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2

How Has the Euro Changed the Monetary Transmission Mechanism?

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I. Introduction

On January 1, 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 (ECB).[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 (EMS), 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 monetary policy in 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 heterogeneous transmission of EA shocks within individual countries. The factor-augmented vector autogression (FAVAR) model 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 areawide factors, quantify their importance in the country-level fluctuations, and trace out the effect of identified aggregate shocks on all country-level

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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 model the EA economy using only EA aggregates. Examples include evidence based on VARs (Peersman and Smets 2003), more structural models (the ECB area-wide model [AWM]; Fagan, Henry, and Mestre 2005), and optimization-based macroeconomic models (Smets and Wouters 2003; Christiano, Motto, and Rostagno 2007; Coenen, McAdam, and Straub, forthcoming [the new AWM]). 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., Mihov 2001; Mojon and Peersman 2003).

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, chaps. 3, 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 characterize the monetary transmission mechanism, we identify unexpected monetary policy shocks and estimate their dynamic effects on the national macroeconomic variables. We are particularly interested in documenting differences over time and across countries in the sensitivity of national economies to such shocks. (In the appendix to the working paper version of this paper [Boivin, Giannoni, and Mojon 2008], we also document the effects of identified oil price shocks.) 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 monetary shocks contribute relatively little to business cycle fluctuations (e.g., Sims and Zha 2006). Instead, monetary policy affects importantly the economy through its systematic reaction to economic conditions. The impulse response functions to monetary policy shocks provide a useful description of the effects of a systematic monetary policy rule by tracing out the responses of various macroeconomic variables following a surprise interest rate change and assuming that policy is conducted subsequently according to that particular policy rule.

The estimated monetary transmission mechanism is largely consistent with conventional wisdom. A monetary policy tightening in the EA as a whole or in Germany triggers an appreciation of the exchange rate and 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 contribute 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 to a widespread reduction in the effect of monetary shocks. In particular, long-term interest rates, as well as consumption, investment, output, and employment, respond less to short-term interest rate shocks in the new monetary policy regime, whereas trade and the effective real exchange rate respond more strongly. While the monetary transmission mechanism has become more homogeneous along the yield curve, 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 of Ferrero, Gertler, and Svensson (forthcoming) with, among other things, a risk premium on intra-area exchange rates for the period prior to the EMU. This deviation from the uncovered interest rate parity is necessary to replicate a larger response of Italian and Spanish interest rates to German monetary shocks. 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: the elimination of the exchange rate premium that plagued some of the European countries by fixing the intra-area exchange rates and a shift in monetary policy, mainly toward a more aggressive response to inflation and output. This latter finding suggests that the change in the transmission mechanism comes not only from the adoption of a single currency but also from the ECB policy.

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

II. 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 FAVAR model described in Bernanke et al. (2005). 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 multidimensional 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.

A. Description of the FAVAR Model

We provide here only a general description of our implementation of the empirical framework and refer the interested reader to Bernanke et al. (2005) 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, this vector of common components includes a short-term interest rate, R_t, to measure the stance of monetary policy. Our specification also includes the growth rate of an oil price index, π_t^{oil}, as an observable factor. Both of these variables are allowed to have a 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," and the level of "productivity," which may not easily be captured by a few time series, but rather by a wide range of economic variables.[3] 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

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

and $\Phi(L)$ is a conformable lag polynomial of finite order that may contain a priori restrictions, as in standard structural VARs. The error term v_t is independently and identically distributed 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," that is, $N > K + 2$. 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, since F_t can always capture arbitrary lags of some fundamental factors.[4]

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 Bernanke et al. (2005), 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 data set X_t to obtain consistent estimates of the common factors.[5] Stock and Watson (2002) and Bai and Ng (2006) 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 Bernanke et al. since we impose the constraint that the observed factors (π_t^{oil} and R_t) are among the factors in the first-step estimation.[6] This guarantees that the estimated latent factors recover dimensions of the common dynamics not captured by the observed factors.[7]

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.[8]

B. *Interpreting the FAVAR Structure*

Various approaches have been used in the literature to model macroeconomic dynamics in the EA. As we illustrate in this subsection, 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 us to answer a broader set of questions.

As in Bernanke et al. (2005) and in Boivin and Giannoni (2006a), we interpret 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 V.A 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 these variables would either be included in C_t or be linear combinations of the elements of C_t. The dynamic evolution of these variables can be approximated by a VAR of the form (1).[9]

The existing approaches that model the dynamics of EA variables can be interpreted as special cases of the FAVAR model, in the case in which the elements of C_t are perfectly observed, so that 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 restrictions imposed on the coefficients of (1)–(2).

One approach is to assume that the elements of C_t are observed and correspond to EA aggregates.[10] Such a 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, for example, to the ECB AWM (Fagan et al. 2005) or even optimization-based macroeconomic models (Smets and Wouters 2003; Christiano et al. 2007; Coenen et al., forthcoming [the new AWM]). 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 multicountry VARs and could be estimated directly, as in, for example, Eichenbaum and Evans (1995) and Scholl and Uhlig (2008).

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 Guiso et al. [1999], Mojon and Peersman [2003], Ciccarelli and Rebucci [2006], and references therein). By 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 shocks 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 that 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 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 that may summarize many features of the economy. We thus do not restrict ourselves to summarizing the state of the economies with particular measures of inflation and of output. Another advantage, as Bernanke et al. 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 one to take a stand on the appropriate measures of prices and real activity that 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 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, Marcellino, and Neglia (2005) compare the effects of monetary policy shocks on output and inflation in Germany, France, Italy, and Spain for alternative specifications of factor models. They find largely homogeneous effects on output gaps and inflation rates across countries. Eickmeier (2006) and Eickmeier and Breitung (2006) characterize the effects of common shocks on GDP and inflation in 12 countries of the EA and in new European Union members that 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 seems to originate in idiosyncratic shocks.

In contrast, in this paper we seek to better understand the role of the monetary policy regime in explaining different monetary transmissions across countries of the EA. 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 many 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 that used by McCallum and Smets (2007), who use a similar FAVAR to study how the responses of wages and employment to monetary shocks in the EA depend on national and sectoral labor market characteristics.

III. Empirical Implementation

A. 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, that is, 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 that these countries account for 90% of the EA population and output, we deem it unlikely that the inclusion of other EA countries would alter our estimates of 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, producer price index and consumer price index (CPI), 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 United Kingdom, the United States, and Japan; the euro/dollar exchange rate; an index of commodity prices; and the price of oil. The database was mostly extracted from Haver Analytics. In a number of cases the Haver data were backdated using older vintages of OECD databases. The definitions of the variables, the source, and details about the data construction are given in the appendix. The graphs of the data are available in the appendix of the worker paper version of this paper.

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.

B. Sample Period

The choice of the sample period is delicate. On the one hand, our interest lies in characterizing the monetary transmission in the period since the start of the monetary union in January 1999. We therefore have about nine 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 1970s, European governments set up mechanisms that aimed at limiting exchange rate fluctuations within Europe.[13] The march to the monetary union has 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 1980s. The last realignment of the French franc to core EMS currencies (the deutsche mark, the Belgian franc, and the Dutch guilder) took place in January 1987. Ex post, we know that the parity between the French franc, the Belgian franc, the Dutch guilder, and 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 currencies 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-1990s because of risk premia, 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. Inflation rates were much further apart in the 1970s and early 1980s than ever since.

For all these considerations and to avoid capturing 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.

C. Preferred Specification of the FAVAR

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

D. 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 $\lambda_i' C_t$ that characterizes the effects of EA-wide fluctuations and a component e_{it} that 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, since 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 monetary shocks get transmitted to the EA and across the different countries.

Several studies have recently attempted to 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 provide an efficient information summary of the main economic time series both at the EA level and for the four 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 with 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 there is a possibility that the tightness of economic variables with the EA business cycle may be uneven across countries and across variables of different kinds. This is why we consider a large number of economic variables rather than a couple of macroeconomic indicators in our analysis.

E. Comovements between European Variables and EA Factors

Table 1 reports the fraction of the volatility in the series listed in the table that is explained by the seven EA-wide factors C_t (i.e., five latent factors, the log change of the oil price, and the EA short-term interest rate). This corresponds to the R^2 statistics obtained by the regressions of these variables on the appropriate set of factors.

Columns 1–3 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 common factors therefore summarize quite well the information contained in these EA series. Not all series, however, are 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 comovement with the common factors.

Instead of estimating latent factors from our large data set, we could alternatively impose key EA macroeconomic variables such as GDP, consumption, inflation, exchange rate, bond yield, and unemployment as observed factors. Our proposed approach dominates, however, since the latent factors explain a substantially larger share of the variance of our sample than intuitive combinations of EA aggregates. The additional explanatory power of the latent factors amounts on average to 10% of the variables' variance.

Columns 4–6 of table 1 report the average across countries of the R^2 statistics for the relevant variables. The R^2 statistics are overall lower

Table 1
R^2 for Regressions of Selected Series on Common Factors

	Euro Area			Average R^2 over Countries		
	1987:1–2007:3 (1)	1987:1–1998:4 (2)	1999:1–2007:3 (3)	1987:1–2007:3 (4)	1987:1–1998:4 (5)	1999:1–2007:3 (6)
Short-term interest rate	1.00	1.00	1.00	.97	.97	1.00
Bond yield	.96	.96	.95	.94	.94	.95
Stock price	.65	.71	.91	.61	.77	.88
Real exchange rate	.78	.82	.93	.73	.79	.93
M1	.43	.65	.73	.42	.65	.53
M3	.70	.92	.74	.50	.71	.69
Deflator GDP	.88	.89	.88	.73	.81	.84
Deflator personal consumption expenditure	.88	.90	.72	.77	.90	.83
Deflator investment	.89	.93	.88	.63	.71	.75
Deflator exports	.86	.80	.97	.72	.71	.94
Deflator imports	.93	.89	.99	.82	.78	.97
CPI	.94	.97	.90	.78	.91	.83
Real GDP	.94	.97	.96	.79	.84	.90
Consumption	.88	.92	.90	.71	.75	.81
Public consumption	.54	.71	.54	.42	.59	.63
Investment	.92	.93	.94	.65	.76	.78
Exports	.70	.71	.93	.67	.68	.88
Imports	.84	.95	.93	.74	.81	.89
Employment	.85	.90	.97	.78	.85	.85
Unemployment rate	.92	.97	.96	.86	.93	.96
Hourly earnings	.94	.97	.69	.79	.92	.74
Unit labor costs	.89	.96	.88	.81	.92	.89
Capacity utilization ratio	.86	.92	.95	.67	.80	.77
Retail	.73	.80	.60	.53	.67	.60

than those for the entire EA area, as expected, to the extent that each country has country-specific features that are not summarized by the common factors C_t and that 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 comovement with the common factors, whereas growth rates of M1, M2, and public consumption show much lower degrees of comovement.

One might think that the relatively low R^2 statistics for M1 and M3 reflect the fact that our panel includes a relatively small number of series of monetary aggregates. This intuition is, however, incorrect. If monetary aggregates constituted an important source of fluctuations for a wide range of variables in our panel, then the R^2 for the monetary aggregate series should be high even if no such series was used for the estimation of the latent factors. In this case, the estimated latent factors should be capturing the common movements in the data that are generated by fluctuations in the monetary aggregates. So in theory, provided that we allow for a sufficiently large number of latent factors, the composition of the panel should not matter for the estimation of latent factors.

Looking across countries reveals that the correlation with the common factors is broadly similar across countries in each of the subsamples. Table 2 reports the average R^2 statistic for each country across the variables listed in table 1. It shows that country-level R^2's 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's 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-1999 and post-1999 periods. 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. This is particularly clear for Spain, since its GDP has grown at a faster pace than that of the rest of the EA since 1995, but is less clear-cut for Italy, which has grown slightly less rapidly than the rest of the EA.

IV. Monetary Policy Regimes and the Monetary Transmission Mechanism

In the last section, we have documented that the variables of each individual country have been on average fairly highly correlated with the

Table 2
Average R^2 for Regressions of Selected Series on EA Factors

	1987:1–2007:3 (1)	1987:1–1998:4 (2)	1999:1–2007:3 (3)
Euro area	.83	.88	.87
Germany	.69	.77	.82
France	.76	.84	.87
Italy	.73	.82	.79
Spain	.76	.84	.78
Netherlands	.64	.74	.86
Belgium	.68	.79	.84

EA-wide common factors. Nonetheless, aggregate shocks affecting the entire EA may have different implications for each individual country. To assess this, we use our estimated FAVAR to characterize the effects of monetary policy shocks, which we measure here as an unanticipated increase in the EA short-term interest rate of 100 basis points on the national economies considered. Our empirical model is well suited for this since it allows us to determine simultaneously the effects of such shocks on all country-level variables.

As mentioned above, the data reveal changes over time in the degree of comovement of key European variables with EA-wide common factors. A natural implication of such changes is that the transmission of monetary policy may have evolved over time. We thus report the effects of monetary policy shocks both for our benchmark sample and for the post-EMU period. The description of the effects of this shock is a natural starting point in a context in which several countries have chosen to adopt a common currency and therefore to submit their economy to a single monetary policy.

A. Identification

To identify monetary policy shocks, we proceed similarly to Bernanke et al. (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, whereas the short-term rate R_t can respond to any innovation in the factors F_t or in oil prices. Of course, we do not 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 responds contemporaneously to unexpected monetary shocks, as is often assumed. These restrictions do not, however, prevent any of the financial variables such as bond yields, stock prices, and exchange rates from responding contemporaneously to the short-term interest rate.

In the next section, we present a theoretical model that is designed to provide some explanations for the monetary transmission mechanism. We note at this point that this model is consistent with the identifying assumptions made here. In particular, both the theoretical model and the FAVAR have the property that output, consumption, and inflation do not respond contemporaneously to monetary shocks.

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 in the EMS. Given the Exchange Rate Mechanism (ERM) 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 IV.E, which discusses the robustness of our results, and are reported in the appendix of the working paper version of this paper.

B. Effects of Monetary Policy Shocks in the Euro Area in the 1988–2007 Period

Figures 1*a*–1*c* report the estimated impulse responses to an unexpected 100 basis point increase in the EA short-term interest rate. While the dark solid lines plot the responses of the variables in each country for the full sample of 1988–2007 along with the 90% confidence intervals (dotted lines), the dashed lines plot the responses for the post-EMU period starting in 1999. The figures plot in a column the responses of a particular variable. The first five plots in each column show the impulse responses in the EA, Germany, France, Italy, and Spain. The bottom two plots combine the responses for all countries in the two different samples. They reveal 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 plots in the first row. These plots show that faced with an unanticipated monetary tightening of 100 basis points, bond yields overall increase on impact by even more than 100 basis points, the EA real exchange rate appreciates by about 2% in the quarter of the shock and is expected to continue appreciating for more than 2 years, and the growth rate of the monetary aggregate M3 falls.

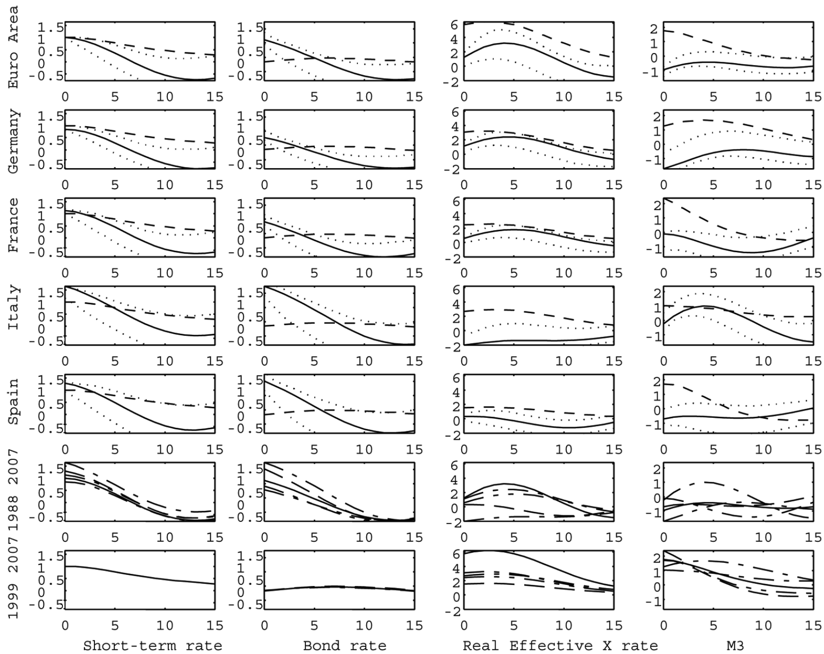

Fig. 1*a*. Impulse response functions to a monetary tightening in EA (shock equals 100 basis point increase in short-term rate; responses are expressed in year-over-year growth rates except for interest rates).

The real GDP yoy growth rate falls by about 1% after a year and a half and does not revert to a positive value before 3 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, investment, and exports.[16] The decline in overall economic activity is furthermore clearly reflected in a fall in employment reaching about 0.7% after 6 quarters and a subsequent increase in the unemployment rate. It is followed by a reduction in hourly earnings and in CPI inflation.

C. *Cross-Country Differences in the 1988–2007 Period*

The transmission of monetary policy disturbances on the EA just described, however, hides heterogeneity across the countries' responses. Looking at the other panels, we observe in figure 1*a* that a surprise increase in the EA short-term interest rate results in much larger interest rate increases in countries such as Italy and Spain than in the other

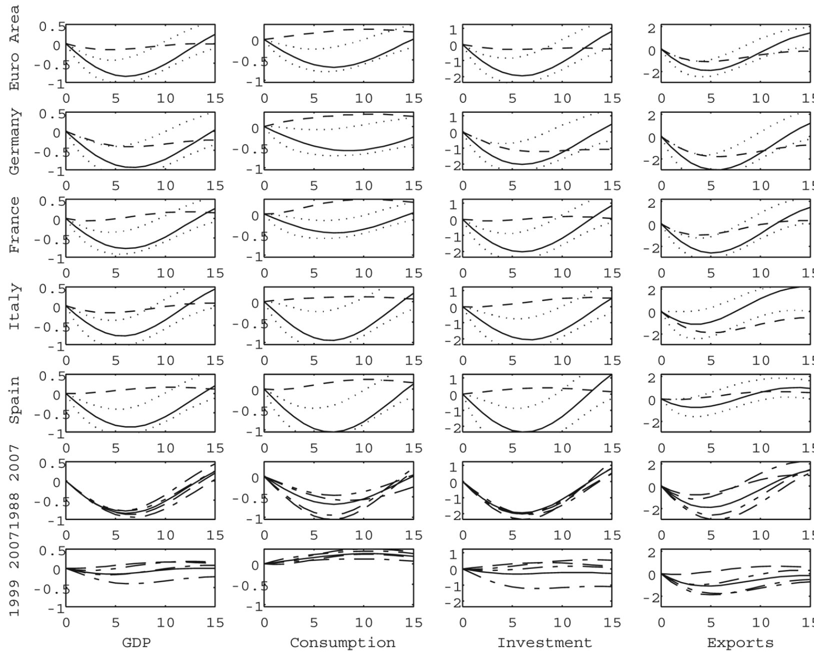

Fig. 1*b*. Impulse response functions to a monetary tightening in EA (shock equals 100 basis point increase in short-term rate; responses are expressed in year-over-year growth rates).

countries.[17] This heterogeneity gets amplified when looking at long-term yields. In fact, the Italian and Spanish bond yields rise almost twice as much as the yields of some other countries such as Germany, France, or the Netherlands.

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' currencies in the pre-EMU period. The Italian and Spanish real effective exchange rates depreciate on impact and in subsequent quarters, whereas the price levels remain unchanged in the period of the shock (figs. 1*a* and 1*c*).[18] Instead, all the other countries see their real exchange rates appreciate on impact and for several quarters after the shock, in response to the monetary tightening.

Following the increase in interest rates and the movements of the exchange rate, we observe a decline in the growth rate of GDP. While the GDP responses appear rather homogeneous across countries, the responses of GDP components are not. Importantly, consumption falls by about twice as much in Italy and Spain as in the other countries,

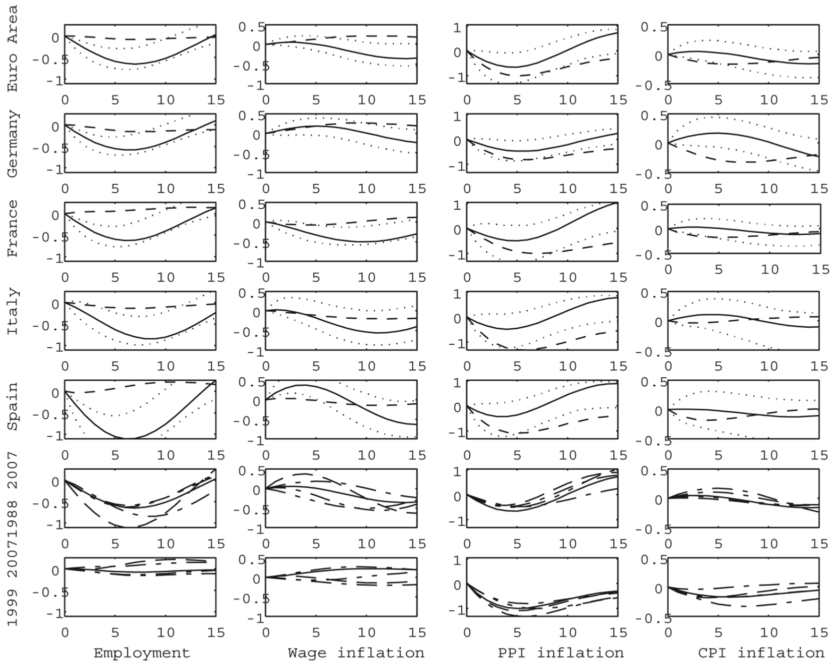

Fig. 1*c*. Impulse response functions to a monetary tightening in EA (shock equals 100 basis point increase in short-term rate; responses are expressed in year-over-year growth rates).

and investment also falls more. The depreciation of the Italian and Spanish real exchange rates, however, mitigates the fall in exports, thus contributing to a more homogeneous 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.

We note that the responses of CPI inflation reveal a temporary "price puzzle" in Germany and Italy following a tightening of the artificial EA interest rate. While the price increases may be explained in Italy by the exchange rate depreciation—a feature that the model we present below is able to replicate—the price increase in Germany is more difficult to rationalize. One possibility is that the artificial EA interest rate may not properly capture surprise monetary shocks for Germany. In fact, when we identify monetary shocks as surprise increases in the German interest rate, for the sample starting in 1988, we obtain almost no price puzzle for Germany (see the figures in the appendix of the working paper version). It is reassuring, however, that all other responses appear to be very similar to the ones reported in our benchmark specification in figures 1*a*–1*c*.

Finally, it should be stressed that the effects of interest rate shocks on M3 (as well as on M1) are quite different across countries. We have seen in Section III.E that the monetary aggregates are markedly more loosely related to the common factors than 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, among other things, 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).

As we noted, the responses that we have documented reveal much larger increases in interest rates and sharper drops in consumption in Italy and Spain than in the other EA countries. Italy, for instance, was subject to considerable speculative attacks in the early 1990s. That forced the Bank of Italy to increase short-term rates considerably more than, for example, in Germany, in order to defend its currency—thereby leading to a more important contraction of economic activity—until it had to abandon the ERM in September 1992. One might thus wonder whether the effects that we uncovered are due to this unusual event that was the crisis of the ERM. To investigate this question, we reestimated the impulse response functions for the entire sample, except that we excluded the observations from the third quarter of 1992 to the second quarter of 1993. We find that the responses of short- and long-term interest rates are almost identical to the one reported in figure 1*a*. The only notable difference is that the response of consumption is slightly smaller in all countries, but we still observe a much larger contraction of consumption in Italy and Spain than in the other EA countries. So the facts that we have documented do not appear to be simply an artifact of a few observations around the ERM crisis.

D. Has the Transmission Changed with the EMU?

To determine whether the monetary transmission has changed since the start of the EMU, we reestimate 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 emphasizing for the post-1999 period, again in the face of a 100 basis point 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. 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 Italy and Spain.[19]

Given the relatively small change in bond yields, measures of economic activity such as real GDP, consumption, and investment fall much less, if at all, in the EMU period. As a result, employment 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.[20] We illustrate this evolution by comparing in figure 2 the response of the long-term interest rate (dashed lines) to the response of an artificial long-term interest rate excluding a term premium (crosses). The latter is obtained by appealing to the expectations hypothesis and is computed as the average response of the short-term interest rate over the subsequent 28 quarters, that is, 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). The responses of these interest rates are represented in the lower right plot of figure 2 for the EA, but they are almost identical for all individual countries in the post-1999 period. Moreover, over the entire sample, 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 EA.

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 international trade. This may be an important feature of the new

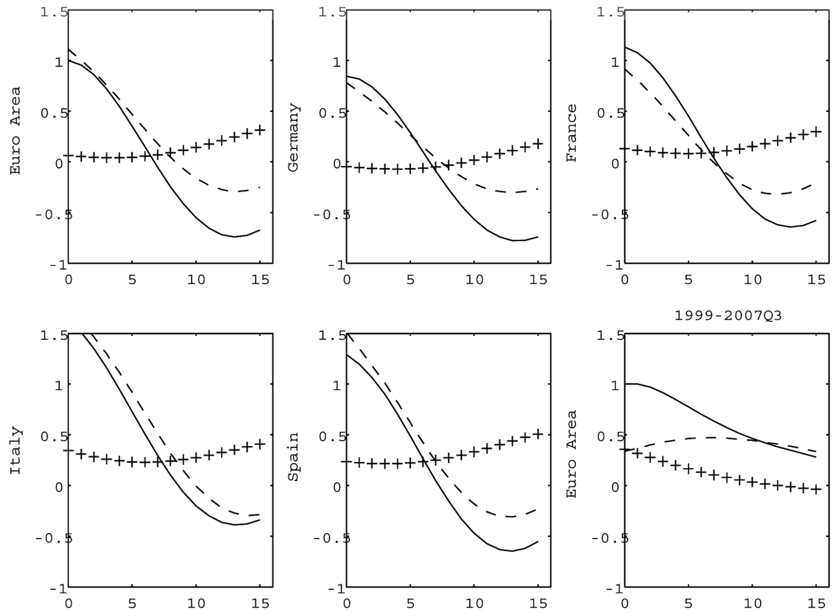

Fig. 2. Responses of short- and long-term interest rates to monetary shock in EA. First five subplots represent responses of interest rates in 1998–2007 sample. Bottom-right plot contains responses for EMU period. The solid line is the short-term interest rate, the dashed line is the bond yield, and the crossed line is the theoretical bond yield without term premium, based on the expectations hypothesis.

monetary policy regime characterized by more stable long-term interest rates and a sharper response of the EA-wide real exchange rate to monetary policy shocks.

Finally, the responses of several variables (some not reported) remain heterogeneous across countries in the EMU period. To name a few, the responses of M1 are twice as negative in Spain and Belgium as 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).

E. 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, and quarter-on-quarter growth rates, and we consider shocks to the German interest rate instead of the EA average interest rate.

Most of the results described above are robust. In particular, the larger response of the Italian and Spanish interest rates and of their consumption are common outcomes of all these alternative specifications when estimated over the full sample. Interestingly, Italy and Spain also stand out in response to an unexpected oil price increase, with Italian and Spanish bond yields increasing more than in the other countries of the EA and consumption falling more (see the appendix of the working paper version). This provides further evidence that bond markets and credibility issues may contribute to the different responses of European economies to various shocks prior to the EMU.

In all specifications considered, we observe a smaller response of consumption after 1999 than in the full-sample estimates, following a monetary tightening. However, the specification with quarter-on-quarter growth rates and several lags shows that, because of a large response of exports, GDP declines as much in the post-1999 period as in the full sample. These impulse response functions, however, are 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 1 carry through. As mentioned above, however, 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.

V. 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 increases in long-term bond yields, depreciations of the Italian and Spanish currencies (in both nominal and real terms), and 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 homogeneous 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 the differences in the transmission of monetary policy both across countries and over time. To do so, we use an open-economy DSGE monetary model along the lines of Clarida, Galí, and Gertler (2002), Obstfeld and Rogoff (2002, 2005), Altissimo, Benigno, and Rodriguez-Palenzuela (2004), Corsetti and Pesenti (2005), Benigno and Benigno (2006), Ferrero et al. (forthcoming), and others.[21] The specific variant considered here builds on the work of Ferrero et al. 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 rate movements.

We proceed by presenting the model. The model is explained in detail in Ferrero et al. (forthcoming), so we merely summarize it here, emphasizing the changes relative to their model. 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.

A. *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 contains a continuum of workers who supply labor to intermediate-goods firms. Each of these firms hires one worker and produces either tradable or nontradable goods that 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 that combine the differentiated intermediate goods into a homogeneous consumption good. In addition, to fit the evidence on imperfect pass-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.[22] 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 Ferrero et al. (forthcoming), 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.[23]

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 that 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 supranational authority—the ECB—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 Ferrero et al. (forthcoming) but similarly to Rotemberg and Woodford (1997) and Christiano et al. (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 do not respond contemporaneously to the monetary shock. In addition, we allow households to form habits in consumption and the firms that do not reoptimize their prices to index them to past inflation. Such deviations from Ferrero et al.'s model allow the model to generate responses of consumption and inflation to shocks that are more in line with the FAVAR estimates.

As a last departure from Ferrero et al., 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., Froot and Thaler 1990; Bekaert and Hodrick 1993; Engel 1996; Mark and Wu 1998; Rossi 2007) or conditionally on monetary policy shocks (Eichenbaum and Evans 1995; Scholl and Uhlig 2008). 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 the model of Ferrero et al.

1. Households

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

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

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; and $L_{kt}(f)$ represents hours worked by worker $f \in [0,1]$ in an intermediate-goods firm, in sector k, that is, either the home tradable sector H (with measure γ) or the domestic nontradable sector N (with measure $1-\gamma$). As in Ferrero et al. (forthcoming), the discount factor θ_t evolves according to $\theta_t = \beta_t\theta_{t-1}$ and $\beta_t \equiv e^{\xi_t}/[1+\psi(\log\bar{C}_t - \bar{\vartheta})]$, where $\bar{C}_t$ corresponds to the household's consumption level but is treated by the household as exogenous, and ξ_t is a preference shock.[24]

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

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

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:

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

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 CPI, which minimizes the cost of consumer expenditures, is given by

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

where the price of tradables is given by $P_{Tt} = [\alpha P_{Ht}^{1-\eta} + (1-\alpha)P_{Ft}^{1-\eta}]^{1/(1-\eta)}$. In the foreign country, we assume symmetric preferences, consumption aggregates, and price indices, which we denote by starred (*) variables and coefficients.[25]

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 been realized. The optimal allocation of (domestically and foreign-produced) tradable goods as well as nontradable goods then takes the usual form:

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

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

As in Ferrero et al. (forthcoming), 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

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

where I_{t-1} is the gross nominal interest rate in domestic currency between periods $t-1$ 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:

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

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

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

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

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

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; 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, that is, the amount of home currency needed in exchange for a unit of foreign currency. In contrast to Ferrero et al. (forthcoming) but as in McCallum and Nelson (2000) or Justiniano and Preston (2006), we introduce an exogenous term $e^{\mu_{t-1}}$ that 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's choice of consumption plans is also characterized by optimal conditions of the form (8) and (9). In addition, given that foreign citizens may hold bonds of both countries, they must be indifferent between holding home and foreign bonds. This results in the following UIP condition:

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

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

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

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

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 firms:

$$Y_{Ht}(f)=\gamma^{-1}\left[\frac{P_{Ht}(f)}{P_{Ht}}\right]^{-\theta}Y_{Ht},$$

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

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

$$Y_{kt}(f)=A_tL_{kt}(f),$$

where the total factor productivity term $A_t=Z_te^{a_t}$, $Z_t/Z_{t-1}=1+g$ describes trend productivity, and 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 in a staggered manner. 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 reoptimized, 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 that reset their price at date t, they all choose an optimal price $P_{k,t}^{o}$ that maximizes

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

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

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

Importing retailers. To model the imperfect pass-through found in the data, we assume that monopolistically competitive retailers import foreign tradable 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 reoptimized, it is indexed to lagged inflation in that sector, according to the rule (13). Since the problem is identical for retailers that 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 a foreign currency. The price index of imported goods in the domestic currency satisfies

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

3. Monetary Policy

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

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

$$i_t = \rho i_{t-1} + (1-\rho)(\phi_\pi E_t \bar{\pi}_{t+h} + \phi_y y_t + \phi_i i^*_t + \phi_e \Delta e_t) + \varepsilon_t, \qquad (14)$$

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 yoy 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 independently and identically distributed shock ε_t measures unexpected interest rate disturbances. The foreign central bank follows a similar rule:

$$i^*_t = \rho^* i^*_{t-1} + (1-\rho^*)(\phi^*_\pi E_t \bar{\pi}^*_{t+h^*} + \phi^*_y y^*_t + \phi^*_i i_t + \phi^*_e \Delta e_t) + \varepsilon^*_t, \qquad (15)$$

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

In the EMU regime, a single common short-term rate prevails, so that $i_t = i^*_t = i^{ea}_t$, 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 rates according to the interest rate rule

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

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

4. Equilibrium Characterization

To close the model, we use equilibrium conditions stating that the supply of tradable 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 $Q_t \equiv \mathcal{E}_t P_t^*/P_t$, are equal to one; inflation is equal to zero; and the real interest rate is equal to $(1 + g)/\beta$, where β is the steady-state value of β_t.

The log-linearized equilibrium conditions are described in the appendix of the working paper version.

B. 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 periods. 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 Obstfeld and Rogoff (2005) or Ferrero et al. (forthcoming) and use 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 did check that the model's predictions are not too sensitive to the chosen parameter values. However, as we will see below, coefficients of the policy rules do play an important role in the shape of the responses to various shocks.

1. Structural Parameters

As mentioned, most structural parameters are taken from Ferrero et al. (forthcoming) 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 growth is 2%. The steady-state discount factor β is set to 0.99. The parameters describing the evolution of the discount factor $\vartheta = -1,000$ and $\psi = 7.2361 \cdot 10^{-6}$ are chosen so that fluctuations in β_t have no noticeable implications on the economy dynamics.[26] The Frisch elasticity of labor supply is $\varphi^{-1} = 0.5$. The elasticity of substitution among intermediate goods $\theta = 11$ results 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 reoptimize their price to $\xi = \tilde{\xi} = 0.66$, corresponding to a mean duration between price reoptimizations of 3 quarters. Smets and Wouters (2002) find evidence that import prices display a degree of price stickiness similar to that of 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 Ferrero et al.

Ferrero et al. assume a log utility function of consumption and no habit persistence or inflation indexing. However, this yields 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.[27] 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 their estimates to calibrate the curvature of the utility of consumption and the degree of inflation indexing to, respectively, $\sigma = 1.37$ and $\delta = \tilde{\delta} = 0.47$.

2. Policy Rule Coefficients

We calibrate the policy rule coefficients for the home and foreign countries 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 1988–97, 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 has occurred over the past year. As the estimates are obtained using monthly data, we convert them for application to quarterly data.[28] We thus have $\rho = 0.79$, $\phi_\pi = 1.22$, $\phi_y = 0.30$, and $\phi_i = 0.41$ for Italy[29] and $\rho^* = 0.82$, $\phi_\pi^* = 1.41$, $\phi_y^* = 0.30$, and $\phi_i^* = 0$ for Germany. Angeloni and Dedola do not include a bilateral deutsche mark/lira exchange rate in their policy rules, but they include the dollar/deutsche mark exchange rate. Since we abstract from the world outside of the EA in the model, we assume that German monetary policy does not respond to the exchange rate ($\phi_e^* = 0$), whereas the annualized 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 generalized method of moments, similarly to Clarida et al. (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 $\phi_y^{ea} = 8.01$.[30] Nonetheless, we verify that our conclusions remain robust to smaller values of these coefficients.

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

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

We assume that μ_t follows an AR(1) process that 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 (2008). We assume that this wedge is very persistent, setting $\rho_\mu = 0.98$, and will consider different values of the parameter ν.

C. *The 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, the cross-country differences in responses as well as their changes with the introduction of the euro that we report in figures 1*a*–1*c*.

1. Pre-EMU Cross-Country Differences

Figures 3*a*–3*d* indicate the responses of key variables to an unexpected interest rate increase of 100 basis points in the foreign economy—which stands for Germany—in the case in which 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, reported in figures 1*a*–1*c*.

Figure 3*a* 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 $\mu_t = 0$). The unexpected increase in the foreign short-term rate is associated with a rise in the long-term rate and 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 (TOT, 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.

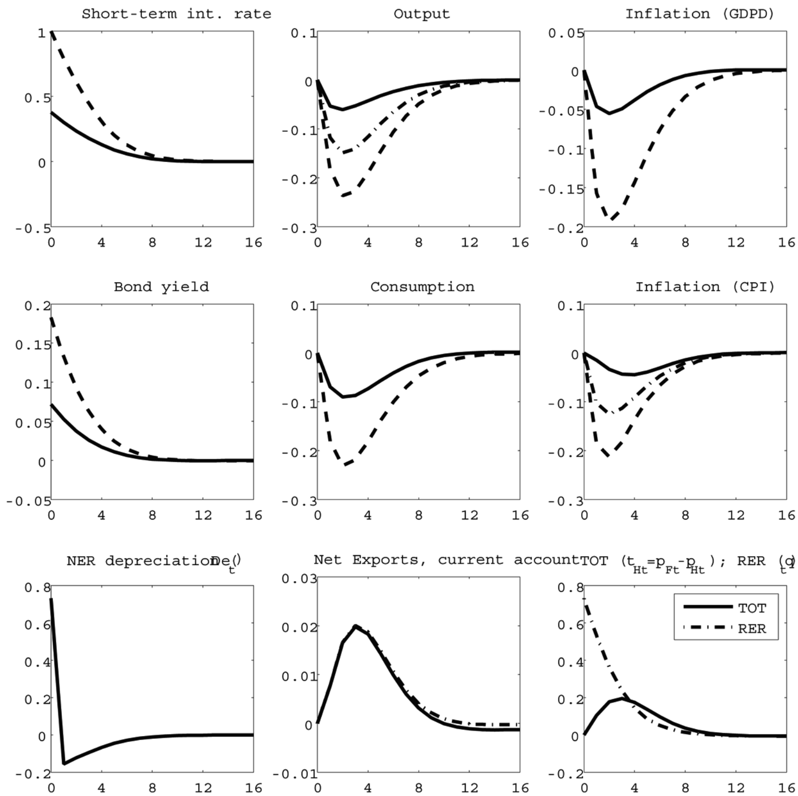

Fig. 3*a*. Model-based responses to a 100 basis point monetary tightening in a foreign country (pre-EMU, $\nu = 0$).

The response of home interest rates just described, however, is at odds with the interest rate responses that we had documented for countries such as Spain and Italy in figure 1*a*. 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 employment 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 3*c*, in the limit, as $\phi_e \rightarrow +1$, the nominal exchange rate is perfectly stabilized, and the

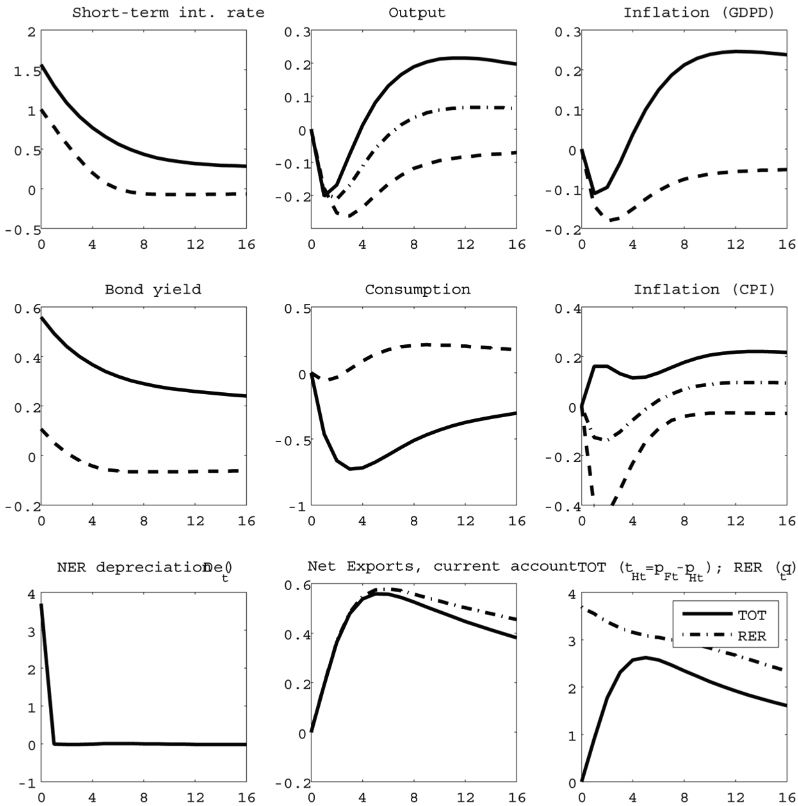

Fig. 3*b*. Model-based responses to a 100 basis point monetary tightening in a foreign country (pre-EMU, $\nu = 0.6$).

impulse responses, which are identical in both countries, thus correspond to those of a single closed economy.[31] In addition, changes in structural parameters do not generically modify the picture presented.

The basic version of the model cannot replicate the transmission of monetary policy observed in low-credibility regimes since long-term rates are tightly tied to expected future riskless short-term rates. One key parameter, however, that allows us to deviate from the standard case and seems to explain the stylized facts reported in figures 1*a*–1*c* is ν. Figure 3*b* reports the model-based responses of the same variables in the case $\nu = 0.6$. 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—since the wedge μ_t suddenly rises in response to an interest rate increase in the foreign country. This wedge suggests that in response to the foreign monetary shock, international investors

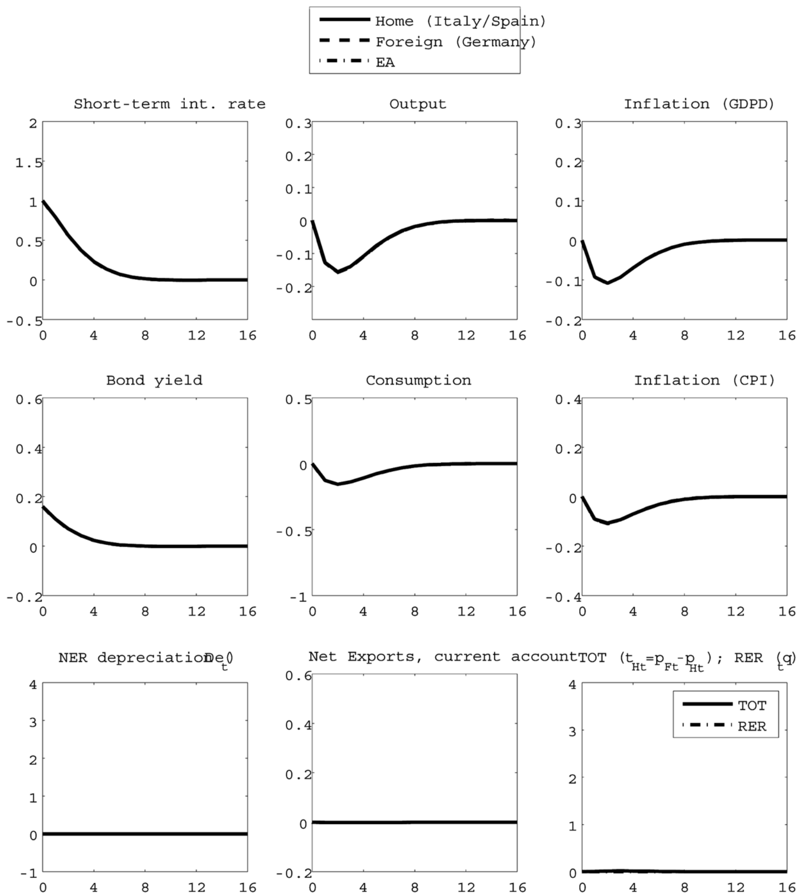

Fig. 3*c*. Model-based responses to a 100 basis point monetary tightening in a common area (monetary union case, $\nu = 0.6$).

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 above. In fact, in figure 3*b*, not only do short- and long-term rates respond more strongly at home than in the foreign country, but these interest rate responses also generate a larger drop in the home country consumption. As in the data, output falls less than consumption because 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.

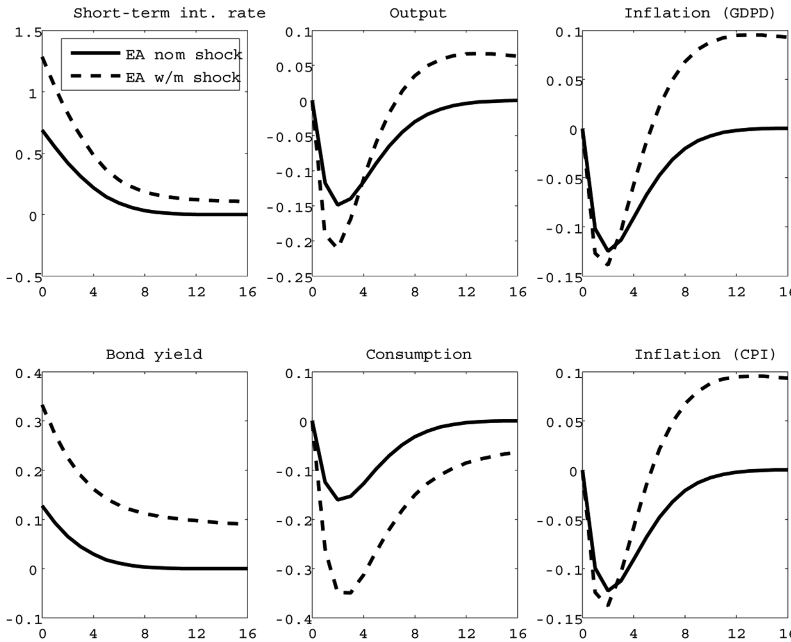

Fig. 3*d*. Model-based responses of aggregate EA variables to a 100 basis point monetary tightening in a foreign economy (solid lines: $\nu = 0$; dashed lines: $\nu = 0.6$).

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. This can explain an apparent "price puzzle" in the home country or in the area as a whole in response to monetary tightening.

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.

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 3*c* reports the responses of the same variables in the case of a

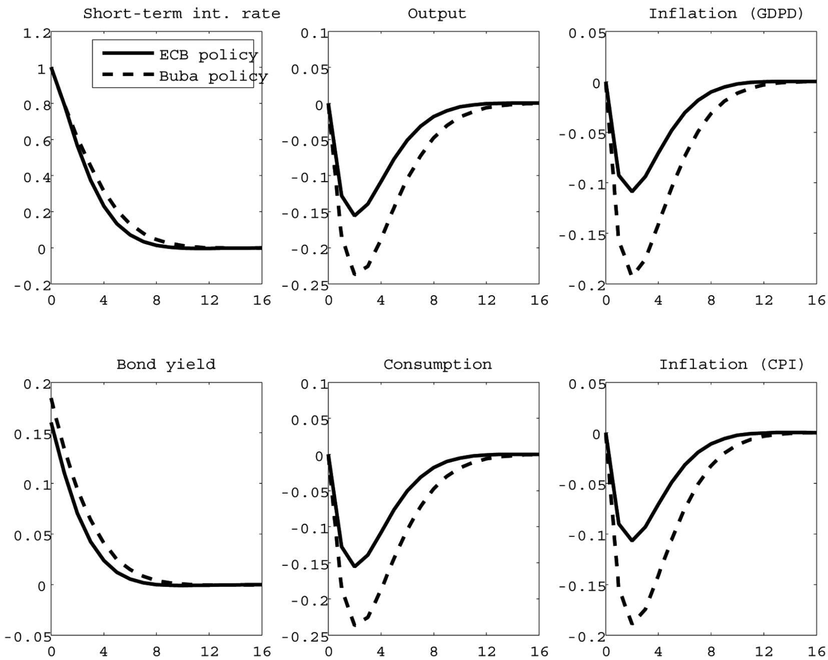

Fig. 3*e*. Model-based responses of EA variables to a 100 basis point monetary tightening in the EA under alternative policy rules (solid lines: ECB policy rule; dashed lines: Bundesbank policy rule).

monetary union, when monetary policy is conducted according to the estimated rule (16). Since both countries are symmetric in the calibration, they both respond identically to the EA interest rate shock.

Comparing figures 3*a*–3*b* on one hand with figure 3*c* on the other hand reveals important differences in the responses to an unexpected increase in the interest rate set by the foreign central bank in the pre-EMU regime and the common central bank in the EMU regime. The model predicts that the home economy benefits in many respects from participating to the monetary union in response to such a shock. In particular, when we remove exchange rate risks 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.

According to the model, removing exchange rate risks may have helped stabilize not only countries such as Italy and Spain but also the entire EA. To isolate the effect of the exchange rate risk, we report in figure 3*d* the model-based responses of the EA variables obtained by aggregating the home and foreign responses, following a monetary shock in the foreign country. The figure reveals that the responses of short- and long-term interest rates, output, consumption, and inflation are all more muted when we remove the risk premium shock μ_t.

The EMU has not only contributed to smaller responses by removing exchange rate risks. The model predicts that a monetary policy that has more consistently aimed at stabilizing inflation and output in the EA, since the start of the EMU, should result in a smaller observed response of aggregate economic activity and inflation to monetary shocks, as observed in the data. To illustrate this, figure 3*e* shows the model-based responses of EA variables to a monetary tightening (of 100 basis points) assuming two different policy rules: the one estimated for the ECB (solid lines) and the one estimated previously (by Angeloni and Dedola [1999]) for the Bundesbank (dashed lines). The figure indicates that stronger responses by the ECB to inflation and output fluctuations, essentially stemming from a very inertial rule, have resulted in smaller responses of economic activity and inflation. It is important to stress, however, that the smaller response of output and inflation is not due to the fact that the economy is less sensitive to monetary policy. All elasticities describing the behavior of the private sector, such as the intertemporal elasticity of substitution and so on, are maintained constant in this experiment. It is only the stronger commitment to inflation and output stabilization that results in such an outcome.[32]

VI. Conclusion

In this paper, we have provided an empirical characterization of the monetary transmission mechanism in 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 monetary shocks on all variables of interest, despite the fact that we have extremely short samples with a relatively stable regime.

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, which may be interpreted as a risk premium shock. 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 when an exchange rate risk has been removed through the monetary union and there is a central bank that is 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 rates have become much more effectively anchored in such countries since the start of the monetary union.

We have also found 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 EA common shocks and show more heterogeneous responses to monetary policy shocks than most other macroeconomic variables.

Appendix

Data Description

The data were extracted from Haver Analytics, and their source is either the OECD Main Economic Indicators or OECD Quarterly National Accounts databases. The sources for monetary aggregates are the national central banks for their respective countries and the ECB for the EA. 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 for some deflators in the EA. Missing data were backdated using yoy growth rates of an earlier vintage of OECD and ECB databases. Table A1 in the appendix of the working paper version gives a full account of the data used.

Endnotes

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1. At that date, the conversion rates of the national currencies of the Eurozone were fixed irrevocably, and a 3-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 have adopted the euro.

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

3. As long as a sufficient number of unobserved factors are included, the inclusion of oil price inflation as an observable factor should not affect our results. It does, however, allow us to identify oil price shocks and document their effects. We report such results in the appendix of the working paper version of this paper.

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

5. While alternative strategies to the estimation of factor models with a large set of indicators exist (see, among others, Forni et al. 2000; Kose, Otrok, and Whiteman 2003; Bernanke et al. 2005; Boivin and Giannoni 2006a; Doz, Giannone, and Reichlin 2007), the evidence suggests that they perform similarly in practice.

6. In contrast to the approach adopted here, Bernanke et al. 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 (forthcoming) and Boivin, Giannoni, and Mihov (forthcoming).

7. 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 $Y_t = [\pi_t^{\text{oil}}, R_t]'$ 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.

8. 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 Bernanke et al. (2005), the bootstrap procedure is such that (1) the factors can be resampled on the basis of the observation equation, and (2) conditional on the estimated factors, the VAR coefficients in the transition equation are bootstrapped as in Kilian (1998).

9. For a formal description of the link between the solution of a dynamic stochastic general equilibrium (DSGE) model in state space form and a VAR, see, e.g., Sims (2000) and Fernández-Villaverde et al. (2007). Boivin and Giannoni (2006a) establish formally the link between DSGE models and the FAVAR representation (1)–(2) in the context of a data-rich environment.

10. 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 et al. (2005). National accounts for the EA, published by Eurostat, start only in 1995.

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 (2006a) argue, e.g., that inflation is imperfectly measured by any single indicator and that it is important to use multiple indicators of it for proper inference.

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 1992–93, and the announcement of the parities between national currencies and the euro in May 1997.

14. For instance, Kose et al. (2003) and Stock and Watson (2005) study the comovement of output, consumption, and investment for a large panel of countries and for Group of 7 countries, respectively. Giannone and Reichlin (2006) analyze the comovement of output across EA countries. In addition, the ECB is carefully monitoring real and nominal heterogeneity across countries (Benalal et al. 2006).

15. Camacho, Peréz-Quirós, and Saiz (2006) argue, however, that the EA business cycle largely reflects the world business cycle.

16. Among the reponses not reported in the figures, the growth rate of M1 also falls, and the stock market drops by 10% on impact. Public consumption, however, remains unchanged for about a year and starts falling only after that.

17. The responses of the variables in Belgium and the Netherlands (not reported) are very similar to those of the EA and countries such as Germany and France but different from the responses in Italy and Spain. The responses of Belgium and the Netherlands are available from the authors on request.

18. 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 four quarters following the shock.

19. The real exchange rate response is larger for the EA than for each of the individual countries since 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.

20. This result is consistent with those 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.

21. For a larger-scale model, see, e.g., Faruquee et al. (2007).

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

23. In fact, macroeconomic models that successfully explain the behavior of investment often assume adjustment costs in investment (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 nondurable expenditures, we do abstract from the effects of investment on future production capacities.

24. This formulation of the discount factor incorporates—in the case in which 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 Ferrero et al. (forthcoming), 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 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).

25. One notable difference with respect to the home economy is that the foreign household consumption of tradable goods has the form

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

26. As mentioned above, the assumption of a variable discount factor is merely a technical device yielding a unique steady state.
27. The degree of habit persistence also proxies for investment adjustment costs in the case in which consumption expenditures include also investment expenditures.
28. 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.
29. Angeloni and Dedola's (1999) estimated policy rule for Spain is similar to that estimated for Italy.
30. 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 in the interest rate: $\Delta i_t^{ea} = 0.91 E_t \bar{\pi}_{t+2}^{ea} + 0.56 y_t^{ea} - 0.07 i_{t-1}^{ea} + \varepsilon_t^{ea}$.
31. Recall that our calibration is such that apart from the policy rules, the home and foreign economies are perfectly symmetric.
32. Boivin and Giannoni (2006b) argue that a stronger commitment to inflation stabilization in U.S. monetary policy since the early 1980s can similarly explain the observed reduction in estimated responses of inflation and output in the U.S. economy in the post-1980 period.

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