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Common stationary and non-stationary factors in the euro area analyzed in a large-scale factor model

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Abstract:

In this paper we rely on techniques recently developed by Bai and Ng (2004a) to estimate common euro-area stationary and non-stationary factors using a large-scale dynamic factor model. We find that euro-area economies share four non-stationary factors or trends and one stationary factor. By means of rotation techniques, we estimate a euro-area business cycle which is a fairly good match to EuroCOIN, the euro-area coincident business cycle indicator published by the CEPR. Fluctuations of common euro-area factors mainly reflect variations of German and French real economic activity as well as of producer prices and financial prices (long-term interest rates and/or real effective exchange rates) in various countries. As concerns the transmission channels, macroeconomic shocks seem to proliferate in the euro area more strongly through trade, exchange rates and long-term interest rates than through stock prices. Among the external driving forces, shocks to US economic activity seem to be more strongly linked to shocks to the euro-area factors than oil price shocks. We finally find evidence of mild overall convergence; results for individual countries are mixed.

Keywords: Dynamic factor models, factor rotation, common trends, international business cycles, international transmission channels

JEL Classification: F02, F40, C32, C50

Non Technical Summary

In this paper we investigate economic comovements in the euro area between 1981 and 2003. This issue is examined by means of a large-scale dynamic factor model. For this purpose, we have constructed a data set with almost 300 variables covering real, nominal and external developments in eight core euro-area countries in a balanced way. Our modelling framework allows us to exploit a lot of information in order to estimate both stationary and non-stationary common factors. To that extent, it has advantages over two other most closely related models used in this context: parametric unobserved component models permit us to estimate both common cycles and trends, but can only handle a small number of variables; by contrast, large-dimensional factor models which have previously been applied to the topic of international business cycle synchronization comprise many variables, but are not suited to estimate non-stationary factors.

The issue is relevant for forecasters who need to anticipate the international transmission of macroeconomic shocks. Moreover, it has to be dealt with by policy makers: business cycle linkages are important in the light of monetary and fiscal policy transmission lags. Moreover, the symmetry of shocks and the degree of international trade have been criteria for countries to adopt a single currency since Mundell (1961), and the Maastricht criteria to join the EMU include convergence of interest rates, inflation rates, budgetary balances and public debt as well as stable exchange rates.

We find four non-stationary factors or common trends and one common stationary factor. Using rotation techniques, we estimate the euro-area business cycle. Our estimate is a fairly good match to EuroCOIN, the euro-area business cycle measure published by the CEPR. Fluctuations of individual common euro-area factors reflect variations of German and French real economic activity as well as of producer prices and financial prices (long-term interest rates and/or real effective exchange rates) in various countries. In addition, we try to interpret the set of common factors along two lines. We ask, firstly, to what extent shocks hitting individuals countries coincide with shocks hitting the euro-area factors, and secondly, to what extent shocks affecting individual variables pooled over all countries, including variables approximating the transmission channels, and global shocks are correlated to shocks to the euro-area factors. Not surprisingly, shocks to the large German and French economies are most highly correlated with common euro-area shocks. As concerns the transmission channels, macroeconomic shocks seem to proliferate in the euro area more strongly through trade, exchange rates and long-term interest rates than through stock prices. No clear conclusions regarding the role of the confidence channel can be drawn based on our model. For this purpose, another type of analysis would be necessary._Among the external driving forces, shocks to US economic activity seem to be more strongly linked to shocks to the euro-area factors than oil price shocks. We finally find evidence of temporary real and nominal divergence, but mild overall convergence.

Nicht technische Zusammenfassung

Dieses Diskussionspapier untersucht den ökonomischen Gleichlauf im Euro-Raum zwischen 1981 und 2003. Diese Fragestellung wird anhand eines großen dynamischen Faktormodells behandelt. Dazu wurde ein Datensatz mit knapp 300 Variablen erstellt, die reale, nominale und außenwirtschaftliche Entwicklungen in acht Kernländern des Euro-Raums in möglichst ausgewogener Weise abbilden. Der hier gewählte Modellrahmen erlaubt, auf der Basis all dieser Variablen gemeinsame stationäre sowie nicht-stationäre Faktoren zu schätzen. Insofern besitzt dieser Ansatz Vorteile gegenüber zwei eng verwandten Modellen, die bislang auf das Thema des internationalen wirtschaftlichen Gleichlaufs angewandt werden: mit parametrischen Unbeobachtete-Komponenten-Modellen lassen sich sowohl gemeinsame Konjunkturzyklen als auch Trends schätzen, in diese Modelle kann aber nur eine begrenzte Anzahl von Variablen einbezogen werden; große Faktormodelle dagegen enthalten viele Variablen, allerdings werden in bisherigen Studien Modelle angewandt, die keine nicht-stationären Faktoren berücksichtigen.

Die Fragestellung ist relevant für Prognostiker, die die internationale Übertragung makroökonomischer Schocks antizipieren müssen. Sie ist auch politisch von Bedeutung: der Konjunkturverbund ist angesichts der Wirkungsverzögerungen geld- und fiskalpolitischer Impulse zu berücksichtigen; ein hoher Grad an Symmetrie von Schocks und an internationaler Handelsverflechtung sind seit Mundell (1961) für einzelne Länder Ausschlag gebend für den Beitritt zu einem gemeinschaftlichen Währungsraum, und zu den Maastricht-Kriterien für den Beitritt zur EWU zählen die Konvergenz der Zinsen, Inflationsraten, Budgetsalden und des öffentlichen Schuldenstands sowie stabile Wechselkurse.

Wir finden vier nicht-stationäre Faktoren oder gemeinsame Trends und einen gemeinsamen stationären Faktor im Euro-Raum. Anhand von Rotationstechniken wird der Euro-Raum-Konjunkturzyklus geschätzt. Dieser ist dem vom CEPR veröffentlichten entsprechenden Maß EuroCOIN sehr ähnlich. Veränderungen der einzelnen gemeinsamen Faktoren spiegeln Fluktuationen der französischen und der deutschen realen wirtschaftlichen Aktivität sowie von Produzentenpreisen und Finanzaktivapreisen (langfristigen Zinsen und/oder realen effektiven Wechselkursen) in mehreren Ländern wider. Darüber hinaus werden die Euro-Raum-Faktoren entlang zweier Dimensionen interpretiert. Zunächst wird untersucht, in welchem Ausmaß einzelne Volkswirtschaften beeinflussende Schocks mit Schocks, die die Euro-Raum-Faktoren treiben, übereinstimmen. Anschließend wird geprüft, in welchem Ausmaß einzelne länderübergreifende Variablen, darunter Maße für die Übertragungskanäle, sowie globale Einflüsse mit den Euro-Raum-Faktoren verbunden sind. Wie erwartet sind makroökonomische Schocks in den großen Ländern Deutschland und Frankreich am stärksten mit gemeinsamen Euro-Raum-Schocks korreliert. Was die Transmissionskanäle angeht, so scheinen sich Schocks im Euro-Raum stärker über den Handel, die Wechselkurse und die langfristigen Zinsen als über Aktienpreise zu übertragen. Über die Bedeutung des Vertrauenskanals lässt sich mit Hilfe des hier gewählten Ansatzes keine eindeutige Schlussfolgerung ziehen. Zu diesem Zweck sollte eine andere Art der Analyse durchgeführt werden. Unter den globalen Einflüssen ist der Zusammenhang zwischen US Schocks und gemeinsamen Schocks im Euro-Raum enger als der zwischen Ölpreisschocks und Euro-Raum-Schocks. Schließlich wird Evidenz für temporäre reale und nominale Divergenz, aber milde Konvergenz insgesamt gefunden.

Contents

Tables and Figures

Common Stationary and Non-Stationary Factors in the Euro Area Analyzed in a Large-Scale Factor Model[*]

1. Introduction

Recently, international economic comovements have again become a focus of public interest. This renewed interest has its roots in the worldwide economic downturn in 2001. Its strength, speed and synchronicity were particular and apparently unexplainable in terms of trade linkages alone. The downturn led researchers to closely investigate the evolution of international economic comovements and its determinants over time. Besides trade, macroeconomic shocks may nowadays proliferate to a stronger extent via financial markets and confidence linkages due to greater international financial integration and transparency enhanced by the new technologies. In addition, the frequency and size of common shocks relative to country-specific shocks that are not transmitted to other economies are likely to influence economic comovements over time.

International linkages have also been examined more extensively in the course of the formation of the EMU. The symmetry of shocks and the degree of international trade have been criteria for countries to adopt a single currency since Mundell (1961). The Maastricht criteria to join EMU include convergence of interest rates, inflation rates, budgetary balances and public debt as well as stable exchange rates, underlining the importance of studying convergence of real and nominal economic fluctuations at business cycle and lower frequencies in Europe.

The present paper investigates economic comovements in the euro area. Our goal is threefold.

- First, we aim at estimating common stationary and non-stationary factors using a large-scale dynamic factor model. This will allow us to examine to what extent euro-area economies comove, whether they share common trends and, if yes, how many.

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- Second, we would like to interpret the common factors economically and identify the underlying driving forces, thereby answering the following questions. Are shocks predominant in some countries more highly correlated with euro-area shocks than shocks predominant in other countries? It is conceivable, for example, that larger economies could act as locomotives for smaller countries. Are euro-area factors mainly driven by real or nominal forces? What role do the different transmission channels such as trade, financial markets and the confidence channel play? How important are external common shocks such as fluctuations in US economic activity or in world commodity prices for the euro area?

  As a byproduct, we derive an estimate for the common euro-area business cycle. Such an estimate, cleaned from measurement error and high frequency movements, may, for example, be useful for the European Central Bank whose task is to monitor aggregate euro-area inflation and, if price stability is likely to be achieved in the medium run, the euro-area business cycle. Moreover, European integration means that business decisions may increasingly depend on the aggregate business cycle.

- The third goal is to assess whether convergence in the euro area has taken place over time. Our framework will enable us to distinguish between real and nominal convergence.

To answer these questions, we adopt a framework that is most closely linked to two literature strands which have both previously addressed the topic of economic linkages in the euro area. The first jointly estimates common trends and cycles by means of small multivariate unobserved components models (see recent studies for the euro area by Carvalho and Harvey (2003) and Luginbuhl and Koopman (2004, LK)). These models assume that national economic activity is driven by latent trends and cycles which are common to all countries in the set and some idiosyncratic components. The trends are modeled as random walks and the cycles as VAR models or processes containing trigonometric terms with time-varying coefficients. These models are estimated using maximum likelihood based on Kalman filtering techniques, and estimation is feasible only when the number of variables included in the model, generally a measure of economic activity for each country, is small.

The second literature strand to which we refer consists of large-scale factor models. Those models have previously been used to investigate the commonality of business cycles in the euro area by Forni and Reichlin (2001, FR) and Marcellino, Stock and Watson (2000, MSW).[1] Compared to the small, fully parameterized unobserved components models, these models can cope with a large cross-section and hence allow much more information to be exploited. This may be desirable. Variables covering global shocks and transmission channels, for example, may influence the economic comovement. More precise factor

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[1] Other studies on international business cycle linkages using this type of factor models are Helbling and Bayoumi (2003) and Lumsdaine and Prasad (2003) who focus on G7 and, respectively, OECD countries, Malek Mansour (2003) who considers a large set of developed and developing countries, and Eickmeier (2004) who investigates business cycle linkages between the US and Germany.

estimation may be achieved if these variables are included in the data set. Moreover, such a large-dimensional framework allows the simultaneous assessment of the relevance of the many different propagation channels and external shocks, which small-scale models or large fully structural models are unable to do (see the discussion in Eickmeier (2004)).[2] If the cross-section is very large, the factors can be estimated consistently by means of principal component analysis (PCA).

Until recently, however, consistent estimation of large-dimensional factor models required the idiosyncratic components to be stationary. In contrast to small unobserved components models, these models were therefore not suited to handle non-stationary factors or common trends without restricting the errors to being stationary (Bai (2004)). In reality, however, the source of non-stationarity of a macroeconomic time series need not be pervasive but can also be idiosyncratic. Bai and Ng (2004a, BN) recently developed new techniques which permit to estimate both stationary and non-stationary factors in a large-dimensional factor framework without imposing this restriction.

The main contribution of the present paper is to apply the BN techniques to a large number of stationary and non-stationary macroeconomic variables of core euro-area countries. In this respect, we go beyond the work by FR and MSW. At the same time we keep the advantage of making use of many variables. This paper further contributes to the literature by investigating extensively the determinants of euro-area comovements. Structural analysis in the large-dimensional factor framework is particularly difficult. The estimated factors are not uniquely identified and cannot be interpreted as such. One possibility to attach an economic meaning to the factors is by identifying structural macroeconomic shocks underlying the common factors using SVAR techniques, as first suggested by Forni and Reichlin (1998) and sometimes referred to as 'structural factor models' (see for example Forni, Lippi and Reichlin (2003)).[3] There exist a number of recent applications in the monetary policy literature (e.g. Giannone, Reichlin and Sala (2002, 2004), Sala (2003), Cimadomo (2003)) and – to our knowledge – one in the international economic linkages literature (see Eickmeier (2004) who, however, treats linkages between the US and Germany in a purely stationary context). Another possibility is not to focus on the deep common structural shocks, but on the factors themselves, as done, for example, by MSW. The authors relate their euro-area factors to factors estimated from individual countries' data only and to individual variables using multi- and univariate correlation measures. We do the same and extend their work by investigating our set of factors along another dimension. We relate it to individual variables, including variables covering the various transmission channels, pooled across countries and to sets of

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[2] Another advantage of large-scale factor models is that the modeller does not need to take a stance on the structure of the economy, but "lets the data speak".

[3] In factor models the number of restrictions to identify the structural shocks or factors is generally much smaller than the number of variables included in the system. This represents an advantage over VAR models, where the number of identifying restrictions needs to be at least equal to the number of variables and where the researcher has to decide which variables are relevant for the identification and, therefore, should be included in the model.

global shock proxies. In addition, we adopt a broad approach to identify individual factors and undertake a large number of factor rotations. This also leads us to propose a way of estimating the common euro-area business cycle in our partly non-stationary framework.

The paper is organized as follows. Section 2 describes the data and the model. Section 3 estimates common non-stationary and stationary euro-area factors. Section 4 interprets the euro-area factors. Section 5 examines whether convergence has taken place over time. Section 6 concludes.

2. Data and the model

Data

We first construct a large data set which contains N^j (between 30 and 37) macroeconomic time series for each country j out of a set of core euro-area countries (Austria, Belgium, Finland, France, Germany, Italy, the Netherlands and Spain), representing 94% of total euro-area real GDP in 2003 (European Central Bank (2004)). The variables are selected so that the real and the nominal domestic side as well as the external side in each country and the different countries are represented in a balanced way if possible. In addition, the data set comprises a few global variables which possibly affect economic activity in the euro area: world energy prices, world non-energy commodity prices, US, UK and Japanese GDP, the nominal US dollar/euro exchange rate, and world trade. Aggregate euro-area variables are not included for the moment; aggregate euro-area GDP and GDP deflator, as taken from the data set underlying the ECB's Area Wide Model, are, however, added at a later stage when factors are interpreted. For each period $t = 1,....,T$, data are collected in a vector Y_t of dimension $N \times 1$, where $N = 282$ denotes the total number of variables in the set (excluding aggregate euro-area measures).

Data are quarterly, and our observation period ranges from 1981Q1 to 2003Q4, hence our time dimension T equals 92. The main reason for the choice of this period is data availability.[4] Our period under consideration is also roughly the same as the period considered by Cavalho and Harvey (2003), termed stabilization and restructuring period by the authors. Finally, the period is long enough to comprise at least two entire business cycles according to the CEPR definition.

Y_t may include I(0) and I(1) variables. For many countries, we tested prices, unit labor costs, compensation of employees and monetary aggregates to be I(2) by means of the standard unit root tests. We therefore include the first differences of these variables for all countries in the set. For more details on the data see Appendix A and Table 1.

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[4] Different time spans and missing observations can be dealt with employing the EM algorithm (Stock and Watson (1998)). But we decide to use a balanced panel here.

The model

It is assumed that Y_t follows an approximate dynamic factor model and can be represented as the sum of two unobserved components, a common euro-area component X_t and an idiosyncratic or variable-specific component Ξ_t, both having dimension $N \times 1$.

$$\mathrm{Y}_t = \mathrm{X}_t + \Xi_t . \tag{1}$$

The *i*th element of Y_t, y_{it}, can be written as

$$y_{it} = x_{it} + \xi_{it} , \tag{2}$$

where $i = 1,...,N$. X_t is a linear combination of the $q < N$ dynamic euro-area factors collected in f_t and their m lags:

$$\mathrm{Y}_t = \sum_{j=1}^{q} \sum_{s=0}^{m_j} \Lambda_{js}{}' \mathrm{f}_{jt-s} + \Xi_t = \Lambda' \mathrm{F}_t + \Xi_t . \tag{3}$$

The factors f_t are labeled euro-area factors because they are common to all or most *N* variables. And for variable *i*,

$$y_{it} = \sum_{j=1}^{q} \sum_{s=0}^{m_j} \lambda_{ijs}{}' \mathrm{f}_{jt-s} + \xi_{it} = \lambda_i{}' \mathrm{F}_t + \xi_{it} . \tag{4}$$

The right hand side of (3) is the static representation of the dynamic factor model which is useful for estimation. The r-vector F_t contains the stacked vectors of dynamic euro-area factors and their lags. The elements of F_t are called static factors. The λ_{ijs} s are the dynamic euro-area factor loadings and are of dimension $q \times 1$. They reflect reactions to fluctuations of the euro-area factors, which may differ across variables. Hence, Λ is of dimension $r \times N$. The factors are assumed to be mutually uncorrelated and to have a VAR representation. The residuals can be weakly serially and cross-correlated.

This model differs from models commonly used (e.g. Stock and Watson (2002), Forni, Hallin, Lippi and Reichlin (2000), Kapetanios and Marcellino (2003)) mainly in that the dynamic factors may be stationary, non-stationary or both.[5] q_0 denotes the number of stationary and $q_1 (= q - q_0)$ the number of non-stationary factors or common trends. In addition, the idiosyncratic components can be I(0) for some variables and I(1) for others. As mentioned in

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[5] Kapetanios and Marcellino's (2003) approach could be extended to cope with non-stationary factors.

the introduction, the source of non-stationarity in Y_t can thus be pervasive, idiosyncratic or both.

Two remarks are in order. First, Bai (2003) recently developed inferential theory for large-scale factor models. His results, however, rely on the errors to be stationary, which is not necessarily the case here. Second, at this stage, nothing can be said about whether the common factors are world factors, European or euro-area factors or other regional factors whose movements affect the variance of the overall euro-area economy substantially or all three. This question has been hotly debated in the past few years, and there is no consensus: Kose, Otrok and Whiteman (2003) and Artis (2003), for example, find evidence of a world, but not a European business cycle, whereas Lumsdaine and Prasad (2003) assert the existence of a European cycle. We will not provide any formal test on the existence of regional cycles, but try to shed some light on the two latter issues when we try to interpret the factors in Section 4.

3. Estimation of the model

The focus of this section is the estimation of the common dynamic factors. Basically there are three methods that permit the estimation of common factors in a large-dimensional, but stationary framework. One has been developed by Forni, Hallin, Lippi and Reichlin (2000) and involves dynamic PCA. A second relies on Kapetanios and Marcellino (2003) and uses a subspace algorithm and linear algebra methods. The last one is based on static PCA and has been suggested by Stock and Watson (1998, 2002). We rely on the latter. We first estimate F_t . We then derive dynamic factors from the static ones employing VAR techniques and, again, static PCA, which is based on Giannone, Reichlin and Sala (2002, GRS).[6] We combine the Stock and Watson-GRS method with the BN techniques, the latter enabling us to account for I(1) and I(0) variables, to estimate our dynamic euro-area factors. The numbers of common stationary and non-stationary factors are estimated by employing the methods derived by Bai and Ng (2002), Breitung and Kretschmer (2004, BK), Forni, Hallin, Lippi and Reichlin (2000) and Johansen (1991, 1995). Let us now explain all steps in detail. For the moment, we assume the number of factors to be known.

- As outlined above, we first aim at estimating F_t . However, we cannot estimate F_t directly from the second part of (3) since Ξ_t may contain non-stationary elements.[7] BN suggest using a trick and differencing Y_t once:

$$\Delta \mathrm{Y}_t = \Lambda' \Delta \mathrm{F}_t + \Delta \Xi_t \,. \tag{5}$$

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[6] GRS show how to estimate q structural shocks from r static factors. We will rely on their idea, but estimate dynamic factors from static factors. Note that this method relies on the factors loadings being orthogonal.

[7] When ξ_{it} is I(1), a regression of the y_{it} on F_t is spurious, even if F_t has been observed, and estimates for λ_i and thus of ξ_{it} are not consistent (BN).

$\Delta\Xi_t$ now contains only stationary elements.

- If $N, T \to \infty$, the r-vector of differenced static common euro-area factors $\Delta \mathrm{F}_t$ can be estimated consistently by applying static PCA to $\Delta \mathrm{Y}_t$[8]:

$$\Delta\hat{\mathrm{F}}_t = \mathrm{V}\Delta\mathrm{Y}_t \ . \tag{6}$$

  V is the $r \times N$ matrix of eigenvectors corresponding to the r largest eigenvalues of $\mathrm{cov}(\Delta\mathrm{Y}_t)$, and r denotes the number of static euro-area factors.[9]

- $\Delta\hat{\mathrm{F}}_t$ is then cumulated, yielding $\hat{\mathrm{F}}_t$:

$$\hat{\mathrm{F}}_t = \sum_{s=1}^{t} \Delta\hat{\mathrm{F}}_s \ . \tag{7}$$

- As already pointed out above, $\hat{\mathrm{F}}_t$ can contain, besides the $q \le r$ dynamic factors $\hat{\mathrm{f}}_t$, their lags.[10] In order to estimate $\hat{\mathrm{f}}_t$, it is assumed that $\hat{\mathrm{F}}_t$ follows a VAR(*h*) model, where *h* is determined by means of the Schwartz information criterion (SIC).

$$\hat{\mathrm{F}}_t = \mathrm{c} + \sum_{s=1}^{h} \mathrm{B}_s \hat{\mathrm{F}}_{t-s} + \mathrm{e}_t \ .^{11} \tag{8}$$

  If $\hat{\mathrm{F}}_t$ contains lagged dynamic factors, $\mathrm{cov}(\mathrm{e}_t)$ will have reduced rank. This means that a linear combination of the r-vector e_t can be found of which the first q elements fully span the factor space and the last $r - q$ elements have no explanatory power. This property is exploited, and the dynamic factors are estimated by applying static PCA to e_t. Let Ω denote the $q \times r$ matrix of the eigenvectors corresponding to the largest q eigenvalues of $\mathrm{cov}(\mathrm{e}_t)$. Then

$$\hat{\mathrm{f}}_t = \Omega\hat{\mathrm{F}}_t \ .^{12} \tag{9}$$

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[8] Stock and Watson (1998) further show that the principal components remain consistent if there is some time variation in Λ and small amounts of data contamination, as long as $\mathrm{T/N} \to 0$.

[9] Errors may be over-differenced, i.e. if ξ_{it} is I(0), first differencing may introduce serial correlation in $\Delta\xi_{it}$. According to BN, it should be weak, however, and the conditions for the consistent estimation of the number of factors and the factors themselves are not violated. In order to check the serial correlation for our case, we computed the first-order autocorrelations of the differenced idiosyncratic components. They have a mean of -0.09, variance of 0.08, and a median of -0.14. The extreme values are not smaller than -0.59 and not larger than 0.69. We therefore conclude that serial correlation is weak here.

[10] While BN focus on static factors, we estimate dynamic factors.

[11] *h* is estimated to be 8. c denotes the constant.

[12] It might be worth drawing attention to the fact that we cumulated the static differenced factors first before estimating a VAR model on the static factors in levels and estimating the dynamic factors in levels rather than fitting a VAR model to the differenced static factors, estimating differenced dynamic factors and cumulating those. This is done because over-differencing might induce a MA unit root in the differenced factors, and an

- Following BN, we now regress $\hat{\mathrm{f}}_t$ on a time trend and a constant and denote the residuals by $\hat{\mathrm{f}}_t^\tau$.[13] We then consider a rotation of $\hat{\mathrm{f}}_t^\tau$:

  $$\hat{\varphi}_t = \mathrm{Z}\hat{\mathrm{f}}_t^\tau, \tag{10}$$

  such that the factors are ordered according to their explanatory power. Z denotes the $q \times q$ matrix of eigenvectors associated with the largest q eigenvalues of $T^{-2}\sum_{t=2}^{T}\hat{\mathrm{f}}_t^\tau\hat{\mathrm{f}}_t^{\tau}{}'$.[14] This rotation also implies that the first q_1 elements of $\hat{\varphi}_t$ are I(1) and the last q_0 elements are I(0).

Up to now, we assumed the number of common factors as given. The number of static factors r, the number of dynamic factors q as well as the numbers of dynamic stationary and non-stationary factors q_0 and q_1 were determined as follows.

Typically, the formal Bai and Ng (2002) model selection criteria are employed to estimate r. q is generally fixed by requiring that either q dynamic principal components (DPCs) together or each of the q DPCs explain at least a certain share of the total variance or the variance of key variables (Forni, Hallin, Lippi and Reichlin (2000)). One might, for example, require that q DPCs span the same space as r static principal components (SPCs). More formal criteria for the determination of q were recently developed by BK. Those are based on canonical correlations between the static factors and their lags. Canonical correlation analysis finds linear combinations of the two factor sets such that the correlation between the first linear combination of the static factors and the first linear combination of the dynamic factors is maximized, the second linear combinations are uncorrelated to the first and yield the largest remaining correlation, etc. (Hamilton (1994), p. 633). The idea is: if, for example, $\hat{\mathrm{F}}_t$ includes one dynamic factor and its first order lag, the first canonical correlation between $\hat{\mathrm{F}}_t$ and $\hat{\mathrm{F}}_{t-1}$ is unity. The number of canonical correlations different from one then equals the number of dynamic factors. Note also that the BK criteria are conditional on r. For details, we refer to Bai and Ng (2002), Forni, Hallin, Lippi and Reichlin (2000) and BK.

It turns out that fixing r is not an easy task since the Bai and Ng (2002) criteria do not give conclusive results here.[15] Given the bunch of criteria and the difficulty involved with the application of the Bai and Ng (2002) criteria to our data set, we choose $r = 9$ and $q = 5$ for the following reasons: 9 SPCs and 5 DPCs both explain almost 40% of the total variance (Tables 2 and 3). In addition, 5 DPCs explain 83% and 49% of aggregate euro-area GDP growth and changes in inflation respectively. If we apply the BK criteria, conditional on

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autoregressive representation of the differences would be inappropriate (Plosser and Schwert (1977), Breitung (1994)).

[13] This corresponds to the linear trend case in BN.

[14] Note that the sum is divided by T^2. This is done because some of the factors are I(1) and their simple variances tend to infinity. Division by T^2 guarantees the finite eigenvalues.

[15] Some of the criteria always suggest the maximum permitted number of factors, while others suggest an insufficient number of factors to explain an economically significant share of the total variance.

$r = 9$, the AIC criterion yields $q = 4$, and the consistent SIC $q = 5$ (Table 4).[16] Finally, our choice is in line with the existing literature. KL find among five euro-area countries six common factors between 1970 and 2001[17] and four between 1987 and 2001. MSW select $r = 6$ factors for their set of euro-area countries explaining 37% of the total variance between 1982 and 1997 and 47% in the 1990s.[18] [19] In Altissimo, Bassanetti, Cristadoro, Forni, Lippi, Reichlin and Veronese (2001), four dynamic factors account for 55% of the total variation in a large euro-area data set between 1987 and 2001.[20]

The next step is to estimate the number of stationary and non-stationary factors. For this purpose the Johansen (1991, 1995) cointegration test is applied to $\hat{\varphi}_t$. Both the trace and the maximum eigenvalue tests indicate one cointegrating equation (Table 5).[21] This suggests the existence of four non-stationary factors or common trends and one stationary factor. The factors $\hat{\varphi}_t$ are plotted in Figure 1.[22] Our results differ slightly from the findings by KL, who find three common trends between 1970 and 2001 and two between 1987 and 2001. Finally, it must be noted that we cannot interpret the I(1) and the I(0) factors as common trends and common cycles in the traditional sense, since the I(1) factors possibly include I(0) components as well. The next section spends some effort to estimate a euro-area business cycle using rotation techniques.

4. Interpreting the euro-area factors

The aim of this section is to interpret the common euro-area factors. We first try to give individual factors an economic meaning. Using rotation techniques, we investigate to what extent shocks driving individual variables are correlated with shocks driving individual factors. As a byproduct, we estimate a common euro-area business cycle. We then try to interpret the set of common factors along two dimensions, the country dimension and the variable dimension. This is done by examining to what extent economic driving forces in individual countries and shocks to individual variables pooled across countries or to global variables, respectively, coincide with shocks which are predominant in the euro area. It should

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[16] Thanks go to Uta Kretschmer and Jörg Breitung for providing us with their Matlab code.

[17] In these models, reduced rank of the covariance matrix of the residuals of the cycle and the trend equations indicates commonality.

[18] MSW focus on static, not on dynamic factors.

[19] One reason that MSW need fewer static factors than we do to explain a similar variance share may be that, in their baseline case, MSW apply PCA to a data set containing some variables like inflation or interest rates in levels, whereas we extract the common factors from a set where these variables are in growth rates. Theoretically, they should be I(0). But according to the usual (not very powerful) unit root tests we performed some inflation and interest rates are I(1), which would suggest first differencing. In a sensitivity analysis, MSW also estimated a factor model on a set which includes these series in first differences, but they do not report the variances shares explained by the factors.

[20] We do not refer to FR here, since the authors restrict the number of European factors to be one.

[21] In our framework, where *N* is large, the factors can be treated as known. We therefore rely on the asymptotic critical values of the Johansen tests. This has, for example, been emphasized in Bernanke and Boivin (2001).

[22] The signs of the factors are not identified. We normalize them such that the link between each factor and the closest variable in terms of the AR residuals' absolute correlation is positive.

be noted, however, that no clear conclusions with respect to causal linkages can be drawn from the rough correlation measures we will use.

Giving individual factors an economic meaning

In order to provide individual factors with an economic meaning, we correlate shocks driving each factor with shocks driving each variable in the set. Our shock estimates are residuals from AR models fitted to each factor and each variable (see, for example, Bai and Ng (2004b) and Den Haan (2000), who use a similar measure).[23] Correlating the AR residuals instead of the variables and factors themselves avoids spurious correlation between non-stationary variables and factors.[24]

It is well known that the factors are only identified up to a rotation. This is not a problem in many applications like forecasting where factors are not considered separately. But it matters here, where we would like to interpret each factor economically. Identification is a very difficult task. We tackle this problem by adopting a broad approach. Besides the case of no rotation, we will consider below a large number of rotations and search for some robust outcome.

As in Canova and de Nicoló (2002), we perform an (orthogonal) Givens rotation of $\hat{\varphi}_t$. I. e. we pre-multiply $\hat{\varphi}_t$ with the $q \times q$ orthonormal rotation matrix $\mathrm{Q}(\theta) = \prod_{l,k} \mathrm{P}_{l,k}(\theta)$. $\mathrm{P}_{l,k}(\theta)$ is of the form

$$\mathrm{P}_{l,k}(\theta) = \begin{bmatrix} 1 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 1 & 0 & \cdots & 0 & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & \cos(\theta) & \cdots & -\sin(\theta) & 0 \\ \vdots & \vdots & \vdots & 1 & \vdots & \vdots \\ 0 & 0 & \sin(\theta) & \cdots & \cos(\theta) & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}, \qquad (11)$$

where θ denotes the rotation angle and the subscript (l,k) indicates that row l and column k are rotated by θ. θ is varied from 0 to $\pi/2$ on a grid, and the number of grids is chosen to be 1000.[25] The rotated factors $\mathrm{Q}(\theta)\hat{\varphi}_t, \forall\theta$ are, like $\hat{\varphi}_t$, orthogonal and explain together the same share of the total variance.

To fix a rotation, we use an economic criterion as well as a statistical criterion. The former consists in maximizing the correlation between the shocks to each of the five (rotated) factors

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[23] The lag lengths of the AR models are determined with the SIC, a constant is included.

[24] Bai and Ng (2004b) also derive formal criteria to test if observed factors coincide with estimated factors. These criteria are, however, not applicable in the present context, since they rely on the errors being stationary.

[25] There are $q(q-1)/2$ possible bivariate rotations for a given θ yielding, for $q = 5$, 10000 rotations.

and to a pre-specified variable y_{it}^* and picking the θ yielding the overall maximum. We select a number of y_{it}^*s to account for the uncertainty on the common euro-area driving forces, namely German, French and Italian GDP, aggregate euro-area GDP, US GDP, world energy prices, aggregate euro-area inflation and the German short-term interest rate. Our choice is driven by the following considerations. Germany, France and Italy are the largest economies in the euro area, and variations in their GDPs are most likely to influence other economies. Aggregate euro-area GDP approximates common euro-area shocks. US GDP and world energy prices cover external shocks. The German Council of Economic Experts (2001, GCEE) and IMF (2001), for example, find that US shocks have a notable impact on the euro-area economies. According to Montfort, Renne, Rüffer and Vitale (2002), Dalsgaard, André and Richardson (2001), Jiménez-Rodríguez and Sánchez (2005) and Peersman (2003), world oil price shocks spread considerably to euro-area countries. To those variables, we add aggregate euro-area inflation and the German short-term interest rate. The reason is that MSW's most influential factor exhibits the highest correlation with these series, and we want to check whether we can replicate their results.[26]

In addition, we fix a rotation by maximizing the contrasts between the correlations, approximated by

$$\sum_{j=1}^{q}\left(\frac{N\sum_{i=1}^{N}b_{ij}^{4}-(\sum_{i=1}^{N}b_{ij}^{2})^{2}}{N^{2}}\right), \tag{12}$$

where b_{ij} denotes the contemporaneous correlation between a shock to variable *i* and a shock to factor *j*. This formula corresponds to Kaiser's (1958) varimax criterion,[27] and is more agnostic compared to the correlation criteria described above.

The correlation measures for the ten variables exhibiting the highest absolute correlations and for all rotations (and for the corresponding predetermined variable) are reported in Table 6[28], which is, again, summarized in Table 7. We can draw two lessons from the analysis. First, not all factors are interpretable in all cases (namely when the correlations of the common euro-area shocks with shocks driving US GDP and aggregate euro-area inflation are maximized and when the varimax criterion is applied). This suggests that these rotations are not suited to align factor estimates and true factors and that we should focus on other rotations. Second, results differ, as expected, somewhat across rotations. But we arrive, nevertheless, at some

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[26] In the MSW study, aggregate euro-area inflation has the highest correlation with the first factor when the estimation is based on the set which includes inflation and interest rates in levels. German short-term interest rates are most highly correlated with the first factor when the estimation is based on a set comprising these series in first differences.

[27] It is usually applied directly to the factor loadings.

[28] We also computed the dynamic correlations to account for phase shifts. Since the results did not change much, we only report static correlations.

robust conclusions: there seems to be at least one, possibly two real German factors (since AR residual series of these factors are most highly correlated with AR residuals of a number of real German variables), one real French factor, at least one, possibly two producer price factors, and a financial price factor highly related to either long-term interest rates and/or exchange rates of various economies. Notice also that in some cases, there appears a factor that is closely linked to Finnish variables. This may come as a surprise at first sight. But the deep Finnish recession in the beginning of the 1990s, worsened by the subsequent banking crisis, may have influenced the factor estimates. This is not desirable since the Finnish slump didn't proliferate much to the rest of the euro area. However, it is well known that "large idiosyncratic components … (can) survive aggregation and be wrongly interpreted as additional common factors" (Forni, Hallin, Lippi and Reichlin (2001)), and one should be aware of it.[29] After all, we find it a bit unsatisfying that we do not have a clear indication on which rotation among the rotations we performed to pick. Future work could address this issue.

Our findings differ somewhat from the results of MSW who, however, do not rotate their factors. According to these authors there also exists a price factor. Their other factors are linked to real effective exchange rates of various countries, the German short-term interest rate, aggregate industrial production growth and changes in the aggregate unemployment rate. MSW are not able to interpret their sixth factor. Differences could be explained by the fact that MSW estimate stationary factors only, while we, in addition, consider non-stationary factors or common trends. If the latter are shared by real rather than by nominal variables, it should not come as a surprise that, based on the case of no rotation, our most important factor is a real one, whereas theirs is a nominal one.

As already sketched in the introduction, another possibility to identify the main driving forces of the euro-area factors would have been to follow Forni and Reichlin (1998) or Giannone, Reichlin and Sala (2002), who estimate a VAR model on the factors and identify macroeconomic shocks by means of usual parameter restrictions. Compared to the method outlined above, this approach has the advantage that variables' movements can be decomposed into movements due to individual structural shocks. By contrast, factors are reduced-form constructs. They may be influenced not just by one but by various shocks and

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[29] Forni, Hallin, Lippi and Reichlin (2001) point out that while in theory, all available series should be included in the data set, in practice, the set should comprise only variables exhibiting strong commonality and small idiosyncratic components. In order to carefully select the variables accordingly, they form a set out of 'core' variables to be included in the set in any case. Then they add 'candidate' variables to the set (one by one or in groups). The final data set contains those 'candidate' variables which do not lead to a decline in the variance share explained by a certain number of common factors previously estimated based on the 'core' variables and model selection criteria. We investigated whether to leave Finland and Germany in the data set. Both countries experienced important transformations in the 1990s. In the spirit of Forni, Hallin, Lippi and Reichlin (2001), we computed the variance shares explained by 9 SPCs of the total set excluding Finnish and German variables, excluding only Finnish variables and excluding only German variables. The shares (41%, 41% and 39%, respectively) are almost identical to the one computed based on the total set (40%, see Table 2), which leads us to keep both countries in our set. Note that those two countries apparently also passed the test in Forni, Hallin, Lippi and Reichlin (2001) who find a leading role in the euro area for Finland.

have to be interpreted with caution, even after rotation. The main difficulty with the more structural approach, however, is that knowledge of the most important shocks underlying the euro-area economy is required. This knowledge would then need to be translated into identifying restrictions. But so far there are still many open questions, for example on the types of relevant shocks, their geographic origins etc.[30] Due to this large uncertainty, for the moment, we will stick to our more agnostic approach.

Estimating the euro-area business cycle

As a byproduct of the rotation exercise, we now estimate the euro-area business cycle. This is achieved by fixing an orthogonal rotation such that the variance share of one of the five factors at business cycle frequencies (6 to 32 quarters, as usually defined) is maximized. The upper panel of Figure 2 plots our euro-area business cycle together with aggregate euro-area GDP growth and with EuroCOIN, the coincident indicator of the euro-area business cycle which is constructed using the large-scale dynamic factor model of Forni, Hallin, Lippi and Reichlin (2000), is published every month by the CEPR and will serve us here as a benchmark.[31] The areas show the recessions in the euro area declared by the recently formed CEPR Euro Area Business Cycle Dating Committee.

Our euro-area business cycle and the EuroCOIN indicator roughly move in parallel, the correlation amounts to 0.51. The earlier dating of the trough(s) in the beginning of the 1990s by our indicator is, however, noticeable. A reason for the difference may be that we have included Finnish variables, whereas EuroCOIN is constructed on the basis of a data set which does not contain Finnish series (see the description on the CEPR webpage and Altissimo, Bassanetti, Cristadoro, Forni, Lippi, Reichlin and Veronese (2001)). Our indicator may capture the Finnish recession at the beginning of the 1990s which preceded the recessions in other euro-area economies. We therefore estimated our euro-area business cycle without Finnish variables (variables 68 to 103 from Table 1). The troughs in 1990/1991 disappear, but this new indicator performs 'worse' in matching EuroCOIN in other periods compared to our previous estimate and we do not report it here.

To what extent do country-specific and euro-area shocks coincide?

We now assess to what extent shocks hitting individual countries - we call them country-specific shocks - and shocks to euro-area factors coincide. In analogy to the preceding paragraphs, our estimates of the euro-area shocks are the residuals from a VAR model on the dynamic euro-area factors. Country-specific shocks are estimated based on three specifications. First, we estimate country-specific dynamic factors out of sets of variables specific to each country as outlined above. As for the euro area, we choose $r = 9$ and $q = 5$ for

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[30] See the discussion in Eickmeier (2004) who overcomes this problem by applying a shock identification scheme which allows dimension reduction.

[31] See www.cepr.org/data/eurocoin/. Monthly EuroCOIN data were converted into quarterly. EuroCOIN has only been constructed based on data available since 1987.

each country. We fit VAR models to each set of country-specific dynamic factors. The residuals represent our country-specific shock estimates. For our second specification, we proceed in the same way, but apply the Bai and Ng (2002) model selection criteria to each set of country-specific variables. Those yield estimates for r ranging between 1 and 5. We would like to choose the same r for each country. Since it is better to over- than to underestimate the number of common factors (Stock and Watson (1998), Kapetanios and Marcellino (2003), Artis, Banerjee and Marcellino (2004)), we choose $r = 5$ for all countries. q is selected such that q DPCs explain roughly the same share of the total variance of a data set including country-specific series yielding 4 for all countries. In order to account for the uncertainty involved with the choice of the number of common country-specific factors, we use a third specification: the residuals from a standard VAR model fitted to key variables of each country – notably GDP, inflation and short-term interest rates –[32] give us further country-specific shock estimates.

We follow Bai and Ng (2004b) and MSW and construct two rough correlation measures between the sets of shocks. The trace R² is defined as the sum of the variances of the projections of the country-specific shocks on the euro-area shocks divided by the sum of the variances of the latter (Stock and Watson (1998)). A value of one indicates that the two sets of shocks are identical. The other measure we rely on is the canonical correlations between the sets of shocks.

Germany and France have relative high trace R²s (between 15% and 38% and between 15% and 32%, respectively) (Table 8). Values are also quite substantial for Belgium, Italy and Austria. They are lowest for Spain. Notice that the trace R²s are sensitive to the specification chosen to estimate country-specific shocks; this holds especially for the Netherlands which exhibit high values when the estimation of country-specific shocks is based on the factor models, but a low value when based on the VAR models on key variables.[33] The canonical correlations yield a similar picture (Table 9).

To what extent do variable-specific and euro-area shocks coincide?

We now correlate our euro-area shocks with shocks affecting specific variables – we call them variable-specific shocks. Estimates for the latter are the residuals from a VAR model fitted to a certain variable, say GDP, pooled over all countries. Again, the trace R² (where the shocks to the variables are regressed on the common factor shocks) and the canonical correlations are our multivariate correlation measures. The same is done with other variables, including variables covering the international transmission channels and monetary and fiscal policy, as well as with global variables. Results are reported in Tables 10 and 11.[34]

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[32] Cochrane (1994) and Monticelli and Tristani (1999), for example, estimate similar small VAR models.

[33] We cannot compare our trace R² with the results of MSW, since euro-area factors are dependent variables in our study whereas they are explanatory variables in theirs.

[34] We consider the stationary factor and the non-stationary factors separately. Reported results are based on the case of no rotation.

On the whole, shocks driving real variables are correlated to a stronger extent with shocks to euro-area factors than shocks driving prices; the trace R^2 amounts to 33% for GDP compared to 13% for the GDP deflator. However, it is not clear whether this points to real forces driving the common economic variation more than nominal ones. Our finding could, instead, be due to the fact that real variables are slightly over-represented compared to nominal variables. We further find that the shocks to the euro-area factors coincide more with shocks to GDP than with shocks to consumption (22%). This is in line with the finding by Kose, Otrok and Whiteman (2003) that world and regional factors explain a larger share of fluctuations in output growth than in consumption growth in most euro-area countries. It is further consistent with the quantity anomaly puzzle emphasized in Backus, Kehoe and Kydland (1992). The puzzle is that international risk sharing theoretically implies high correlations of consumption across countries and lower cross-country output correlations, whereas empirically, consumption is found to be correlated to a weaker extent than output. Shocks to investment seem to be linked to a stronger extent to shocks to the euro-area factors (29%) than shocks to consumption. Interestingly, the measure is much lower (18%) for the unemployment rate suggesting that unemployment is mainly a country-specific phenomenon. We further find that the trace R^2 associated with producer prices is larger than the one associated with consumer prices. This is not surprising given that the basket for producer prices includes a much larger share of tradables than the basket for consumer prices.

Shocks affecting monetary policy variables are less strongly correlated with shocks to the euro-area factors than shocks to government spending. This holds only for shocks to the non-stationary factors, but not for shocks to the stationary factor to which shocks to the short-term interest rates are more strongly linked; this is consistent with the view that, due to shorter reaction and transmission lags, monetary policy is employed more extensively to stabilize the economy than fiscal policy.

Among the transmission channels, trade seems to play the largest role. The trace R^2 amounts to 18% for real exports and 26% for real imports.[35] The exchange rate and other financial prices seem to be less important for euro-area comovements, but all still explain a non-negligible part (12% to 16%). Interestingly, shocks driving confidence explain shocks to euro-area factors relatively well (25%); the trace R^2 associated with the stationary factor is particularly large (47%). The canonical correlation measure yields similar results. But the first canonical correlation of euro-area shocks with shocks to the real effective exchange rates and long-term interest rates are larger than with shocks affecting real trade measures. Finally, global variables (US GDP, world energy prices and world non-energy commodity prices) also exhibit a notable explanatory power (18%), with shocks to US GDP being apparently linked to a somewhat stronger extent to euro-area shocks than shocks to world energy prices.

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[35] Note that we do not distinguish between intra- and extra-euro-area trade. The latter should mainly be affected by external driving forces.

Overall, our results regarding the relative importance of the different transmission channels are comparable with those of previous studies. The GCEE (2001), Canova, Ciccarelli and Ortega (2004), Eickmeier (2004) and Artis, Galvão and Marcellino (2003), for example, point out the dominant roles of trade and exchange rates for the international business cycle transmission.[36]

5. Has convergence taken place over time?

We next assess whether convergence has taken place. We say that this is the case if the common euro-area factors have become more important over time for economic fluctuations, or, put differently, if the variance explained by the (differenced) common component relative to the variance of the (differenced) variables has increased over time.[37] We focus on the variance of the total data set as well as on aggregate euro-area and individual countries' GDP growth and inflation growth. Separately looking at GDP growth and inflation growth should enable us to distinguish between real and nominal convergence. Previous studies have shown that results depend crucially on the chosen periods. We follow Brada, Kutan and Zhou (2005) and consider five-year rolling samples.

The upper panel of Figure 3 shows evidence of mild overall convergence: the variance share of the total differenced data set explained by the common component increased from 66% between 1981 and 1985 to 74% between 1999 and 2003. The variance share of euro-area inflation growth explained by the common factors declined somewhat in the first half of the 1990s, possibly caused by the German unification, before rising again. It is, after all, larger at the end of the total sample than at the beginning, pointing to overall nominal convergence. The variance share of aggregate GDP growth explained by the common component also decreases somewhat before increasing again. Conclusions regarding real convergence or divergence should, however, not be drawn without caution: the variance share of aggregate euro-area GDP growth explained by the common component is very large over the entire sample, and there is not much room left for further increases.

The medium and lower panels of Figure 3 report our findings for individual economies. Results are mixed. In Belgium and the Netherlands, there is clear evidence of real convergence over time, whereas the euro-area factors seem to have become less important for German and Austrian GDP growth. Most countries exhibit increases of our real measure at the end of the sample, being consistent with the latest global synchronized slowdown. Finally, the decline in Spain in the 1990s may be explained by the fact that, unlike our other euro-area

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[36] Theoretically it is not clear whether trade and financial markets lead to a negative or a positive shock transmission (see the discussion in Kose, Prasad and Terrones (2003)), whereas a positive relationship is generally found empirically between economic comovement and trade intensity and between the former and financial market integration (Otto, Voss and Willard (2003), Kose, Otrok and Whiteman (2003), Imbs (2004)). Our correlation measures are restricted to being positive, and we therefore cannot shed light on this discussion.

[37] The number of common static factors r is kept fixed at 9.

economies, Spain was affected by the financial crises in Latin America, which may have temporarily lowered the importance of the euro-area factors for Spain. The graphs suggest some nominal convergence for Germany, Belgium and Italy. The strong decrease of the measure in France since the mid-1990s and the temporary collapse in the Netherlands from 1991 to 1995 to 1992 to 1997 are difficult to explain.

In Figure 4 we plot output growth and inflation (and inflation growth) cross-country differentials. While we are reluctant to draw strong conclusions on the issue of real convergence in the euro area based on our factor analysis, the upper graph suggests real convergence. Evidence of overall real cyclical and growth convergence also is reported by KL and Carvalho and Harvey (2003). Our findings regarding overall nominal convergence are roughly consistent with the lower panel of Figure 4 as well as with European Central Bank (2003) and Angeloni and Ehrmann (2004). According to those studies, there is evidence of a decline in euro-area inflation differentials between 1990 and 1999, a slight short increase and a stabilization of the differentials at a relatively low level thereafter. Finally, Brada, Kutan and Zhou's (2005) results concerning real and nominal convergence between Germany and France and between each of these two countries and the most recent EU member states are mixed, supporting our findings with respect to individual countries.

6. Conclusion

In this paper, we applied the large-scale factor model recently developed by BN to extract common stationary and non-stationary factors in the euro area. Investigating non-stationary factors in this context using a lot of variables has, to our knowledge, not been done before.

We find that the euro-area economies share four non-stationary factors or trends and one stationary factor. Due to the uncertainty related to the estimation of the number of common factors, however, this result should be interpreted cautiously. Using rotation techniques, we estimate a euro-area business cycle which is a fairly good match to EuroCOIN, the euro-area business cycle measure published by the CEPR. Correlation measures of the projection errors suggest that fluctuations of individual common euro-area factors mainly reflect variations of German and French real economic activity as well as of producer prices and financial prices (long-term interest rates and/or real effective exchange rates) in various countries. Not surprisingly, shocks to the large German and French overall economies are most highly correlated with common euro-area shocks. Spanish macroeconomic shocks have the lowest correlation with euro-area shocks.

As concerns the transmission channels, macroeconomic shocks seem to proliferate in the euro area more strongly through trade, exchange rates and long-term interest rates than through stock prices. Movements in confidence measures seem to play a non-negligible role and a larger role for the stationary factor than for the non-stationary factors. This, however, is not clear evidence that shocks are transmitted internationally through an independent confidence channel. Yet the notable explanatory power of our confidence shock measures could simply reflect endogenous movements of confidence to variations of variables approximating other transmission channels or global shocks. Among the external driving forces, shocks to US economic activity seem to be more strongly linked to shocks to the euro-area factors than oil price shocks. We finally find evidence of temporary real and nominal divergence, but mild overall convergence; results for individual countries are mixed.

Future work could be devoted to developing some criteria which will allow us to fix one out of the many factor rotations we performed in Section 4. By testing the degree of integration of the idiosyncratic components, we could further investigate whether the source of non-stationarity of key variables is mainly pervasive or idiosyncratic.[38] We could finally try to properly identify common macroeconomic structural shocks using SVAR techniques and to perform impulse-response analyses.

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[38] The BN techniques were originally designed for this purpose.

Appendix A

The data set incorporates a large number of variables ($N = 282$) mainly taken from the OECD Economic Outlook and the Main Economic Indicators and complemented by statistics from national central banks and statistical bureaus. The set includes real GDP and components, industrial production series, capacity utilization, passenger cars, employment data, unit labor costs and productivity, prices, interest rates and monetary aggregates, stock prices, survey-based confidence measures, real trade variables, real effective exchange rates and current account balances from all countries. In addition, some variables covering influences from outside the euro area are added.

Where necessary, the series were seasonally adjusted using the X-11 method and/or converted into quarterly series. This frequency was chosen in order to include national account series, which are generally not available on a monthly basis. Logarithms were taken of all non-negative series that were not already in ratios or percentage form. The series were first differenced. Outliers were defined as observations that differed from the median by more than three times the sample interquartile range of the differenced series. Those were removed by setting them equal to this extreme bound.[39] The first differences are then normalized to have means of zero and variances equal to one. This is done to account for the difference in measurement units with the data set, which can influence factor estimates. Moreover, it guarantees that the variables with a relatively large variance do not dominate the process of estimating the common factors.

In constructing the data set, one problem that needed to be addressed was the break in the series caused by German unification in 1990. Most German series are extended by applying West German growth rates to the German levels retrospectively from the end of 1991 on. For more details, see Appendix A of Eickmeier (2004).

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[39] There is no consensus on the definition of outliers. Watson (2003) and Stock and Watson (2002), for example, define them as observations differing from the median by more than six and ten times, respectively, the interquartile range.

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Table 1: Data set

Number	Country	Series	Source[1)]
1	Austria	GDP, volume, market prices	OECD - ECO
2		Total domestic expenditure, volume	OECD - ECO
3		Government expenditure (without inventories)	OECD - ECO
4		Private final consumption expenditure	OECD - ECO
5		Private total fixed capital formation, volume	OECD - ECO
6		Private residential fixed capital formation, volume	OECD - ECO
7		Private non-residential fixed capital formation, volume	OECD - ECO
8		Industrial production	OECD - MEI
9		Industrial production, manufacturing	OECD - MEI
10		Capacity util. rate, manuf. (business tendency survey)	DS - MEI
11		Passenger cars registered	OECD - MEI
12		Total employment	OECD - ECO
13		Unemployment rate	OECD - ECO
14		Labor force participation rate	OECD - ECO
15		Dependent employment	OECD - ECO
16		Compensation of employees, value	OECD - ECO
17		Unit labor costs (business sector)	OECD - ECO
18		Productivity	OECD - ECO
19		Consumer price, harmonized	OECD - ECO
20		WPI all items	OECD - MEI
21		GDP deflator, market prices	OECD - ECO
22		Short-term interest rate	OECD - ECO
23		Long-term interest rate (gov. bonds)	OECD - ECO
24		M1	ZEWI/TAWO
25		M3	ZEWI/TAWO
26		Main stock price index: VSE WBI index	OECD - ECO
27		Imports (goods & services), volume	OECD - ECO
28		Exports (goods & services), volume	OECD - ECO
29		Real effective exchange rate	IMF - IFS
30		Current account	OECD - ECO
31	Belgium	GDP, volume, market prices	OECD - ECO
32		Total domestic expenditure, volume	OECD - ECO
33		Government expenditure (without inventories)	OECD - ECO
34		Private final consumption expenditure	OECD - ECO
35		Private total fixed capital formation, volume	OECD - ECO
36		Private residential fixed capital formation, volume	OECD - ECO
37		Private non-residential fixed capital formation, volume	OECD - ECO
38		Industrial production	OECD - MEI
39		Industrial production excl. construction	NBB
40		Industrial production, consumer durable goods	OECD - MEI
41		Industrial production, consumer non-durable goods	OECD - MEI
42		Industrial production, intermediate goods	OECD - MEI
43		Industrial productio, investment goods	OECD - MEI
44		Capacity util. rate, manuf. (business tendency survey)	DS - MEI
45		Passenger cars registered	OECD - MEI
46		Total employment	OECD - ECO
47		Unemployment rate	OECD - ECO
48		Labor force particIndustrial productionation rate	OECD - ECO
49		Dependent employment	OECD - ECO
50		Unit labor costs (business sector)	OECD - ECO
51		Consumer price, harmonized	OECD - ECO
52		PPI manufactured goods	OECD - MEI
53		PPI consumer goods	OECD - MEI
54		PPI intermediate goods	OECD - MEI
55		PPI investment goods	OECD - MEI
56		GDP deflator, market prices	OECD - ECO
57		Short-term interest rate	OECD - ECO
58		Long-term interest rate (gov. bonds)	OECD - ECO
59		M1	ZEWI/TAWO
60		M3	ZEWI/TAWO

61		Main stock price index: all shares index	DS - MEI
62		Consumer confidence	DS - EU
63		Industrial confidence	DS - EU
64		Imports (goods & services), volume	OECD - ECO
65		Exports (goods & services), volume	OECD - ECO
66		Real effective exchange rate	IMF - IFS
67		Current account	OECD - ECO
68	Finland	GDP, volume, market prices	OECD - ECO
69		Total domestic expenditure, volume	OECD - ECO
70		Government expenditure (without inventories)	OECD - ECO
71		Private final consumption expenditure	OECD - ECO
72		Private total fixed capital formation, volume	OECD - ECO
73		Private residential fixed capital formation, volume	OECD - ECO
74		Private non-residential fixed capital formation, volume	OECD - ECO
75		Industrial production	OECD - MEI
76		Industrial production, manufacturing	OECD - MEI
77		Industrial production, consumer goods	OECD - MEI
78		Industrial production, intermediate goods	OECD - MEI
79		Industrial production, investment goods	OECD - MEI
80		Capacity util. rate, manuf. (business tendency survey)	DS - MEI
81		Passenger cars registered	OECD - MEI
82		Total employment	OECD - ECO
83		Unemployment rate	OECD - ECO
84		Labor force participation rate	OECD - ECO
85		Dependent employment	OECD - ECO
86		Compensation of employees, value	OECD - ECO
87		Unit labor costs (business sector)	OECD - ECO
88		Productivity	OECD - ECO
89		Consumer price, harmonized	OECD - ECO
90		PPI manufacturing	OECD - MEI
91		PPI consumer goods	OECD - MEI
92		PPI intermediate goods	OECD - MEI
93		PPI investment goods	OECD - MEI
94		GDP deflator, market prices	OECD - ECO
95		Short-term interest rate	OECD - ECO
96		Long-term interest rate (gov. bonds)	OECD - ECO
97		M1	ZEWI/TAWO
98		M3	ZEWI/TAWO
99		Main stock price index: all shares index	DS - MEI
100		Imports (goods & services), volume	OECD - ECO
101		Exports (goods & services), volume	OECD - ECO
102		Real effective exchange rate	IMF - IFS
103		Current account	OECD - ECO
104	France	GDP, volume, market prices	OECD - ECO
105		Total domestic expenditure, volume	OECD - ECO
106		Government expenditure (without inventories)	OECD - ECO
107		Private final consumption expenditure	OECD - ECO
108		Private total fixed capital formation, volume	OECD - ECO
109		Private residential fixed capital formation, volume	OECD - ECO
110		Private non-residential fixed capital formation, volume	OECD - ECO
111		Industrial production	OECD - MEI
112		Industrial production, manufacturing	OECD - MEI
113		Industrial production, consumer goods	OECD - MEI
114		Industrial production, investment goods	OECD - MEI
115		Capacity util. rate, manuf. (business tendency survey)	DS - MEI
116		Passenger cars registered	OECD - MEI
117		Total employment	OECD - ECO
118		Unemployment rate	OECD - ECO
119		Labor force participation rate	OECD - ECO
120		Dependent employment	OECD - ECO

121		Compensation of employees, value	OECD - ECO
122		Unit labor costs (business sector)	OECD - ECO
123		Productivity	OECD - ECO
124		Consumer price, harmonized	OECD - ECO
125		PPI manufactured products	OECD - MEI
126		PPI intermediate goods	OECD - MEI
127		GDP deflator, market prices	OECD - ECO
128		Short-term interest rate	OECD - ECO
129		Long-term interest rate (gov. bonds)	OECD - ECO
130		M1	ZEWI/TAWO
131		M3	ZEWI/TAWO
132		Main stock price index: Paris stock exchange SBF 250	OECD - MEI
133		Consumer confidence	DS - EU
134		Industrial confidence	DS - EU
135		Imports (goods & services), volume	OECD - ECO
136		Exports (goods & services), volume	OECD - ECO
137		Real effective exchange rate	IMF - IFS
138		Current account	OECD - ECO
139	Germany	GDP, volume, market prices	Bundesbank
140		Government consumption	Bundesbank
141		Private final consumption expenditure	Bundesbank
142		Private total fixed capital formation, volume	Bundesbank
143		Private residential fixed capital formation, volume	Bundesbank
144		Private non-residential fixed capital formation, volume	Bundesbank
145		Industrial production	OECD - MEI
146		Industrial production, manufacturing	DS - Thomson
147		Industrial production, consumer goods	DS - Thomson
148		Industrial production, consumer durable goods	DS - Eurostat
149		Industrial production, consumer non durable goods	DS - Eurostat
150		Industrial production, intermediate goods	DS - Thomson
151		Industrial production, capital goods	DS - Thomson
152		Capacity utilization rate, manufacturing	DS - MEI
153		Passenger cars registered	OECD - MEI
154		Total employment	Bundesbank
155		Unemployment rate	Bundesbank
156		Hours worked	Bundesbank
157		Dependent employment	Bundesbank
158		Compensation of employees	Bundesbank
159		Unit labor costs	Bundesbank
160		Productivity	Bundesbank
161		Consumer price, harmonized	OECD - ECO
162		PPI manufacturing	OECD - MEI
163		PPI investment goods	OECD - MEI
164		GDP deflator, market prices	Bundesbank
165		Short-term interest rate	OECD - ECO
166		Long-term interest rate (gov. bonds)	OECD - ECO
167		M1	ZEWI/TAWO
168		M3	DS - Bundesbank
169		Main stock price index: CDAX	OECD - MEI
170		Consumer confidence	DS - EU
171		Industrial confidence	DS - EU
172		Imports (goods & services), volume	OECD - ECO
173		Exports (goods & services), volume	OECD - ECO
174		Real effective exchange rate	IMF - IFS
175		Current account	OECD - ECO
176	Italy	GDP, volume, market prices	OECD - ECO
177		Government expenditure (without inventories)	Banca D'Italia
178		Private final consumption expenditure	Banca D'Italia
179		Private total fixed capital formation, volume	Banca D'Italia
180		Private residential fixed capital formation, volume	Banca D'Italia

181		Private non-residential fixed capital formation, volume	Banca D'Italia
182		Industrial production	OECD - MEI
183		Industrial production, consumer goods	OECD - MEI
184		Industrial production, intermediate goods	OECD - MEI
185		Industrial production, investment goods	OECD - MEI
186		Capacity util. rate, manuf. (business tendency survey)	DS - MEI
187		Passenger cars registered	OECD - MEI
188		Total employment	OECD - ECO
189		Unemployment rate	OECD - ECO
190		Labor force participation rate	OECD - ECO
191		Dependent employment	OECD - ECO
192		Compensation of employees, current prices	OECD - QNA
193		Unit labor costs (business sector)	OECD - ECO
194		Consumer price, harmonized	OECD - ECO
195		PPI total	OECD - MEI
196		PPI intermediate goods	DS - Instituto, DS - MEI
197		PPI investment goods	DS - Instituto, DS - MEI
198		GDP deflator, market prices	Banca D'Italia
199		Short-term interest rate	OECD - ECO
200		Long-term interest rate (gov. bonds)	OECD - ECO
201		M1	ZEWI/TAWO
202		M3	ZEWI/TAWO
203		Main stock price index: ISE MIB Storico Generale	OECD - MEI
204		Consumer confidence	DS - EU
205		Industrial confidence	DS - EU
206		Imports (goods & services), volume	OECD - ECO
207		Exports (goods & services), volume	OECD - ECO
208		Real effective exchange rate	IMF - IFS
209		Current account	OECD - ECO
210	Netherlands	GDP, volume, market prices	OECD - ECO
211		Total domestic expenditure, volume	OECD - ECO
212		Government expenditure (without inventories)	OECD - ECO
213		Private final consumption expenditure	OECD - ECO
214		Private total fixed capital formation, volume	OECD - ECO
215		Private residential fixed capital formation, volume	OECD - ECO
216		Private non-residential fixed capital formation, volume	OECD - ECO
217		Industrial production	OECD - MEI
218		Industrial production, manufacturing	OECD - MEI
219		Capacity util. rate, manuf. (business tendency survey)	DS - MEI
220		Passenger cars registered	OECD - MEI
221		Total employment	OECD - ECO
222		Unemployment rate	OECD - ECO
223		Labor force participation rate	OECD - ECO
224		Dependent employment	OECD - ECO
225		Compensation of employees, value	OECD - ECO
226		Unit labor costs (business sector)	OECD - ECO
227		Productivity	OECD - ECO
228		Consumer price, harmonized	OECD - ECO
229		PPI manufacturing	OECD - MEI
230		PPI consumer goods	OECD - MEI
231		PPI intermediate goods	OECD - MEI
232		PPI investment goods	OECD - MEI
233		GDP deflator, market prices	OECD - ECO
234		Short-term interest rate	OECD - ECO
235		Long-term interest rate (gov. bonds)	OECD - ECO
236		M1	ZEWI/TAWO
237		M3	ZEWI/TAWO
238		Main stock price index	DS - IMF/IFS, De Nederl. Bank
239		Consumer confidence	DS - EU
240		Industrial confidence	DS - EU

241		Imports (goods & services), volume	OECD - ECO
242		Exports (goods & services), volume	OECD - ECO
243		Real effective exchange rate	IMF - IFS
244		Current account	OECD - ECO
245	Spain	GDP, volume, market prices	OECD - ECO
246		Total domestic expenditure, volume	OECD - ECO
247		Government final consumption expenditure	OECD - ECO
248		Private final consumption expenditure	OECD - ECO
249		Total fixed investment	OECD - ECO
250		Industrial production	OECD - MEI
251		Industrial production, manufacturing	OECD - MEI
252		Industrial production, consumer goods	OECD - MEI
253		Industrial production, intermediate goods	DS - MEI
254		Industrial production, investment goods	OECD - MEI
255		Capacity util. rate, manuf. (business tendency survey)	DS - MEI
256		Passenger cars registered	OECD - MEI
257		Total employment	OECD - ECO
258		Unemployment rate	OECD - ECO
259		Compensation of employees, current prices	OECD - QNA
260		Unit labor costs (business sector)	OECD - ECO
261		Consumer price, harmonized	OECD - ECO
262		PPI manufacturing	OECD - MEI
263		PPI consumer goods	OECD - MEI
264		PPI intermediate goods	OECD - MEI
265		PPI investment goods	OECD - MEI
266		GDP deflator	DS - IMF/IFS
267		Short-term interest rate	OECD - ECO
268		Long-term interest rate (gov. bonds)	OECD - ECO
269		M1	OECD - ECO
270		M3	OECD - ECO
271		Main stock price index: MSE general index	DS - MEI
272		Imports (goods & services), volume	OECD - ECO
273		Exports (goods & services), volume	OECD - ECO
274		Real effective exchange rate	IMF - IFS
275		Current account	OECD - ECO
276	World	Energy prices	HWWA
277		Commodity prices without energy	HWWA
278		UK GDP, volume, market prices	OECD - ECO
279		US GDP, volume, market prices	OECD - ECO
280		Nominal exchange rate Euro/USD	OECD - MEI
281		World Trade	OECD - MEI
282		Jap GDP	OECD - ECO

1) ECO: Economic Outlook, MEI: Main Economic Indicators, IFS: International Financial Statistics, DS: Datastream, ZEWI/TAWO: Bundesbank source.

Table 2: Cumulative share of the total variance explained by static principal components (SPCs)

SPC	Total set
1	0.124
2	0.179
3	0.221
4	0.261
5	0.292
6	0.322
7	0.347
8	0.372
9	0.396
10	0.418
11	0.440
12	0.461
13	0.481
14	0.500
15	0.518
16	0.536
17	0.553
18	0.569
19	0.585
20	0.600
21	0.615
22	0.630
23	0.643
24	0.657
25	0.669
26	0.682
27	0.693
28	0.705
29	0.717
30	0.728

Table 3: Cumulative share of the variance explained by dynamic principal components (DPCs)

DPC	Total set	Aggr. GDP[1]	Aggr. inflation[2]
1	0.145	0.558	0.094
2	0.223	0.698	0.173
3	0.282	0.745	0.284
4	0.330	0.782	0.375
5	0.375	0.833	0.491
6	0.416	0.860	0.591
7	0.453	0.879	0.654
8	0.486	0.900	0.723
9	0.518	0.919	0.776
10	0.548	0.931	0.816

[1] first difference

[2] second difference of euro-area GDP deflator

Table 4: Information criteria to estimate *q* according to Breitung and Kretschmer (2004)[1]

Factor	AIC	SIC
1	1.424	3.202
2	1.110	2.471
3	0.901	1.901
4	0.772	1.466
5	0.976	1.420
6	1.309	1.559
7	1.764	1.875
8	2.858	2.886
9	4.941	4.941

[1] conditional on $r = 9$.

Table 5: Johansen cointegration test applied to $\hat{\varphi}_t$ [1]

Hypothesized # coint. equ.	Eigenvalue	Trace stat.	5% crit. value	1% crit. value	Max-eig. stat.	5% crit. value	1% crit. value
None	0.605	134.609 **	87.31	96.58	82.690 **	37.52	42.36
At most 1	0.229	51.919	62.99	70.05	23.192	31.46	36.65
At most 2	0.201	28.727	42.44	48.45	20.001	25.54	30.34
At most 3	0.066	8.726	25.32	30.45	6.072	18.96	23.65
At most 4	0.029	2.654	12.25	16.26	2.654	12.25	16.26

*(**) denotes rejection of the hypothesis at the 5%(1%) level.

[1] Linear deterministic trend and intercept, no lags of the first differenced terms. Augmenting the number of lags in differences by one, does not change the results.

Table 6: Correlations between shocks to individual factors and variables, largest ten correlations[1)]

No rotation

Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation
145	0.516	143	0.541	125	0.396	162	0.453	20	0.438
146	0.516	18	0.541	162	0.396	195	0.454	54	0.443
63	0.526	145	0.561	54	0.398	28	0.471	124	0.454
42	0.530	160	0.581	166	0.419	18	0.472	243	-0.457
176	0.538	146	0.598	52	0.420	281	0.495	161	0.457
184	0.541	2	0.610	276	0.465	264	0.498	52	0.470
122	-0.547	139	0.618	235	0.472	231	0.529	90	0.495
111	0.658	1	0.623	229	0.473	276	0.531	162	0.507
123	0.665	144	0.627	231	0.479	229	0.559	231	0.523
112	0.688	150	0.648	129	0.550	262	0.583	229	0.551
104	0.703	142	0.710	58	0.588	54	0.597	92	0.590

y_{it}* = GER GDP (139); maximized correlation 0.719

Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation
66	-0.375	90	0.483	150	0.482	176	0.433	42	0.483
167	0.392	235	0.489	145	0.483	218	0.437	88	0.486
238	0.401	52	0.505	151	0.491	185	0.440	63	0.487
174	-0.409	276	0.540	146	0.533	34	0.442	72	0.519
203	0.409	92	0.542	144	0.554	110	0.454	231	0.521
102	-0.415	166	0.544	18	0.572	144	0.472	73	0.530
220	0.416	20	0.555	158	0.576	182	0.483	123	0.574
280	0.426	54	0.563	1	0.584	145	0.506	104	0.579
199	-0.453	162	0.588	142	0.599	146	0.531	68	0.583
137	-0.461	231	0.632	160	0.663	142	0.537	112	0.614
99	0.481	229	0.665	139	0.719	150	0.626	111	0.634

y_{it}* = FRA GDP (104); maximized correlation 0.704

Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation
63	0.525	145	0.539	54	0.405	195	0.488	277	0.405
145	0.529	18	0.548	92	0.410	28	0.490	29	-0.425
146	0.530	143	0.548	162	0.415	52	0.491	161	0.429
42	0.530	146	0.578	166	0.425	162	0.494	52	0.430
122	-0.538	160	0.589	52	0.432	281	0.507	124	0.430
176	0.547	2	0.610	276	0.469	264	0.519	243	-0.449
184	0.558	139	0.622	235	0.478	276	0.570	90	0.455
111	0.653	1	0.622	229	0.488	231	0.571	162	0.466
123	0.663	144	0.623	231	0.492	229	0.604	231	0.483
112	0.685	150	0.631	129	0.548	262	0.609	229	0.503
104	0.704	142	0.707	58	0.592	54	0.631	92	0.550

Table 6 cont.

y_{it}* = ITA GDP (176); maximized correlation 0.579

Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation
171	0.546	4	0.403	52	0.390	230	0.529	29	0.391
32	0.549	150	0.451	90	0.406	281	0.536	79	0.393
111	0.576	5	0.460	57	0.407	90	0.554	107	0.396
176	0.579	144	0.534	199	0.422	195	0.556	232	0.403
184	0.606	18	0.540	162	0.424	162	0.614	206	0.429
145	0.623	143	0.550	235	0.435	262	0.621	88	0.442
123	0.626	160	0.559	231	0.441	52	0.623	158	0.454
146	0.634	1	0.560	229	0.441	276	0.687	73	0.497
112	0.636	2	0.569	129	0.443	231	0.704	68	0.523
150	0.674	139	0.576	92	0.491	54	0.709	74	0.541
104	0.681	142	0.622	58	0.540	229	0.754	72	0.602

y_{it}* = aggregate euro-area GDP; maximized correlation 0.799

Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation
262	0.450	175	0.337	145	0.559	32	0.421	76	0.489
166	0.452	243	0.340	104	0.565	184	0.433	87	-0.498
124	0.469	74	0.362	158	0.570	110	0.450	73	0.503
92	0.531	280	-0.364	146	0.604	219	0.453	72	0.547
54	0.536	271	-0.378	144	0.609	145	0.459	176	0.557
162	0.546	102	0.386	142	0.683	142	0.471	104	0.562
52	0.570	174	0.389	18	0.694	146	0.472	123	0.568
90	0.580	137	0.408	160	0.707	200	0.485	112	0.569
276	0.634	73	0.425	1	0.707	31	0.500	88	0.584
231	0.677	29	0.435	139	0.770	171	0.512	111	0.604
229	0.687	72	0.446	EA GDP	0.799	150	0.539	68	0.666

y_{it}* = world energy prices (276); maximized correlation 0.687

Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation
171	0.548	4	0.394	73	0.386	281	0.533	175	0.384
32	0.549	150	0.431	90	0.401	230	0.534	232	0.399
111	0.568	5	0.458	57	0.410	195	0.561	107	0.403
176	0.578	144	0.521	162	0.416	90	0.565	79	0.406
184	0.604	18	0.534	235	0.426	262	0.622	206	0.441
123	0.621	143	0.545	229	0.427	162	0.623	88	0.453
145	0.629	160	0.549	231	0.427	52	0.627	158	0.454
112	0.631	1	0.549	199	0.427	276	0.687	73	0.508
146	0.642	2	0.562	129	0.429	231	0.711	68	0.535
104	0.678	139	0.565	92	0.488	54	0.711	74	0.558
150	0.686	142	0.609	58	0.531	229	0.761	72	0.619

Table 6 cont.

y_{it}^* = US GDP (279); maximized correlation 0.226

Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation
137	-0.495	229	0.350	166	0.416	2	0.541	108	0.487
20	0.497	161	0.355	158	0.440	160	0.542	136	0.492
280	0.507	68	-0.357	142	0.449	147	0.550	176	0.503
162	0.523	231	0.360	1	0.451	151	0.565	42	0.511
52	0.539	162	0.361	160	0.460	139	0.587	63	0.516
262	0.556	88	-0.370	173	0.462	1	0.592	122	-0.518
231	0.557	58	0.384	235	0.464	144	0.614	68	0.552
29	-0.565	220	-0.396	58	0.478	145	0.655	123	0.626
276	0.567	138	-0.415	18	0.483	142	0.673	104	0.646
54	0.597	87	0.459	139	0.525	146	0.687	112	0.661
229	0.602	92	0.468	129	0.553	150	0.708	111	0.662

y_{it}^* = GER short-term interest rate (165); maximized correlation 0.438

Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation
66	-0.375	90	0.483	150	0.482	176	0.433	42	0.483
167	0.392	235	0.489	145	0.483	218	0.437	88	0.486
238	0.401	52	0.505	151	0.491	185	0.440	63	0.487
174	-0.409	276	0.540	146	0.533	34	0.442	72	0.519
203	0.409	92	0.542	144	0.554	110	0.454	231	0.521
102	-0.415	166	0.544	18	0.572	144	0.472	73	0.530
220	0.416	20	0.555	158	0.576	182	0.483	123	0.574
280	0.426	54	0.563	1	0.584	145	0.506	104	0.579
199	-0.453	162	0.588	142	0.599	146	0.531	68	0.583
137	-0.461	231	0.632	160	0.663	142	0.537	112	0.614
99	0.481	229	0.665	139	0.719	150	0.626	111	0.634

y_{it}^* = aggregate euro-area inflation; maximized correlation 0.194

Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation
151	0.547	42	0.473	72	-0.408	24	-0.402	122	-0.473
144	0.578	166	0.479	146	-0.411	255	0.406	112	0.476
18	0.617	58	0.481	52	0.413	89	0.415	87	-0.496
145	0.645	123	0.485	54	0.414	92	0.427	123	0.512
1	0.651	231	0.494	174	-0.418	90	0.428	74	0.512
142	0.665	96	0.497	229	0.424	184	0.428	111	0.522
160	0.683	254	0.498	137	-0.434	134	0.429	104	0.523
146	0.688	171	0.508	151	-0.435	240	0.430	72	0.546
139	0.710	104	0.528	29	-0.463	176	0.432	88	0.552
150	0.732	129	0.532	102	-0.500	100	0.444	107	0.553
EA GDP	0.761	235	0.532	280	0.540	182	0.493	68	0.663

Table 6 cont.

Varimax

Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation	Variable	Correlation
176	0.559	17	-0.428	102	0.350	230	0.551	46	0.444
139	0.560	129	0.439	89	0.364	195	0.575	175	0.450
151	0.562	1	0.456	240	0.366	92	0.608	173	0.457
184	0.567	5	0.458	203	-0.377	262	0.611	76	0.474
160	0.585	18	0.469	200	0.389	90	0.633	79	0.478
123	0.585	160	0.471	57	0.391	52	0.637	206	0.485
112	0.588	2	0.495	160	-0.397	276	0.665	88	0.531
104	0.651	144	0.514	92	0.402	162	0.669	73	0.532
145	0.667	139	0.514	73	0.407	54	0.702	68	0.597
146	0.689	143	0.526	199	0.459	231	0.735	74	0.621
150	0.752	142	0.605	58	0.507	229	0.787	72	0.676

[1] The rotation is fixed by maximizing the correlation between shocks to each component of $\hat{\varphi}_t$ and to y_{it}^* is maximized, and picking θ which yields the overall maximum.

Table 7: Summarizing Table 6

Rotation	Factor interpretation
No rotation	1 FRA real factor 1 GER real factor 2 producer price factors 1 long-term interest rate factor (also related to NLD producer prices)
y^*_{it} 1) = GER GDP (139) and GER short-term interest rates (165)	2 GER real factors 1 FRA real factor 1 producer price factor 1 factor difficult to interpret (related to FIN stock prices, exchange rates, ITA short-term interest rates)
y^*_{it} 1) = FRA GDP (104)	1 GER real factor 1 FRA real factor 2 producer price factors 1 long-term interest rate factor (also related to NLD producer prices)
y^*_{it} 1) = ITA GDP (176) and world energy prices (276)	1 GER real factor 1 FRA/GER real factor 1 FIN real factor 1 producer price factor 1 producer price/long-term interest rate factor
y^*_{it} 1) = euro-area GDP	2 GER real factors 1 exchange rate factor 1 producer price factor 1 FRA/FIN factor
y^*_{it} 1) = US GDP (279)	1 GER real factor 1 FRA real factor 1 producer price factor 2 factors difficult to interpret (one is related to FRA/NLD/BEL long-term interest rates and GER/AUT real variables
y^*_{it} 1) = euro-area inflation	1 GER real factor 1 exchange rate factor 1 FIN/FRA real factor 2 factors difficult to interpret (one is related to ITA real variables, other to NLD/FRA long-term interest rates)
Varimax	2 GER real factors 1 producer price factor 1 FIN real factor 1 factor difficult to interpret (related to BEL/ITA interest rates, FIN investment and producer prices, GER productivity)

1) predetermined variable.

Table 8: Trace R² (country-specific shocks), all factors[1)]

	$r = 9, q = 5$	$r = 5, q = 4$	VAR[2)]
AUT	0.254	0.269	0.154
BEL	0.278	0.249	0.159
FIN	0.263	0.214	0.091
FRA	0.317	0.254	0.149
GER	0.379	0.355	0.154
ITA	0.209	0.273	0.123
NLD	0.316	0.280	0.063
ESP	0.217	0.205	0.029

[1)] defined as the sum of the variances of the projections of the VAR residuals of the observables divided by the sum of the variances of the VAR residuals of the factors.

[2)] fitted to GDP, the short-term interest rate and the first difference of the GDP deflator.

Table 9: Canonical correlations (country-specific shocks), all factors

	1	2	3	4	5
Based on dynamic factor models, $r = 9$, $q = 5$					
AUT	0.838	0.551	0.379	0.266	0.095
BEL	0.767	0.682	0.373	0.168	0.040
FIN	0.755	0.690	0.383	0.306	0.149
FRA	0.790	0.577	0.473	0.389	0.130
GER	0.805	0.732	0.578	0.448	0.165
ITA	0.607	0.536	0.462	0.340	0.012
NLD	0.761	0.650	0.562	0.461	0.310
ESP	0.605	0.573	0.443	0.176	0.072
Based on dynamic factor models, $r = 5$, $q = 4$					
AUT	0.780	0.591	0.475	0.193	-
BEL	0.765	0.625	0.145	0.082	-
FIN	0.679	0.659	0.377	0.275	-
FRA	0.732	0.614	0.348	0.124	-
GER	0.813	0.706	0.472	0.414	-
ITA	0.660	0.634	0.590	0.142	-
NLD	0.787	0.633	0.476	0.304	-
ESP	0.644	0.599	0.379	0.059	-
Based on VAR models fitted to key variables[1)]					
AUT	0.691	0.424	0.122	-	-
BEL	0.585	0.432	0.359	-	-
FIN	0.620	0.280	0.217	-	-
FRA	0.595	0.459	0.224	-	-
GER	0.742	0.290	0.132	-	-
ITA	0.544	0.521	0.053	-	-
NLD	0.376	0.325	0.256	-	-
ESP	0.320	0.179	0.135	-	-

[1)] fitted to GDP, the short-term interest rate and the first difference of the GDP deflator

Table 10: Trace R^2 (variable-specific shocks)1)

	All factors	Non-stat. factors9)	Stationary factor9)
Real			
GDP2)	0.328	0.323	0.289
Consumption2) 3)	0.218	0.238	0.107
Investment2)	0.287	0.301	0.294
Unemploym. rate	0.180	0.150	0.235
Nominal			
GDP deflator	0.131	0.130	0.090
CPI	0.164	0.153	0.105
PPI4)	0.257	0.224	0.374
Monetary policy			
Short-term interest rates	0.109	0.091	0.301
M1	0.103	0.125	0.121
Gov. expend.2) 7)	0.152	0.149	0.145
Trade			
Exports2)	0.182	0.158	0.231
Imports2)	0.258	0.262	0.261
Exchange rate5)	0.162	0.153	0.224
Financial markets			
Long-term interest rates	0.162	0.094	0.364
Stock prices	0.122	0.126	0.107
Confidence6)	0.254	0.214	0.472
Global variables8)	0.181	0.151	0.329
US GDP	0.126	0.095	0.273
Energy prices	0.028	0.009	0.094

1) defined as the sum of the variances of the projections of the VAR residuals of the observables divided by the sum of the variances of the VAR residuals of the factors.

2) real

3) private; total fixed investment for ESP.

4) manufacturing; total for ITA; for AUT WPI.

5) real effective exchange rate

6) consumer and industrial confidence; data not available for AUT, FIN, ESP.

7) for ESP and GER only government consumption.

8) US GDP, world energy prices, world commodity prices without energy.

9) based on the case of no rotation.

Table 11: Canonical correlations (variable-specific shocks)[1]

	All factors					Non-stationary factors[9]				Stat. factor[9]
	1	2	3	4	5	1	2	3	4	1
Real										
GDP[2]	0.842	0.573	0.442	0.425	0.353	0.842	0.532	0.459	0.329	0.538
Consumption[2] [3]	0.702	0.532	0.341	0.282	0.172	0.705	0.505	0.299	0.181	0.327
Investment[2]	0.858	0.584	0.429	0.262	0.105	0.837	0.533	0.428	0.249	0.543
Unemploym. rate	0.641	0.429	0.339	0.217	0.195	0.556	0.411	0.242	0.212	0.485
Nominal										
GDP deflator	0.568	0.508	0.286	0.165	0.078	0.510	0.469	0.291	0.150	0.301
CPI	0.726	0.481	0.322	0.166	0.096	0.622	0.481	0.250	0.113	0.324
PPI[4]	0.864	0.443	0.358	0.257	0.139	0.743	0.407	0.347	0.246	0.612
Monetary policy										
Short-term interest rates	0.504	0.399	0.322	0.231	0.205	0.457	0.304	0.232	0.201	0.549
M1	0.454	0.363	0.311	0.285	0.110	0.444	0.392	0.352	0.122	0.347
Gov. expend.[2] [7]	0.650	0.391	0.307	0.270	0.221	0.608	0.368	0.307	0.181	0.380
Trade										
Exports[2]	0.603	0.507	0.382	0.270	0.169	0.505	0.465	0.336	0.192	0.480
Imports[2]	0.689	0.603	0.415	0.281	0.170	0.647	0.601	0.418	0.185	0.511
Exchange rate[5]	0.723	0.503	0.371	0.194	0.103	0.718	0.367	0.242	0.068	0.473
Financial markets										
Long-term interest rates	0.701	0.438	0.310	0.222	0.071	0.463	0.392	0.187	0.098	0.604
Stock prices	0.613	0.377	0.337	0.215	0.123	0.565	0.347	0.266	0.137	0.327
Confidence[6]	0.696	0.514	0.385	0.371	0.159	0.618	0.483	0.309	0.186	0.687
Global variables[8]	0.808	0.384	0.195	-	-	0.669	0.378	0.170	-	0.574
US GDP	0.770	-	-	-	-	0.637	-	-	-	0.522
Energy prices	0.348	-	-	-	-	0.215	-	-	-	0.307

[1] between residuals from VAR models fitted to observables and factors

[2] real

[3] private; total fixed investment for ESP.

[4] manufacturing; total for ITA; for AUT WPI.

[5] real effective exchange rate

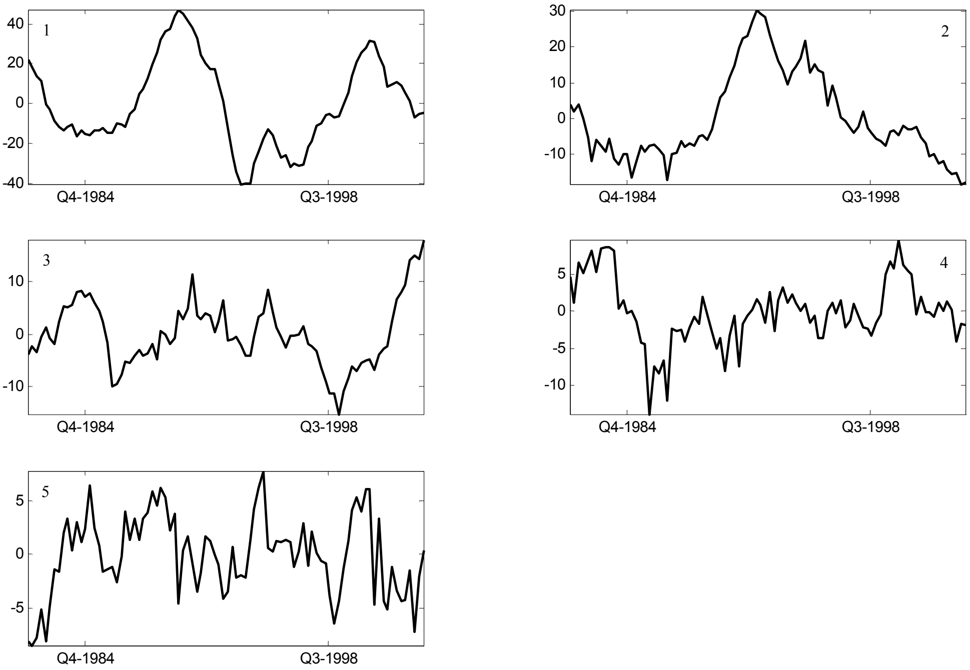
[6] consumer and industrial confidence; data not available for AUT, FIN, ESP.

[7] for ESP and GER only government consumption.

[8] US GDP, world energy prices, world commodity prices without energy.

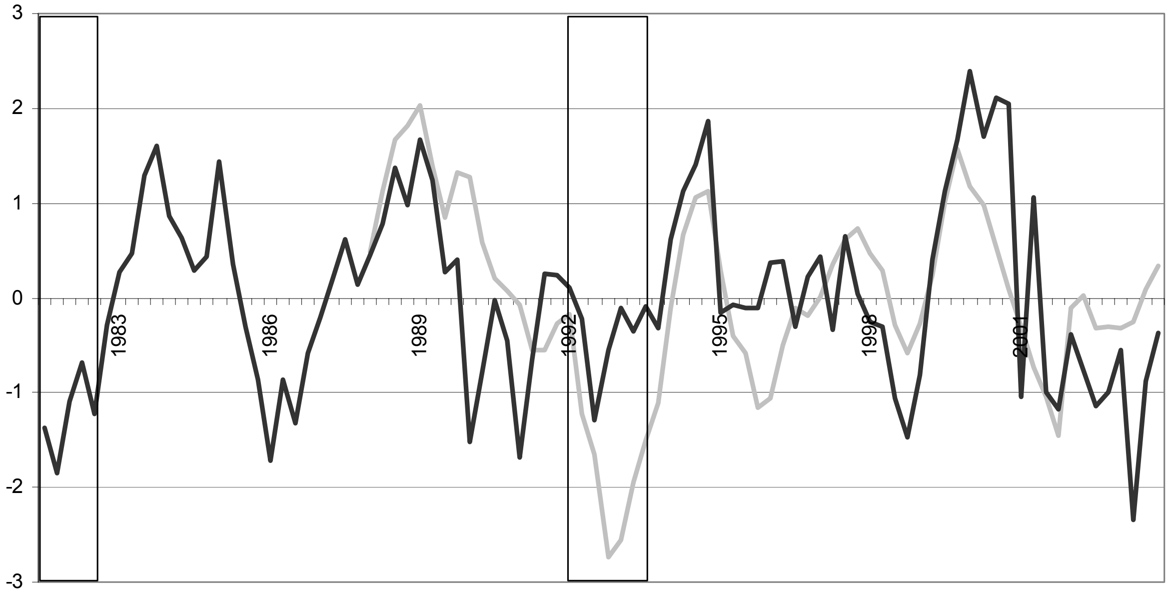
[9] based on the case of no rotation.

Figure 1: Common euro-area non-stationary (1-4) and stationary factors (5) ($\hat{\varphi}_t$)[1]



[1] The mean growth rates are zero by construction.

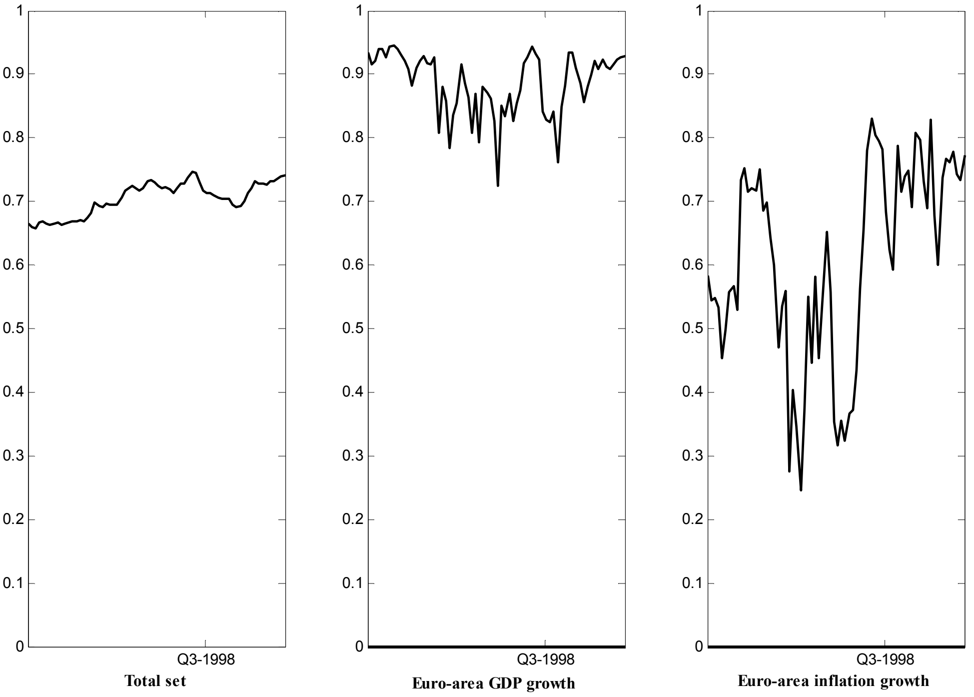
Figure 2: Euro-area business cycle estimate (black), EuroCOIN (gray), recessions declared by the CEPR-Euro Area Business Cycle Dating Committee (areas)[1]



[1] The series are normalized to have a mean of zero and a variance of one.

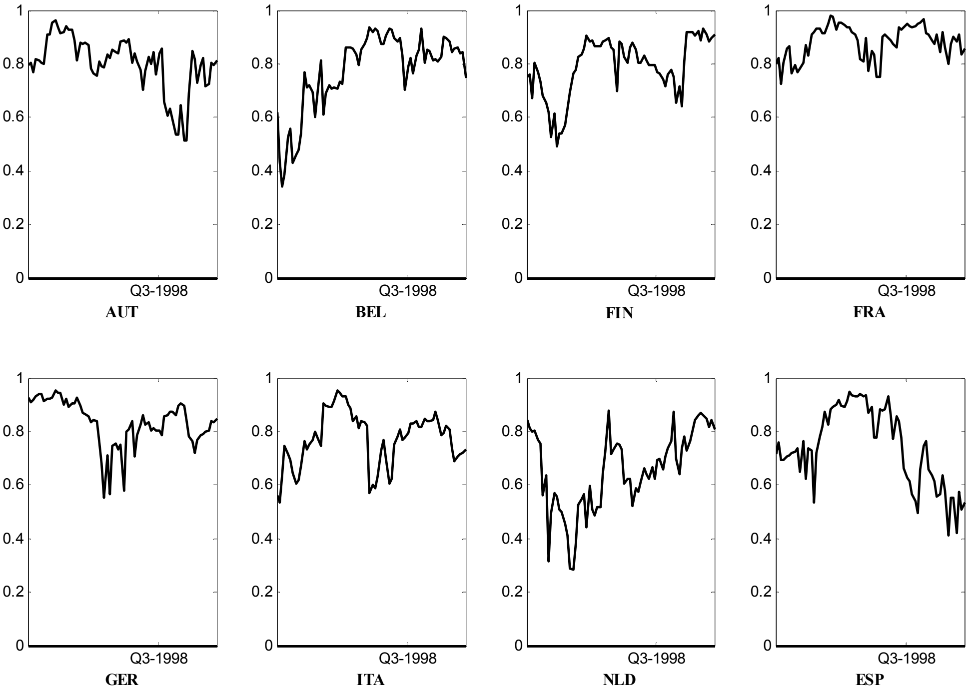
Figure 3: Variance share explained by the common factors – rolling 5-year samples1)

Total and euro-area aggregates



Total set **Euro-area GDP growth** **Euro-area inflation growth**

GDP growth of individual countries

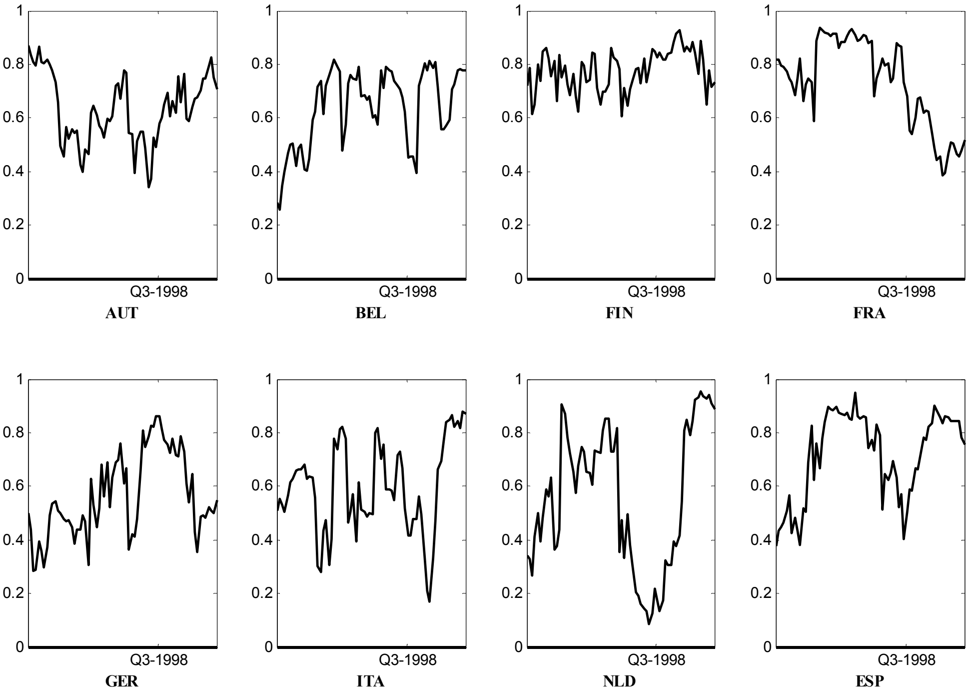


AUT **BEL** **FIN** **FRA**

GER **ITA** **NLD** **ESP**

Figure 3 cont.

Inflation growth$^{2)}$ of individual countries



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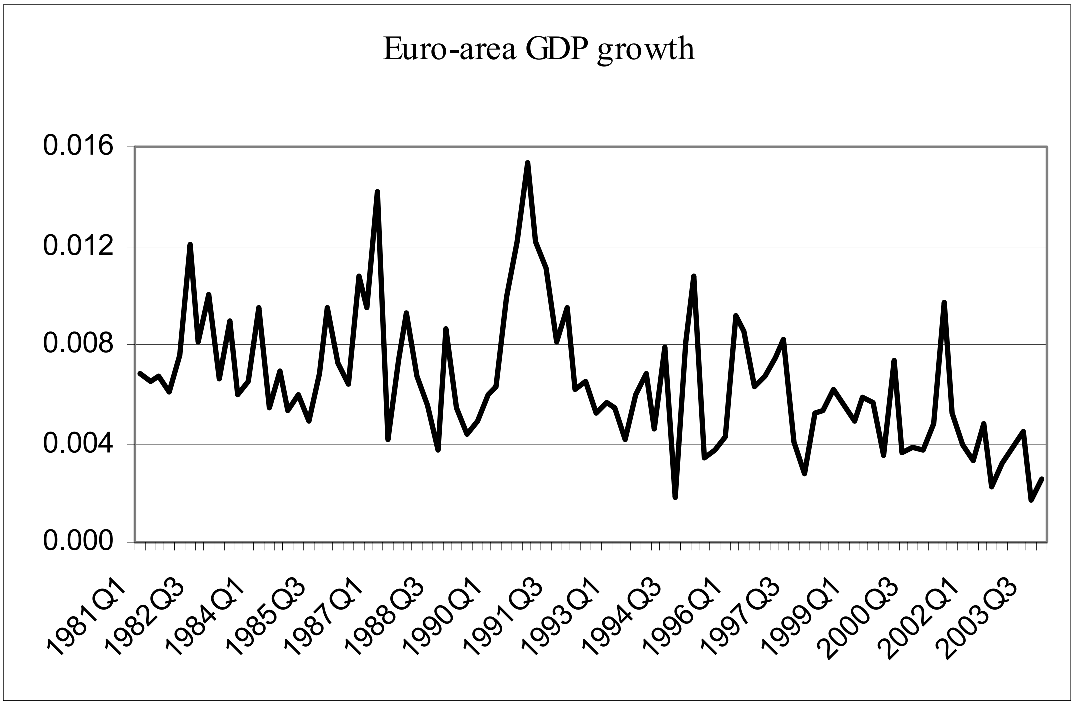
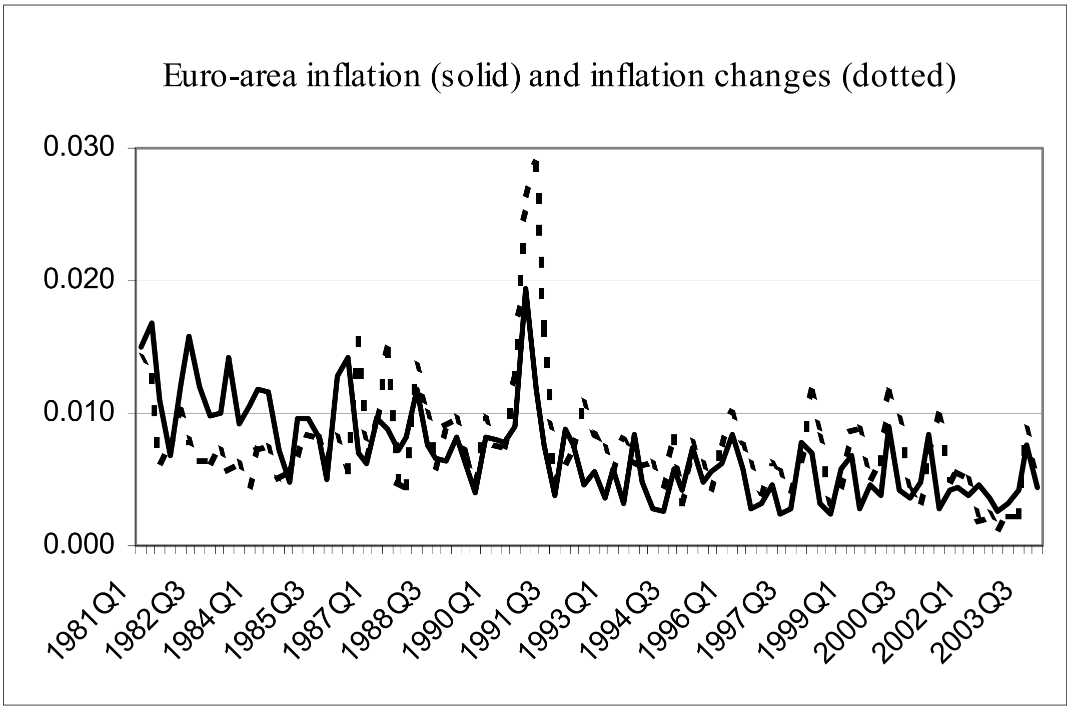
1) The variance share indicated in time *t* in the graphs shows the variance share between *t* - 20 (quarters) and *t*. The entire period is considered.

2) GDP deflator.

Figure 4: Standard deviations of GDP growth and inflation across core euro-area countries





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