,07	0,13	0,16	0,2	0,06	0,06	1				
IRL	-0,041	0,06	-0,16	-0,031	-0,017	-0,05	0,018	0,13	0,074	0,026	0,026	0,06	1			
NOR	0,11	0,12	0,42	0,1	0,12	0,19	0,13	0,35	0,007	0,11	-0,09	0,12	0,07	1		
PRT	0,54	0,62	0,4	0,54	0,5	0,62	0,3	0,5	0,36	0,64	0,42	0,18	0,07	0,18	1	
SWE	0,23	0,46	0,32	0,3	0,3	0,33	0,34	0,41	0,03	0,23	0,48	0,29	0,05	0,29	0,13	1

Table 2 Correlations across first differences of the cyclical component in European outputs

	AUT	BEL	DNK	FRA	DEU	ITA	LUX	NDL	ESP	CHE	GBR	GRC	IRL	NOR	PRT	SWE
AUT	1															
BEL	0,56	1														
DNK	0,38	0,18	1													
FRA	0,54	0,54	0,65	1												
DEU	-0,32	-0,59	0,08	-0,29	1											
ITA	0,55	0,6	0,24	0,64	-0,31	1										
LUX	0,099	-0,081	0,29	0,27	0,4	0,26	1									
NDL	0,39	0,71	0,52	0,55	-0,33	0,51	0,025	1								
ESP	0,36	0,33	0,065	0,34	-0,31	0,47	0,18	0,09	1							
CHE	0,65	0,84	0,13	0,52	-0,59	0,65	-0,13	0,65	0,37	1						
GBR	-0,31	-0,65	-0,051	-0,25	0,59	-0,37	0,18	-0,57	-0,33	-0,58	1					
GRC	-0,11	-0,16	0,11	0,05	0,04	-0,16	0,11	-0,14	-0,005	-0,2	0,42	1				
IRL	-0,23	-0,06	-0,18	-0,18	-0,18	0,03	-0,28	-0,41	-0,02	0,05	-0,06	0,006	1			
NOR	0,07	0,08	0,34	0,1	-0,05	0,22	0,23	0,39	0,013	0,2	-0,25	0,07	-0,12	1		
PRT	0,41	0,52	0,27	0,48	-0,19	0,62	0,05	0,45	0,22	0,6	-0,11	-0,009	-0,017	-0,07	1	
SWE	0,17	0,33	0,24	0,21	-0,012	0,24	-0,18	0,36	-0,08	0,95	-0,14	0,19	0,04	0,13	0,06	1

4. Conclusions

In this paper we study long run and short run co-movements and convergence across European outputs from a time series perspective, using different techniques. Dynamic principal component analysis shows that there are three common components at zero frequency (three common trends) across the 16 European economies and two common permanent components across the six original European Community countries. These results, confirmed by cointegration analysis, contrast the convergence hypothesis and also the purely technological interpretation of unit root in real outputs (which imply one common trend). However, the small number of common stochastic trends and in particular the large part of total variance in output fluctuations at zero frequency captured by the first principal component, suggests that economic growth in European industrialised economies cannot be reduced exclusively to idiosyncratic country-specific factors. The conclusion is that a relatively small set of common components interact with individual economic characteristics to determine growth rates and the feature of *long run dynamics* prevent output levels from diverging by too much. Furthermore, dynamic principal components analysis at the business cycle frequencies and correlations across cycles of outputs (as derived by Beveridge and Nelson's decomposition) show that there is less evidence of important short run co-movements in Europe. This latter outcome suggests that idiosyncratic transitory shocks at country level are important and stabilisation policy response may represent a fundamental problem for designing an effective European monetary policy institution facing this problem.

References

Barro, R.J., 1991, Economic Growth in a Cross-Section of Countries, *Quarterly Journal of Economics*, 106, 407-43.

_____ and V. Grilli, 1994, *European Macroeconomics*, Macmillan Press Ltd.

____ and J.W. Lee, 1994a, Losers and Winners in Economic Growth, *Proceedings of the World Bank Annual Conference on Development Economics*, The World Bank, 267-297.

____ and ____ , 1994b, Sources of Economic Growth, *Carnegie Rochester Conference on Public Policy*, 40, 1-46.

____ and X. Sala-i-Martin, 1991, Convergence across States and Regions, *Brookings Papers on Economic Activity*, 1, 107-82.

____ and ____, 1992, Convergence, *Journal of Political Economy*, 100, 223-51.

_____ and _____, 1995, *Economic Growth*, McGraw-Hill, Inc.

Baumol, W.J., 1986, Productivity Growth, Convergence, and Welfare, *American Economic Review*, 76, 1072-85.

Bernard, A.B. and S.N. Durlauf, 1991, Convergence of International Output Movements, Working Paper N. 3717, NBER.

_____ and _____, 1995, Convergence in International Output, *Journal of Applied Econometrics*, 10, 97-108.

Beveridge, S., and C. Nelson 1981, A New Approach to Decomposition of Economic Time Series into Permanent and Transitory Components with Particular Attention to Measurement of the Business Cycle, *Journal of Monetary Economics*, 7, 151-174.

Blanchard, O. and D. Quah, 1989, The Dynamic Effects of Aggregate Supply and Demand Disturbances, *American Economic Review*, 79, 1146-1164.

Brillinger, D. R., 1981, *Time Series: Data Analysis and Theory*, (Holden-Day San Francisco, CA)

Campbell, J.Y. and N.G. Mankiw, 1989, International Evidence on the Persistence of Economic Fluctuations, *Journal of Monetary Economics*, 23, 319-333.

Caselli, F., Esquivel, G., and F., Lefort, 1995, Reopening the Convergence Debate: A New Look at Cross-Country Growth Empirics, manuscript, Harvard University.

Cogley, T., 1990, International Evidence on the Size of the Random Walk in Output, *Journal of Political Economy*, 98, 501-518.

De Long, B., 1988, Productivity Growth, Convergence and Welfare: Comment, *American Economic Review*, 78, 1138-1154.

Doornick, J., and D., Hendry 1994, PC-FIML Manual.

Dowrick, S., and D., Nguyen, 1989, OECD Comparative Economic Growth 1950-85: Cactch-Up and Convergence, *American Economic Review*, 79, 1010-30.

Durlauf, S.N., 1989, Output Persistence, Economic Structure, and Choice of Stabilisation Policy, *Brooking Papers on Economic Activity*, 2, 69-136.

Forni, M. and L. Reichlin, 1995, Let' s Get Real: A Dynamic Factor Analytical Approach to Disaggregate Business Cycle, paper presented at CEPR Workshop- Empirical Macroeconomics, June 1995.

Islam, N., 1995, Growth Empirics: A Panel Approach, *Quarterly Journal of Economics*, 110.

Johansen, S., 1991, Estimation and Hypothesis Testing of Cointegrating Vectors in Gaussian Vector Autoregressive Models, *Econometrica*, 59, 1551-1558.

King, R., Plosser, C., Stock, J. and M. Watson, 1991, Stochastic Trends and Economic Fluctuations, *American Economic Review*, 81, 819-840.

Knight, M., Loayza N., and D. Villanueva, 1993, Testing the Neoclassical Growth Model, *IMF Staff Papers*, 40, 512-541.

Mankiw, G. N., Romer D., and D. Weil, 1992, A Contribution to the Empirics of Growth, *Quarterly Journal of Economics,* 107, 407-437.

Phillips, P.C.B. and S. Ouliaris, 1988, Testing for Cointegration Using Principal Components Methods, *Journal of Economic Dynamics and Control*, 12, 205-30.

Quah, D., 1990, International Patterns of Growth: Persistence in Cross-Country Disparities, Working Paper MIT.

____ , 1993, Galton's Fallacy and Tests of the Convergence Hypothesis, *Scandinavian Journal of Economics*, 95, 427-443.

Sala-i-Martin, X., 1994, Cross-Sectional Regressions and the Empirics of Economic Growth, *European Economic Review*, 38, 739-747.

1. Maria Cristina Marcuzzo [1985] "Yoan Violet Robinson (1903-1983)", pp. 134
2. Sergio Lugaresi [1986] "Le imposte nelle teorie del sovrappiù", pp. 26
3. Massimo D'Angelillo e Leonardo Paggi [1986] "PCI e socialdemocrazie europee. Quale riformismo?", pp. 158
4. Gian Paolo Caselli e Gabriele Pastrello [1986] "Un suggerimento hobsoniano su terziario ed occupazione: il caso degli Stati Uniti 1960/1983", pp. 52
5. Paolo Bosi e Paolo Silvestri [1986] "La distribuzione per aree disciplinari dei fondi destinati ai Dipartimenti, Istituti e Centri dell'Università di Modena: una proposta di riforma", pp. 25
6. Marco Lippi [1986] "Aggregations and Dynamic in One-Equation Econometric Models", pp. 64
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8. Mario Forni [1986] "Storie familiari e storie di proprietà. Itinerari sociali nell'agricoltura italiana del dopoguerra", pp. 165
9. Sergio Paba [1986] "Gruppi strategici e concentrazione nell'industria europea degli elettrodomestici bianchi", pp. 56
10. Nerio Naldi [1986] "L'efficienza marginale del capitale nel breve periodo", pp. 54
11. Fernando Vianello [1986] "Labour Theory of Value", pp. 31
12. Piero Ganugi [1986] "Risparmio forzato e politica monetaria negli economisti italiani tra le due guerre", pp. 40
13. Maria Cristina Marcuzzo e Annalisa Rosselli [1986] "The Theory of the Gold Standard and Ricardo's Standard Comodity", pp. 30
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15. Giovanni Bonifati [1986] "Saggio dell'interesse e domanda effettiva. Osservazioni sul cap. 17 della General Theory", pp. 42
16. Marina Murat [1986] "Betwin old and new classical macroeconomics: notes on Lejonhufvud's notion of full information equilibrium", pp. 20
17. Sebastiano Brusco e Giovanni Solinas [1986] "Mobilità occupazionale e disoccupazione in Emilia Romagna", pp. 48
18. Mario Forni [1986] "Aggregazione ed esogeneità", pp. 13
19. Sergio Lugaresi [1987] "Redistribuzione del reddito, consumi e occupazione", pp. 17
20. Fiorenzo Sperotto [1987] "L'immagine neopopulista di mercato debole nel primo dibattito sovietico sulla pianificazione", pp. 34
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22. Leonardo Paggi [1987] "Contemporary Europe and Modern America: Theories of Modernity in Comparative Perspective", pp. 38
23. Fernando Vianello [1987] "A Critique of Professor Goodwin's 'Critique of Sraffa'", pp. 12

24. Fernando Vianello [1987] "Effective Demand and the Rate of Profits. Some Thoughts on Marx, Kalecki and Sraffa", pp. 41

25. Anna Maria Sala [1987] "Banche e territorio. Approccio ad un tema geografico-economico", pp. 40

26. Enzo Mingione e Giovanni Mottura [1987] "Fattori di trasformazione e nuovi profili sociali nell'agricoltura italiana: qualche elemento di discussione", pp. 36

27. Giovanna Procacci [1988] "The State and Social Control in Italy During the First World War", pp. 18

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29. Maria Cristina Marcuzzo (a cura di) [1988] "Richard F. Kahn. A discipline of Keynes", pp. 118

30. Paolo Bosi [1988] "MICROMOD. Un modello dell'economia italiana per la didattica della politica fiscale", pp. 34

31. Paolo Bosi [1988] "Indicatori della politica fiscale. Una rassegna e un confronto con l'aiuto di MICROMOD", pp. 25

32. Giovanna Procacci [1988] "Protesta popolare e agitazioni operaie in Italia 1915-1918", pp. 45

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34. Margherita Russo [1988] "The effect of technical change on skill requirements: an empirical analysis", pp. 28

35. Carlo Grillenzoni [1988] "Identification, estimations of multivariate transfer functions", pp. 33

36. Nerio Naldi [1988] ""Keynes' concept of capital", pp. 40

37. Andrea Ginzburg [1988] "locomotiva Italia?", pp. 30

38. Giovanni Mottura [1988] "La 'persistenza' secolare. Appunti su agricoltura contadina ed agricoltura familiare nelle società industriali", pp. 40

39. Giovanni Mottura [1988] "L'anticamera dell'esodo. I contadini italiani della 'restaurazione contrattuale' fascista alla riforma fondiaria", pp. 40

40. Leonardo Paggi [1988] "Americanismo e riformismo. La socialdemocrazia europea nell'economia mondiale aperta", pp. 120

41. Annamaria Simonazzi [1988] "Fenomeni di isteresi nella spiegazione degli alti tassi di interesse reale", pp. 44

42. Antonietta Bassetti [1989] "Analisi dell'andamento e della casualità della borsa valori", pp. 12

43. Giovanna Procacci [1989] "State coercion and worker solidarity in Italy (1915-1918): the moral and political content of social unrest", pp. 41

44. Carlo Alberto Magni [1989] "Reputazione e credibilità di una minaccia in un gioco bargaining", pp. 56

45. Giovanni Mottura [1989] “Agricoltura familiare e sistema agroalimentare in Italia”, pp. 84

46. Mario Forni [1989] “Trend, Cycle and ‘Fortuitous cancellation’: a Note on a Paper by Nelson and Plosser”, pp. 4

47. Paolo Bosi , Roberto Golinelli , Anna Stagni [1989] “Le origini del debito pubblico e il costo della stabilizzazione”, pp. 26

48. Roberto Golinelli [1989] “Note sulla struttura e sull’impiego dei modelli macroeconometrici”, pp. 21

49. Marco Lippi [1989] “A Shorte Note on Cointegration and Aggregation”, pp. 11

50. Gian Paolo Caselli e Gabriele Pastrello [1989] “The Linkage between Tertiary and Industrial Sector in the Italian Economy: 1951-1988. From an External Dependence to an International One”, pp. 40

51. Gabriele Pastrello [1989] “Francois quesnay: dal Tableau Zig-zag al Tableau Formule: una ricostruzione”, pp. 48

52. Paolo Silvestri [1989] “Il bilancio dello stato”, pp. 34

53. Tim Mason [1990] “Tre seminari di storia sociale contemporanea”, pp. 26

54. Michele Lalla [1990] “The Aggregate Escape Rate Analysed throught the Queueing Model”, pp. 23

55. Paolo Silvestri [1990] “Sull’autonomia finanziaria dell’università”, pp. 11

56. Paola Bertolini, Enrico Giovannetti [1990] “Uno studio di ‘filiera’ nell’agroindustria. Il caso del Parmigiano Reggiano”, pp. 164

57. Paolo Bosi, Roberto Golinelli, Anna Stagni [1990] “Effetti macroeconomici, settoriali e distributivi dell’armonizzazione dell’IVA”, pp. 24

58. Michele Lalla [1990] “Modelling Employment Spells from Emilia Labour Force Data”, pp. 18

59. Andrea Ginzburg [1990] “Politica Nazionale e commercio internazionale”, pp. 22

60. Andrea Giommi [1990] “La probabilità individuale di risposta nel trattamento dei dati mancanti”, pp. 13

61. Gian Paolo Caselli e Gabriele Pastrello [1990] “The service sector in planned economies. Past experiences and future prospectives”, pp. 32

62. Giovanni Solinas [1990] “Competenze, grandi industrie e distretti industriali,. Il caso Magneti Marelli”, pp. 23

63. Andrea Ginzburg [1990] “Debito pubblico, teorie monetarie e tradizione civica nell’Inghilterra del Settecento”, pp. 30

64. Mario Forni [1990] “Incertezza, informazione e mercati assicurativi: una rassegna”, pp. 37

65. Mario Forni [1990] “Misspecification in Dynamic Models”, pp. 19

66. Gian Paolo Caselli e Gabriele Pastrello [1990] “Service Sector Growth in CPE’s: An Unsolved Dilemma”, pp. 28

67. Paola Bertolini [1990] “La situazione agro-alimentare nei paesi ad economia avanzata”, pp. 20

68. Paola Bertolini [1990] "Sistema agro-alimentare in Emilia Romagna ed occupazione", pp. 65

69. Enrico Giovannetti [1990] "Efficienza ed innovazione: il modello "fondi e flussi" applicato ad una filiera agro-industriale", pp. 38

70. Margherita Russo [1990] "Cambiamento tecnico e distretto industriale: una verifica empirica", pp. 115

71. Margherita Russo [1990] "Distretti industriali in teoria e in pratica: una raccolta di saggi", pp. 119

72. Paolo Silvestri [1990] " La Legge Finanziaria. Voce dell'enciclopedia Europea Garzanti", pp. 8

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74. Enrico Giovannetti [1990] "Illusioni ottiche negli andamenti delle Grandezze distributive: la scala mobile e l''appiattimento' delle retribuzioni in una ricerca", pp. 120

75. Enrico Giovannetti [1990] "Crisi e mercato del lavoro in un distretto industriale: il bacino delle ceramiche. Sez I", pp. 150

76. Enrico Giovannetti [1990] " Crisi e mercato del lavoro in un distretto industriale: il bacino delle ceramiche. Sez. II", pp. 145

78. Antonietta Bassetti e Costanza Torricelli [1990] "Una riqualificazione dell'approccio bargaining alla selezioni di portafoglio", pp. 4

77. Antonietta Bassetti e Costanza Torricelli [1990] "Il portafoglio ottimo come soluzione di un gioco bargaining", pp. 15

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82. Gian Paolo Caselli e Gabriele Pastrello [1991] "The 1990 Polish Recession: a Case of Truncated Multiplier Process", pp. 26

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93. Gian Paolo Caselli e Luca Martinelli [1993] "Italian GPN growth 1890-1992: a unit root or segmented trend representatin?", pp. 30

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100. Mario Forni [1994] "Consumption Volatility and Income Presistence in the Permanent Income Model", pp. 30

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