Macroeconomic Dynamics in the Euro Area*

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March 31, 2008

Abstract

This paper characterizes the transmission mechanism of monetary and oil-price shocks across countries of the euro area, documents how this mechanism has changed with the introduction of the euro, and explores some potential explanations. The factor-augmented VAR (FAVAR) framework used is sufficiently rich to jointly model the euro area dynamics while permitting the transmission of shocks to be different across countries. We find important heterogeneity across countries in the effect of macroeconomic shocks before the launch of the euro. In particular, we find that German interest-rate shocks triggered stronger responses of interest rates and consumption in some countries such as Italy and Spain, than in Germany itself. According to our estimates, the creation of the euro has contributed 1) to a greater homogeneity of the transmission mechanisms across countries, and 2) to an overall reduction in the effects of this shock. Using a structural open-economy model, we argue that the combination of a change in the policy reaction function — mainly toward a more aggressive response to inflation and output — and the elimination of an exchange rate risk can explain the evolution of the monetary transmission mechanism observed empirically.

JEL Classification: E31, E4, E5, C3, D2

Keywords: Euro area; factor models; FAVAR; monetary policy; oil price shocks; interest-rate parity; risk premium.

*We thank Daron Acemoglu, Andrea Ferrero, Bruce Preston, Veronica Rappoport for valuable discussions and comments. Boivin and Giannoni are grateful to the National Science Foundation for financial support (SES-0518770).

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1 Introduction

On January 1st, 1999, the euro officially became the common currency for 11 countries of continental Europe, and a single monetary policy started under the authority of the European Central Bank.[1] The European Monetary Union[2] (EMU) followed decades of monetary policies set by national central banks to serve domestic interests, even though these national policies were constrained by monetary arrangements such as the European Monetary System which was designed to limit exchange rate fluctuations. Approaching the tenth anniversary of the EMU, we begin to have sufficient data to potentially observe effects of the monetary union on business cycle dynamics.

This paper has three objectives. The first is to characterize the transmission mechanism of macroeconomic shocks on the Euro Area (EA) and across its constituent countries. The second is to document how this transmission might have changed since the creation of the euro. The third objective consists of providing a set of explanations, based on a structural open-economy model, for the observed differences over time and across countries in the responses of key macroeconomic variables.

Our first two objectives require an empirical model that captures empirically the EA-wide macroeconomic dynamics, while allowing us to estimate the potentially heterogenous transmission of EA shocks within individual countries. The factor-augmented VAR model (FAVAR) proposed by Bernanke, Boivin and Eliasz (2005) is a natural framework in this context. By pooling together a large set of macroeconomic indicators from individual countries, it allows us to identify area-wide factors, quantify their importance in the country-level fluctuations, and trace out the effect of identified aggregate shocks on all country-level variables. It also allows us to measure the spillovers between individual countries and the EA.

Many papers have attempted to characterize the dynamics of European economies. One common strategy has been to modeling the EA economy using only EA aggregates. Examples include evidence based on VARs (Peersman and Smets, 2003), more structural models (the ECB Area Wide

[1] At that date, the conversion rates of the national currencies of the Eurozone were fixed irrevocably, and a three-year transition period started until the introduction of the euro banknotes and coins, in January 2002. Since then other countries such as Greece, Slovenia, Malta and Cyprus adopted the euro.

[2] We refer to the EMU as the stage III of the European Monetary Union, which involves the launch of the euro in January 1999.

Model; Fagan, Henry and Mestre, 2005) and optimization-based macroeconomic models (Smets and Wouters, 2003, Christiano et al., 2007; the New AWM; Coenen et al., 2006). Alternatively, authors have estimated models using country-level data either to analyze the effects of various macroeconomic shocks or for forecasting, using models of national central banks (Fagan and Morgan, 2006) or VARs (e.g., Mojon and Peersman, 2003; Mihov, 2001).

An important feature of the FAVAR is that it allows us to model jointly the dynamics of EA-wide variables and country-level variables within a single consistent empirical framework. In that respect, we see our empirical strategy as an improvement over the numerous papers that have compared impulse responses to shocks on the basis of models estimated separately for each country (e.g., Angeloni, Kashyap, and Mojon, 2003. chap. 3 and 5). The estimated model suggests that a significant fraction of country-level variables such as the components of output and prices, employment, productivity and asset prices, can be explained by EA-wide common factors.

In order to understand the transmission of macroeconomic shocks, we need to identify structural shocks among these common factors. We identify two key macroeconomic shocks and estimate their dynamic effects on the national macroeconomic variables. These shocks are an unexpected monetary policy shock and a shock to the price of oil. We are particularly interested in documenting differences over time and across countries in the sensitivity of national economies to these shocks.

The estimated transmission mechanisms of these shocks are largely consistent with conventional wisdom. For instance, monetary policy tightening in the EA as a whole or in Germany triggers an appreciation of the exchange rate, a downward adjustment of demand and eventually of prices. For the period preceding the EMU, we find considerable heterogeneity in the transmission of these shocks across countries. In particular, we find larger responses of long-term interest rates in Italy and in Spain, which contributes to larger contractions of consumption in these two countries. Also, restrictive monetary policy in the EA tended to trigger a depreciation of the lira and the peseta, and a smaller decline of exports of these countries than in the rest of the EA.

The creation of the euro has contributed 1) to a greater homogeneity of the transmission mechanisms across countries, and 2) to an overall reduction in the effect of monetary shocks. In particular, long-term interest rates, as well as consumption, investment, output, employment respond less to short-term interest rate shocks in the new monetary policy regime, while trade and the real exchange rate respond more strongly. While the monetary transmission mechanism appears to have become more homogenous on several key real and nominal variables, some striking asymmetries persist, for instance in the response of national monetary aggregates to common interest rate shocks, suggesting pervasive differences in national savings practices.

We use a structural open-economy model to explore some potential explanations for this evolution of the transmission mechanism of monetary policy. More precisely, we extend the model from Ferrero, Gertler and Svensson (2007) with some features to be able to qualitatively replicate the stylized facts summarized above. One key feature needed in order to replicate the facts appears to be an "exchange-rate risk premium" on intra-area exchange rates for the period prior to the EMU. Using a calibrated version of this model, we show that the combination of two ingredients can replicate the evolution of the estimated transmission mechanism since the start of the EMU: 1) a shift in monetary policy, mainly toward a more aggressive response to inflation and output, and 2) the elimination of the exchange-rate premium that plagued some of the European countries by fixing the intra-area exchange rates. This suggests that the ECB has played a key role for the change in the transmission mechanism of some macroeconomic shocks.

The rest of the paper is organized as follows. Section 2 reviews the econometric framework. It discusses the formulation and estimation of the FAVAR and its relation to the existing literature. In Section 3, we discuss the empirical implementation, describing the data used in our estimation, our preferred specification of the FAVAR as well as its basic empirical properties. Section 4 studies the effects of monetary and oil price shocks in the EA and in individual countries, and discusses their changes since the creation of the EMU in 1999. Section 5 attempts to explain the cross-country differences as well as the changes over time in the monetary transmission mechanism. Section 6 concludes.

2 Econometric Framework

We are interested in modeling empirically the EA wide macroeconomic dynamics, while allowing heterogeneity in the transmission of EA shocks within individual countries. A natural framework to achieve this goal is the factor-augmented vector autoregression model (FAVAR) described in

Bernanke, Boivin and Eliasz (2005) (BBE). The model is estimated using indicators from individual European economies as well as from the EA. The general idea behind our implementation is to decompose the fluctuations in individual series into a component driven by common European fluctuations, and a component that is specific to the particular series considered. EA-wide common shocks can then be identified from the multi-dimensional common components. The FAVAR also allows us to characterize the response of all data series to macroeconomic disturbances, such as monetary policy shocks or oil price shocks. Importantly, by modeling jointly EA and country-level dynamics, this framework allows each country's sensitivity to EA shocks to be different.

2.1 Description of the FAVAR model

We only provide here a general description of our implementation of the empirical framework and refer the interested reader to BBE for additional details. We assume that the economy is affected by a vector C_t of common EA-wide components to all variables entering the data set. Since we will be interested in characterizing the effects of monetary policy and oil price shocks, this vector of common components includes a short-term interest rate, R_t, to measure the stance of monetary policy, and the growth rate of an oil price index, π_t^{oil}. Both of these variables are allowed to have pervasive effect throughout the economy and will thus be considered as common components of all variables entering the data set. The rest of the common dynamics is captured by a $K \times 1$ vector of unobserved factors F_t, where K is relatively small. These unobserved factors may reflect general economic conditions such as "economic activity," the "general level of prices," the level of "productivity," which may not easily be captured by a few time series, but rather by a wide range of economic variables. We assume that the joint dynamics of π_t^{oil}, F_t, and R_t are given by

$$C_t = \Phi(L)C_{t-1} + v_t \tag{1}$$

where

$$C_t = \begin{bmatrix} \pi_t^{oil} \\ F_t \\ R_t \end{bmatrix},$$

and $\Phi(L)$ is a conformable lag polynomial of finite order which may contain a priori restrictions, as in standard structural VARs. The error term v_t is iid with mean zero and covariance matrix Q.

The system (1) is a VAR in C_t. The additional difficulty, with respect to standard VARs, however, is that the factors F_t are unobservable. We assume that the factors summarize the information contained in a large number of economic variables. We denote by X_t this $N \times 1$ vector of "informational" variables, where N is assumed to be "large," i.e., $N > K + 2$. We assume furthermore that the large set of observable "informational" series X_t is related to the common factors according to

$$X_t = \Lambda C_t + e_t \tag{2}$$

where Λ is an $N \times (K + 2)$ matrix of factor loadings, and the $N \times 1$ vector e_t contains (mean-zero) series-specific components that are uncorrelated with the common components C_t. These series-specific components are allowed to be serially correlated and weakly correlated across indicators. Equation (2) reflects the fact that the elements of C_t, which in general are correlated, represent pervasive forces that drive the common dynamics of X_t. Conditional on the observed short-term interest rate R_t, the variables in X_t are thus noisy measures of the underlying unobserved factors F_t. Note that it is in principle not restrictive to assume that X_t depends only on the current values of the factors, as F_t can always capture arbitrary lags of some fundamental factors.[3]

The empirical model (1) and (2) provides a convenient decomposition of all data series into components driven by the EA factors C_t (i.e., the short-term interest rate, oil prices and other latent dimensions of aggregate dynamics, such as real activity and inflation) and by series-specific components unrelated to the general state of the economies, e_t. For instance, (2) specifies that indicators of country-level economic activity or inflation are driven by a European interest rate, EA latent factors F_t, and a component that is specific to each individual series (representing, e.g., measurement error or other idiosyncrasies of each series). The dynamics of the EA common components are in turn specified by (1).

As in BBE, we estimate our empirical model using a variant of a two-step principal component approach. In the first step, we extract principal components from the large date set X_t to obtain

[3] In fact, Stock and Watson (1999) refer to (2) as a dynamic factor model.

consistent estimates of the common factors.[4] Stock and Watson (2002) show that the principal components consistently recover the space spanned by the factors when N is large and the number of principal components used is at least as large as the true number of factors. In the second step, we add the oil price inflation and the short-term interest rate to the estimated factors, and estimate the structural VAR (1). Our implementation differs slightly from that of BBE as we impose the constraint that the observed factors (π_t^{oil} and R_t) are among the factors in the first-step estimation.[5] This guarantees that the estimated latent factors recover dimensions of the common dynamics not captured by the observed factors.[6]

This procedure has the advantages of being computationally simple and easy to implement. As discussed by Stock and Watson (2002), it also imposes few distributional assumptions and allows for some degree of cross-correlation in the idiosyncratic error term e_t. Boivin and Ng (2005) document the good forecasting performance of this estimation approach compared to some alternatives.[7]

2.2 Interpreting the FAVAR structure

Various approaches have been used in the literature to model macroeconomic dynamics in the EA. As we illustrate in this section, these approaches can be interpreted as special cases of the FAVAR framework. Our approach thus merges some of the strengths of these existing approaches and allows to answer a broader set of questions.

As in Bernanke, Boivin and Eliasz (2005) and in Boivin and Giannoni (2006b), we interpret

[4] While alternative strategies to the estimation of factor models with a large set of indicators exist (see, among others, Forni, Lippi, Hallin and Reichlin, 2000; Kose, Otrok and Witheman 2003; BBE; Doz, Giannone and Reichlin, 2006; Boivin and Giannoni, 2006b), the evidence suggests that they perform similarly in practice.

[5] In contrast to the approach adopted here, BBE do not impose the constraint that the observed factors are among the common components in the first step. They instead remove these observed factors from the space covered by the principal components, by peforming a transformation of the principal components exploiting the different behavior of what they call "slow-moving" and "fast-moving" variables, in the second step. Our approach here follows Boivin and Giannoni (2007) and Boivin, Giannoni and Mihov (2007).

[6] More specifically, we adopt the following procedure in the first step of the estimation. Starting from an initial estimate of F_t, denoted by $F_t^{(0)}$ and obtained as the first K principal components of X_t, we iterate through the following steps: (1) we regress X_t on $F_t^{(0)}$ and the observed factors $Y_t = [\pi_t^{oil}, R_t]'$ to obtain $\hat{\lambda}_Y^{(0)}$; (2) we compute $\tilde{X}_t^{(0)} = X_t - \hat{\lambda}_Y'^{(0)} Y_t$; (3) we estimate $F_t^{(1)}$ as the first K principal components of $\tilde{X}_t^{(0)}$; (4) we repeat steps (1)-(3) multiple times.

[7] Note that this two-step approach implies the presence of "generated regressors" in the second step. According to the results of Bai (2003), the uncertainty in the factor estimates should be negligible when N is large relative to T. Still, the confidence intervals on the impulse response functions used below are based on a bootstrap procedure that accounts for the uncertainty in the factor estimation. As in BBE, the bootstrap procedure is such that 1) the factors can be re-sampled based on the observation equation, and 2) conditional on the estimated factors, the VAR coefficients in the transition equation are bootstrapped as in Kilian (1998).

the common component C_t as corresponding to the vector of theoretical concepts or variables that would enter a structural macroeconomic model of the EA. For instance, the structural open-economy model that we consider in section 5.1 fully characterizes the equilibrium evolution of inflation, output, interest rates, net exports and other variables in two regions. In terms of the notation in our empirical framework, all of these variables would be in C_t, or linear combinations thereof. The dynamic evolution of these variables implied by such an open-economy model can be approximated by an unrestricted VAR of the form (1).[8]

The existing approaches to model the EA can be interpreted as special cases of the FAVAR model where the elements of C_t are perfectly observed, in which case, the system (1)-(2) boils down to a VAR. Interpreted in this way, the various existing empirical models differ about the assumptions they make about: the variables included in C_t, the indicators used to measure C_t, and the amount of restrictions imposed on the coefficients of (1)-(2).

One approach is to assume that the element of C_t are observed and correspond to EA aggregates.[9] Such model can be estimated directly using a VAR on EA aggregates only (e.g. Peersman and Smets, 2003), or a constrained version of a VAR corresponding, e.g., to the ECB Area Wide Model (Fagan, Henry and Mestre, 2005), or even optimization-based macroeconomic models (Smets and Wouters, 2003, Christiano et al., 2007; the New AWM; Coenen et al., 2006).[10] Models estimated only on EA aggregates are silent about the regional effects of a shock.

A second approach is to assume that the elements of C_t are observed and correspond to variables of different regions. In that case, the FAVAR boils down to multi-country VARs and could be estimated directly, as in, e.g., Eichenbaum and Evans (1995), Scholl and Uhlig (2006).

A third approach is to assume that elements of C_t are observed and correspond to variables of a specific country. A large literature has in fact analyzed the cross-country differences in the response of monetary policy using country-level models that are estimated separately (see Guido et al. 1999, Mojon and Peersman, 2003, Ciccarelli and Rebucci, 2006 and references therein). By

[8] For a formal description of the link between the solution of a DSGE model in state-space form and a VAR see, e.g., Fernández-Villaverde, Rubio-Ramírez, Sargent and Watson (2007) and references therein.

[9] The estimation of aggregate models for the EA has a relatively short history since there did not exist sufficiently long historical time series of consistent EA national accounts before the launch of the euro and the publication of Fagan, Henry and Mestre (2005). National accounts for the EA, published by Eurostat, start only in 1995.

[10] Boivin and Giannoni (2006b) propose to estimate DSGE models using a large data set, and establish the link between the DSGE model and the FAVAR representation (1)-(2).

construction these models focus on country-specific shocks and do not explicitly identify the effects of EA-wide shocks such as changes in the stance of monetary policy that would affect all countries simultaneously. The transmission of such shock could potentially be amplified through trade and expectation spillovers[11]

Importantly, in all these cases, since the variables necessary to capture the EA dynamics are observed, there is no need to use the large set of indicators X_t. However, there are reasons to believe that some relevant macroeconomic concepts are imperfectly observed. First, some concepts are simply measured with error.[12] Second, some of the macroeconomic variables which are key for the model's dynamics may be fundamentally latent. For instance, the concept of "potential output" often critical in monetary models cannot be measured directly. By using a large data set, one is able to extract empirically the components that are most important in explaining fluctuations in the entire data set. While each common component does not need to represent any single economic concept, the common components C_t should constitute a linear combination of all of the relevant latent variables driving the set of noisy indicators X_t to the extent that we extract the correct number of common components from the data set.

An advantage of this empirical framework is that it provides summary measures of the state of these economies at each date, in the form of factors which may summarize many features of the economy. We thus do not restrict ourselves simply to measures of inflation or output. Another advantage, as BBE argue, is that this framework should lead to a better identification of the monetary policy shock than standard VARs, because it explicitly recognizes the large information set that the central bank and financial market participants exploit in practice, and also because, as just argued, it does not require to take a stand on the appropriate measures of prices and real activity which can simply be treated as latent common components. Moreover, for a set of identifying assumptions, a natural by-product of the estimation is to provide impulse response functions for any variable included in the data set. This is particularly useful in our case, since we want to understand the effects of macroeconomic shocks on a wide range of economic variables

[11] van Els et al. (2003) show that spillovers across countries tend to reinforce the effects of monetary policy on output and on prices. See also Fagan and Morgan (2006).

[12] Boivin and Giannoni (2006b) argue, for example, that inflation is imperfectly measured by any single indicator, and that it is important to use multiple indicators of it for proper inference.

across EA countries.

Other papers have in fact followed a similar route. Sala (2001) estimates the effects of German and EA composite interest-rate shocks using a factor model. He stresses large asymmetries in the response of either output or prices to this shock. Favero et al. (2005) compare the effects of monetary policy shocks on output and inflation in Germany, France, Italy and Spain for alternative specification of factor models. They find largely homogenous effects on output gaps and inflation rates across countries. Eickmeier and Breitung (2006) and Eickmeier (2006) characterize the effects of common shocks on GDP and inflation of 12 countries of the EA and for new European Union member states who will adopt the euro in the future. They conclude that these common shocks transmit rather homogeneously across countries so that the remaining heterogeneity across EA countries seem to originate in idiosyncratic shocks rather than asymmetric transmission.

In contrast, in this paper we seek to better understand how the monetary policy regime might explain why shock transmit differently in different countries of the area. In that regard, we believe that countries of the EA, and their move toward a common currency, provide a unique experiment for monetary economists. For this reason our focus is not strictly on the response of countries' GDPs and inflation rates, but on any relevant dimensions of the economy. We thus seek to take full advantage of the FAVAR structure to document the effect of various shocks on various measures of real activity, such as GDP and its components, employment and unemployment, various inflation measures and financial variables. Although our scope is broader, our approach is similar to McCallum and Smets (2007), who use a similar FAVAR to study the role national and sectoral labor market characteristics imply wage rigidities that influence the monetary transmission mechanism.

3 Empirical implementation

3.1 Data

The data set used in the estimation of our FAVAR is a balanced panel of 245 quarterly series, for the period running from 1980:1 to 2007:3. We limited the sample to the six largest economies of the EA, i.e. Germany, France, Italy, Spain the Netherlands and Belgium for which we could gather a balanced panel of 33 economic quarterly time series that are available back to 1980. Given these countries account for 90% of the EA population and output, we deem unlikely that the inclusion of other EA countries would alter our estimates EA business cycle characteristics.

The 33 economic variables that we gathered for each country and the EA include two interest rates, M1, M3, the effective exchange rate, an index of stock prices, GDP and its decomposition by expenditure, the associated deflators, PPI and CPI indices, the unemployment rate, employment, hourly earnings, unit labor cost measures, capacity utilization, retail sales and number of cars sold. In addition to these 231 country level and EA level variables, we also include an interest rate and real GDP for the three G7 countries not in the EA: the UK, the U.S. and Japan, the euro/dollar exchange rate, and index of commodity prices and the price of oil. The database was mostly extracted from Haver. In a number of cases the Haver data were backdated using older vintages of OECD databases. The definition of the variables, the source, and details about the data construction are given in Appendix A.

We take year-on-year (yoy) growth rates of all time series except for interest rates, unemployment rates and capacity utilization rates. The yoy transformation is preferred to limit risks of noise due to improper or lack of seasonal adjustment in the data.

3.2 Sample period

The choice of the sample period is delicate. On the one hand, our interest lies in the functioning on the monetary union, which started in January 1999. We therefore have about 9 years of data that correspond to the strict monetary union. However, the objective of stabilizing exchange rates within what would become the EA started much earlier. In fact, already in the seventies, European governments set up mechanisms that aimed at limiting exchange rate fluctuations within Europe.[13] The march to the monetary union has however been gradual and each country has progressed at its own speed. The pegs of Austria, Belgium and the Netherlands to the Deutsche mark were not realigned after the early 1980's. The last realignment of the French franc to core EMS currencies (the Deutsche mark, the Belgian Franc and the Dutch Crown) took place in January 1987. Ex post, we know that the parity between the French Franc, the Belgian Franc, the Dutch Guilder and

[13] Major steps in this process include the start of the EMS in 1979, the entrance of Spain and Portugal into the EMS in 1986, the post-reunification exchange rate crisis of 1992-1993 and the announcement of the parities between national currencies and the euro in May 1997.

the Deutsche Mark hardly changed at all since January 1987. However, a significant risk premium for fear of realignment plagued the French currency until 1995. Finally, countries such as Italy and Spain — as well as Greece, Portugal, Ireland and Finland, which are not in our sample — saw their currency fluctuate vis-à-vis their future partners in the monetary union well into the 1990s. Although interest rates remained much higher in Italy and Spain, than in Germany up until the mid 1990's because of risk premia (see Figure 1a), changes in the interest rates set by the Bundesbank would be echoed in domestic monetary conditions because of the official peg to the Deutsche Mark.

Another key aspect of the process of monetary integration is the degree of nominal convergence. We note from Figure 1b that inflation rates were much further apart in the 1970's and early 1980's than ever since.

For all these considerations, and to avoid the large changes on nominal variables that have occurred in the early 1980s, we propose to describe the effects of standard common shocks starting in 1988. We will also contrast the results with estimates for a sample corresponding to the strict monetary union regime starting in 1999.

3.3 Preferred specification of the FAVAR

For the model selection, the sample size severely constrains the class of specifications we can consider, especially the number of lags in (1), as well as the number of factors gets large. We were thus forced to consider models with no more than 8 factors and 3 lags. Among those, our approach has been to search for the most parsimonious model for which the key conclusions we are emphasizing below are robust to the inclusion of additional factors and lags. Based on this, our preferred specification is one with a vector of common components C_t containing 5 latent factors in addition to the short-term interest rate and the oil price inflation, and a VAR equation (1) with one lag. Moreover, we show below that these common factors explain a meaningful fraction of the variance of country level variables.

3.4 European factors and EA-countries' dynamics

To assess whether our FAVAR model provides a reasonable characterization of the individual series, we now determine the importance of area-wide fluctuations for individual countries. Note that from equation (2), each of the variables X_{it} of our panel can be decomposed into a component $\lambda_i' C_t$ which characterizes the effects of EA-wide fluctuations, and a component e_{it} which is specific to the series considered:

$$X_{it} = \lambda_i' C_t + e_{it}. \tag{3}$$

It is important to note that each variable may be affected very differently by the multidimensional vector C_t summarizing EA-wide fluctuations, as the estimated vectors of loadings λ_i may take arbitrary values. We first start by determining the extent to which key European variables are correlated with EA factors over three samples. We then discuss how the importance of these factors has changed over time. In the next section, we document how various macroeconomic shocks get transmitted to the EA, and across the different countries.

Several studies have recently attempted to the determine the degree of comovement of a few macroeconomic series across countries.[14] Forni et al. (2000) and Favero et al. (2005) show that a small number of factors provides an efficient information summary of the main economic time series both at the EA level and for the 4 largest countries of the EA. Eickmeier (2006) and Eickmeier and Breitung (2006) confirm these results but also stress that country-level inflation and output fluctuations are somewhat less correlated to EA wide common factors than their EA counterparts. However, Agresti and Mojon (2003) show that the comovement of either consumption or investment across EA countries is smaller than the comovement of GDP. Hence the possibility that the tightness of economic variables to the EA business cycle may be uneven across countries and of a different magnitude for variables of different kinds. This is why we consider a large number of economic variables, rather than focusing on a couple of macroeconomic indicators and compare their variance decomposition in terms of EA wide factors.

3.4.1 Comovements between European variables and EA factors

Table 1 reports the fraction of the volatility in the series listed in the first column, that is explained by the 7 factors C_t (i.e., 5 latent factors, the log change of the oil price, and the EA short-term

[14] For instance Kose, Otrok, Whiteman (2003), Stock and Watson (2005) study the comovement of output, consumption and investment, respectively for a large panel of countries, and for G7 countries. Giannone and Reichlin (2006) analyse the comovement of output across EA countries. In addition, the ECB is carefully monitoring real and nominal heterogeneity across countries (Benalal et al, 2006).

	Euro Area			Average R^2 over countries		
	1987:1 –2007:1	1987:1 –1998:4	1999:1 –2007:1	1987:1 –2007:1	1987:1 –1998:4	1999:1 –2007:1
Short-term interest rate	1.00	1.00	1.00	0.97	0.97	1.00
Bond rate	0.96	0.96	0.95	0.94	0.94	0.95
Stock price	0.65	0.71	0.91	0.61	0.77	0.88
REX	0.78	0.82	0.93	0.73	0.79	0.93
M1	0.43	0.65	0.73	0.42	0.65	0.53
M3	0.70	0.92	0.74	0.50	0.71	0.69
Deflator GDP	0.88	0.89	0.88	0.73	0.81	0.84
Deflator PCE	0.88	0.90	0.72	0.77	0.90	0.83
Deflator investment	0.89	0.93	0.88	0.63	0.71	0.75
Deflator exports	0.86	0.80	0.97	0.72	0.71	0.94
Deflator imports	0.93	0.89	0.99	0.82	0.78	0.97
CPI	0.94	0.97	0.90	0.78	0.91	0.83
Real GDP	0.94	0.97	0.96	0.79	0.84	0.90
Consumption	0.88	0.92	0.90	0.71	0.75	0.81
Public consumption	0.54	0.71	0.54	0.42	0.59	0.63
Investment (GKF)	0.92	0.93	0.94	0.65	0.76	0.78
Exports	0.70	0.71	0.93	0.67	0.68	0.88
Imports	0.84	0.95	0.93	0.74	0.81	0.89
Employment	0.85	0.90	0.97	0.78	0.85	0.85
Unemployment rate	0.92	0.97	0.96	0.86	0.93	0.96
Hourly earnings	0.94	0.97	0.69	0.79	0.92	0.74
Unit labor costs	0.89	0.96	0.88	0.81	0.92	0.89
CAP	0.86	0.92	0.95	0.67	0.80	0.77
Retail	0.73	0.80	0.60	0.53	0.67	0.60

Table 1: R2 for regressions of selected series on common factors

interest rate). This corresponds to the R^2 statistics obtained by the regressions of these variables on the appropriate set of factors.

The three columns labeled *Euro Area* report the R^2 statistics obtained by regressing the respective EA-wide series on the common factors for our entire sample, a subsample representing the period preceding the monetary union, and the sample starting in 1999 representing the period in which the EMU is in place. These numbers indicate that most of the variables listed are strongly correlated with the common factors, both before and after the monetary union.[15] While the short-term interest rate is a common factor by assumption, other key variables such as EA real GDP growth, CPI inflation, bond yields and the unemployment rate all have R^2 statistics above 0.9. The

[15] Camacho et al. (2007) argue however that the the euro area business cycle largely reflects the world business cycle.

	1987:1-2007:1	1987:1–1998:4	1999:1–2007:1
Euro-Area	0.83	0.88	0.87
Germany	0.69	0.77	0.82
France	0.76	0.84	0.87
Italy	0.73	0.82	0.79
Spain	0.76	0.84	0.78
Netherlands	0.64	0.74	0.86
Belgium	0.68	0.79	0.84

Table 2: Average R2 for regressions of selected series on EA factors

common factors therefore summarize quite well the information contained in these EA series. Not all series are however as strongly correlated with the common factors. For instance the growth rate of the monetary aggregate M1 and public consumption for the EA, with R^2 statistics of only 0.43 and 0.54, display much less co-movement with the common factors.

The last three columns of Table 1 report the average across countries of the R^2 statistics for the relevant variables. The R^2 statistics are overall lower than those for the entire EA area, as expected, to the extent that each country has country-specific features not summarized by the common factors C_t, and which tend to average out when considering the EA as a whole. Nonetheless, the table shows that on average over the six European countries, most of the variables are also strongly correlated with the common factors. Again, for the entire sample, country-level measures of GDP growth, short and long interest rates, inflation, employment and unemployment all show on average high degrees of co-movement with the common factors, while growth rates of M1, M2 and public consumption show much lower degrees of co-movement.

Looking across countries reveals that the correlation with the common factors is broadly similar across countries in each of the subsamples. Table 2 represents the average R^2 statistic for each country, across the variables listed in the previous table. It shows that country-level R^2 vary between 0.64 and 0.77 for the entire sample, between 0.74 and 0.84 in the first subsample, and between 0.78 and 0.87 in the post-EMU sample.

Table 2 also shows that in the case of Germany, the Netherlands and Belgium, the R^2 are sensibly lower for the entire sample than for each of the subsamples considered. This suggests that the relationship between the variables in those countries and the common factors must have changed between the pre-99 and post-99 period. Finally, we observe that Italian and Spanish variables have become somewhat less tied to EA wide developments over time. This comes essentially from the growth rates of real variables. Effectively, we notice in Figure 1c that Spanish GDP growth (purple line) has sustained a faster pace than the rest of the EA since 1995. The case of Italy (light blue), which growth rate has been tracking the EA one from below is less obvious.

4 Monetary Policy Regimes and the Transmission of Macroeconomic Shocks

In the last section, we documented that the variables of each individual country were on average fairly highly correlated with the EA-wide common factors. Nonetheless, aggregate shocks affecting the entire EA may have different implications on each individual country. To assess this, we use our estimated FAVAR to characterize the effects of various macroeconomic shocks on the national economies considered. Our empirical model is well suited for this as it allows us to determine simultaneously the effects of such shocks on all country-level variables.

In addition, as mentioned above, the data reveal changes over time in the degree of co-movement of key European variables with EA-wide common factors. A natural implication of such changes is that the effects of EA-wide macroeconomic shocks may have evolved over time. We thus report the effects of macroeconomic shocks both for our benchmark sample and for the post-EMU period.

4.1 Monetary policy transmission

We start by characterizing the effects of a monetary policy shock, which we measure here as an unanticipated increase in the EA short-term interest rate of 100 basis points (bp). The description of the effects of this shock is a natural starting point in a context where several countries have chosen to adopt a common currency and therefore to submit their economy to a single monetary policy. It is important to note that it is not because we believe that monetary policy shocks constitute an important source of business cycle fluctuations that we are interested in documenting the effects of such shocks. In fact, much of the empirical literature finds that such monetary shocks contribute only little to business cycle fluctuations (e.g.,Sims and Zha, 2006). Instead, monetary policy affects importantly the economy through its systematic response to economic conditions. As such, the responses to monetary policy shocks (assuming that policy be conducted subsequently with the systematic policy estimated in historical data) provides a useful description of the effects of monetary policy.

4.1.1 Identification

To identify monetary policy shocks, we proceed similarly to Bernanke, Boivin and Eliasz (2005) by assuming in the spirit of VAR analyses, that the latent factors F_t and the oil price inflation π_t^{oil} cannot respond contemporaneously to a surprise interest rate change, while the short term rate R_t can respond to any innovation in the factors F_t or in oil prices. Of course, we don't restrict in any way the response of factors F_t and π_t^{oil} in the periods following the monetary shock. This constitutes a minimal set of restrictions needed to identify monetary policy shocks. We also impose that all prices and quantity series respond to monetary policy only through its lagged effect on F_t (and potentially π_t^{oil}). This guarantees that none of these variables will respond contemporaneously to monetary policy, as is typically thought to be reasonable. Note that with these restrictions, nothing prevents any of the financial variables such as stock prices and exchange rates from responding contemporaneously to the short-term interest rate.

Our assumption that the monetary policy instrument is the short-term EA interest-rate is certainly appropriate for the post-EMU period during which the ECB has set the short-term EA interest rate. It may be less appropriate however for the pre-EMU period, during which each national central bank could in principle choose its own interest rate. As in Peersman and Smets (2003), Smets and Wouters (2003) and many others, during the pre-EMU period, our monetary policy shock is a fictitious shock that we estimate would have been generated by the ECB, had it existed.

In the pre-EMU period, the German central bank, i.e., the Bundesbank, assumed a central role in setting the level of interest rates for all countries participating to the European Monetary System. Given the Exchange Rate Mechanism in place, which limited fluctuations in nominal exchange rates, most of the other national central banks had to respond to changes in interest rates by the Bundesbank. For this reason, we verified the robustness of our results for the pre-EMU period by identifying a monetary policy shock as a surprise increase in the German short-term interest rate. The results obtained are briefly described in section 4.3 that discusses the robustness of our results.

4.1.2 Effects of monetary policy shocks in the Euro-Area in the 1988-2007 period

Figures 2a–2d report the estimated impulse responses to a 100 basis point surprise increase in the EA short-term interest rate. While the dark blue lines plot the responses of the variables in each country for the full sample of 1988-2007 along with the 90% confidence intervals, the light blue lines plot the responses for the post-EMU period starting in 1999. The figures plot in each pair of rows the responses of a particular variable. The last two plots in each pair of rows combine the responses for all countries, in the two different samples. So while the first seven plots in each pair of rows reveal the changes in impulse responses over time, in the EA and in the six countries, the last two plots show the differences across regions in each sample.

We first start by describing the response of the EA economy in the 1988-2007 period, by focusing on the top left plot of each pair of rows. These plots show that faced with an unanticipated monetary tightening of 100 bp, bond yields overall increase on impact by even more than 100 bp, stock market returns fall by about 10%, the EA real exchange rate (REX) appreciates by about 2% in the quarter of the shock and is expected to continue appreciating for more than 2 years, and the growth rates of monetary aggregates M1 and M3 fall. The real GDP yoy growth rate falls by about 1% after a year and a half and does not revert to positive value before three years. Our point estimate of the impact of monetary policy on output tends to be larger than in Smets and Wouters (2003) and various estimates reported in Angeloni et al. (2003). The large drop in output reflects a broad-based decline in aggregate consumption (C), gross capital formation (GKF) or investment, and exports (EX). Public consumption (PuC) however remains unchanged for about a year and starts falling only after that. The decline in overall economic activity is clearly reflected in a fall in employment (EMP) reaching about 0.7% after 6 quarters, and a subsequent increase in the unemployment rate (UR) and a reduction in hourly earnings and then eventually in unit labor costs, the GDP deflator and CPI inflation.

4.1.3 Cross-country differences in the 1988-2007 period

The transmission of monetary policy disturbances on the EA just described hides however heterogeneity across countries responses. Looking at the other panels, we observe in Figure 2a that a surprise increase in the EA short-term interest rate results in much larger interest-rate increases in countries such as Italy (light blue line) and Spain (purple line) than in the other countries. This heterogeneity gets amplified when looking at long-term yields. In fact, the Italian and Spanish bond yield rise almost twice as much as the yields of some other countries such as Germany, France or the Netherlands. Stock prices typically fall markedly following the monetary shock, as expected, due to rising interest rates and expected future profit growth, but the responses appear very similar across countries, which is in line with the near colinearity of national stock prices (Figure 1).

Consistent with the larger rise in bond yields in Italy and Spain over the whole sample and with the interest-rate parity condition, the Italian and Spanish currencies depreciate with respect to the other countries's currencies in pre-EMU period. The Italian and Spanish real effective exchange rates (REX) depreciate on impact and in subsequent quarters, while the price levels remain unchanged in the period of the shock (Figure 2b).[16] Instead, all of the other countries see their real exchange rates appreciate on impact and for several quarters after the shock, after the monetary tightening.

Following the increase in interest rates, the movements of the exchange rate and the fall in stock prices, we observe a decline in the growth rate of GDP. While the GDP responses appear rather homogenous across countries, the GDP components are not. Importantly, consumption falls by about twice as much in Italy and Spain than in the other countries, and investment also falls more. The depreciation of the Italian and Spanish real exchange rates however mitigates the fall in exports (EX), and reduces imports (IM) more sharply, thus contributing to a more homogenous output response.

These figures thus clearly reveal how diverse responses of bond yields and exchange rates affect differently the various European economies, when we consider economic adjustments in the pre-EMU period.

[16] Recall that the variables in the FAVAR are expressed in yoy growth rates. The impulse response functions of yoy growth rates and (log) levels are identical for the first 4 quarters following the shock.

Finally, it should be stressed that the effects of interest rate shocks on M1 and M3 are quite different across countries. We have seen in section 3.4.1 that their tightness to the common factors are markedly looser than for most other variables under consideration. This may reflect the pervasive differences in the national habits and in the availability of savings instruments across countries of the EA. The ECB (2007) report on financial integration points to, inter alia, the large differences in financial assets of household sectors across countries (from four times annual consumption in Belgium and Italy to only twice in France and Germany), large differences in the composition of financial wealth, and different pass-through of the market interest rate to deposit interest rates (see Kok Sørensen and Werner, 2006, and references therein).

4.1.4 Has the transmission changed with the EMU?

To answer this question, we re-estimate the effects of a monetary policy shock using the 37 quarterly observations that correspond to the post-1999 period corresponding to the EMU. The scarcity of degrees of freedom implies that we should be extremely cautious in interpreting the results. We nevertheless trust that the estimates provide an indication on the direction of evolution of the effects of monetary policy with respect to the full sample estimates.

Several results are worth underlying for the post-99 period, again in the face of a 100 bp increase in the short-term interest rate. First, the short-term interest rate responses are indistinguishable for all countries, given that they refer to the same currency. Second, the rise in bond yields in the EMU period is almost half of the one estimated for the entire sample, and the large differences across countries that were observable prior to the EMU vanish entirely. Stock markets returns display similar responses possibly with more heterogeneity in the more recent period. The EA effective exchange rate appreciates considerably more than it did over the full sample. One reason for this is that real exchange rates uniformly appreciate in EA countries, including in Italy and in Spain.[17]

Given the relatively small change in bond yields, measures of economic activity such as real GDP, consumption, investment fall much less, if at all in the EMU period. As a result, employment

[17] The real exchange rate response is larger for the EA than for each of the individual countries as much of the trade of the individual countries is with other European economies, whereas the EA real exchange rate measures appreciations and depreciations solely relative to countries outside of the EA.

falls much less, and the unemployment rate's increase is sensibly smaller.

Altogether, it appears that a major characteristic of the new monetary policy regime is the lack of response of long-term interest rates to surprise increases in the short-term interest rate.[18] We illustrate this evolution by comparing in Figure 3 the response of the long-term interest rate to the response an artificial long-term interest rate excluding a term premium. The latter obtained by appealing to the expectations hypothesis and computed as the average response of the short-term interest rate over the subsequent 28 quarters, i.e. a theoretical bond of 7-year maturity. A striking difference between the full sample and the post-1999 regime is that, since the launch of the euro, the response of long-term interest rates displays a smaller term premium (i.e., a smaller difference between the market long-term rate and the artificial rate). Moreover, the term premium gap is the largest in Italy and in Spain, which suggests that, prior to the launch of the euro, the premium for the risk of devaluation or depreciation of the peseta and the lira, increased markedly following a tightening of the monetary policy stance in the euro area.

While most measures of economic activity appear to fall less in the EMU period, presumably in part because of smaller bond yield responses, much of the remaining output adjustment appears to be driven by internationally trade. This may be an important feature of the new monetary policy regime characterized by more stable long-term interest rates and a sharper responses of the EA-wide real exchange rate to monetary policy shocks.

Finally, the responses of several variables remain heterogenous across countries, in the EMU period. To name a few, the responses of M1 are twice as negative in Spain and Belgium than in France, Germany and Italy. M3 increases in all countries, though to a different extent. Relatively larger responses of German exports and investment carry through to a larger GDP response than in other EA countries. Public consumption responses range from positive in Belgium and Italy — the two countries with the largest stock of government debt — to sharply negative in the Netherlands. We also note some differences in labor market dynamics, aspects analyzed in depth in McCallum and Smets (2007).

[18] This result is consistent with the ones of Ehrmann et al. (2007) who use daily interest rates to compare the responses of French, German, Italian and Spanish long-term yields to news in France, Germany, Italy and Spain before and after 1999.

4.2 The effects of an oil price shocks

We next briefly study the effects of an unexpected increase in oil prices. This shock is an ideal experiment in the sense that it affects simultaneously all the EA countries, and it is, arguably, an exogenous source of economic fluctuations (see Hamilton, 2003; Cavallo and Wu, 2007; Blanchard and Galí, 2007; and Kilian, 2008).

The identification of the oil price shock is similar to the one in Blanchard and Galí (2008), although we implement it in the context of our FAVAR. Basically, the oil price shock can affect all other latent and observed factors instantaneously and through them, all the variable of the model. However, we assume that the oil price responds to other factors only after a one quarter lag.

Figures 4a-4f show the response of selected variables to 10 % increase in the yoy inflation of oil prices, both for the 1988-2007 sample and for the post-1999 sample. As expected, import prices, CPI Food and Energy increase by about 1 % and 1.5 %, CPI increases by about 0.1% percent. Turning to quantities, we estimate that an increase in the price of oil reduces the yoy growth rate of output by about 0.1% for the EA. This is broadly in line with Blanchard and Galí (2007) who stressed the reduction in the effects of oil price shocks in the last two decades when compared with samples that include the seventies.

Two other results should be stressed. First, bond yields increase more in Italy and in Spain than in the other countries or the EA as a whole, and consumption declines by more in these countries as well. This result is consistent with our findings in response to a monetary shock, and provides further evidence that bond markets and credibility issues are the locus of an important asymmetry in business cycle adjustments across countries prior to the EMU. Second, we note that the responses of CPI inflation rates tend to be less persistent in the recent sample, both at the EA level and in all countries but the Netherlands. Again, this is indicative that the ECB monetary policy has better anchored inflation expectations than any of the national central banks had before the EMU.

4.3 Robustness

In view of the small number of degrees of freedom we have available to estimate the above set of results, we have conducted a series of robustness checks with respect to the econometric specification of the FAVAR. In particular, we estimated the above impulse response functions with models that admit additional lags, additional latent factors, quarter-on-quarter growth rates, and considering shocks to the German interest rate instead of the EA average interest rate.

Most of the results above described are robust. In particular the larger response of the Italian and Spanish interest rates and of their consumption to the policy shock and the oil shock are common outcomes of all these alternative specifications, when estimated over the full sample.

Likewise, we observe at least a smaller response of consumption after 1999 with respect to the full sample estimates. However, the specification with quarter-on-quarter growth rates and several lags shows that, due to a large response of exports, GDP declines as much in the post-1999 period as in the full sample. These impulse responses functions are however much less precisely estimated than in our benchmark specification.

In the case in which the monetary policy shock is defined in terms of the German short-term interest rate, nearly all the results reported in Figure 2 carry through. We notice however that the price puzzle for German CPI is very much attenuated. This reflects that the identification of area-wide monetary shocks in the period prior to the euro is difficult. However, except for the response of German prices, nearly all other impulse responses are strikingly similar for a German or an area-wide monetary policy shock.

5 Explaining the Evolution of the Transmission Mechanism: The Role of Monetary Regimes and Interest-Rate Parity

As discussed in the previous section, the empirical characterization of the transmission of monetary policy in the EA displays a rich picture. In the pre-EMU period, interest-rate surprises in Germany or in the EA as a whole are found to cause larger responses of short-term rates in Italy and Spain, relatively large increase in long-term bond yields, depreciations of the Italian and Spanish currencies (both in nominal and real terms), a sharp contraction in consumption and investment in these countries. Such reductions in activity are offset by a relatively strong improvement in net exports, thereby resulting in a moderate contraction of real GDP. In the EMU period, however, a similar increase in the EA interest rate results in a much more homogenous response of individual EA countries, and a quantitatively smaller reduction in economic activity measures.

While the European economy has changed in many dimensions since the monetary union, we now attempt to determine to what extent the monetary regime in place can explain both the differences in the transmission of monetary policy across countries and over time. To do so, we use an open-economy DSGE monetary model along the lines of Obstfeld and Rogoff (2002, 2005), Clarida, Galí and Gertler (2002), Corsetti and Pesenti (2005), Altissimo et al. (2004), Benigno and Benigno (2006), and Ferrero, Gertler and Svensson (2007) (henceforth FGS) and others.[19] The specific variant considered here builds on FGS. This framework, while stylized, is sufficiently rich to generate a nontrivial effect of monetary policy variables such as output, consumption, net exports, and inflation measures. It also allows for different consumption responses across regions, and a switching of expenditures in consumption and net exports in response to real exchange rates movements.

We proceed by presenting the model. The model is explained in details in FGS, so we merely summarize it here, emphasizing the changes relative to FGS. We next discuss the calibration of the model parameters, including those characterizing monetary policy. Finally, we analyze the model's implications, attempting to provide an explanation for the stylized facts just described.

5.1 A stylized two-country model

The model involves two large countries, Home (H) and Foreign (F), of equal size. Each country is populated by a representative household that consumes tradable and nontradable goods and that contains a continuum of workers who supply labor to intermediate-goods firms. Each of these firms hires one worker and produces either tradable or non-tradable goods which it sells on a monopolistically competitive market. These firms optimally reset their prices at random time intervals. In each sector, we also have competitive final-goods firms which combine the differentiated intermediate goods into a homogenous consumption good. In addition, to fit the evidence on imperfect pass-

[19] For a larger-scale model, see, e.g., Faruquee, Laxton, Muir, and Pesenti (2007).

through (e.g., Campa and Goldberg, 2006), we assume as in Monacelli (2005) that monopolistically competitive importers of foreign tradable goods resell them to residents at prices set in domestic currency in a staggered fashion.[20] In order to account for different consumption behavior across countries, we assume incomplete financial markets across countries (even though the household provides perfect insurance within each country), by assuming that a single bond is traded internationally. As in FGS, one simplification is that we treat as nondurable consumption all domestic interest-rate sensitive expenditures, including what is commonly labeled as investment. However, as mentioned in Woodford (2003, chap. 5), to the extent that we are not interested in distinguishing consumption and investment, this should not affect importantly the model's predictions for the other variables.[21]

We will consider two monetary regimes. The pre-EMU regime is characterized by distinct central banks in each country, each setting short-term interest rates according to a generalized Taylor rule which may include responses to exchange-rate fluctuations. Area-wide variables are obtained by aggregating the relevant variables across the two countries. In the post-EMU regime, instead, a supra-national authority — the European Central Bank — is assumed to set an EA wide interest rate, according to a generalized Taylor rule involving area-wide variables.

In order for the model to be consistent with the identifying assumptions made in our empirical FAVAR to identify the monetary policy shocks, we assume in contrast to FGS but similarly to Rotemberg and Woodford (1997), Christiano, Eichenbaum and Evans (2005) that the households' aggregate consumption decisions and all firms' pricing decisions are made prior to the realization of exogenous shocks, so that prices and consumption respond do not respond contemporaneously to the monetary shock. In addition, we allow households to form habit in consumption, and the firms who don't reoptimize their prices to index them to past inflation. Such deviations from FGS allow the model to generate responses of consumption and inflation to shocks that are more in line

[20] Corsetti and Dedola (2005) propose an alternative model of limited pass-through in which distributing imported goods requires nontradables.

[21] In fact, macroeconomic models that successfully explain the behavior of investment often assume adjustment costs in the rate of investment spending (e.g., Basu and Kimball, 2003; Christiano, Eichenbaum and Evans, 2005). As shown in Woodford (2003), such adjustment costs yield a log-linearized Euler equation for investment that is very similar to the one for consumption in the presence of internal habit formation. It follows that the intertemporal allocation of aggregate expenditures can be approximated by a similar Euler equation, in which the degree of habit formation also serves as a proxy for investment adjustment costs. Nonetheless, in treating investment similarly to non-durable expenditures, we do abstract from the effects of investment on future production capacities.

with the FAVAR estimates.

As a last departure from FGS, we allow for a wedge in the uncovered interest rate parity (UIP) condition. This wedge, assumed to be exogenous here, is meant to capture deviations from the UIP, argued by Devereux and Engel (2002) to be needed in order to explain the disconnect between fluctuations in exchange rates and other macroeconomic variables. Empirical evidence for such deviations from UIP have also often been reported in the empirical literature, whether unconditionally (e.g., Bekaert and Hodrick, 1993; Engel, 1996; Froot and Thaler, 1990; Mark and Wu, 1998; Rossi, 2007), or conditionally on monetary policy shocks (Eichenbaum and Evans, 1995; Scholl and Uhlig, 2006). While Bekaert, Wei, and Xing (2007) find smaller departures from the UIP than reported previously, when adjusting for small sample bias, they find evidence of a time-varying risk premium displaying a highly persistent component in expected exchange rate changes. As discussed below, such a wedge will prove to be important in explaining the differential responses of consumption and investment across countries, in the pre-EMU period.

We now describe the environment, following closely FGS.

5.1.1 Households

We assume that in each country, the representative household maximizes a lifetime expected utility of the form

$$E_{t-1}\left\{\sum_{s=0}^{\infty}\theta_{t+s-1}\left[\frac{\left(C_{t+s}-\omega C_{t+s-1}\right)^{1-\sigma}}{1-\sigma}-\left(\int_0^{\gamma}\frac{L_{Ht+s}\left(f\right)^{1+\varphi}}{1+\varphi}df+\int_{\gamma}^{1}\frac{L_{Nt+s}\left(f\right)^{1+\varphi}}{1+\varphi}df\right)\right]\right\} \quad (4)$$

where E_{t-1} is the expectation operator, conditional on the information up to the end of period $t-1$, C_t denotes aggregate consumption, $\omega \in (0,1]$ is the degree of internal habit persistence, $\sigma^{-1} > 0$ would correspond to the elasticity of intertemporal substitution in the absence of habit formation, φ is the inverse of the Frisch elasticity of labor supply, $L_{kt}\left(f\right)$ represents hours worked by worker $f \in [0,1]$ in an intermediate-goods firm, in sector k, i.e., either the home tradable sector H (with measure γ) or the domestic nontradable sector N (with measure $1-\gamma$). As in FGS, the discount factor θ_t evolves according to $\theta_t = \beta_t\theta_{t-1}$, and $\beta_t \equiv e^{\xi_t}/\left[1+\psi\left(\log\bar{C}_t-\bar{\vartheta}\right)\right]$ where $\bar{C}_t$ corresponds to the household's consumption level but is treated by the household as exogenous, and where ξ_t

is a preference shock.[22]

The consumption index C_t is an aggregate of tradable C_{Tt} and nontradable C_{Nt} consumption goods

$$C_t \equiv \frac{C_{Tt}^{\gamma} C_{Nt}^{1-\gamma}}{\gamma\left(1-\gamma\right)}$$

with $\gamma \in [0,1]$ representing the share of tradable goods. The consumption of tradable goods combines in turn home-produced goods C_{Ht}, and foreign-produced goods C_{Ft} as follows

$$C_{Tt} \equiv \left[\alpha^{\frac{1}{\eta}}\left(C_{Ht}\right)^{\frac{\eta-1}{\eta}} + \left(1-\alpha\right)^{\frac{1}{\eta}}\left(C_{Ft}\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}.$$

The coefficient $\alpha \in (0.5, 1]$ denotes home bias in tradables, and η is the elasticity of substitution among domestically produced and imported tradables. The home consumer price index (CPI) which minimizes cost of consumer expenditures is given by

$$P_t = P_{Tt}^{\gamma} P_{Nt}^{1-\gamma}$$

where the price of tradables is given by $P_{Tt} = \left[\alpha P_{Ht}^{1-\eta} + \left(1-\alpha\right) P_{Ft}^{1-\eta}\right]^{\frac{1}{1-\eta}}$. In the foreign country, we assume symmetric preferences, consumption aggregates, and price indices which we denote by starred (*) variables and coefficients.[23]

Optimal behavior on the part of each household requires first an optimal allocation of consumption spending across differentiated goods. While we assume that households choose their level of total consumption on the basis of information available at date $t-1$, we let them choose the allocation of their consumption basket after the contemporaneous shocks have realized. The optimal allocation of (domestically- and foreign-produced) tradables goods as well as nontradable goods

[22] This formulation of the discount factor incorporates — in the case that the representative household stands for a continuum of households — the stimulative effect on individual consumption of an increase in average consumption, as in Uzawa (1968). However, as emphasized in FGS, the parameter ψ is calibrated to such a small value that this effect is negligible. It merely serves as a technical device to guarantee a unique steady state in the case of incomplete financial markets across countries. One can alternatively obtain a such a unique steady state by assuming a constant discount factor β, but introducing a debt-elastic interest rate premium in the budget constraints (7) and (10) below, as in Benigno (2001), Kollmann (2002), Schmitt-Grohe and Uribe (2003), and Justiniano and Preston (2006).

[23] One notable difference with respect to the home economy is that the foreign household consumption of tradable goods is of the form $C_{Tt}^{*} \equiv \left[\left(1-\alpha\right)^{\frac{1}{\eta}}\left(C_{Ht}\right)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}}\left(C_{Ft}^{*}\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$.

takes then the usual form

$$C_{Tt} = \gamma \left(\frac{P_{Tt}}{P_t}\right)^{-1} C_t, \qquad C_{Nt} = (1-\gamma)\left(\frac{P_{Nt}}{P_t}\right)^{-1} C_t, \tag{5}$$

$$C_{Ht} = \alpha \left(\frac{P_{Ht}}{P_{Tt}}\right)^{-\eta} C_{Tt}, \qquad C_{Ft} = (1-\alpha)\left(\frac{P_{Ft}}{P_{Tt}}\right)^{-\eta} C_{Tt}. \tag{6}$$

As in FGS, we assume that there is a single internationally traded one-period bond. We denote by B_t the nominal holdings at the beginning of period $t+1$, denominated in units of the home currency. The household's budget constraint in the home country is then given by

$$P_t C_t + B_t = I_{t-1} B_{t-1} + \int_0^\gamma W_{Ht}(f) L_{Ht}(f)\, df + \int_\gamma^1 W_{Nt}(f) L_{Nt}(f)\, df + \Upsilon_t \tag{7}$$

where I_{t-1} is the gross nominal interest rate in domestic currency between period $t-1$ and t, $W_{kt}(f)$ is the nominal wage obtained by worker f in sector k, and Υ_t combines aggregate dividends, lump sum taxes and transfers. Maximizing the utility function (4) subject to (7) yields the following optimal choice of expenditures

$$E_{t-1}\{\Lambda_t P_t\} = E_{t-1}\left\{(C_t - \omega C_{t-1})^{-\sigma} - \omega\beta_t (C_{t+1} - \omega C_t)^{-\sigma}\right\} \tag{8}$$

where Λ_t is the household's marginal utility of additional nominal income at date t. This expression makes clear that the plan for aggregate consumption at date t is made on the basis of information available at date $t-1$. The marginal utilities of income must in turn satisfy the Euler equation

$$1 = E_t\left\{ I_t \frac{\beta_t \Lambda_{t+1}}{\Lambda_t} \right\}. \tag{9}$$

Furthermore, the optimal choice of labor supply equalizes the real wage with the marginal rate of substitution between consumption and leisure.

The representative household in the foreign country is very similar. One difference, however, between the two countries is that the foreign bond is not traded internationally. The foreign household's budget constraint, expressed in units of the foreign currency is then

$$P_t^* C_t^* + D_t^* + \frac{B_t^*}{\mathcal{E}_t} = I_{t-1}^* D_{t-1}^* + \frac{I_{t-1} B_{t-1}^*}{\mathcal{E}_t e^{\mu_{t-1}}} + \int_0^\gamma W_{Ft}^*(f) L_{Ft}^*(f)\, df + \int_\gamma^1 W_{Nt}^*(f) L_{Nt}^*(f)\, df + \Upsilon_t^* \quad (10)$$

where the labor income indicates that foreign workers and firms operate in either the foreign tradable sector or the nontradable sector, D_t^* represents the foreign household's holdings of the foreign debt while B_t^* denotes the foreign household's holdings of the domestic bond, issued in the home currency, and $\mathcal{E}_t$ is the nominal exchange rate, i.e., the amount of home currency needed in exchange for a unit of foreign currency. In contrast to FGS, but as in McCallum and Nelson (2000) or Justiniano and Preston (2006) we introduce an exogenous term $e^{\mu_{t-1}}$ which can be interpreted as a risk premium shock, or a bias in the foreign household's expectation of the period-t revenue from holding home bonds. This shock can alternatively be interpreted as a bias in the foreign household's date $t-1$ forecast of the date t exchange rate, $\mathcal{E}_t$, as in Kollmann (2002).

The foreign household choice of consumption plans is also characterized by optimal conditions of the form (8) and (9). In addition, given that foreign citizen may hold bonds of both countries, they must be indifferent between holding home and foreign bonds. This results in the following uncovered interest-rate parity (UIP) condition

$$E_t \left\{ I_t \frac{\mathcal{E}_t}{\mathcal{E}_{t+1} e^{\mu_t}} \frac{\beta_t^* \Lambda_{t+1}^*}{\Lambda_t^*} \right\} = E_t \left\{ I_t^* \frac{\beta_t^* \Lambda_{t+1}^*}{\Lambda_t^*} \right\}. \quad (11)$$

5.1.2 Firms

We have three types of firms: final-goods firms, intermediate-goods firms, and importing retailers.

Final-goods firms. In each sector H and N, final goods firms, which are acting on a competitive market, combine intermediate goods to produce output

$$Y_{Ht} \equiv \left[\gamma^{-\frac{1}{\theta}} \int_0^\gamma Y_{Ht}(f)^{\frac{\theta-1}{\theta}}\, df \right]^{\frac{\theta}{\theta-1}}, \qquad Y_{Nt} \equiv \left[(1-\gamma)^{-\frac{1}{\theta}} \int_\gamma^1 Y_{Nt}(f)^{\frac{\theta-1}{\theta}}\, df \right]^{\frac{\theta}{\theta-1}}$$

where $\theta > 1$ is the elasticity of substitution among intermediate goods. Cost minimization for the final-goods firms implies the following demand functions for intermediate-goods producing firms

$$Y_{Ht}(f) = \gamma^{-1}\left(\frac{P_{Ht}(f)}{P_{Ht}}\right)^{-\theta} Y_{Ht}, \quad Y_{Nt}(f) = (1-\gamma)^{-1}\left(\frac{P_{Nt}(f)}{P_{Nt}}\right)^{-\theta} Y_{Nt} \tag{12}$$

where the price indices P_{Ht} and P_{Nt} aggregate underlying prices $P_{kt}(f)$.

Each intermediate firm f in sector $k = H, N$ produces output $Y_{kt}(f)$ by hiring labor $L_{kt}(f)$ and using the production function

$$Y_{kt}(f) = A_t L_{kt}(f)$$

where the total factor productivity term $A_t = Z_t e^{a_t}$, and $Z_t/Z_{t-1} = 1 + g$ describes trend productivity, while e^{a_t} denotes temporary fluctuations in total factor productivity. As the firm competes to attract labor, its nominal marginal cost is $MC_{kt}(f) = W_{kt}(f)/A_t$.

Intermediate firms. Intermediate firms are assumed to set prices on a staggered manner. As in Calvo (1983), a fraction $1-\xi$ of firms (chosen independently of the history of price changes) can choose a new price in each period. Our informational assumptions imply that the firms that get to reset their prices must do so using information available at period $t-1$. In addition, we assume that if a price is not re-optimized, it is indexed to lagged inflation in sector $k = H, N$ according to the rule

$$P_{kt}(f) = P_{k,t-1}(f) \left(\frac{P_{k,t-1}}{P_{k,t-2}}\right)^{\delta}, \tag{13}$$

for some $\delta \in [0,1]$. Given that the problem is the same for all firms of sector k which reset their price at date t, they all choose an optimal price $P^o_{k,t}$ that maximizes

$$E_{t-1}\left\{\sum_{s=0}^{\infty} \xi^s \Lambda_{t,t+s}\left[P^o_{kt}\left(\frac{P_{k,t+s-1}}{P_{k,t-1}}\right)^{\delta} - MC_{k,t+s}(f)\right] Y_{k,t+s}(f)\right\}$$

subject to the demand for their good (12). In the previous expression, $\Lambda_{t,t+s} = \beta_{t,t+s}\Lambda_{t+s}/\Lambda_t$ is the stochastic discount factor between periods t and $t+s$, $\beta_{t,t+s} = \Pi_{j=0}^{s-1}\beta_{t+j}$, for $s \geq 1$, and $\beta_{t,t} = 1$.

The price index then satisfies

$$P_{kt} = \left[(1-\xi) \left(P_{kt}^{o}\right)^{1-\theta} + \xi \left(P_{k,t-1} \left(\frac{P_{k,t-1}}{P_{k,t-2}} \right)^{\delta} \right)^{1-\theta} \right]^{\frac{1}{1-\theta}}.$$

Importing retailers. To model the imperfect pass-through found in the data, we assume that monopolistically competitive retailers import foreign tradables goods and sell them to domestic consumers, as in Monacelli (2005). These retailers also set their prices in a staggered fashion so that the law of one price does not hold at the consumer level. As for the intermediate firms, a fraction $1-\tilde{\xi}$ of retailers choose a new price in each period, on the basis of information available at period $t-1$. Again, if a price is not re-optimized, it is indexed to lagged inflation in that sector, according to the rule (13). Since the problem is identical for retailers which reset their price at date t, they all choose an optimal price $P_{F,t}^{o}$ in domestic currency that maximizes

$$E_{t-1} \left\{ \sum_{s=0}^{\infty} \tilde{\xi}^{s} \Lambda_{t,t+s} \left[P_{Ft}^{o} \left(\frac{P_{F,t+s-1}}{P_{F,t-1}} \right)^{\tilde{\delta}} - \mathcal{E}_t P_{F,t+s}^{*} \right] C_{F,t+s} \right\}$$

subject to the demand for the imported good (6). In the above expression, $P_{F,t}^{*}$ denotes the price of foreign tradable goods in foreign currency. The price index of imported goods in domestic currency satisfies

$$P_{Ft} = \left(1-\tilde{\xi}\right) \left(P_{Ft}^{o}\right) + \tilde{\xi} P_{F,t-1} \left(\frac{P_{F,t-1}}{P_{F,t-2}} \right)^{\tilde{\delta}}.$$

5.1.3 Monetary Policy

As mentioned above, we consider two distinct monetary regimes, one referring to the pre-EMU period in which each national central banks sets its own interest rate according to a generalized forward-looking Taylor rule, and one referring to the monetary union, in which a supra-national central bank sets common short-term interest rates.

More specifically, in the pre-EMU regime, we assume that the home national central banks sets its short-term riskless interest rate according to

$$i_t = \rho i_{t-1} + (1-\rho) \left[\phi_{\pi} E_t \bar{\pi}_{t+h} + \phi_y y_t + \phi_i i_t^{*} + \phi_e \Delta e_t \right] + \varepsilon_t \tag{14}$$

where $i_t \equiv \log(I_t/I)$ corresponds to the deviations of the interest rate from its steady-state value, $\bar{\pi}_t \equiv \log(P_t/P_{t-4})$ denotes deviations of year-over-year CPI inflation around the steady state (assumed to be zero), y_t represents percent deviations of output from trend, $\Delta e_t = \log(\mathcal{E}_t/\mathcal{E}_{t-1})$ denotes percent nominal depreciation of the home currency, and the iid shock ε_t measures unexpected interest-rate disturbances. The foreign central bank follows a similar rule

$$i_t^* = \rho^* i_{t-1}^* + (1-\rho^*)\left[\phi_\pi^* E_t \bar{\pi}_{t+h^*}^* + \phi_y^* y_t^* + \phi_i^* i_t + \phi_e^* \Delta e_t\right] + \varepsilon_t^* \tag{15}$$

where, again, the stars refer to foreign variables or coefficients. Note that we allow for cross-country interactions as the national central banks may respond to fluctuations in the exchange rate or to the other country's interest rate.

In the EMU regime, a single common short-term rate prevails, so that $i_t = i_t^* = i_t^{ea}$ where ea stands for Euro-area variables, and $\Delta e_t = 0$ in all periods. We assume that the common central bank — corresponding to the ECB — sets interest rate according to the interest-rate rule

$$i_t^{ea} = \rho^{ea} i_{t-1}^{ea} + (1-\rho^{ea})\left[\phi_\pi^{ea} E_t \bar{\pi}_{t+h}^{ea} + \phi_y^{ea} y_t^{ea}\right] + \varepsilon_t^{ea} \tag{16}$$

where area-wide inflation and output are defined as $\bar{\pi}_t^{ea} = (\bar{\pi}_t + \bar{\pi}_t^*)/2$, $y_t^{ea} = (y_t + y_t^*)/2$.

Clarida, Galí and Gertler (1998) and Angeloni and Dedola (1999) argue that such rules provide a good characterization of monetary policy in a number of countries, including Germany and Italy, before the monetary union.

5.1.4 Equilibrium characterization

To close the model, we use equilibrium conditions stating that supply of tradables and nontradable goods must be equal to the respective demands in each country, and that international financial markets clear. To characterize the response of various variables to monetary shocks, we solve a log-linear approximation to the model's equilibrium conditions around a deterministic state, using standard techniques. We thus implicitly assume that the shocks are small enough for the approximation to be valid. In the steady state, both economies are symmetric, the trade balance and foreign debt are equal to zero, output in each sector grows at the constant trend productivity growth rate g, the relative prices of all goods, including the real exchange rate

$$Q_t \equiv \frac{\mathcal{E}_t P_t^*}{P_t}$$

are equal to 1, inflation is equal to zero, and the real interest rate is equal to $(1+g)/\beta$, where β the steady-state value of β_t.

The log-linearized equilibrium conditions are described in Appendix B.

5.2 Model calibration

We calibrate the model's parameters in order to provide its quantitative predictions, and to determine whether we can replicate at least some of the stylized facts mentioned above. In particular we focus our attention on changes in responses of key macroeconomic variables between the pre-EMU and EMU period. We also focus on the difference in responses across countries in the pre-EMU period, especially the differences between Italy and Spain on the one hand, and Germany along with other EA countries on the other hand. We assume that Home (H), stands for Italy or Spain, and Foreign (F) stands for Germany along with the other EA countries.

We calibrate the structural parameters describing the behavior of the private sector similarly to earlier studies such as FGS or Obstfeld and Rogoff (2005), and used estimated coefficients for the policy rules. While the calibration of the structural parameters sacrifices somewhat the model's ability to replicate the empirical responses, we check that the model's predictions are not too sensitive the chosen parameter values. However, as we will see below, coefficients of the policy rules do play an important role on the shape of the responses to various shocks.

5.2.1 Structural parameters

As mentioned, most structural parameters are taken from FGS and are roughly in line with values chosen in other studies (e.g., Obstfeld and Rogoff, 2005) and with some microeconomic data. We set the same values for both countries. The steady-state growth rate of the economy g is set to 0.5%, so that annual grow is 2%. The steady-state discount factor β is set to 0.99. The parameters describing the evolution of the discount factor $\vartheta = -1000$ and $\psi = 7.2361 \cdot 10^{-6}$ are chosen so that fluctuations in β_t have no noticeable implications on the economy dynamics.[24] The Frisch elasticity of labor supply is $\varphi^{-1} = 0.5$. The elasticity of substitution among intermediate goods $\theta = 11$ resulting in a steady-state markup of 10% in the tradable and nontradable sectors. We set the probability that intermediate-goods firms and importing retailers do not re-optimize their price to $\xi = \tilde{\xi} = 0.66$, corresponding to a mean duration between price re-optimizations of 3 quarters. Smets and Wouters (2002) find evidence that import prices display a similar degree of price stickiness as domestic prices on the basis of estimated responses to monetary shocks in the EA. For the parameters that determine the openness of the economies, we set the share of tradables in the consumption basket γ to 0.25, the preference share for home tradables $\alpha = 0.7$ (it would be 0.5 in the absence of home bias), and the elasticity of substitution between home and foreign tradables is $\eta = 2$, as in FGS.

FGS assume a log utility function of consumption, and no habit persistence or inflation indexing. This yields however sharp responses in inflation and consumption to monetary shocks, in contrast to the empirical evidence. To generate more realistic hump-shaped responses of consumption expenditures and output of the model economy we assume some degree of habit persistence ω.[25] We calibrate this parameter at 0.59 which corresponds to the (median) estimate obtained by Smets and Wouters (2003), in their model of the EA. We similarly use the estimates of Smets and Wouters (2003) to calibrate the curvature of the utility of consumption and the degree of inflation indexing to respectively $\sigma = 1.37$ and $\delta = \tilde{\delta} = 0.47$.

5.2.2 Policy rule coefficients

We calibrate the policy rule coefficients for the home and foreign country, in the pre-EMU period using estimates of Angeloni and Dedola (1999, Table 9b). These authors estimate interest rate rules of the form (14)-(15) jointly for Italy and Germany, for the period 1988-1997, which covers nearly entirely our pre-EMU sample. Their preferred specification involves horizons on inflation expectations of $h = h^* = 0$, so that the central banks set interest rates in response to inflation that

[24] As mentioned above, the assumption of a variable discount factor is merely a technical device yielding a unique steady state.

[25] As mentioned above, the degree of habit persistence also proxies for investment adjustment costs in the case that consumption expenditure includes also investment expenditures.

has occurred over the past year. As the estimates are obtained using monthly data, we convert them for application to quarterly data.[26] We thus have $\rho = 0.79$, $\phi_\pi = 1.22$, $\phi_y = 0.30$, $\phi_i = 0.41$ for Italy,[27] and $\rho^* = 0.82$, $\phi_\pi^* = 1.41$, $\phi_y^* = 0.30$, $\phi_i^* = 0$ for Germany. Angeloni and Dedola (1999) do not include a bilateral DM/Lira exchange rate in their policy rules, but they include the $/DM exchange rate. Since we abstract form the world outside of the EA in the model, we assume that German monetary policy does not respond to the exchange rate ($\phi_e^* = 0$), while the Italian interest rate responds with a short-run coefficient of 0.4 to the exchange rate depreciation. This is meant to capture the fact that the Italian central bank was required to maintain its exchange rate within narrow bands, as long as it took part in the exchange rate mechanism. This results in a long-run coefficient $\phi_e = 5$.

For the post-EMU period, we estimate an interest-rate rule of the form (16) on EA data, using GMM, similarly to Clarida, Galí and Gertler (1998). We use as instruments: the current value of inflation and detrended output as well as three latent factors extracted from the EA indicators. Our preferred horizon is $h = 2$. As the estimated coefficient on the lagged interest rate is relatively high, $\rho^{ea} = 0.93$, the implied long-run responses to expected inflation and output fluctuations are also quite strong: $\phi_\pi^{ea} = 13.03$ and $\phi_y^{ea} = 8.01$.[28] Nonetheless, we verify that our conclusions remain robust to smaller values of these coefficients.

5.2.3 Wedge in uncovered interest-rate parity

The remaining parameters that we need to calibrate refer to the process describing the wedge in the uncovered interest-rate parity, μ_t. The UIP condition (11) can be log-linearized to yield

$$i_t - i_t^* = E_t \Delta e_{t+1} + \mu_t. \tag{17}$$

[26] For the conversion, we assume that monthly values of (annualized) short term interest rates are constant in a given quarter, and equal to the corresponding (annualized) quarterly rate. In that case, the coefficient on the quarterly lagged interest rate is $\rho = \rho_m / (3 - 2\rho_m)$ where ρ_m is the policy coefficient on the monthly lagged interest rate. The long-run coefficients on inflation, output, and the foreign interest rate remain unchanged at the quarterly frequency.

[27] Angeloni and Dedola (1999)'s estimated policy rule for Spain is similar to that estimated for Italy.

[28] While this representation of the policy rule appears very aggressive, it is important to realize that this is due to the large coefficient on the lagged interest rate. The policy rule may equivalently be written in terms of changes of the interest rate: $\Delta i_t^{ea} = 0.91\ E_t \bar{\pi}_{t+2}^{ea} + 0.56\ y_t^{ea} - 0.07 i_{t-1}^{ea} + \varepsilon_t^{ea}$.

We assume that μ_t follows an AR(1) process which is allowed to respond to monetary shocks

$$\mu_t = \rho_\mu \mu_{t-1} + \nu \varepsilon_t^* + \varepsilon_{\mu t}$$

where ε_t^* are foreign monetary policy shocks and $\varepsilon_{\mu t}$ denotes other possible shocks to that wedge. By allowing μ_t to respond to monetary shocks, we hope to capture in an arguably reduced form the effect of monetary shocks on the risk premium emphasized by Scholl and Uhlig (2006). We assume that this wedge is very persistent, setting $\rho_\mu = 0.98$, and will consider different values of the parameter ν.

5.3 Model's quantitative predictions: Explaining the changes in the monetary transmission mechanism

Having calibrated the model, we can now determine whether it can replicate the stylized facts mentioned above, namely, cross-country differences in responses mentioned in Figures 2a-2f, as well as the changes observed after the EMU.

5.3.1 Pre-EMU cross-country differences

Figures 5a-5d indicate the responses of key variables to an unexpected interest-rate increase of 100 bp in the foreign economy — which stands for Germany — in the case that both economies set their interest-rates according to the estimated policy rules (14) and (15). This is meant to replicate the effects of a monetary policy tightening in the pre-EMU period.

Figure 5a shows the responses of the home economy (i.e., Italy or Spain, solid lines) and the foreign economy (i.e., Germany, dashed lines) in the absence of a wedge in the UIP condition ($\nu = 0$, so $\mu_t = 0$). As the figure makes clear, the unexpected increase in the foreign short-term rate is associated with a raise in the long-term rate, a drop in output, consumption, and inflation. As the domestic currency depreciates more than prices adjust, the domestic real exchange rate (q_t) also depreciates, and home terms of trade (measuring foreign prices relative to domestic prices, in domestic currency) increase. This stimulates an increase in net exports of home goods. Note that investors in the internationally traded security do not require as large an increase in the home interest rate as that observed for the foreign interest rate. The reason is that the domestic currency is expected to have depreciated beyond its long term value, so that it is expected to appreciate slightly in subsequent periods.

The response of home interest rates just described is however at odds with the interest-rate responses we had documented for countries such as Spain and Italy in Figure 2a. In fact, in pre-EMU data, these short and long-term rates increased significantly more than those estimated for Germany and other countries. They were also associated with sharp contractions in consumption and the work force in those countries. Instead, the model-based responses display a milder response of the home variables. One might think that by letting the home country's central bank respond more to exchange rate fluctuations (i.e., a larger ϕ_e), we may generate stronger responses of interest rates and consumption at home. However, even for very large values of ϕ_e, we cannot produce larger responses of the home interest-rate, output and consumption than in the foreign economy. As shown in Figure 5c, in the limit, as $\phi_e \to +\infty$, the nominal exchange rate is perfectly stabilized, the variables have identical responses in both countries.[29] In addition, changes in structural parameters don't generically modify the picture presented.

The standard version of the model cannot replicate the transmission of monetary policy observed in a low-credibility regimes unless long-term rates react to short term rates over and beyond the reaction implied by the expectation hypothesis, as in Atkeson and Kehoe (2008). One key parameter, however, that allows us to deviate from the standard case and that seems to explain the stylized facts reported in Figure 2a-2f is ν. Figure 5b reports the model-based responses of the same variables in the case that $\nu = 0.6$. In that case, an unexpected increase in the foreign short-term rate triggers a much larger increase in the home interest rate — as observed in the data — as the wedge μ_t suddenly rises in response to an interest-rate increase in the foreign country. This wedge suggests that upon the foreign monetary shock, international investors require a higher return on domestic (internationally traded) bonds than they do on foreign securities, even after accounting for the rational expectation of nominal exchange rate changes.

Such an exchange-rate risk premium appears important to explain the stylized facts reported

[29] Recall that our calibration is such that apart from the policy rules, the home and foreign economies are perfectly symmetric.

above. In fact, in Figure 5b, not only do short- and long-term rates respond more strongly at home than in the foreign country, but these interest-rate responses do also generate a larger drop in the home country consumption. As in the data, output falls less than consumption due to the fact that home-country net exports increase. Note also that while monetary policy reduces activity in both regions, prices do increase in the home country as a result of the currency depreciation. Interestingly, prices aggregated for both regions (dashed-dotted line) can also increase following the monetary tightening, to the extent that inflation in the depreciating country more than offsets the inflation reduction in the other region.

The exercise just performed thus suggests that conditional on EA-wide (or German) monetary shocks, changes in the risk premium on Italian and Spanish securities may provide an important explanation for the large observed responses in bond yields, and the fact that consumption and investment used to fall considerably more in those countries than in the rest of the EA.

5.3.2 Monetary Union and changes in the monetary transmission mechanism

By adopting the euro as their currency, all EMU countries essentially eliminated exchange rate risks relative to the other member countries. Figure 5c reports the responses of the same variables in the case of a monetary union, when monetary policy is conducted according to the estimated rule (16). Since both countries are considered as symmetric in the calibration, they both respond identically to the EA interest-rate shock.

Figure 5d compares the responses in the pre-EMU and EMU regimes for the home economy, in response to an unexpected increase of 100 bp in the interest rate set by the foreign central bank or of the common central bank, in the post-EMU case. The model predicts that the home economy benefits in many respects from participating to the monetary union, in response such a shock. In particular, by removing any exchange-rate risk in the EMU regime, home (short- and long-term) interest-rates increase by less, as we observed in the empirical responses. As a result, home consumption falls by less and output remains more stable. In addition, a stronger commitment by the common central bank to stabilize prices, as suggested by our estimated policy rule (16), implies that inflation moves by less following the shock.

For the foreign economy, Figure 5e shows that output and inflation also respond less to the shock, in the EMU regime. It is important to stress, however, that the smaller response of output and inflation is not due to the fact that the economy is sensitive to monetary policy. Instead, it is the stronger commitment to inflation and output stabilization that results in such an outcome.[30] The model thus predicts that a monetary policy that has more consistently aimed at stabilizing inflation and output in the EA, since the EMU, should result in a smaller observed response of aggregate economic activity to monetary shocks, as observed in the data.

6 Conclusion

In this paper, we have provided an empirical characterization of the dynamics of key European economies, exploiting the richness of the cross-country differences and the fact that a major change in monetary regime has occurred in 1999 with the adoption of the euro by 11 European countries. The combination of the cross-country heterogeneity and the changes over time provides a unique laboratory for the analysis of numerous macroeconomic indicators.

Focusing on six major European economies, we have argued that a large fraction of the fluctuations in these economic variables can be captured by a low-dimensional vector of common components. This finding is useful to the extent that it allows us to characterize the effects of macroeconomic disturbances on all variables of interest, despite the fact that our samples with a relatively stable regime are extremely short.

Looking at the EA as a whole, in the 1988-2007 sample, we have found that the responses of key macroeconomic variables to monetary disturbances conceal important heterogeneity across countries. Such responses can be rationalized by a two country model, provided that we allow for a disturbance in the uncovered-interest-rate parity condition. In addition despite the short samples, we have detected preliminary evidence of important changes in the transmission of monetary policy since the start of the EMU.

We have argued that some of the changes since 1999 can be explained by the change in the monetary regime. In particular, our model predicts that by removing an exchange-rate risk through

[30] Boivin and Giannoni (2006a) argue that a stronger commitment to inflation stabilization in US monetary policy since the early 1980s can similarly explain the observed reduction in estimated responses of inflation and output in the US economy in the post-1980 period.

the monetary union, and by having a central bank more decisively focused on inflation and output stabilization, the impact of monetary disturbances on measures of economic activity has been reduced, as observed in the data. While private consumption and investment in Italy and Spain appear to have been especially hard hit by German monetary policy disturbances in the pre-EMU period, the new monetary regime has contributed to stabilizing them more effectively, in part because long-term interest rate have become much more effectively anchored in such countries since the start of the monetary union.

We also find that the exchange rate channel has become relatively more powerful in the monetary union period, than in the previous decade and that national monetary aggregates appear much less driven by euro area common shocks and show more heterogenous responses to monetary policy shocks than most other macroeconomic variables.

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A Data description

The data were extracted from HAVER and their source is either the OECD MEI or OECD Quarterly National Accounts databases. The sources for monetary aggregates are the national central banks for their respective country and the ECB for the euro area. The national accounts published in HAVER are available starting at different dates: 1978 in France, 1981 in Italy, 1988 in the Netherlands, 1991 in Germany, 1995 in Spain and Belgium and 1995 of some deflators in the Euro area. Missing data were backdated using yoy growth rates of an earlier vintage of OECD and ECB databases.

Table A1 gives a full account of the data preparation.

B Model's Log-Linearized Equilibrium Conditions

We now describe the log-linearized equilibrium conditions of the model. We use lower-case variables to denote percent deviations from the deterministic steady state, except when noted.

The domestic household's optimal plan of consumption (c_t) over time involves the log-linear Euler equation

$$\lambda_t = \lambda_{t+1} + E_t \left(i_t - \pi_{t+1} \right) + \hat{\beta}_t, \tag{18}$$

where $i_t \equiv \log \left(I_t / \bar{I} \right)$ correponds to the deviation of the nominal interest rate from steady state, $\pi_t \equiv \log \left(P_t / P_{t-1} \right)$ is the quarterly CPI inflation rate, the marginal utility of income λ_t satisfies

$$E_{t-1}\lambda_t = E_{t-1} \left\{ \frac{1}{(1-\omega)(1-\beta\omega)} \left[-\sigma \left(1 + \beta\omega^2 \right) c_t + \sigma\omega c_{t-1} + \sigma\beta\omega c_{t+1} - \beta\omega (1-\omega) \hat{\beta}_t \right] \right\}, \tag{19}$$

and the percent deviations of the discount factor β_t from steady state evolve according to

$$\hat{\beta}_t = -\psi\beta c_t + \xi_t. \tag{20}$$

Note that in the absence of habit formation, the above expression reduces to: $E_{t-1}\lambda_t = -\sigma E_{t-1} c_t$.

Domestic output y_t depends on home tradable (y_{Ht}) and nontradable (y_{Nt}) output:

$$y_t = \gamma y_{Ht} + (1-\gamma) y_{Nt} \tag{21}$$

where the demand for home tradables

$$y_{Ht} = (1-\alpha)\alpha\eta \left(\tau_{Ht} - \tau_{Ft} \right) + (1-\gamma) \left[\alpha x_t + (1-\alpha) x_t^* \right] + \alpha c_t + (1-\alpha) c_t^* \tag{22}$$

depends on the terms of trade $\tau_{Ht} \equiv \log \left(P_{Ft} / P_{Ht} \right)$, $\tau_{Ft} \equiv \log \left(P_{Ht}^* / P_{Ft}^* \right)$, as well as the home and domestic relative prices of nontradables $x_t \equiv \log \left(P_{Nt} / P_{Tt} \right)$, $x_t^* \equiv \log \left(P_{Nt}^* / P_{Tt}^* \right)$, and aggregate consumption in both regions. The demand for home nontradables is given by

$$y_{Nt} = -\gamma x_t + c_t. \tag{23}$$

The share of net exports in GDP is given by $nx_t \equiv \left(P_{Ht} Y_{Ht} - P_{Tt} C_{Tt} \right) / \left(Y_t P_t \right)$ and is assumed to have a steady-state value of 0. A first-order approximation yields

$$nx_t = \gamma \left[y_{Ht} - c_t - (1-\alpha) \tau_{Ht} - (1-\gamma) x_t \right]. \tag{24}$$

The terms of trade and the relative price of nontradables evolve according to

$$\tau_{H,t} = \tau_{H,t-1} + \pi_{F,t} - \pi_{H,t} \tag{25}$$

$$x_t = x_{t-1} + \pi_{N,t} - \pi_{H,t} - (1-\alpha) \left(\tau_{H,t} - \tau_{H,t-1} \right). \tag{26}$$

A log-linearization of the optimal price-setting condition for domestic indetermediate producers yields an extension of the standard New Keynesian Phillips curve

$$E_{t-1} \left(\pi_{k,t} - \delta\pi_{k,t-1} \right) = \kappa E_{t-1} mc_{k,t} + \beta E_{t-1} \left(\pi_{k,t+1} - \delta\pi_{k,t} \right) \tag{27}$$

where $\kappa \equiv (1-\xi)(1-\beta\xi) / (\xi (1+\varphi\theta)) > 0$, in each of the sectors $k = H, F$, and the marginal cost in the domestic traded-goods sector satisfies

$$mc_{H,t} = \varphi y_{Ht} - (1+\varphi)\, a_t - \lambda_t + (1-\alpha)\, \tau_{Ht} + (1-\gamma)\, x_t, \tag{28}$$

while

$$mc_{N,t} = \varphi y_{Nt} - (1+\varphi)\, a_t - \lambda_t - \gamma x_t \tag{29}$$

in the domestic nontraded-goods sector. Inflation of the GDP deflator is given by

$$\pi_{Yt} = \gamma \pi_{Ht} + (1-\gamma)\, \pi_{Nt} \tag{30}$$

while CPI inflation is

$$\pi_t = \gamma \pi_{Ht} + (1-\gamma)\, \pi_{Nt} + \gamma\, (1-\alpha)\, (\tau_{H,t} - \tau_{H,t-1})\, , \tag{31}$$

where the last term captures the effects of imported goods.

Given the imperfect pass-through, imported goods inflation $\pi_{F,t}$ (in domestic currency) is also determined by a Phillips curve-type equation

$$E_{t-1}\left(\pi_{F,t} - \tilde{\delta}\pi_{F,t-1}\right) = \tilde{\kappa} E_{t-1}\hat{\psi}_{F,t} + \beta E_{t-1}\left(\pi_{F,t+1} - \tilde{\delta}\pi_{F,t}\right) \tag{32}$$

where $\tilde{\kappa} \equiv \left(1-\tilde{\xi}\right)\left(1-\beta\tilde{\xi}\right)/\tilde{\xi} > 0$, and $\hat{\psi}_{F,t}$ represents the percent deviation from steady state (equal to 1) of the gap between the foreign price expressed in domestic currency and the domestic price of the same goods. That price gap eveolves in turn according to

$$\hat{\psi}_{F,t} = \hat{\psi}_{F,t-1} + \Delta e_t + \pi^*_{Ft} - \pi_{Ft} \tag{33}$$

where π^*_{Ft} is the inflation of foreign tradable goods in foreign currency, while π_{Ft} is inflation in the prices of the same goods in the home country.

While equations (18)–(33) determine home variables, a similar set of equations determines the corresponding foreign variables. We also need a specification of monetary policy in each region. As mentioned in the text, we assume, in the pre-EMU case that the interest rate is set in each region according to the linear interest-rate rules (14) and (15). Instead in the EMU case, we assume that the nominal exchange rate is fixed, $\Delta e_t = 0$, that short-term interest rates are equal in both regions, and that the EA-wide interest rate i^{ea}_t is set according to the rule (16).

Finally, to close the model, we use our linearized UIP condition

$$i_t - i^*_t = E_t \Delta e_{t+1} + \mu_t \tag{34}$$

and the linearized condition chracterizing the evoluiton of foreign debt

$$b_t = \beta^{-1} b_{t-1} + n x_t.$$

For reference, the percent deviations of the real exchange rate from its steady-state value of 1 can be expressed as follows

$$q_t = \hat{\psi}_{Ft} + (1-\alpha)\, \tau_{Ft} + \alpha \tau_{Ht} + (1-\gamma)\, (x^*_t - x_t)\, .$$

Table A1: Data sources and definition of euro area and country level data

	Name	Haver	Euro area	Germany	France	Italy	Spain	Netherlands	Belgium	Series definition
1	ST rate	MEI	ECB 80-93					ECB 80-85	ECB	3-Month PIBOR (%)
2	10 Bond rate	MEI				ECB 80-91				10-Year Government Bond Yields (% p.a.)
3	Stock price	MEI	AV 80-86							National Share Price Index (2000=100)
4	REX	MEI								Real Effective Exchange Rate (2000=100)
5	PGDP	NAQ	AV 80-94	OEO 80-90		OEO 80	OEO 80-94	OEO 80-87	OEO 80-94	Implicit Price Deflator: GDP (SA, 2000=100)
6	PCE	NAQ	AV 80-94	OEO 80-90		OEO 80	OEO 80-94	=CPI 80-87	OEO 80-94	*Implicit Price Deflator: Private Cons. (SA, 2000=100)*
7	PINV	NAQ	AV 80-94	OEO 80-90		OEO 80	OEO 80-94	OEO 80-87	OEO 80-94	*Implicit Price Deflator: GFCF (SA, 2000=100)*
8	PEX	NAQ	AV 80-07	OEO 80-90		OEO 80	OEO 80-94	OEO 80-87	OEO 80-94	*Implicit Price Deflator: Exports (SA, 2000=100)*
9	PIM	NAQ	AV 80-07	OEO 80-90		OEO 80	OEO 80-94	OEO 80-87	OEO 80-94	*Implicit Price Deflator: Imports (SA, 2000=100)*
10	GDP	NAQ		OEO 80-90		OEO 80	OEO 80-94	OEO 80-87	OEO 80-94	*Gross Domestic Product (SA, Mil.2000.Euros)*
11	C	NAQ		OEO 80-90		OEO 80	OEO 80-94	OEO 80-87	OEO 80-94	*Private Final Consumption Exp. (SA, Mil.2000.Euros)*
12	PuC	NAQ		OEO 80-90		OEO 80	OEO 80-94	OEO 80-87	OEO 80-94	Gov. Final Consumption Exp. (SA, Mil.2000.Euros)
13	GKF	NAQ		OEO 80-90		OEO 80	OEO 80-94	OEO 80-87	OEO 80-94	*Gross Fixed Capital Formation (SA, Mil.2000.Euros)*
14	EX	NAQ	AV 80-07	OEO 80-90		OEO 80	OEO 80-94	OEO 80-87	OEO 80-94	*Exports of Goods & Services (SA, Mil.2000.Euros)*
15	IM	NAQ	AV 80-07	OEO 80-90		OEO 80	OEO 80-94	OEO 80-87	OEO 80-94	*Imports of Goods & Services (SA, Mil.2000.Euros)*
16	CAP	MEI	AV 80-84							Mfg Survey: Rate of Capacity Uilisation (SA, %)
17	Retail	MEI	AV 80-89				=C 80-90			Retail Sales: Volume (SA, 2000=100)
18	P_Cars	MEI	AV 80-07							Passenger Cars Registered (SA, 2000=100)
19	PPI	MEI	AV 80-81							PPI: Manufactured Products (NSA, 2000=100)
20	CPI	MEI	AV 80-90	CPI 80-94, HICP 95-07	CPI 80-89, HICP 90-07	CPI 80-89, HICP 90-07	CPI 80-90, HICP 91-07	CPI 80-90, HICP 91-07	CPI 80-90, HICP 91-07	European Harmonized CPI (NSA, 2000=100)
21	CPI_F	MEI	AV 80-90				=CPI 80-90			Consumer Price Index: Food (NSA, 2000=100)
22	CPI_FE	MEI	AV 80-90							Cons. Price Index: Fuel & Electricity (NSA, 2000=100)
23	CoreCPI	MEI	AV 80-95							CPI: All Items excl Food, Energy (NSA, 2000=100)
24	CPI_Rent	MEI	AV 80-94						=C 80-83	Consumer Price Index: Rent (NSA, 2000=100)
25	EMP	MEI							=EA 06-07	Civilian Employment (SA, Thous)
26	UR	MEI	AV 80-95							Standardized Unemployment Rate (SA, %)
27	Hearnings	MEI							=EA 80-96	Hourly Earnings: Manufacturing (SA, 2000=100)
28	ULC	MEI								Unit Labor Costs (Trend, 2000=100)
29	ULC_Manuf	MEI								Unit Labor Costs: Manufacturing (Trend, 2000=100)
30	ULC_Cons	MEI								Unit Labor Costs: Construction (Trend, 2000=100)
31	ULC_Mser	MEI								Unit Labor Costs: Market Services (Trend, 2000=100)
32	M1	NCB	ECB			ECB 80-96	ECB	ECB 80-81	ECB 80-96	Money Supply: M1 (SA, EOP, Mil.Euros)
33	M3	NCB	ECB			ECB 80-96	NCB	ECB 80-81	ECB 80-96	Money Supply: M3 (SA, EOP, Mil.Euros)

Note: Haver indicates the default source; Other columns indicate the alternative source and definition of the series. MEI is the OECD Main Economic Indicator, NAQ the OECD quarterly national account, NCB the natioanl Central Bank, ECB, the European Central Bank, OEO the OECD Economic Outlook, AV is the country average using current population for weights. Merging two sources done by applying y-o-y growth rates backward to the level of the data available in the most recent source. Shaded cells indicate the replacement of some missing observations with an alternative time series.

Table A1 continued: Data source and definition for international time series

	series	Haver	backdating	series definition
232	US ST rate	FRB		U.S.: Federal Open Market Committee: Fed Funds Target Rate (EOP, %)
233	JP ST rate	BoJ		Japan: Overnight Call Rate: Uncollateralized [Effective Rate] (EOP, %)
234	UK ST rate	BoE	BIS 80-83	United Kingdom: Base Rate {Repo Rate} (EOP, %)
235	US LT rate	FRB		U.S.: 10-Year Treasury Bond Yield at Constant Maturity (AVG, %)
236	JP LT rate	JSDA	BIS 80-84	Japan: 10-Year Benchmark Government Bond Yield (EOM, %)
237	UK LT rate	BoE	BIS 80-84	UK: Government Bonds, 10-Year Nominal Par Yield (AVG, %)
238	US GDP	BEA		U.S.: Gross Domestic Product (SAAR, Bil.Chn.2000$)
239	JP GDP	CAO	OECD 80-93	Japan: Gross Domestic Product (SAAR, Bil.Chn.2000.Yen)
240	UK GDP	ONS		U.K.: Gross Domestic Product (SA, Mil.Chained.2003.Pounds)
241	euro/dollar	OECD		Euro Zone + GR in 2001: Exchange Rate: Average (Euro/US$)
242	Pcom	CRB		KR-CRB Spot Commodity Price Index: All Commodities (1967=100)
243	Oil Price	WSJ		Spot Oil Price: West Texas Intermediate [Prior'82=Posted Price] ($/Barrel)

Note: Haver indicates the default source and backdating the sourse used to backdate the data.

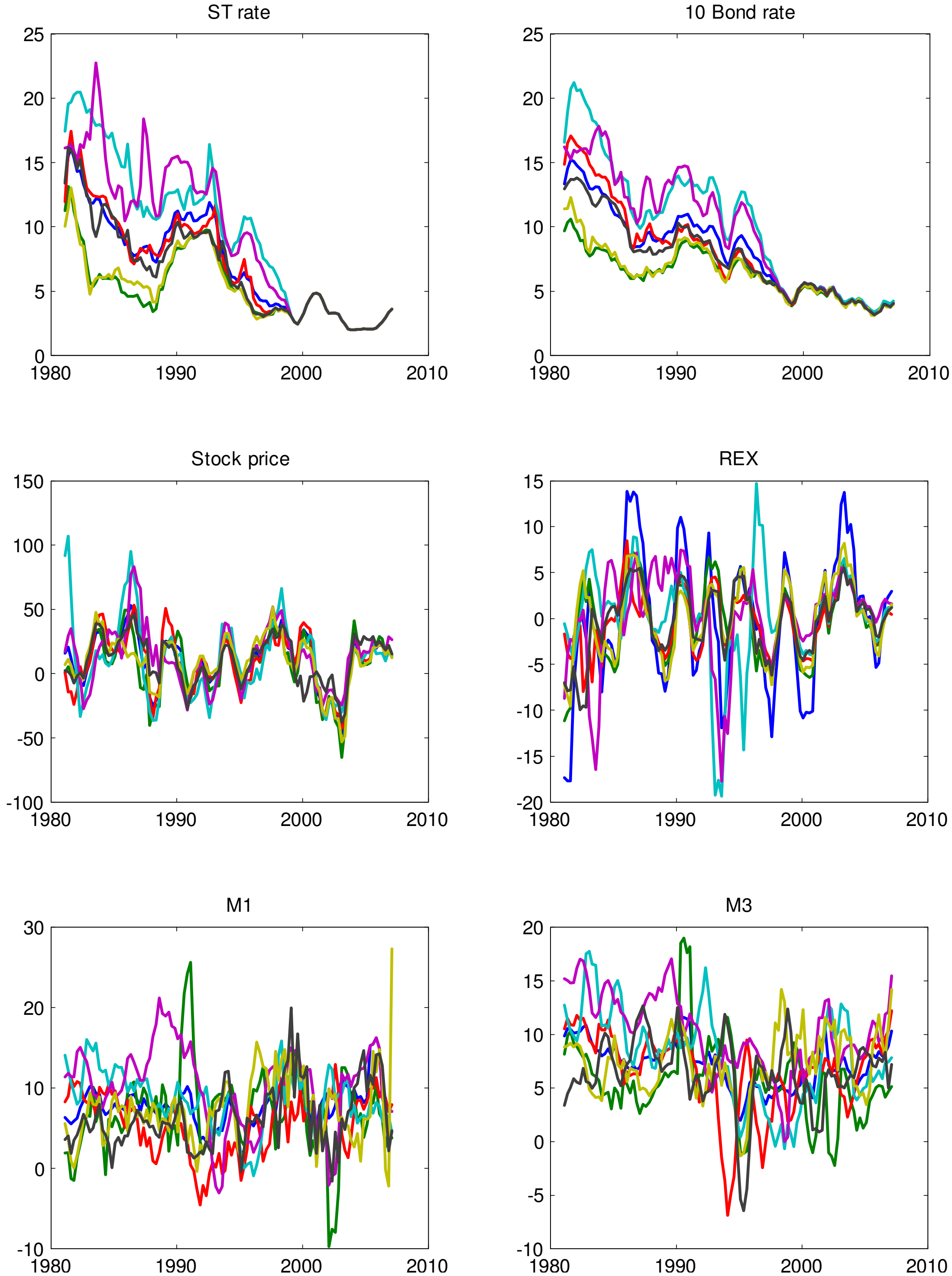

Figure 1a: Main financial and monetary data series in EA and six countries

(year-over-year growth rates, except for interest rates)

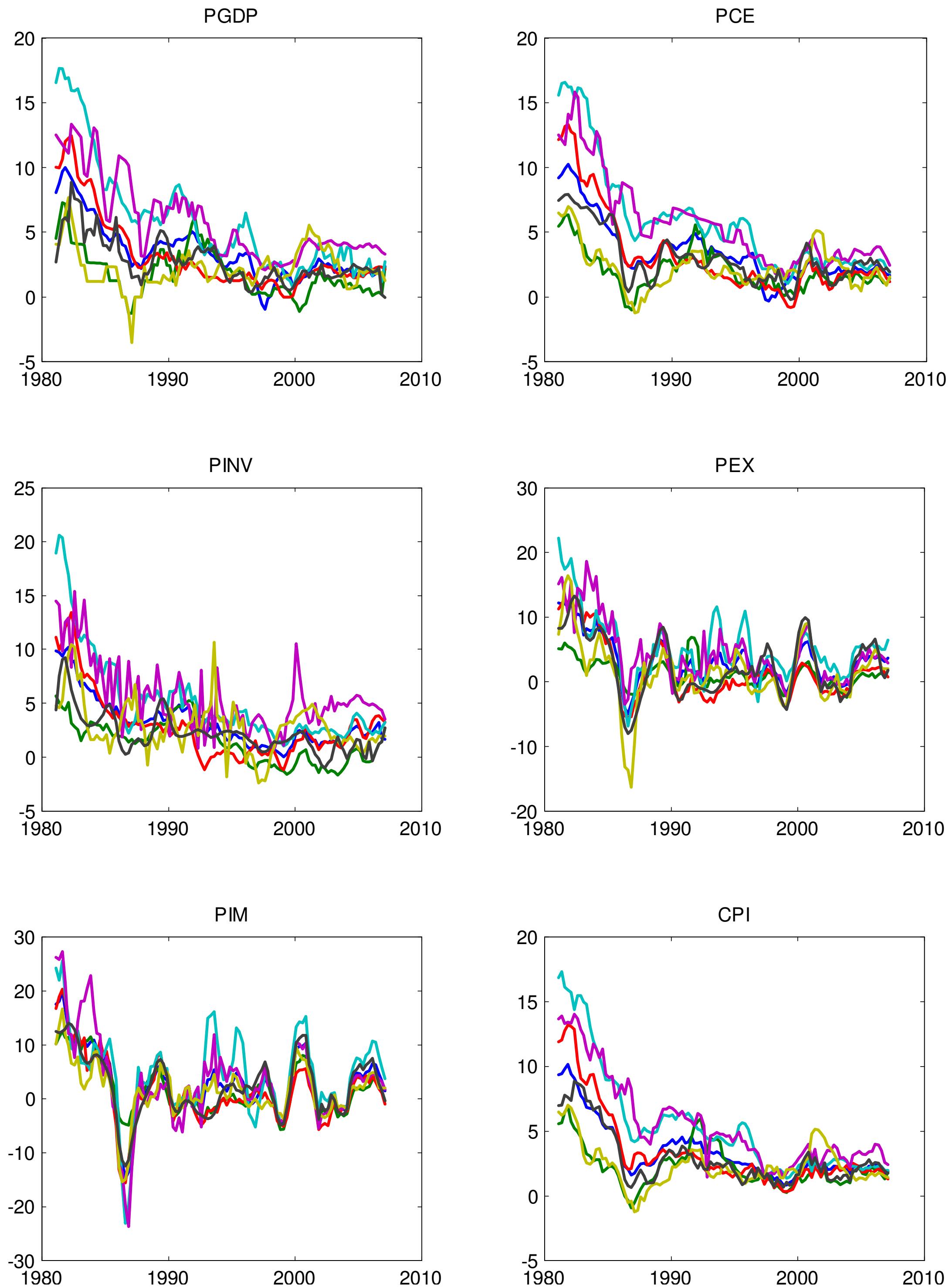

Figure 1b: Main price data series in EA and 6 countries

(year-over-year growth rates)

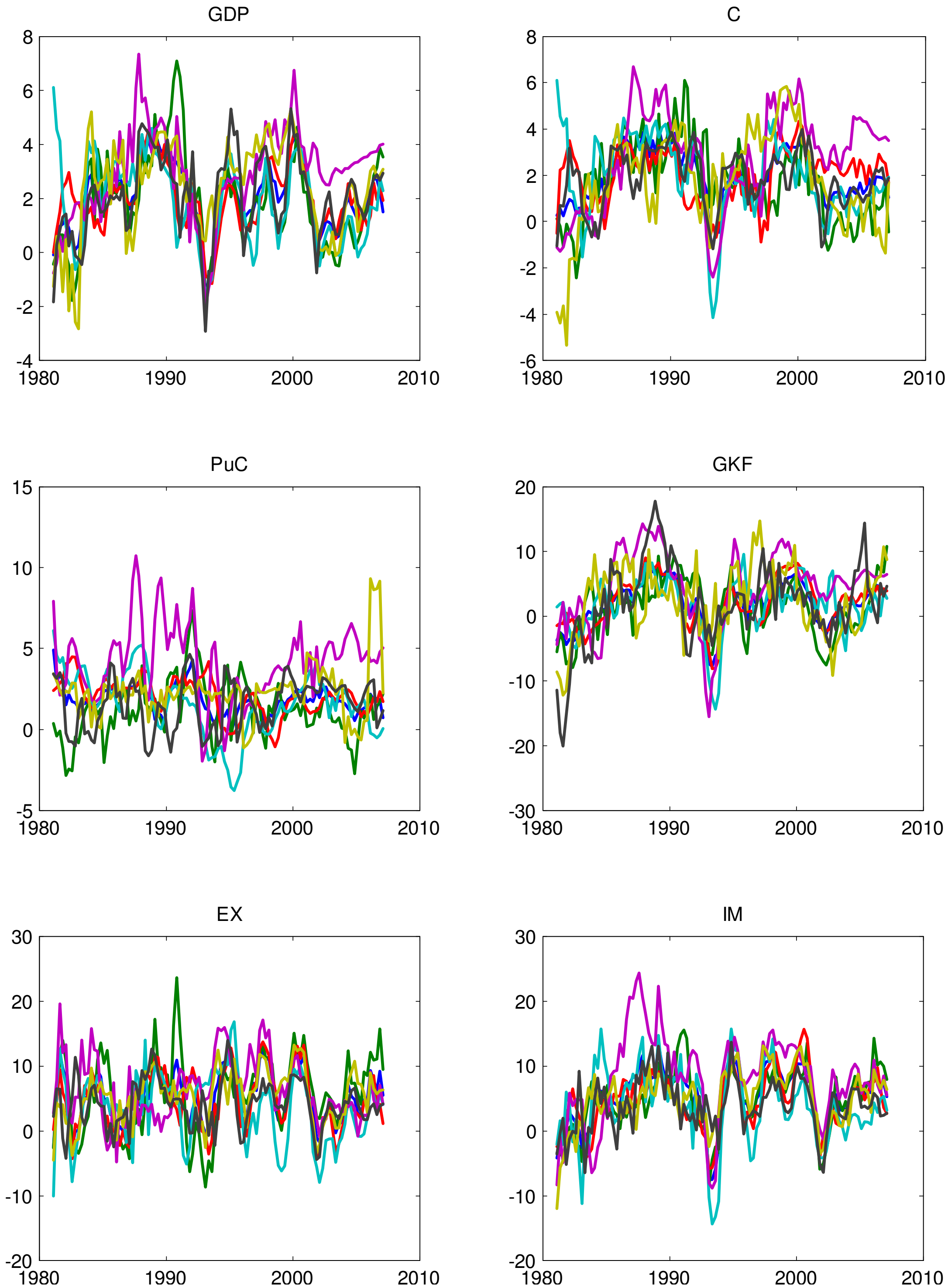

Figure 1c: Real GDP and its components in EA and 6 countries

(year-over-year growth rates)

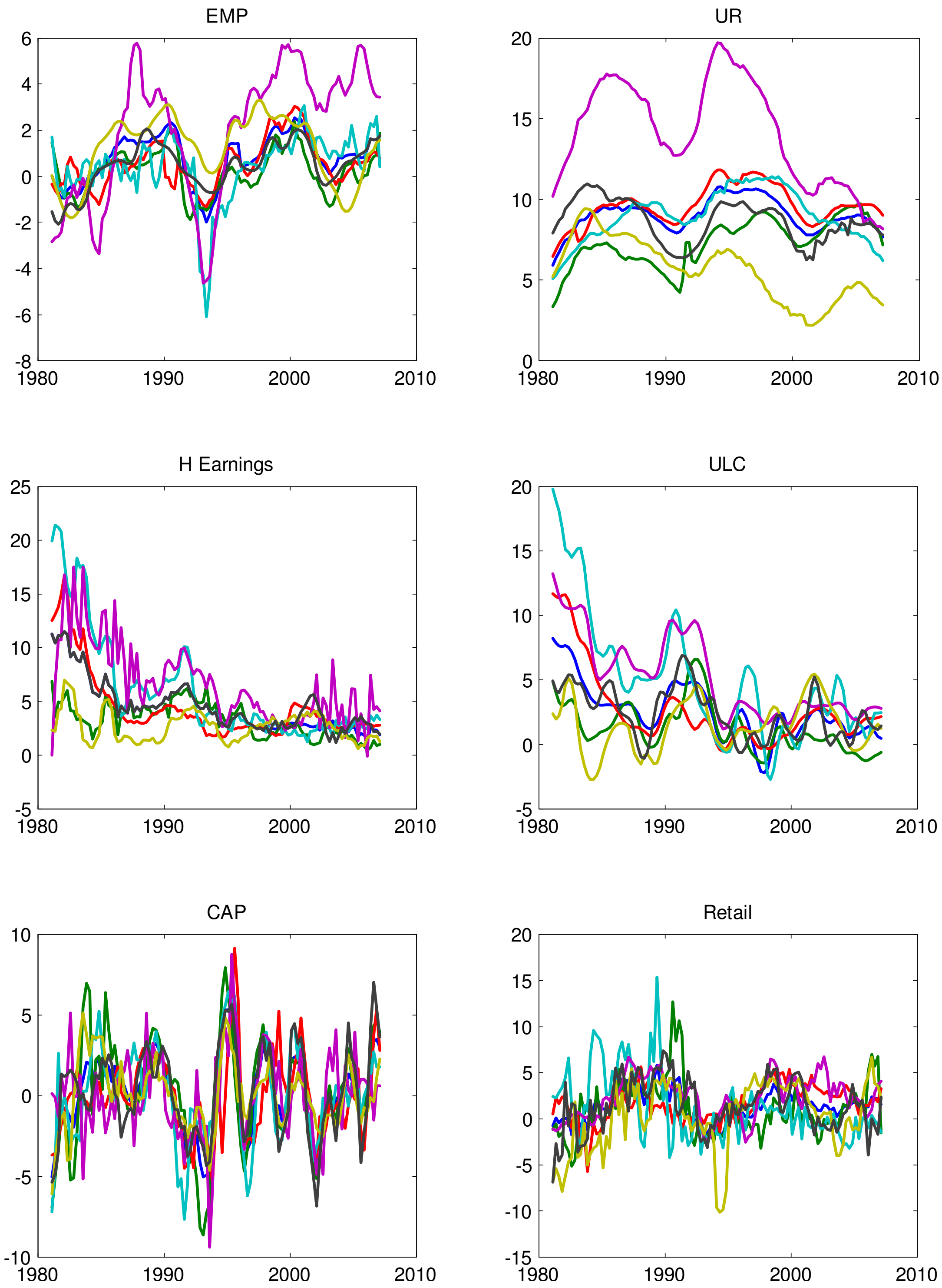

Figure 1d: Labor market series. CAP and retail sales in EA and 6 countries

(year-over-year growth rates, except for unemployment rate)

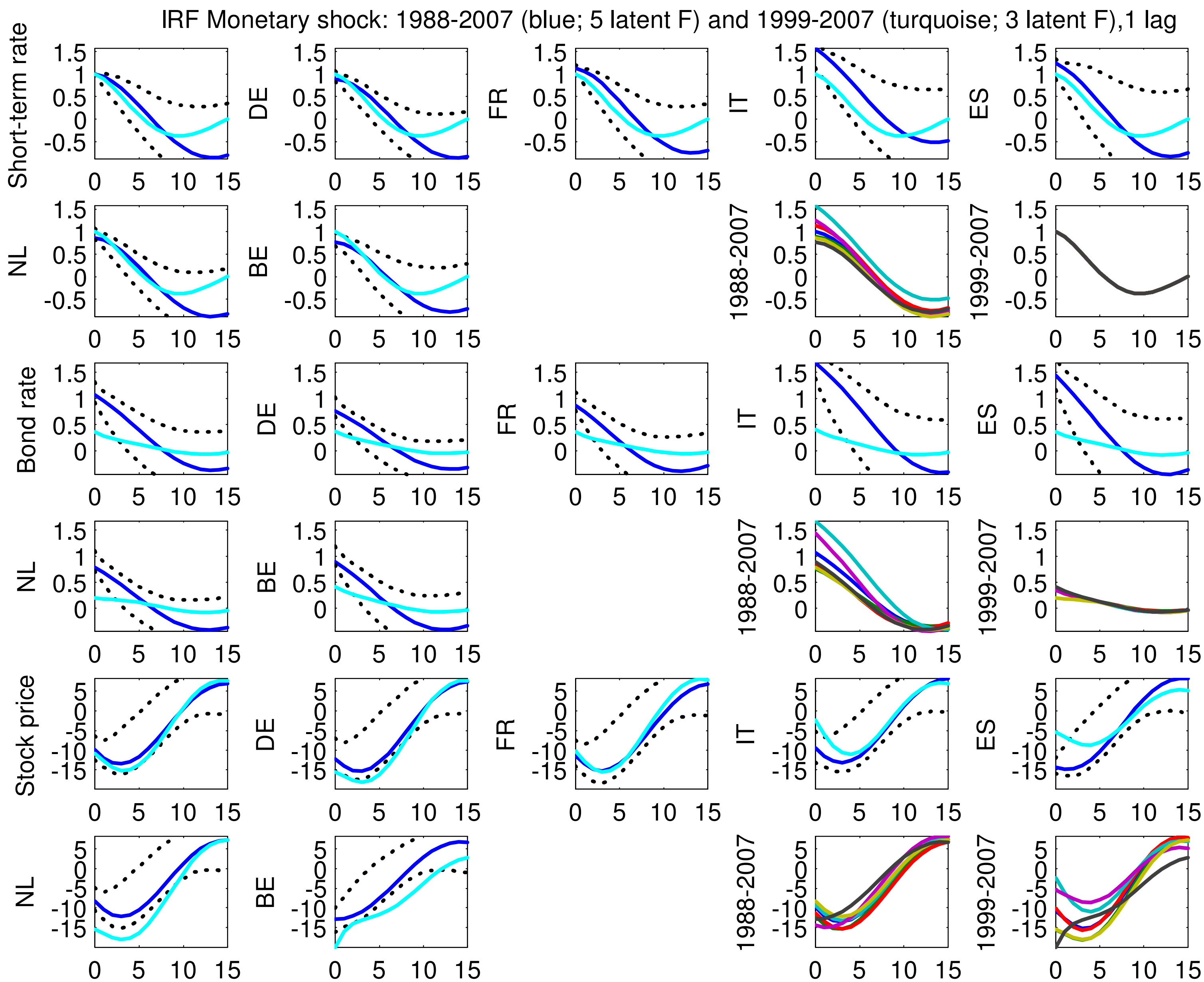

Figure 2a: Impulse response functions to a monetary tightening in EA (100 bp increase in short-term rate)

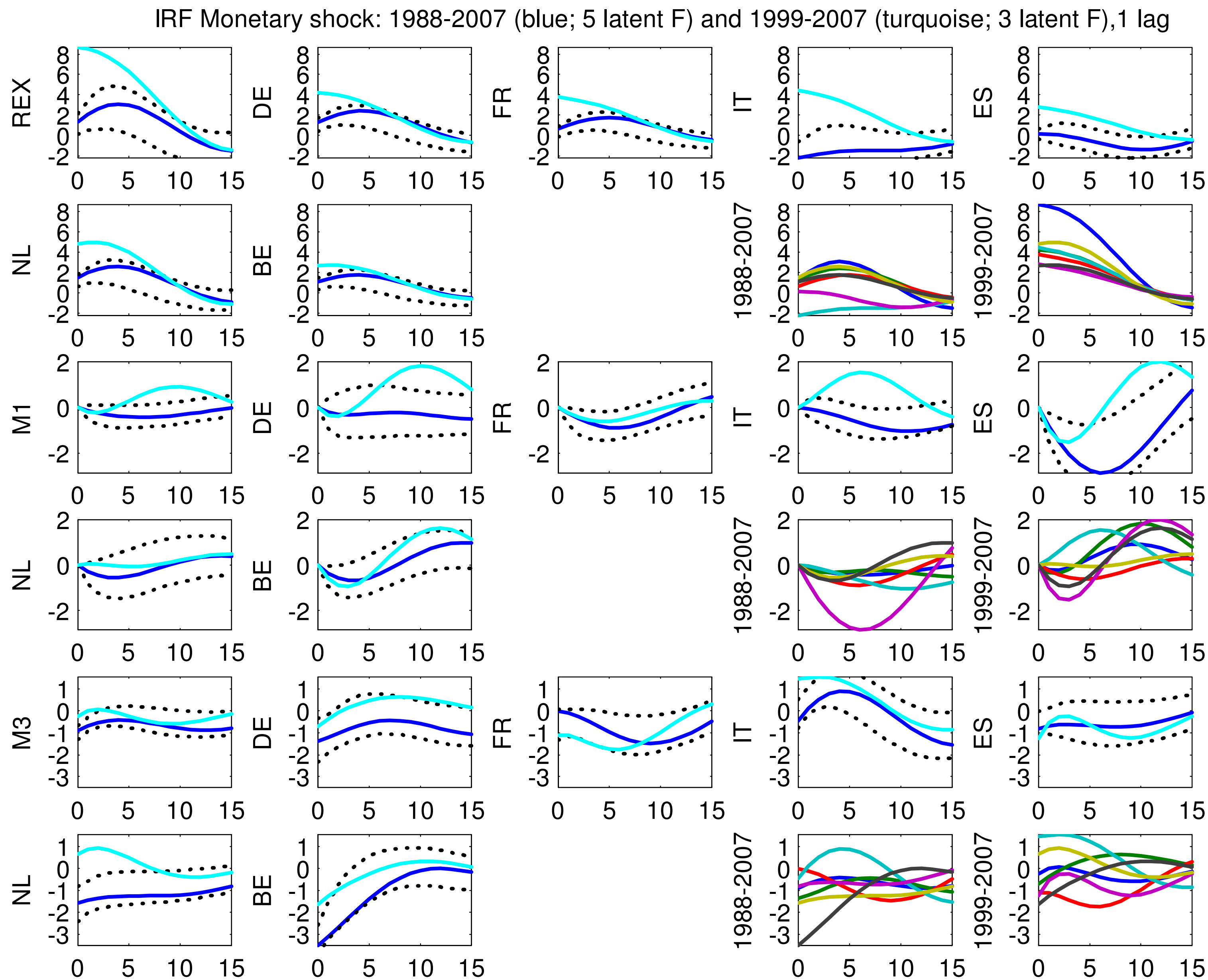

Figure 2b: Impulse response functions to a monetary tightening in EA (100 bp increase in short-term rate)

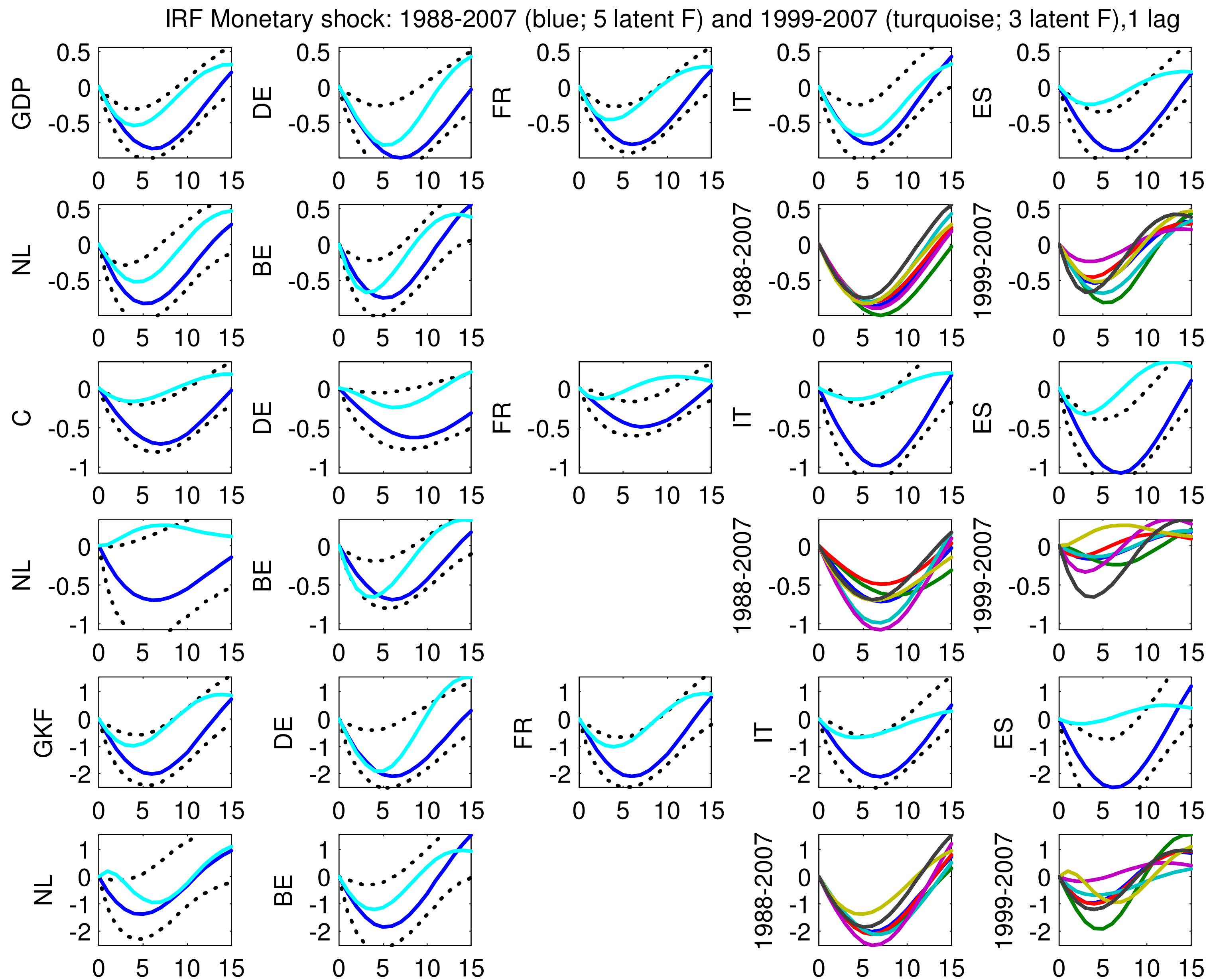

Figure 2c: Impulse response functions to a monetary tightening in EA (100 bp increase in short-term rate)

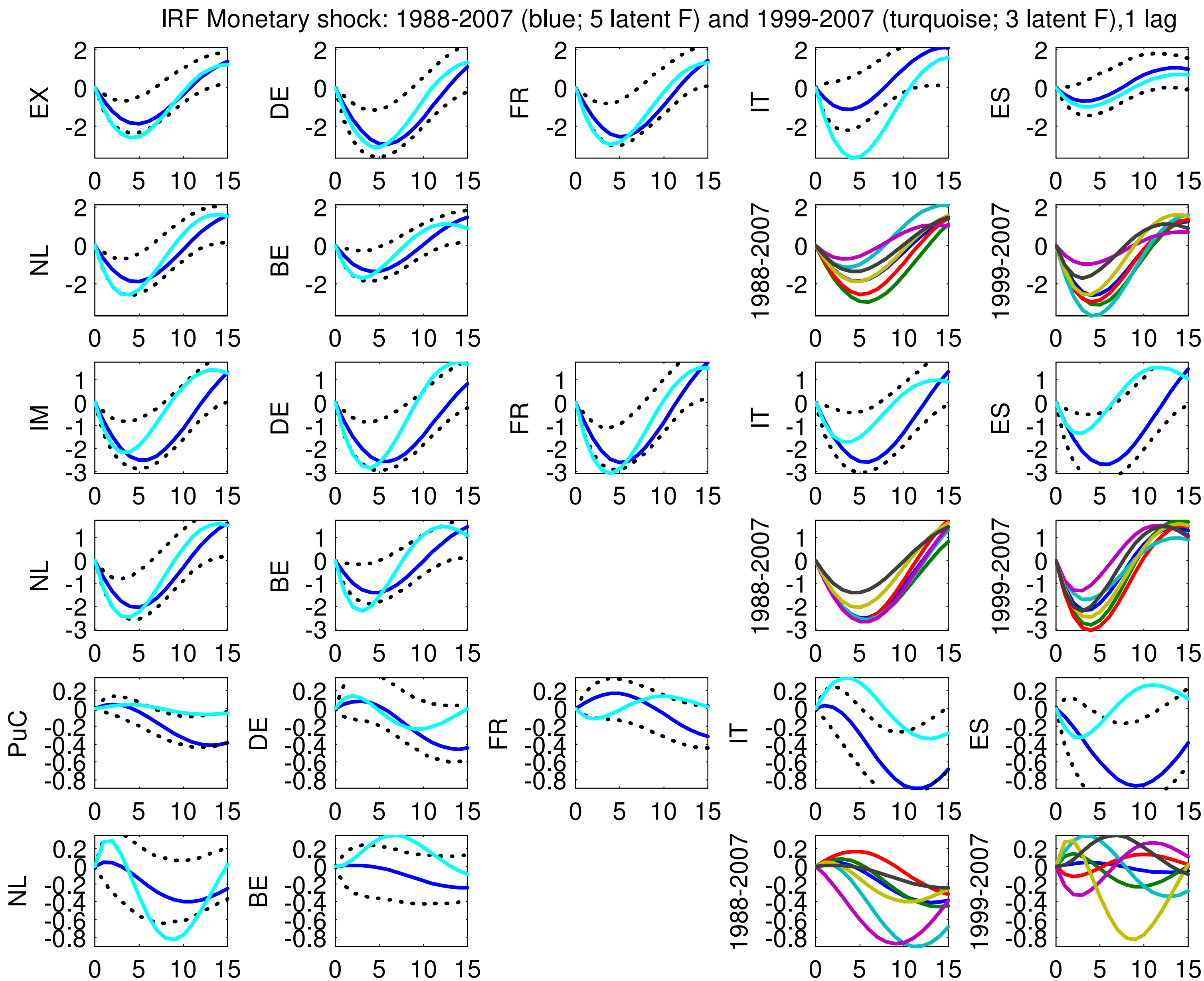

Figure 2d: Impulse response functions to a monetary tightening EA (100 bp increase in short-term rate)

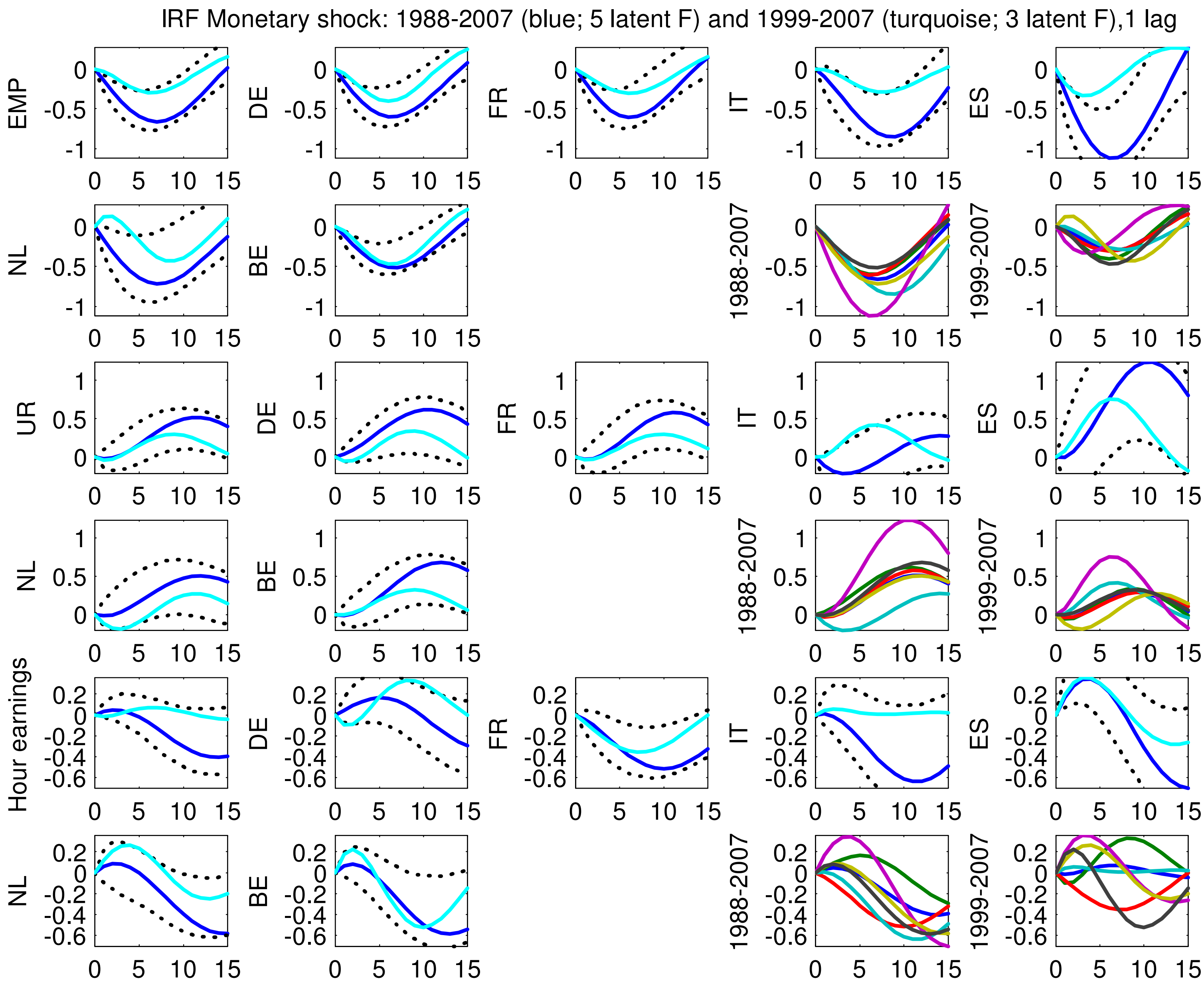

Figure 2e: Impulse response functions to a monetary tightening in EA (100 bp increase in short-term rate)

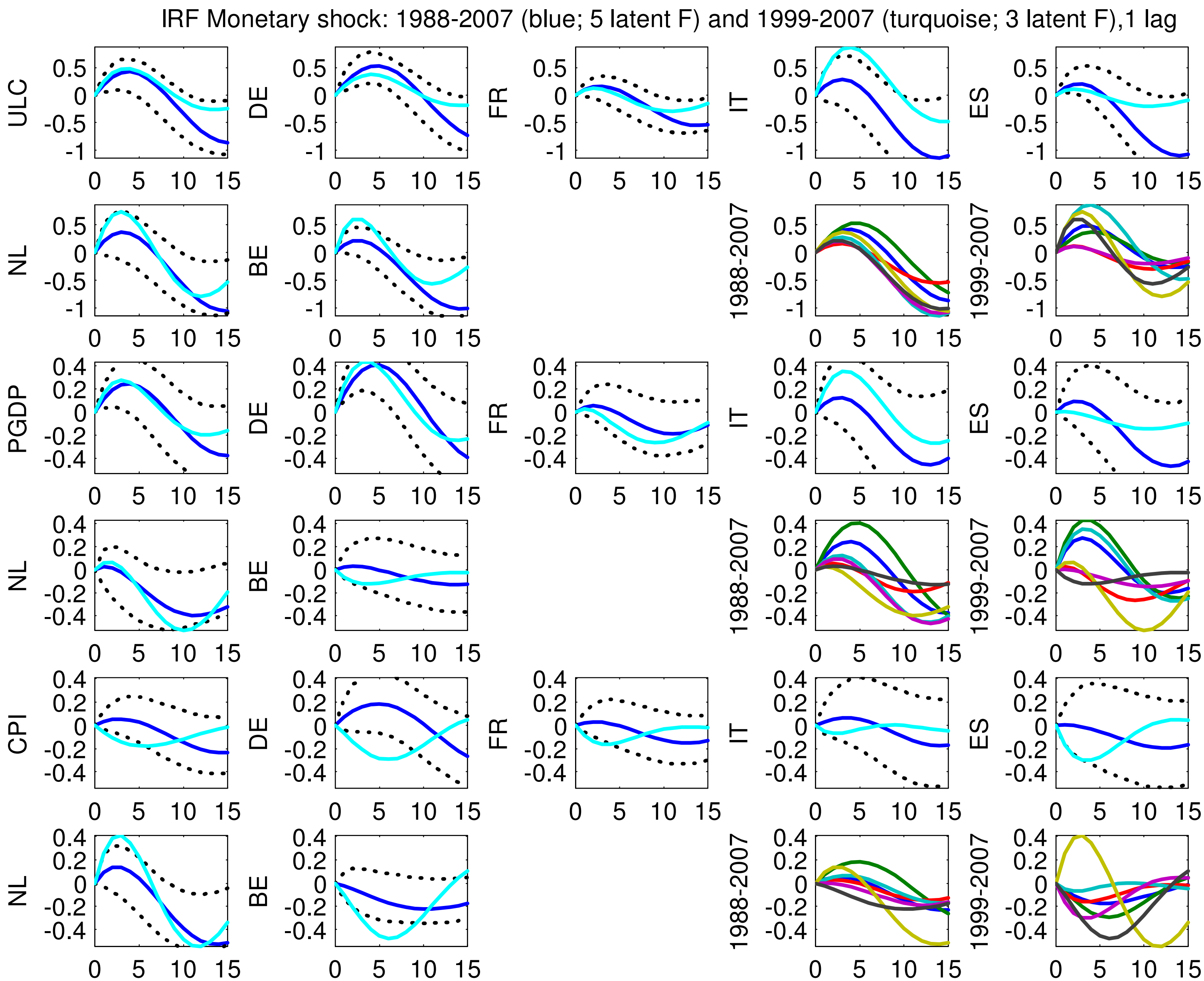

Figure 2f: Impulse response functions to a monetary tightening in EA (100 bp increase in short-term rate)

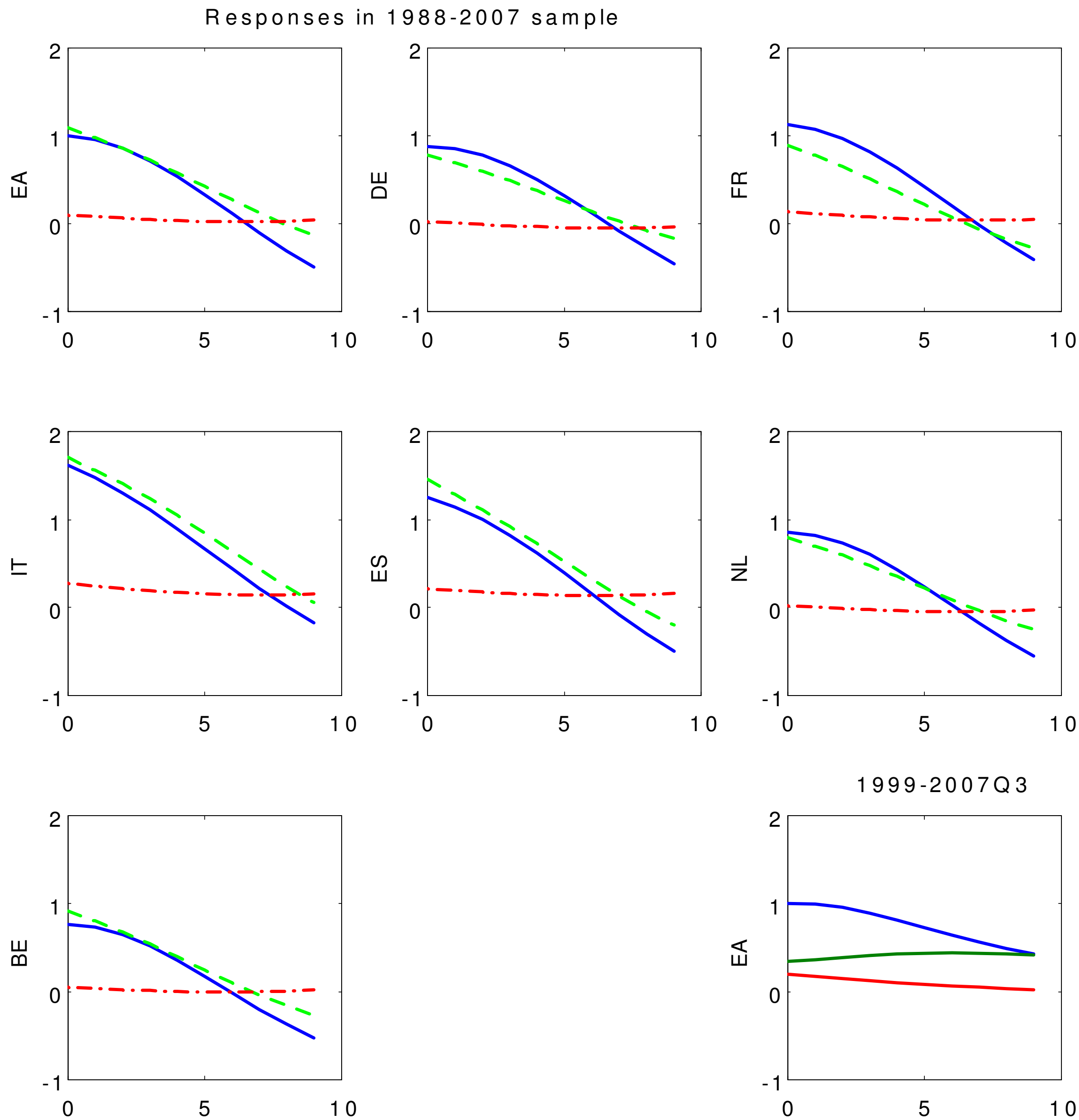

Figure 3. Responses of short and long-term interest rates to monetary policy shock in EA

Notes: Blue solid line: short-term interest rate; Green dashed line: bond yield; Red dashed-dotted line: theoretical bond yield without term premium, based on expectations hypothesis.

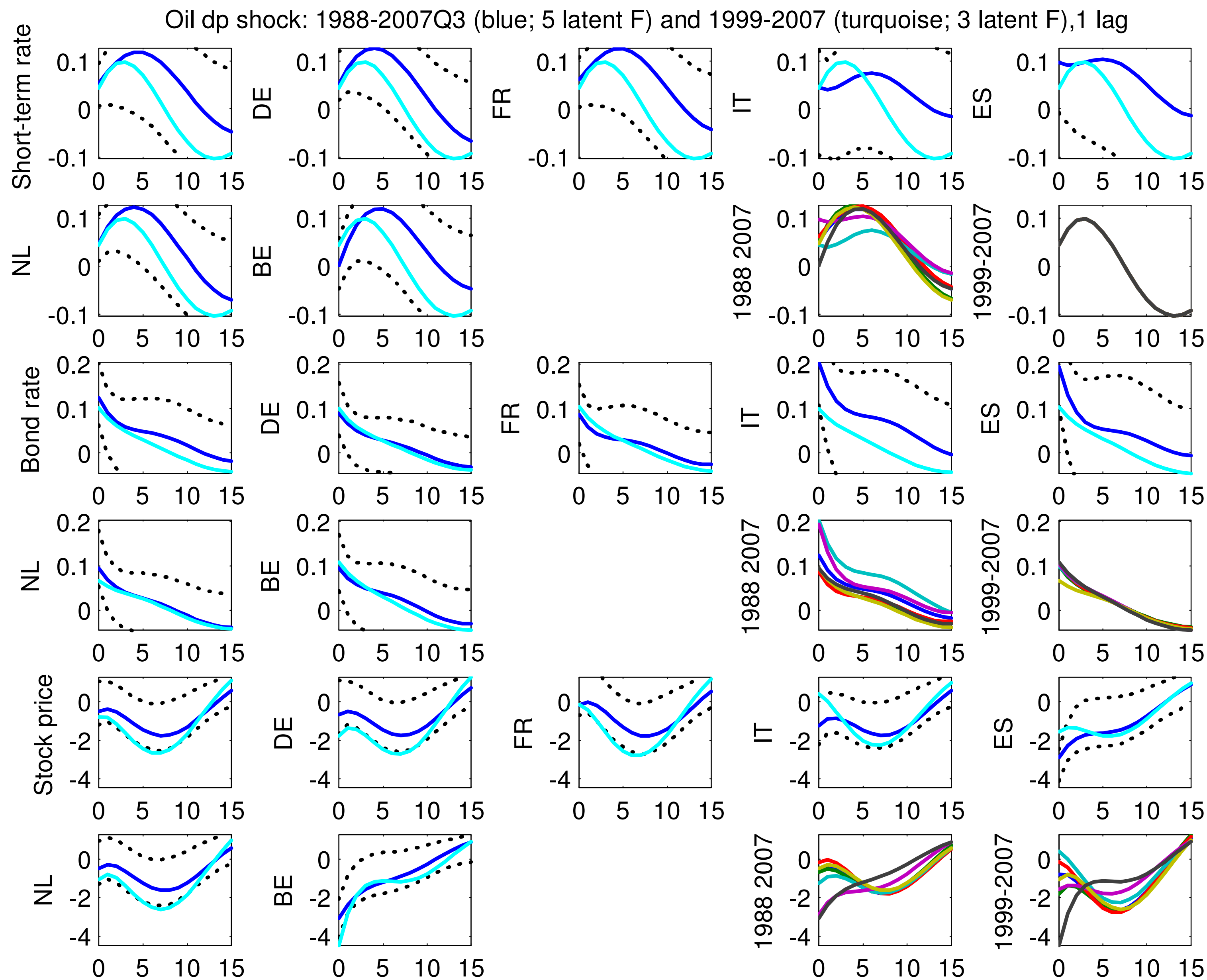

Figure 4a: Impulse response functions to a 10% increase in oil prices

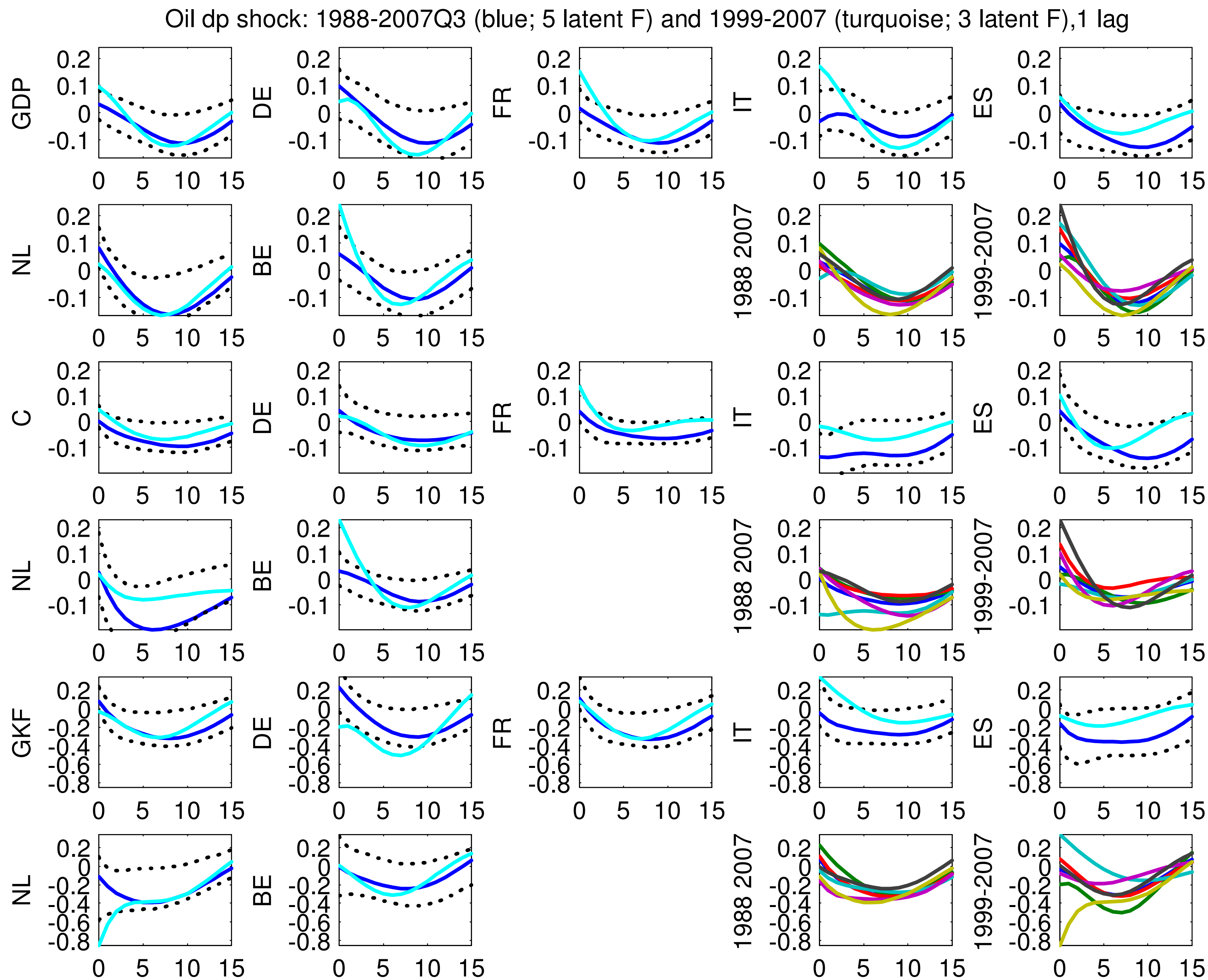

Figure 4b: Impulse response functions to a 10% increase in oil prices (cont.)

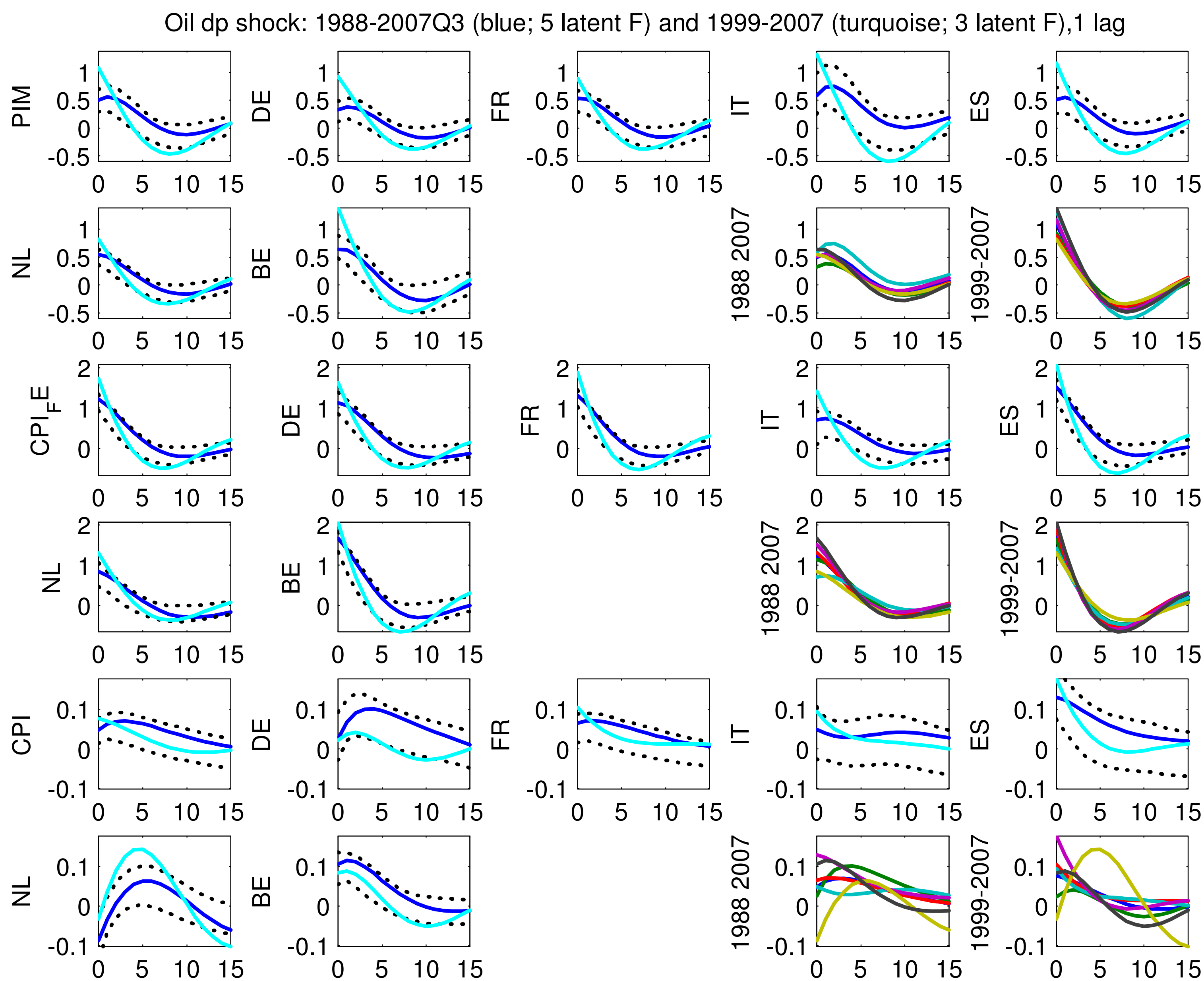

Figure 4c: Impulse response functions to a 10% increase in oil prices (cont.)

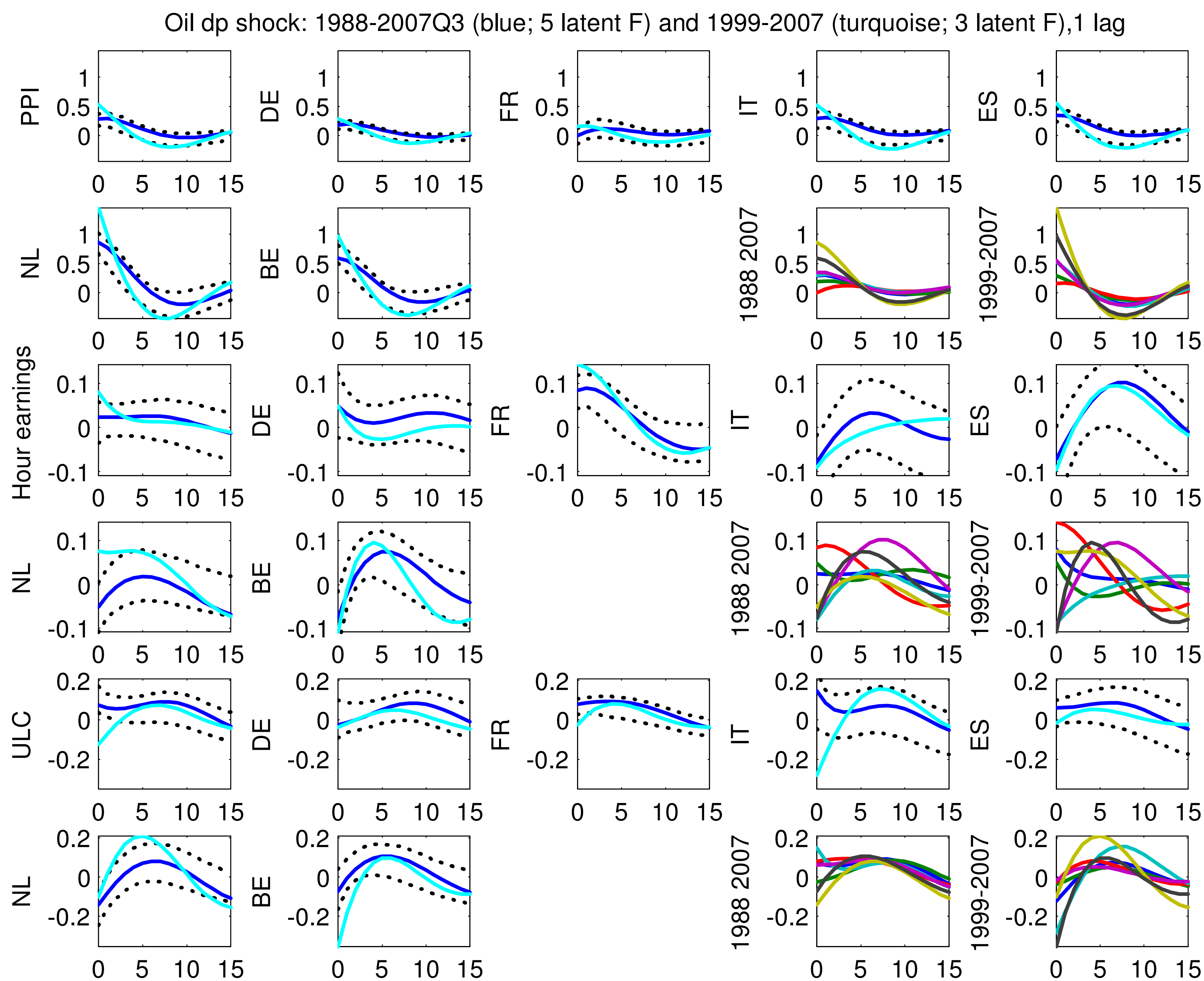

Figure 4d: Impulse response functions to a 10% increase in oil prices (cont.)

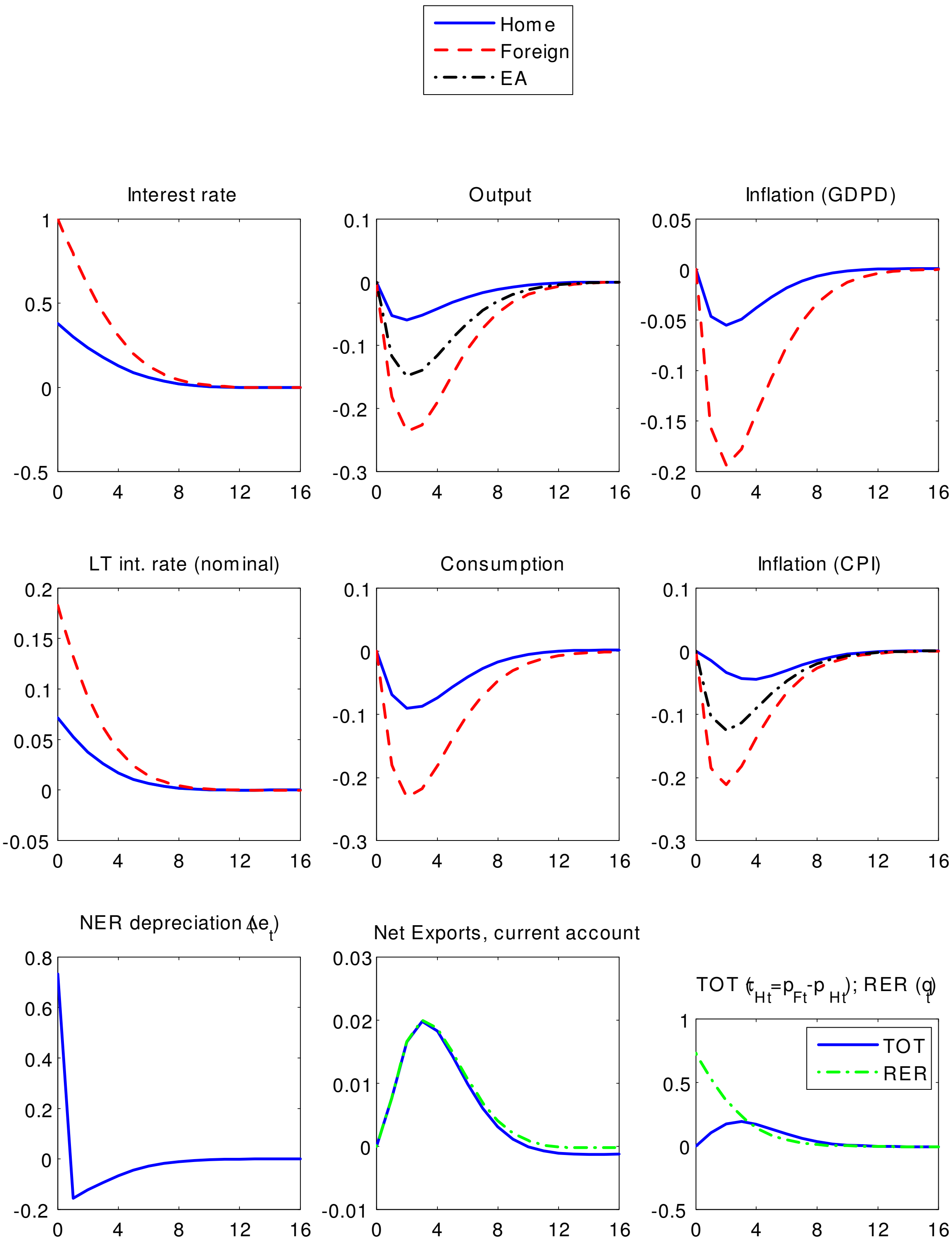

Figure 5a: Model-based responses to a 100bp monetary tightening in foreign country ($\nu = 0$).

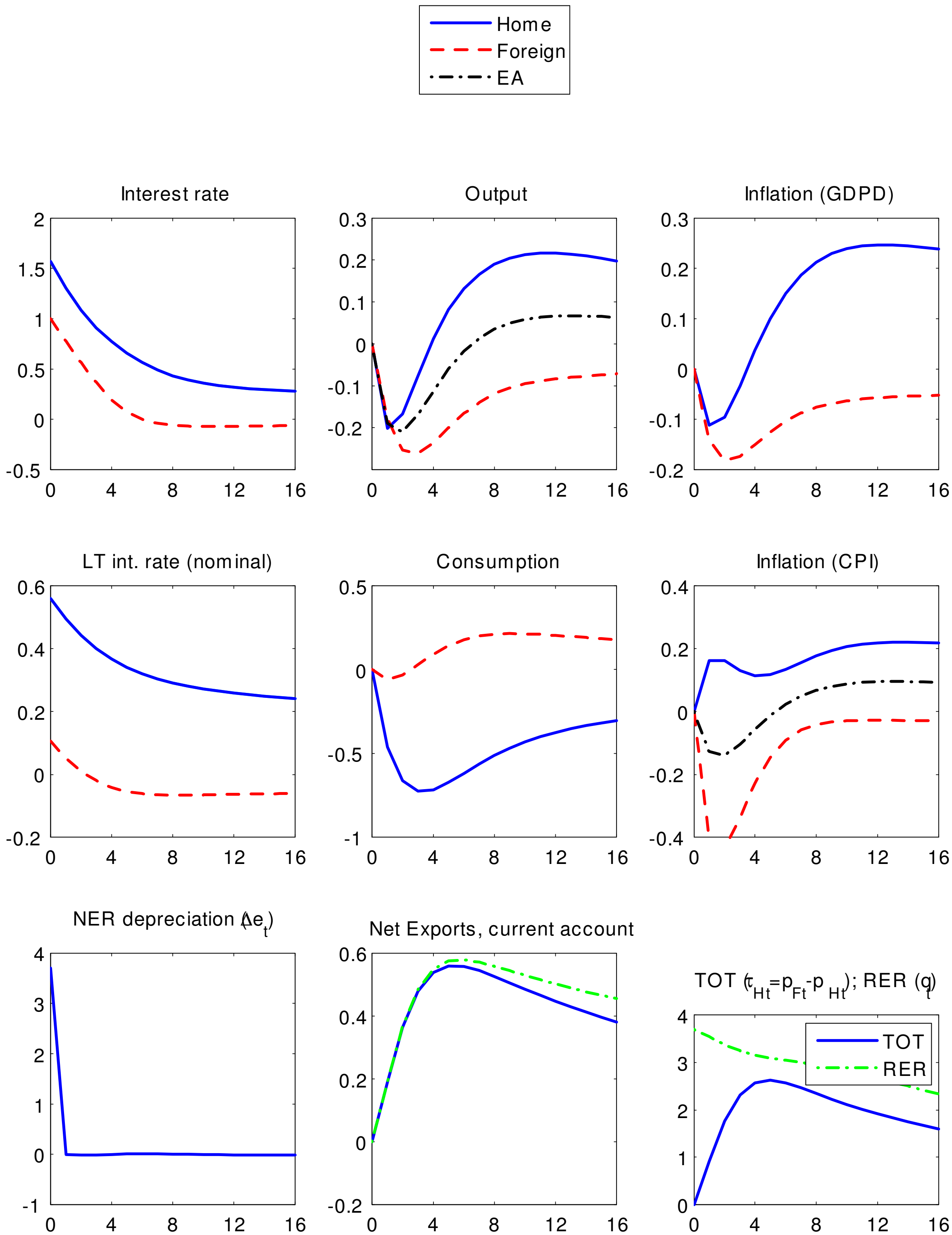

Figure 5b: Model-based responses to a 100bp monetary tightening in foreign country ($\nu = 0.6$).

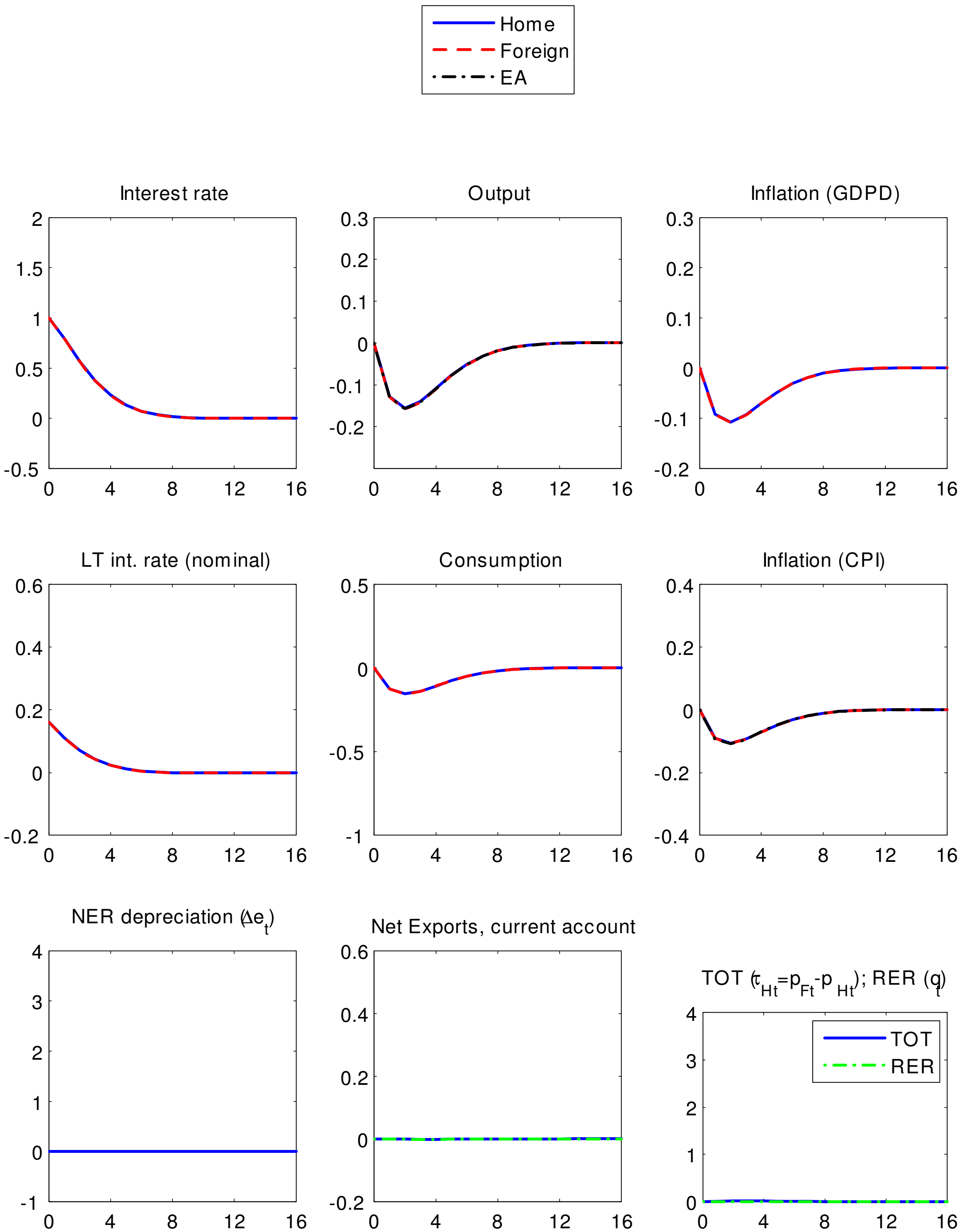

Figure 5c: Model-based responses to a 100bp monetary tightening in common area (monetary union case, $\nu = 0.6$).

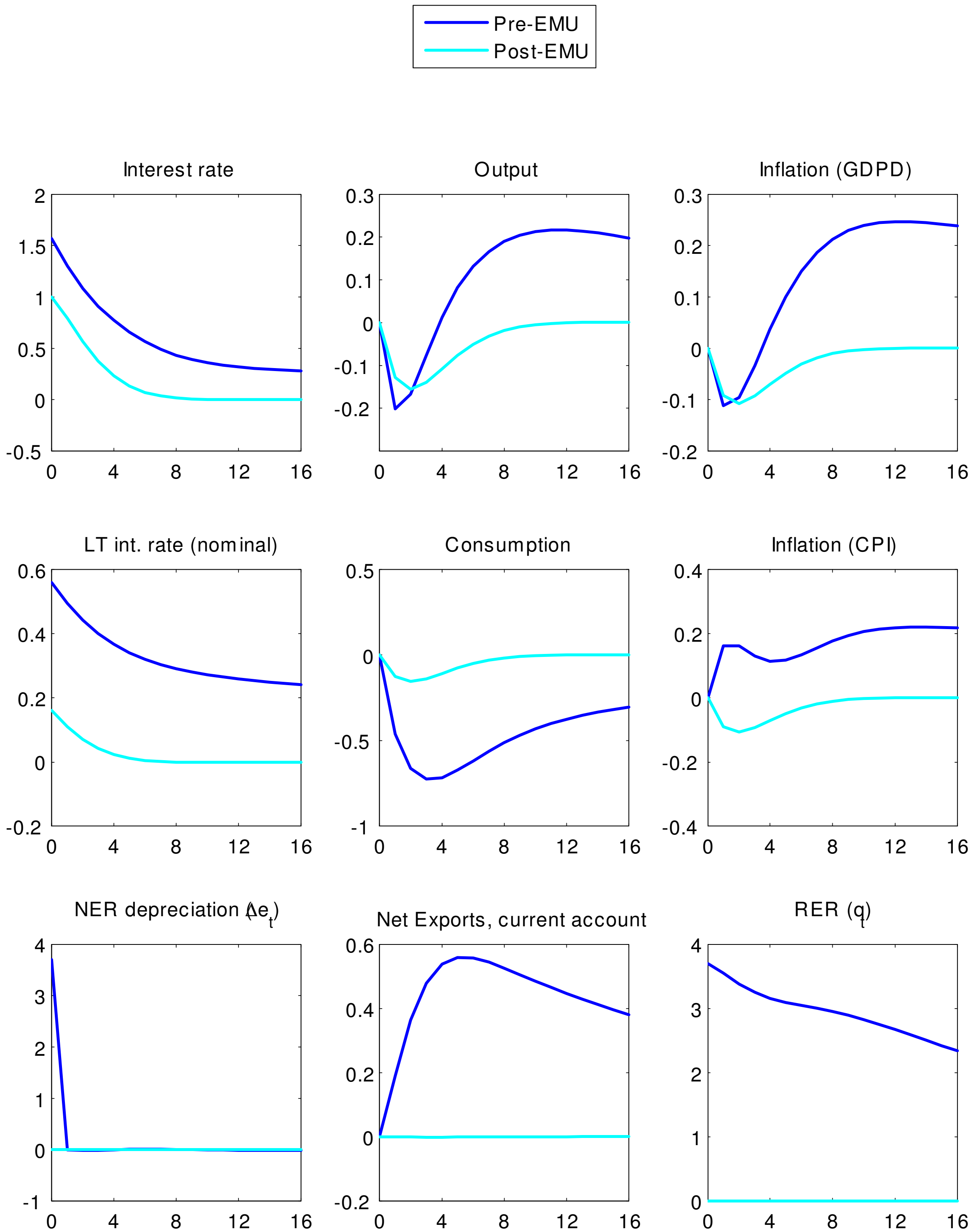

Figure 5d: Model-based responses of Home variables to a 100bp monetary tightening in foreign economy or common area ($\nu = 0.6$).

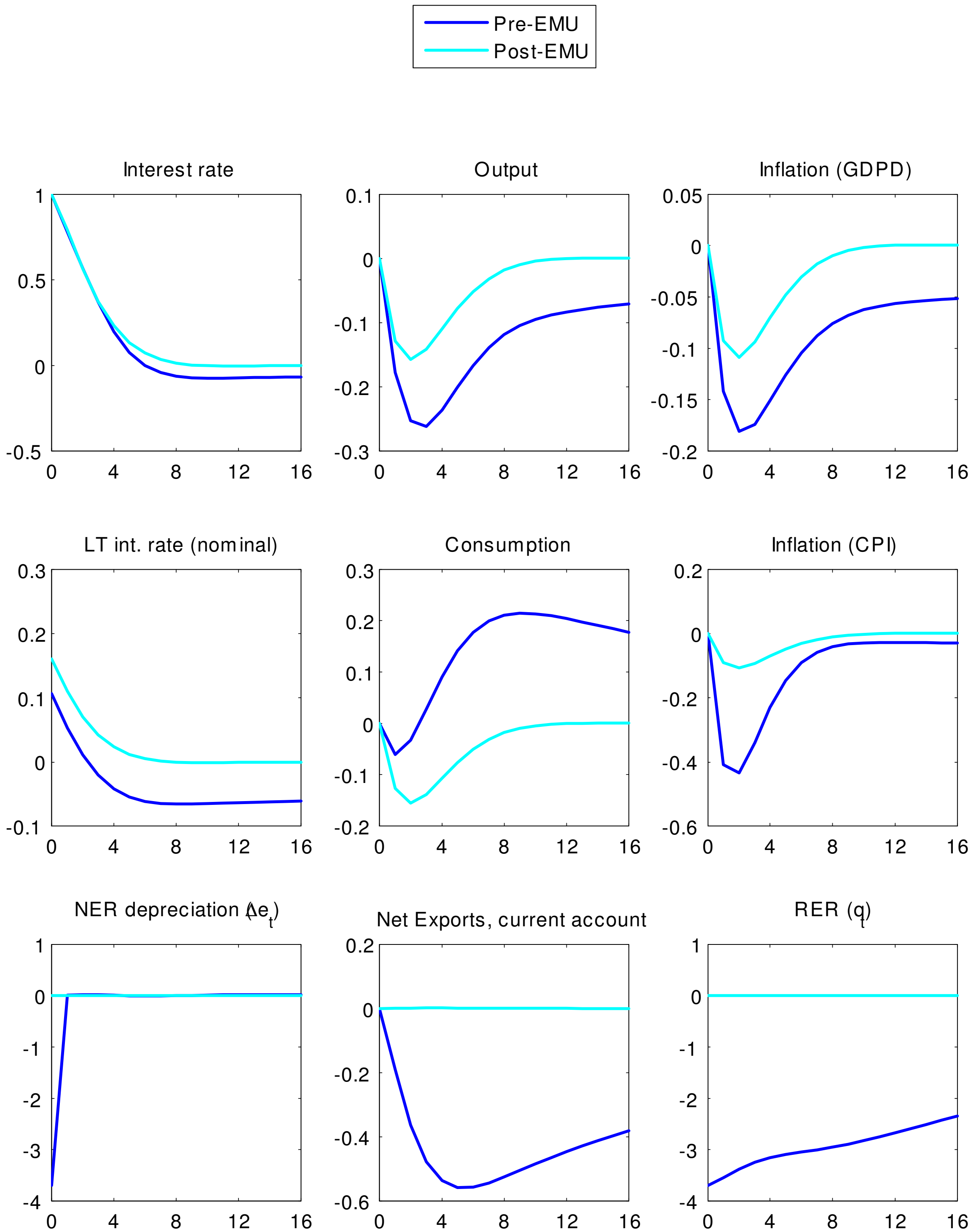

Figure 5e: Model-based responses of Foreign variables to a 100bp monetary tightening in foreign economy or common area ($\nu = 0.6$).