COLLEGIUM OF ECONOMIC ANALYSIS
WORKING PAPER SERIES

Central bank credibility, long-term yields and the effects of monetary integration

Marcin Kolasa and Dominik Supera

SGH KAE Working Papers Series Number: 2021/061 January 2021

Central bank credibility, long-term yields and the effects of monetary integration*

Marcin Kolasa[†]
Dominik Supera[‡]

Abstract

Forming a monetary union implies equalization of short-term interest rates across the member states as monetary policy is delegated to a common central bank, but also leads to integration of risk-free bond markets. In this paper we develop a quantitative open economy model where long-term bond yields matter for real allocations. We next use the model to shed light on the macroeconomic effects of convergence in bond prices within a currency union. Our focus is on a small open economy, where the pre-accession level of interest rates is high due to floating exchange rate and relatively low central bank focus on stabilizing inflation. We find that, from the perspective of social welfare in the country adopting a common currency, the benefits associated with lower long-term yields can outweigh the costs related to a loss of monetary independence.

JEL: E30, E43, E44, E52, F45
Keywords: monetary integration, bond yields, central bank credibility

*This project was financed by 6th research grant of Narodowy Bank Polski. The authors would like to thank Marek Jarocinski, Urban Jermann, Bartosz Mackowiak, Juan Rubio-Ramirez, Michał Rubaszek, Grzegorz Wesołowski and Amir Yaron for useful discussions and suggestions. The paper also benefited from comments of the participants to the CEF conference in Milan and a seminar at Narodowy Bank Polski.

[†]SGH Warsaw School of Economics; E-mail: mkolas(at)sgh.waw.pl.
[‡]Wharton School, University of Pennsylvania; E-mail: superad(at)wharton.upenn.edu.

1 Introduction

It is well understood that giving up monetary independence by entering a monetary union entails costs as the central bank of an accession country can no longer freely adjust the short-term interest rates to stabilize the local economy whenever its business cycle deviates from that observed in the rest of the common currency area. The experience of the Economic and Monetary Union (EMU) in Europe also shows that fixing credibly the exchange rate leads to the integration of bond markets across the euro-area countries. This process has been documented in a number of studies, see e.g. Cappiello et al. (2006) or Ehrmann et al. (2011), and we illustrate it in Figure 1 that plots the long-term yields on government bonds issued by the euro area countries. The speed and extent of convergence in yields in the run-up to the euro adoption was remarkable, and resulted in a sharp drop in the long-term interest rates for countries like Greece, Italy, Portugal or Spain. The yields diverged again during the Great Recession only when sovereign debt of some debt-ridden EMU countries ceased to be considered risk-free.

In fact, if one abstracts away from default and liquidity risk or some form of preferred habitat, unification of the bond markets across the countries forming a monetary union is not surprising as bonds issued by the member states are denominated in the same currency and hence there is no reason for the financial investors to price them differently. It is also important to note that, since the short term interest rate in a common currency area is set at the same level for all member countries, convergence in long-term rates related to monetary integration also implies convergence in the term premia.

We argue that these aspects of monetary integration have not yet received much of attention from the literature that attempts to evaluate the costs and benefits of setting up a monetary union using structural macroeconomic models. Most of the related studies focus on the costs of relinquishing monetary independence by relying on setups that abstract away from bond prices and hence cannot capture the effects of convergence in long-term rates and term premia.[1] This paper aims to fill this gap. We focus on the EU new member states from Central and Eastern Europe (CEE) that still pursue independent monetary policy, but are obliged to eventually adopt the euro. The long-term interest rates in these countries are consistently above those observed in the euro area. These economies have also a relatively short history of stable inflation and fairly volatile exchange rates. Hence, in their case, fixing the exchange rate and delegating the monetary policy to a central bank of bigger reputation can decrease inflation risk and lower long-term yields, which could have positive impact on social welfare.

[1]The literature that uses micro-founded models to quantitatively evaluate the welfare costs of fixing the exchange rate includes, among others: Schmitt-Grohe and Uribe (2001), Kollmann (2002), Carre and Collard (2003), Gali and Monacelli (2005) and Lama and Rabanal (2014). The following papers look at this issue from the perspective of EU new member states: Ca'Zorzi et al. (2012), Gradzewicz and Makarski (2013), Ferreira-Lopes (2014).

We start our analysis with an empirical investigation of the effects of euro adoption on the long-term interest rates and risk premia in the EU new member states. Using a difference in difference approach on a sample of countries that have already adopted the common currency and those that are still outside the euro area, we document a significant effect of entering the Eurozone, both on the long-term yields and term premium. We next develop a macroeconomic model to analyze if the macroeconomic effects of long-term interest rate convergence after fixing the exchange rate can compensate the loss of monetary autonomy. The model can be thought of as a two-country extension of the New Keynesian macro-financial setup considered by Andreasen et al. (2016). Its key feature is the presence of financial intermediaries that trade short and long-term risk-free bonds subject to a preferred habitat constraint. Since private agents cannot access the bond markets directly, their consumption and investment decisions depend not only on the current and expected future paths of the short-term interest rates, but also on long-term yields, and hence on the term premia. Consequently, and unlike in the standard macro-financial setup without frictions in financial intermediation (see e.g. Rudebusch and Swanson, 2012), the amount of risk in the economy has non-trivial effects on real allocations. Since forming a monetary union implies convergence of bond yields between the member states, the proposed framework allows us to capture the effect of this process on key macroeconomic aggregates and social welfare.

We present the quantitative implications of our model by taking the perspective of a small economy that is bound to join a large monetary union. To this end, we estimate our two-country model to Poland and the euro area under a floating exchange rate regime. We document a reasonable degree of success in matching the key moments observed in the data. We next compare the allocations before and after adopting the euro. We find that social welfare in Poland is higher in the latter case, despite increased volatility of output and consumption, and the gains are sizable. These gains are related to import of credibility as the common monetary policy responds more aggressively to deviations of inflation from the target than does the Polish monetary authority, but also to integration of bond markets since, after Poland adopts the euro, foreign financial investors are no longer exposed to risk associated with asymmetric interest rate movements and volatility of the bilateral exchange rate. In the case of Poland, this means a decrease in the short and long-term rates to the levels observed in the euro area. Overall, our results indicate that for an economy where the nominal interest rates are relatively high, the benefits associated with entering a common currency area might well outweigh the costs related to a loss of monetary independence.

The rest of this paper is structured as follows. Section two offers an empirical analysis on the effects of monetary integration on bond yields and risk premia. Section three introduces the macroeconomic model and section four presents its estimation. The model-based implications for the effects of monetary integration are discussed in section five. Section six concludes.

2 Bond prices and monetary integration: empirical evidence

In this section we present empirical evidence on the effect of euro adoption on long-term yields and term premium in the EU new member states. We use a sample of the current euro area members (Latvia, Lithuania, Slovakia and Slovenia), as well as those countries in the region that are still outside of the Eurozone (Czech Republic, Bulgaria, Poland and Romania), treating the latter as a control group.[2] The sample period spans from January 2003 to December 2015. Because of bond price data availability, for some countries the sample starts later, but for all four current euro area members we have data both well before and after the euro adoption.[3] We use daily bond prices collected from Bloomberg. We consider actively traded bonds issued by the central government in local currency, with fixed or no coupon, and with fixed maturity (perpetual bonds, variable coupon bonds, inflation-linked bonds are not included). In order to reflect a sufficient market depth, the residual maturity brackets have been fixed as ranging from 3 months up to 30 years.

If the governments issued a full spectrum of zero-coupon bonds every day, we could observe the yield curve on the market. However, this is not the case since the number of issued bonds is very limited and includes mostly coupon bearing bonds. Therefore, there is a need for a yield curve model to infer spot rates from prices of the existing bonds. In our analysis, we use the method developed by Nelson and Siegel (1987).[4] The zero-coupon yield-curve estimates are then used as an input to decomposing the long-term yields into the sum of the compounded expected future short-term interest rates over the maturity of a bond, and a risk (or term) premium that compensates investors for the uncertain return on holding the bond. These two components are not directly observable, and affine models of the term structure of interest rates are usually used in the literature to extract them. In our analysis, we use a 5-factor regression-based approach developed by Adrian et al. (2013).

Figure 2 presents the estimated yield-to-maturity for a 10-year sovereign bond of the CEE countries and Germany. The current euro area members are plotted with solid lines while dashed lines are used for the remaining economies. The yields are strongly correlated over our sample period and many CEE countries exhibit a high level of synchronization of their

[2]We exclude from our sample Hungary and Estonia. In the case of Estonia, the number of outstanding bonds is not sufficient to estimate the Nelson-Siegel model that we use to fit the term structure of interest rates. For Hungary, we have experienced technical problems in estimating the Nelson-Siegel model (large volatility of bond yields at short maturities and problems with convergence).

[3]The data for Latvia start in July 2012, for Lithuania in October 2012, for Bulgaria in December 2005, for Romania in April 2011 and for Slovenia in May 2009. The dates of the euro area accession are: Latvia – Jan 2014, Lithuania – Jan 2015, Slovakia – Jan 2009, Slovenia – Jan 2007.

[4]More refined methods that potentially improve the flexibility of the estimated yield curves and the data fit are available in the literature, see e.g. Svensson (2003), BIS (2005) or Gurkaynak et al. (2007). We opt for Nelson and Siegel (1987) as we deal with data in which there are periods of limited number of tradable bonds, in which case the most parsimonious approach is recommended.

long-term rates with Germany. The lowest correlation with German yields can be observed in Bulgaria and Slovenia (correlation coefficient of about 0.5), while for the remaining countries the coefficient is at least 0.8 (0.9 for the Czech Republic). The yields have been showing a downward trend as from at least 2012. It is important to note, however, that for all CEE countries the long-term interest rates are visibly above those observed in Germany.

Our estimates of the term premium on 10-year bonds are plotted in Figure 3. Although we are not showing it on the graph, it should be stressed that the Adrian-Crump-Moench model fits our data extremely well for all the sample countries, allowing us to decompose the yields without concerns about measurement error. Similarly to yields, the term premia are highly correlated and have been trending downwards since about 2012. Interestingly, the premia in CEE countries are not always higher than in Germany. In particular, over most of our sample period the term premium in Poland was markedly below that estimated for Germany and the difference between them turned negative only recently.[5]

We next check to what extent the observed cross-country differences between the yields and premia in CEE countries can be related to the euro area membership. To this end, we perform a difference-in-difference analysis, where we compare the long-term yields and term premia in the CEE countries before and after their accession to the EA. As a control group we use the economies that have not yet joined the common currency area, i.e. Bulgaria, the Czech Republic, Poland and Romania. The baseline panel regression model that we estimate using monthly data is

$$Y_{i,t} = \alpha_i + \alpha_t + \alpha_{ea} EA_{i,t} + \alpha_{cds} CDS_{i,t} + \varepsilon_{i,t} \tag{1}$$

where the dependent variable $Y_{i,t}$ is the 10-year yield or term premium for country i at time t, α_i are country fixed effects, α_t are time fixed effects, $EA_{i,t}$ is the dummy variable which equals unity when country i is a member of the euro area at time t and zero otherwise, $CDS_{i,t}$ is the 5-year credit default swap spread (source: Bloomberg), and $\varepsilon_{i,t}$ is the error term. The main coefficient of interest is α_{ea} that measures the effect of euro adoption, and the inclusion of credit default swaps in the regression is aimed to control for sovereign default risk. As a robustness check, we also run a regression in which the euro area dummy EA_{it} is replaced with a dummy variable $ERM_{i,t}$ indicating either euro area membership or participation in the European Exchange Rate Mechanism (ERM).[6]

[5]See Jabłecki et al. (2016) for more discussion of these developments. It also needs to be stressed that the presented estimates of the term premia in CEE countries might not be as robust as those obtained for economies where longer time series are available. Our experiments with an alternative approach developed by Bauer et al. (2012) give support to this concern. This means that our regression analysis presented below should be treated with caution whenever the term premia estimates are used as a dependent variable. However, it has to be stressed that key to this paper's results are not the developments observed in the term premia, but long-term yields, for which concerns about measurement can be considered minor.

[6]The following countries in our sample participated in the ERM: Latvia (July 2012 – December 2013), Lithuania (October 2012 – December 2014) and Slovakia, for which we take into account only the period when

Table 1 presents the regression outcomes for long-term yields. We find a significantly negative effect of euro area membership of about 20 bps or about 30 bps if we control for sovereign default risk. This effect becomes insignificant for the ERM dummy, indicating that entering the Eurozone is more than just fixing or strongly limiting the fluctuations of the currency against the euro. Table 2 shows the results for the term premium. The effect of euro adoption is even more significant than for yields, amounting to about 55 bps irrespective of whether we control for country default risk or not. It is also worth mentioning that in all CEE economies that have joined the euro area, the term premium at the moment of entry was higher than in Germany. This means that adopting the euro by this group of countries was followed by significant convergence in their term premia towards the levels observed in the Eurozone. Finally, and in contrast to the regressions for yields, the results obtained with the ERM dummy are now significant and not very different in magnitude from the baseline specification.

We conclude that the empirical evidence is consistent with significant effects of euro adoption on bond prices in the CEE region. Countries that decide to enter the Eurozone can expect significant convergence of their long-term interest rates to the levels observed in the rest of the common currency area, which may have important effect on welfare and potentially impact the outcomes of the cost-benefit analysis of giving up monetary independence.

3 Model

We consider a two-country model, with the world population normalized to unity and the relative size of the home economy $\omega_H \in [0;1]$. Each country is populated by households, several types of firms, as well as fiscal and monetary authorities. Problems faced by these agents are fairly standard in the New Keynesian literature, except that we assume recursive preferences as in Epstein and Zin (1989) to help the model match the level and volatility of the bond risk premia. An important feature of the model is the presence of financial intermediaries, owned by foreign households and transmitting bond prices to private agents. As our model can be considered an open economy extension of Andreasen et al. (2016), we follow closely the notation used in their paper, denoting variables related to the foreign economy with an asterisk.

3.1 Households

Preferences of a representative household in the home economy are defined recursively using the formulation of the value function V_t proposed by Rudebusch and Swanson (2012)

the Slovak koruna was fluctuating against the euro within the narrow (1.9%) band (June 2008 – December 2008).

$$V_t = \begin{cases} u_t + \beta \left(\mathbb{E}_t \left[V_{t+1}^{1-\phi_3} \right] \right)^{\frac{1}{1-\phi_3}}, & u_t > 0 \\ u_t - \beta \left(\mathbb{E}_t \left[(-V_{t+1})^{1-\phi_3} \right] \right)^{\frac{1}{1-\phi_3}}, & u_t < 0 \end{cases} \tag{2}$$

where period utility u_t depends on consumption c_t , labor effort h_t and preference shocks d_t as follows

$$u_t = \frac{d_t}{1-\phi_2} \left(\left(\frac{c_t - bc_{t-1}}{(\mu^*)^t} \right)^{1-\phi_2} - 1 \right) + \phi_0 \frac{(1-h_t)^{1-\phi_1}}{1-\phi_1} \tag{3}$$

In the formulas above, β is the subjective discount factor, b is the degree of habit formation, ϕ_0 controls the relative weight of leisure in utility, ϕ_1 and ϕ_2 describe the curvature of period utility with respect to labor and consumption, ϕ_3 controls the level of risk aversion and μ^* is the steady state (gross) rate of the world-wide technological progress.[7] Note that for $\phi_3 = 0$ we obtain the standard expected utility formulation.

Home households face the following real budget constraint

$$c_t + \frac{i_t}{(\mu_\Upsilon^*)^t} + b_t + f_t b_t^* + t_t = w_t h_t + r_t^k k_t + \frac{b_{t-1} \exp\{r_{t-1}^b\}}{\pi_t} + f_t \Gamma_{t-1} \frac{b_{t-1}^* \exp\{r_{t-1}^{b*}\}}{\pi_t^*} + div_t \tag{4}$$

where b_t and b_t^* are holdings of one-period deposits (or credit) in the financial intermediary, denominated in the domestic and foreign currency, respectively, with the nominal risk-free rates of return r_t^b and r_t^{b*},[8] w_t denotes the wage rate, r_t^k is the rental rate on capital k_t, t_t stands for lump sum taxes, div_t are dividends, $\pi_t \equiv P_t/P_{t-1}$ is (gross) inflation of final goods prices, $f_t \equiv F_t P_t^*/P_t$ is the real exchange rate, with the nominal exchange rate F_t defined as the home currency price of one unit of foreign currency.

Household optimization is additionally subject to the capital accumulation constraint

$$k_{t+1} = (1-\delta)k_t + i_t - \frac{\kappa}{2} \left(\frac{i_t}{k_t} - \psi \right)^2 k_t \tag{5}$$

where κ controls the magnitude of capital adjustment costs and ψ is a constant guaranteeing that these costs are zero on the balanced growth path.

The problem of foreign households is analogous, except that they have access to bonds denominated only in their own country's currency. This assumption simplifies the model

[7] More precisely, $\mu^* \equiv (\mu_\Upsilon^*)^{\frac{\theta}{1-\theta}} \mu_z^*$, where μ_Υ^* and μ_z^* are the (deterministic) growth rates of investment-specific and labor-augmenting technological progress, respectively, and θ is the capital share in production. See Greenwood et al. (1997) for derivations. The habit-adjusted consumption in the period utility formula (3) is normalized by the deterministic trend in the economy $(\mu^*)^t$ to impose the existence of a balanced growth path.

[8] As in Schmitt-Grohe and Uribe (2003), the return on foreign currency bond holdings is additionally affected by the risk premium factor $\Gamma_t \equiv 1 + \gamma(\exp\{-f_t b_t^*/y_t\} - 1)$, where y_t is home economy's aggregate output to be defined later. The risk premium is introduced only to induce stationarity of the model. As we will see later, the estimated value of γ is very low so that it does not significantly affect the model dynamics.

solution and can be justified by the fact that we treat (and later calibrate) the foreign country as large so that it can be essentially considered a closed economy.

3.2 Financial intermediaries

Perfectly competitive financial intermediaries intermediate between households and the market of short-term and long-term bonds denominated either in the home or foreign currency. For simplicity, we assume that short-term bonds are one-period, while the long-term bond maturity is a fixed number $L > 1$. We abstract away from any type of credit risk, so the bonds can be thought of as issued by credibly solvent governments of the two countries.

Financial intermediaries pay the interest on deposits accepted from households that is equal to the expected one-period rate of return on their bond portfolio of a given currency. We also assume that financial intermediaries face a form of preferred habitat constraint so that their home (foreign) currency portfolio consists of a constant fraction ω (ω^*) of long-term bonds, with the remaining funds allocated in short-term bonds. This parameter can also be thought of as a reduced-form way of capturing the extent to which agents' intertemporal choices depend on the long-term rates and the risk premium they include. The interest rate offered to households is then

$$r_t^b = (1-\omega)r_t + \omega\mathbb{E}_t\left[\log P_{L-1,t+1} - \log P_{L,t}\right] \tag{6}$$

$$r_t^{b*} = (1-\omega^*)r_t^* + \omega^*\mathbb{E}_t\left[\log P^*_{L-1,t+1} - \log P^*_{L,t}\right] \tag{7}$$

where r_t (r_t^*) is the home (foreign) short-term interest rate while $P_{L,t}$ ($P^*_{L,t}$) is the period t nominal price of a home (foreign) currency bond maturing in period $t+L$.

Since financial intermediaries are owned by foreign households,[9] they price bonds using their stochastic discount factor so that (for $k = 2, 3, ...$)

$$P_{k,t} = \mathbb{E}_t\left[\beta^* \frac{\lambda^*_{t+1}}{\lambda^*_t}\frac{1}{\pi_t}\frac{f_t}{f_{t+1}}P_{k-1,t+1}\right] \tag{8}$$

$$P^*_{k,t} = \mathbb{E}_t\left[\beta^* \frac{\lambda^*_{t+1}}{\lambda^*_t}\frac{1}{\pi^*_t}P^*_{k-1,t+1}\right] \tag{9}$$

where λ_t^* is the marginal utility of (habit-adjusted) consumption of foreign households, and the prices of one-period bonds are $P_{1,t} = \exp\{-r_t\}$ and $P^*_{1,t} = \exp\{-r^*_t\}$.

The continuously compounded yield to maturity can be obtained using the formula

$$r_{k,t} = -\frac{1}{k}\log P_{k,t} \tag{10}$$

[9] This assumption reflects the fact that a large share of the financial sector (and banks in particular) in the CEE countries is foreign-owned, and the bond markets are open to foreigners.

Following Rudebusch and Swanson (2012), we define the term premium as the difference between the actual and risk-neutral yield

$$TP_{k,t} = r_{k,t} - \tilde{r}_{k,t} \tag{11}$$

where

$$\tilde{r}_{k,t} = -\frac{1}{k}\log \tilde{P}_{k,t} \tag{12}$$

and

$$\tilde{P}_{k,t} = \exp\{-r_t\}\mathbb{E}_t\left[\tilde{P}_{k-1,t+1}\right] \tag{13}$$

The formulas for yields and term premium on foreign bonds can be obtained analogously.

3.3 Firms

Several types of firms operate in each economy. Perfectly competitive aggregators sell final goods at price P_t, producing them with the following CES technology

$$\tilde{y}_t = \left(\varpi^{\frac{1}{\nu}} y_{H,t}^{\frac{\nu-1}{\nu}} + (1-\varpi)^{\frac{1}{\nu}} y_{F,t}^{\frac{\nu-1}{\nu}}\right)^{\frac{\nu}{\nu-1}} \tag{14}$$

where ϖ controls the home bias and ν is the elasticity of substitution between home and imported goods. These are combined at the previous stage of production from intermediate varieties indexed by i according to

$$y_{H,t} = \left[\int_0^1 y_{H,i,t}^{\frac{\eta-1}{\eta}} \mathrm{d}i\right]^{\frac{\eta}{\eta-1}} \tag{15}$$

$$y_{F,t} = \left[\int_0^1 y_{F,i,t}^{\frac{\eta-1}{\eta}} \mathrm{d}i\right]^{\frac{\eta}{\eta-1}} \tag{16}$$

where η is the elasticity of substitution between individual varieties.

The intermediate inputs are produced by monopolistically competitive firms that use the Cobb-Douglas production function

$$y_{H,i,t} + y^*_{H,i,t} = a_t k_{i,t}^{\theta}[(\mu^*)^t h_{i,t}]^{1-\theta} \tag{17}$$

to supply domestic and foreign markets, where a_t is a productivity shock. The profit maximization by these firms is subject to the demand sequences consistent with optimization performed by final goods producers. Additionally, each intermediate goods producer faces a Calvo price rigidity so that with exogenous probability $1-\alpha$ it is allowed to reoptimize its price $P_{H,i,t}$, which is otherwise equal to its previous period level. We assume that the law of one price holds, i.e. $P^*_{H,i,t} = P_{H,i,t}/F_t$.

The production structure and optimization problems in the foreign country are analogous.

3.4 Monetary and fiscal authorities

The fiscal authority collects taxes from households and issues public debt to finance purchase of final goods. Government spending is assumed to fluctuate around its balanced growth path subject to stochastic shocks g_t. Since the Ricardian equivalence holds in the model, there is no need to specify the details of the government financing decisions.

The home monetary authority controls the short-term nominal interest rate, setting them according to a Taylor-like rule

$$r_t - r_{ss} = \rho_r(r_{t-1} - r_{ss}) + (1 - \rho_r)\left(\beta_\pi \log\left(\frac{\pi_t}{\pi_{ss}}\right) + \beta_y \log\left(\frac{y_t}{(\mu^*)^t Y_{ss}}\right)\right) \tag{18}$$

where ρ_r controls the degree of interest smoothing while β_π and β_y are the feedback coefficients to deviations of, respectively, inflation from the target π_{ss} and output from its balanced growth path $(\mu^*)^t Y_{ss}$, with Y_{ss} denoting aggregate output in the normalized steady state.

The foreign central bank follows a feedback rule of the same functional form. When we consider a monetary union, country-specific rules are replaced with a common one that responds to the area-wide inflation and output, both calculated using the country weights.

3.5 Market clearing

We impose a standard set of market clearing conditions. In particular, clearing of the final goods market implies

$$\tilde{y}_t = c_t + \frac{i_t}{\Upsilon^t} + (\mu^*)^t g_t \tag{19}$$

and the aggregate resource constraint can be written as

$$y_t s_t = a_t k_t^\theta [(\mu^*)^t h_t]^{1-\theta} \tag{20}$$

where $s_t \equiv \int_0^1 \left(\frac{P_{H,i,t}}{P_{H,t}}\right)^{-\eta} \mathrm{d}i$ is the price dispersion index and $P_{H,t}$ is the price of $y_{H,t}$ (and of $y^*_{H,t}$ as the law of one price holds) consistent with optimization by final goods producers.

Similar market clearing conditions hold for the foreign economy. The evolution of the home economy's net foreign assets position can be written as

$$f_t b^*_t = f_t \Gamma_{t-1} b^*_{t-1} \frac{\exp\{r^{b*}_{t-1}\}}{\pi^*_t} + y_t - \tilde{y}_t \tag{21}$$

3.6 Exogenous shocks

The model economies are driven by three pairs of stochastic shocks commonly used in DSGE models. These are the domestic disturbances to technology a_t, household preferences d_t and government spending g_t, as well as their foreign counterparts a_t^*, d_t^* and g_t^*. As in Andreasen et al. (2016), shocks to technology and government spending follow independent AR(1) processes while preference shocks are assumed to be white noise.

4 Estimation

We estimate the model parameters to match a number of key macroeconomic and financial moments in the data for Poland (home economy in the model) and the euro area (foreign economy). The sample period is 2002Q1-2016Q1. We estimate the model using the Simulated Method of Moments (SMM). In this procedure, we minimize the weighted sum of squared distances between the selected empirical and model-implied moments generated by the third-order approximation of the model around the deterministic steady state. This level of approximation is necessary for the model to generate variable excess returns on long-term bond holdings.[10]

Similarly to Andreasen et al. (2016), we use the following quarterly time series to estimate our model: GDP growth, consumption growth, investment growth, inflation, 3-month nominal yield, 10-year nominal yield, 10-year term premium, and the ratio of government spending to GDP.[11] In the estimation procedure, we test whether the model is able to match the means, standard deviations, autocorrelations of order one, contemporaneous correlations of the observable series of the same country, and correlations between the same variables of the two countries. We impose a unit weight on the means and standard deviations, and a weight of 0.5 on the autocorrelations and correlations.

As it is standard in the literature, some parameter values are chosen outside of the estimation procedure and reported in Table 3. Unless stated otherwise, these calibrated parameters are kept symmetric between the two model economies. We set the relative size of the small country (Poland) equal to 3%, which is consistent with GDP data for the euro area and Poland. The home bias parameter for the home country ϖ is set to 0.75, in line with the average share of imports in Polish GDP, corrected for the import content of

[10]For details on the SMM procedure, see for example Ruge-Murcia (2012). To calculate the moments at each estimation step, we use stochastic simulations. The model is simulated for 11,000 periods, starting from the deterministic steady state, and the first 1,000 observations are dropped. This proved to be much more time efficient than relying on analytical formulas derived by Andreasen et al. (2016) or on the non-linear moving average representation of Lan and Meyer-Gohde (2013). We later verify that the moments obtained with our simulations are similar to those obtained with these two approaches.

[11]Data on GDP and its components are taken from the national accounts (ESA 2010) statistics provided by Eurostat. Inflation is the Harmonized Index of Consumer Prices obtained from Eurostat. The 3-month and 10-year rates as well as the term premium are estimated as described in Section 2.

exports estimated by the OECD. Assuming that the difference in home bias between the two model economies results only from their different size implies the steady state share of imports in the euro area ϖ^* of 0.008 so that it is essentially a closed economy. The elasticity of substitution between home goods and imports ν is set to a conventional value of 1.5. Following the literature, we calibrate the capital share in the production function θ at 0.36 and the elasticity of substitution between intermediate varieties η at 6, the latter implying an average markup of 20%. The weight on leisure in utility ϕ_0 is adjusted at every stage of the estimation procedure such that it guarantees the steady state share of time devoted to labor of about one-third. We also fix the Frisch elasticity of labor supply at 0.5, which implies ϕ_1 equal to 4.

The remaining model parameters are estimated within the SMM procedure and the estimation results are summarized in Table 4. To ensure a well defined and non-degenerate steady state, during estimation we restrict the following parameters to be the same in both countries: household discount factor β, curvature of the (habit-adjusted) consumption component of utility ϕ_3, and fraction of long-term bonds in the portfolio of financial intermediaries ω. Since Poland is a catching-up economy that has been growing at a significantly higher rate than the euro area in our sample, we also include and estimate additional intercepts in the measurement equations for the mean growth in output, consumption and investment in this country, restricting them to be equal for the first two variables, in line with the balanced growth property embedded in the model.

Despite not imposing any prior assumptions, the estimated values of the parameters controlling the degree of nominal and real rigidities are very similar to those found in the DSGE literature employing Bayesian methods, with the degree of habit persistence, investment adjustment costs and price stickiness lower in Poland than in the euro area. The estimated relative risk aversion is higher than found in the microeconomic literature (Barsky et al., 1997), but significantly below values providing best fit in macro-financial models without the feedback from long-term bond prices to the rest of the economy (Rudebusch and Swanson, 2012). A higher value of this coefficient and of the intertemporal elasticity of substitution in Poland can be almost entirely attributed to differences in the habit persistence. Importantly for our results, there are significant differences in the monetary policy rules of the two countries, with the euro area featuring significantly stronger feedback to deviations of inflation from its steady state level. As in Andreasen et al. (2016), we obtain a very high weight of long-term bonds in financial intermediaries' portfolio.

As evidenced in Tables 5 and 6, the model performs very well in matching the means and standard deviations of the data. In particular, it is able to reproduce well these moments for financial variables (short and long-term rates, term premium) without compromising its ability to match key moments for real variables. In line with the data, our model generates higher mean interest rates in Poland compared to the euro area, but a lower term premium.

As we discuss later, this is to a large extent due to relatively small aggressiveness of the Polish monetary policy to deviations of inflation from the target, which results in high volatility of the short-term interest rate and exchange rate, and hence in a high risk compensation required by foreign financial intermediaries, especially over short maturities. The calibrated model does also a great job in matching the volatility of output, investment, consumption and financial variables in both economies. In terms of autocorrelations, the model captures relatively well the low persistence in standard macroeconomic variables and high persistence in financial variables. It also reproduces well high and positive correlation between GDP and its components within each of the two economies. In line with the data, our model generates low correlation between the real and financial side of the economy. In order to match positive term premia in both economies, the model implies a negative correlation between consumption growth and inflation, which is not necessarily visible in the data.[12] It also replicates high and positive comovement between inflation, interest rates and term premia.

Finally, it is worth highlighting that our model does very well in accounting for the cyclical linkages between the two economies. It captures the tight comovement of the same variables in both countries, making a clear improvement over a standard international real business cycle framework. The model also attributes a large share of fluctuations observed in Poland to shocks originating in the euro area,[13] and hence does not suffer from the deficiency identified in estimated small open economy DSGE models (Justiniano and Preston, 2010).

5 Simulating the effects of monetary integration

We now use our model to simulate the long-term effects of adopting the euro by Poland. To this end, we check how social welfare as well as some moments of key macrovariables change if the nominal exchange rate between out two economies is irrevocably fixed and independent monetary policy in Poland is replaced by a common one run by the European Central Bank. To give some idea on how each of these two aspects contributes to our results, we also consider an intermediate case, in which the exchange rate is freely floating and the monetary policy rule in Poland responds to local variables as in equation (18), but its parametrization is as that estimated for the euro area.[14]

Before we present the results, it is instructive to highlight the key mechanisms at work. First of all, in a common currency area, the policy rate is set at an area-wide level. For

[12] This is a classic asset pricing result that entails investors requiring positive premia on long-term bonds if the nominal price of the bond is low (inflation is high) when consumption growth is low.

[13] This share is at least 40% for GDP, its components and inflation, and above 75% for short and long-term interest rates.

[14] This parametrization includes the level of the inflation target π_{ss}, interest rate smoothing parameter ρ_r as well as the two feedback coefficients β_π and β_y.

a relatively small accession country like Poland or any other one in the CEE region, this means that the short-term rate responds very little to deviations of the local business cycle from the common one observed in the whole monetary union. This cost of losing monetary independence can be small, or even turn into a gain, if commitment to stabilization of the central bank in the accession economy is not well established. Then, by replacing it with a more credible foreign authority that is more successful in fighting inflation and stabilizing the cycle can prove beneficial – a channel described in the literature as import of credibility (Giavazzi and Pagano, 1988; Herrendorf, 1997). In our framework this mechanism will be particularly strong as inflation volatility affects the prices of long-term bonds that households indirectly hold. Moreover, in our model entering a monetary union implies unification of the bond markets. Since foreign intermediaries can trade both home and foreign bonds, and we abstract away from sovereign default or the possibility of exiting the Eurozone in the future, their prices will converge. As a result, not only the short-term rate of the home country, but also the long-term rate and the term premium will be the same as in the rest of the common currency area.[15] This will affect allocations and welfare in a way that, to our knowledge, has not been so far evaluated in the literature. Since, as we discussed before, the long-term interest rates in the CEE region are significantly higher than in the euro area, the effects related to convergence in bond prices can be sizable.

Table 7 presents the quantitative evaluation of the strengths of these mechanisms. Since the estimated monetary policy reaction function for the euro area features stronger feedback to inflation and output than in Poland, the credibility channel is at work. Even if we keep the exchange rate floating, replacing the coefficients estimated for Poland with those obtained for the euro area leads to stabilization gains, especially strong for inflation, the nominal exchange rate and the interest rates (see the second column). As a result, the average levels of the interest rates significantly decline, boosting consumption and investment. The fall in short-term rates is larger than that for the long-term rates so the term premium goes up. The scenario brings clearly positive welfare gains, amounting to about 0.3% of steady-state consumption. If we additionally fix the exchange rate (third column), inflation volatility further declines, but that of output goes back roughly to where it was under independent monetary policy. The means of the short and long-term rates go further down to the levels observed in the euro area, consumption and investment increase, and the term premium goes up as its average level in Poland is well below that observed in the Eurozone. Welfare gains are clearly positive, adding another 0.2% of steady-state consumption compared to the intermediate case.

These findings confirm that the key mechanism affecting the cost-benefit analysis of adopting the euro is convergence in bond yields, and not in their risk premia. In particular,

[15] More precisely, in our model there will be still a (small) spread between the home and foreign interest rates even after fixing the exchange rate because of the risk premium term described in footnote 8.

the benefits for an accession country can still be positive even if the resulting equalization of bond prices implies a marked increase in the term premium. It is also worth noting that, since both short and long-term rates in Poland are significantly above the levels observed in the euro are, adopting the euro would shift the whole Polish yield curve down, and this shift would be actually stronger for shorter maturities. In this sense, our findings on the positive effects of bond price integration for Poland related to entering the Eurozone do not hinge on the high estimated value of the share of long-term bonds in the financial intermediaries' portfolio.

6 Conclusions

In this paper we have looked at the effects of integration of risk-free bond markets within a monetary union from a perspective of a small open accession economy. Focusing on the EU new member states from the CEE region, we documented that entering the Eurozone was associated with a significant decrease in their long-term rates, and possibly also in the term premia. We next developed an open economy model to examine the implications of the interest rate convergence on the costs and benefits of monetary integration. Our results indicate that relinquishing monetary independence by a country where interest rates are high because of its central bank's relatively low commitment to stabilize inflation and high exchange rate volatility may be beneficial for social welfare.

It has to be stressed that our findings are based on a model where agents are rational and bubbles are ruled out. We also focus on long-term effect and abstract away from transition dynamics. As the history of the EMU tells us, adopting the euro may lead to inefficient boom-bust cycles in countries with initially high interest rates, which may be costly for welfare and justify policy intervention (see e.g. Brzoza-Brzezina et al., 2014). However, if a way is found to smooth out such a boom with appropriate policy instruments, the prospect of long-term benefits associated with bond market integration should be taken seriously while contemplating a decision to join.

References

Adrian, Tobias, Richard K. Crump, and Emanuel Moench (2013) 'Pricing the term structure with linear regressions.' *Journal of Financial Economics* 110(1), 110–138

Andreasen, Martin M., Jesus Fernandez-Villaverde, and Juan F. Rubio-Ramirez (2016) 'The Pruned State-Space System for Non-Linear DSGE Models: Theory and Empirical Applications.' Working Papers 2016-07, FEDEA, September

Barsky, Robert B., F. Thomas Juster, Miles S. Kimball, and Matthew D. Shapiro (1997) 'Preference Parameters and Behavioral Heterogeneity: An Experimental Approach in the Health and Retirement Study.' *The Quarterly Journal of Economics* 112(2), 537–579

Bauer, Michael D., Glenn D. Rudebusch, and Jing Cynthia Wu (2012) 'Correcting Estimation Bias in Dynamic Term Structure Models.' *Journal of Business & Economic Statistics* 30(3), 454–467

BIS (2005) 'Zero-coupon yield curves: technical documentation.' BIS Papers 25, Bank for International Settlements, July

Brzoza-Brzezina, Michal, Pascal Jacquinot, and Marcin Kolasa (2014) 'Can We Prevent Boom-Bust Cycles During Euro Area Accession?' *Open Economies Review* 25(1), 35–69

Cappiello, Lorenzo, Robert F. Engle, and Kevin Sheppard (2006) 'Asymmetric Dynamics in the Correlations of Global Equity and Bond Returns.' *Journal of Financial Econometrics* 4(4), 537–572

Carre, Martine, and Fabrice Collard (2003) 'Monetary union: A welfare based approach.' *European Economic Review* 47(3), 521–552

Ca'Zorzi, Michele, Roberto A. De Santis, and Fabrizio Zampolli (2012) 'The Minimum Economic Dividend for Joining a Currency Union.' *German Economic Review* 13(2), 127–141

Ehrmann, Michael, Marcel Fratzscher, Refet S. Gurkaynak, and Eric T. Swanson (2011) 'Convergence and Anchoring of Yield Curves in the Euro Area.' *The Review of Economics and Statistics* 93(1), 350–364

Epstein, Larry G, and Stanley E Zin (1989) 'Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: A Theoretical Framework.' *Econometrica* 57(4), 937–969

Ferreira-Lopes, Alexandra (2014) 'The Welfare Cost of the EMU for Transition Countries.' *Prague Economic Papers* 2014(4), 446–473

Gali, Jordi, and Tommaso Monacelli (2005) 'Monetary Policy and Exchange Rate Volatility in a Small Open Economy.' *Review of Economic Studies* 72(3), 707–734

Giavazzi, Francesco, and Marco Pagano (1988) 'The advantage of tying one's hands : EMS discipline and Central Bank credibility.' *European Economic Review* 32(5), 1055–1075

Gradzewicz, Michal, and Krzysztof Makarski (2013) 'The business cycle implications of the euro adoption in Poland.' *Applied Economics* 45(17), 2443–2455

Greenwood, Jeremy, Zvi Hercowitz, and Per Krusell (1997) 'Long-Run Implications of Investment-Specific Technological Change.' *American Economic Review* 87(3), 342–362

Gurkaynak, Refet S., Brian Sack, and Jonathan H. Wright (2007) 'The U.S. Treasury yield curve: 1961 to the present.' *Journal of Monetary Economics* 54(8), 2291–2304

Herrendorf, Berthold (1997) 'Importing Credibility through Exchange Rate Pegging.' *Economic Journal* 107(442), 687–694

Jabłecki, Juliusz, Andrzej Raczko, and Grzegorz Wesołowski (2016) 'Negative bond term premia - a new challenge for Polish conventional monetary policy.' In *Inflation mechanisms, expectations and monetary policy,* ed. Bank for International Settlements, vol. 89 of *BIS Papers chapters* (Bank for International Settlements) pp. 303–315

Justiniano, Alejandro, and Bruce Preston (2010) 'Can structural small open-economy models account for the influence of foreign disturbances?' *Journal of International Economics* 81(1), 61–74

Kollmann, Robert (2002) 'Monetary policy rules in the open economy: effects on welfare and business cycles.' *Journal of Monetary Economics* 49(5), 989–1015

Lama, Ruy, and Pau Rabanal (2014) 'Deciding to enter a monetary union: The role of trade and financial linkages.' *European Economic Review* 72(C), 138–165

Lan, Hong, and Alexander Meyer-Gohde (2013) 'Solving DSGE models with a nonlinear moving average.' *Journal of Economic Dynamics and Control* 37(12), 2643–2667

Nelson, Charles R, and Andrew F Siegel (1987) 'Parsimonious Modeling of Yield Curves.' *The Journal of Business* 60(4), 473–489

Rudebusch, Glenn D., and Eric T. Swanson (2012) 'The Bond Premium in a DSGE Model with Long-Run Real and Nominal Risks.' *American Economic Journal: Macroeconomics* 4(1), 105–143

Ruge-Murcia, Francisco (2012) ‘Estimating nonlinear dsge models by the simulated method of moments: With an application to business cycles.’ *Journal of Economic Dynamics and Control* 36(6), 914–938

Schmitt-Grohe, Stephanie, and Martin Uribe (2001) ‘Stabilization Policy and the Costs of Dollarization.’ *Journal of Money, Credit and Banking* 33(2), 482–509

_ (2003) ‘Closing small open economy models.’ *Journal of International Economics* 61(1), 163–185

Svensson, Lars (2003) ‘Estimating Forward Interest Rates with Extended Nelson and Siegel Methods.’ *Sveriges Riksbank, Quarterly Review* 3, 13–26

Tables and figures

Table 1: Effect of euro adoption on long-term yields

Model	(1)	(2)	(3)	(4)
$EA_{i,t}$	-0.215^{***} (0.066)	-0.317^{***} (0.074)		
$ERM_{i,t}$			-0.082 (0.075)	-0.012 (0.075)
$CDS_{i,t}$		0.830^{***} (0.056)		0.840^{***} (0.056)
Country effects	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes
Number of observations	804	690	804	690

Note: The dependent variable is the 10-year yield on sovereign bonds issued by the eight considered EU new member states indexed by i, $CDS_{i,t}$ is the price of credit default swaps on sovereign bonds, $EA_{i,t}$ is a dummy variable indicating euro area membership, and $ERM_{i,t}$ is a dummy variable indicating either euro area or ERM participation. Robust standard errors in parentheses. ***, **, * denote statistical significance at 1%, 5% and 10%.

Table 2: Effect of euro adoption on the term premium

Model	(1)	(2)	(3)	(4)
$EA_{i,t}$	-0.556^{***} (0.116)	-0.579^{***} (0.128)		
$ERM_{i,t}$			-0.505^{***} (0.165)	-0.416^{**} (0.192)
$CDS_{i,t}$		0.559^{***} (0.076)		0.552^{***} (0.078)
Country effects	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes
Number of observations	804	690	804	690

Note: The dependent variable is the term premium on 10-year sovereign bonds issued by the eight considered EU new member states indexed by i, $CDS_{i,t}$ is the price of credit default swaps on sovereign bonds, $EA_{i,t}$ is a dummy variable indicating euro area membership, and $ERM_{i,t}$ is a dummy variable indicating either euro area or ERM participation. Robust standard errors in parentheses. ***, **, * denote statistical significance at 1%, 5% and 10%.

Table 3: Calibrated parameters

Parameter	Poland	Euro area	Description
ω_H	0.03		Relative size of home economy
h_{ss}	0.3395		Steady-state hours worked
θ	0.36		Capital share in output
η	6		EoS btw. intermediate varieties
ϕ_1	4		Leisure curvature in utility function
ω_H	0.03		Relative size of home economy
ν	1.5		EoS btw. domestic products and imports
ϖ	0.75	0.992	Home bias

Note: EoS stands for elasticity of substitution.

Table 4: Estimated parameters

Parameter	Poland	Euro area	Description
μ_z^*	1.0015		Rate of labor-neutral tech. progress
μ_Υ^*	1.0001		Rate of investment-specific tech. progress
β	0.9972		Discount factor
ϕ_2	0.8687		Consumption curvature in utility function
ω	0.9446		Share of long-term bonds in portfolio
γ	0.000006		International risk premium
ϕ_3	-71.1395	-70.8582	Risk aversion coefficient in preferences
b	0.2309	0.6740	Habits in consumption
κ	6.9999	9.3277	Capital adjustment cost
α	0.7821	0.8686	Calvo probability in price setting
G_{ss}/Y_{ss}	0.1915	0.1843	Steady-state share of government spending
π_{ss}	1.0025	1.0046	Steady-state inflation
ρ_r	0.9485	0.8831	Interest rate smooting in Taylor rule
β_π	1.5682	2.3826	Feedback to inflation in Taylor rule
β_y	0.2723	0.3291	Feedback to output in Taylor rule
ρ_a	0.8243	0.8963	Inertia of productivity shocks
ρ_G	0.9199	0.6440	Inertia of government spending shocks
σ_a	0.0136	0.0073	Volatility of productivity shocks
σ_G	0.0189	0.0074	Volatility of government spending shocks
σ_d	0.0011	0.0043	Volatility of preference shocks
			Implied
ϕ_0	0.5114	0.4541	Weight on leisure in utility function
RRA	53.9896	31.4164	Relative risk aversion
IES	0.5349	0.0583	Intertemporal elasticity of substitution

Note: See Andreasen et al. (2016) for the RRA and IES formulas that are applicable to preferences assumed in this paper.

Table 5: Moment matching

Moment	Data	Model
Mean		
Output growth PL	3.7451	3.4072
Output growth EA	0.9856	0.6293
Consumption growth PL	3.0149	3.4062
Consumption growth EA	0.7934	0.6286
Investment growth PL	4.8279	4.7202
Investment growth EA	0.3889	0.6756
Inflation PL	1.9826	2.4897
Inflation EA	1.6462	1.4098
Short rate PL	4.3877	3.9861
Short rate EA	1.4863	1.7088
10Y rate PL	5.1307	4.2411
10Y rate EA	3.1748	3.1977
10Y term premium PL	0.2989	0.2742
10Y term premium EA	1.5810	1.5162
G/Y PL	0.1879	0.1940
G/Y EA	0.2069	0.1855
Standard deviations		
Output growth PL	2.7846	2.8470
Output growth EA	2.5834	2.2289
Consumption growth PL	1.9336	1.9445
Consumption growth EA	1.4542	1.5869
Investment growth PL	9.6921	8.4897
Investment growth EA	5.6578	5.9517
Inflation PL	2.7247	3.4569
Inflation EA	2.5203	2.1672
Short rate PL	1.6218	1.3671
Short rate EA	1.4356	1.1157
10Y rate PL	1.3148	1.5119
10Y rate EA	1.2409	1.6734
10Y term premium PL	0.7929	0.7846
10Y term premium EA	1.1214	1.0367
G/Y PL	0.0094	0.0093
G/Y EA	0.0060	0.0062
Autocorrelation		
Output growth PL	0.0920	0.0247
Output growth EA	0.6543	0.1625
Consumption growth PL	0.7807	0.2647
Consumption growth EA	0.4965	0.4747
Investment growth PL	0.1740	-0.1353
Investment growth EA	0.5574	0.0097
Inflation PL	0.2899	0.5350
Inflation EA	-0.3681	0.9668
Short rate PL	0.9362	0.9840
Short rate EA	0.9696	0.9952
10Y rate PL	0.9441	0.9813
10Y rate EA	0.9781	0.9782
10Y term premium PL	0.9324	0.9760
10Y term premium EA	0.9671	0.9736
G/Y PL	0.9710	0.9150
G/Y EA	0.9649	0.9639

Table 6: Moment matching - continued

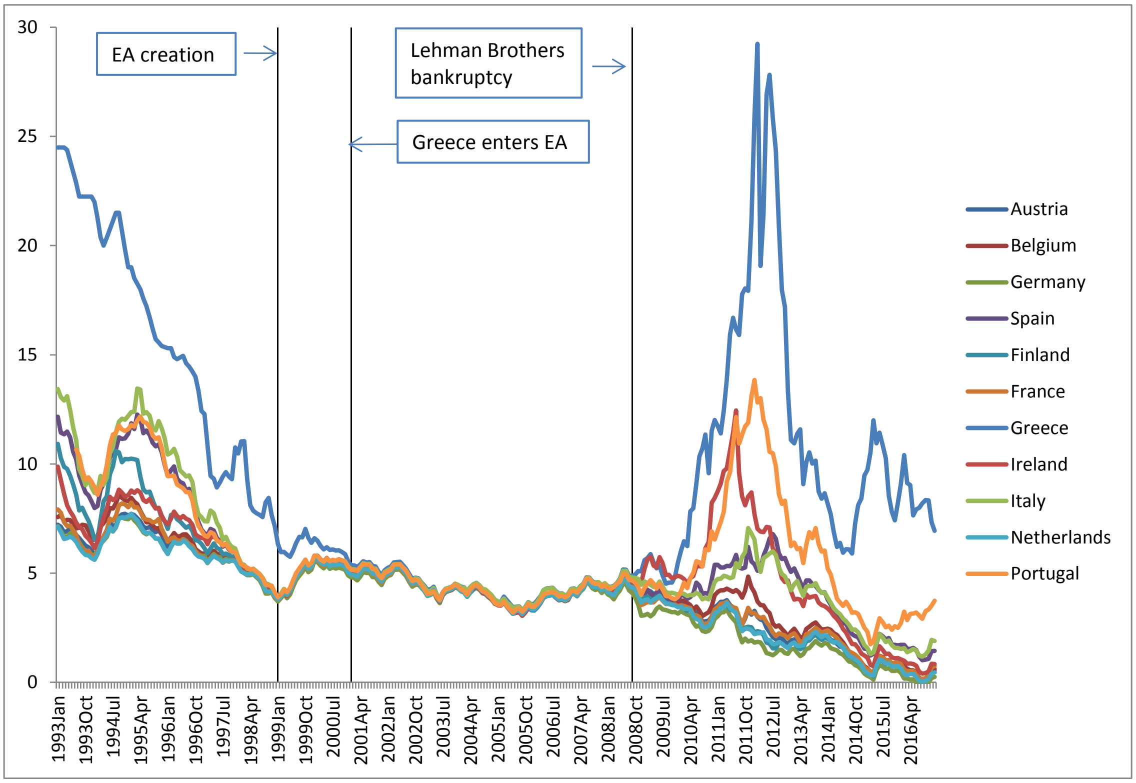
Correlation between	Data	Model
Output growth PL, Consumption growth PL	0.4581	0.4508
Output growth EA, Consumption growth EA	0.6851	0.7549
Output growth PL, Investment growth PL	0.4252	0.9319
Output growth EA, Investment growth EA	0.9000	0.9012
Output growth PL, Inflation PL	-0.0107	-0.0439
Output growth EA, Inflation EA	0.1730	-0.1826
Output growth PL, Short rate PL	-0.0102	-0.0973
Output growth EA, Short rate EA	0.0854	-0.0357
Output growth PL, 10Y rate PL	0.0939	-0.0557
Output growth EA, 10Y rate EA	-0.0587	-0.1178
Output growth PL, 10Y term premium PL	0.1247	-0.0556
Output growth EA, 10Y term premium EA	-0.2147	-0.1467
Consumption growth PL, Investment growth PL	0.4950	0.3813
Consumption growth EA, Investment growth EA	0.6469	0.5130
Consumption growth PL, Inflation PL	0.2089	-0.3381
Consumption growth EA, Inflation EA	-0.0371	-0.2533
Consumption growth PL, Short rate PL	0.0213	-0.0716
Consumption growth EA, Short rate EA	0.1692	-0.0487
Consumption growth PL, 10Y rate PL	0.1433	-0.1256
Consumption growth EA, 10Y rate EA	-0.0560	-0.2075
Consumption growth PL, 10Y term premium PL	0.1750	-0.1358
Consumption growth EA, 10Y term premium EA	-0.2302	-0.2417
Investment growth PL, Inflation PL	0.1056	0.1155
Investment growth EA, Inflation EA	0.1622	-0.1180
Investment growth PL, Short rate PL	0.0096	-0.0687
Investment growth EA, Short rate EA	0.1110	-0.0241
Investment growth PL, 10Y rate PL	0.0109	-0.0222
Investment growth EA, 10Y rate EA	-0.1043	-0.0514
Investment growth PL, 10Y term premium PL	0.0087	-0.0231
Investment growth EA, 10Y term premium EA	-0.2881	-0.0724
Inflation PL, Short rate PL	0.3643	0.6250
Inflation EA, Short rate EA	0.2895	0.7954
Inflation PL, 10Y rate PL	0.4796	0.6268
Inflation EA, 10Y rate EA	0.3464	0.9932
Inflation PL, 10Y term premium PL	0.4921	0.4339
Inflation EA, 10Y term premium EA	0.2797	0.8955
Short rate PL, 10Y rate PL	0.8685	0.8202
Short rate EA, 10Y rate EA	0.8038	0.7836
Short rate PL, 10Y term premium PL	0.7643	0.2688
Short rate EA, 10Y term premium EA	0.4749	0.4610
10Y rate PL, 10Y term premium PL	0.9833	0.7215
10Y rate EA, 10Y term premium EA	0.8967	0.8990
Output growth PL, Output growth EA	0.3329	0.3826
Consumption growth PL, Consumption growth EA	0.2686	0.6879
Investment growth PL, Investment growth EA	0.4369	0.3418
Inflation PL, Inflation EA	0.5985	0.5490
Short rate PL, Short rate EA	0.7273	0.6916
10Y rate PL, 10Y rate EA	0.9255	0.8881
10Y term premium PL, 10Y term premium EA	0.9081	0.9874

Table 7: Simulated effects of euro adoption by Poland

Moment	Independent monetary policy	Same monetary policy rule	Euro area membership
		Means	
Output	-	0.4083	0.5403
Consumption	-	0.2706	0.4152
Investment	-	0.1666	0.1954
Inflation	2.4899	1.7531	1.3478
Short-term rate	3.9860	2.6690	1.7121
Long-term rate	4.2411	3.4653	3.1346
Term premium	0.2743	0.8513	1.4513
		Standard deviations	
Output	2.6844	2.6667	2.8080
Consumption	2.0325	2.0080	1.9827
Investment	1.1783	1.1717	1.2994
Inflation	3.4568	1.8798	2.1338
Ex. rate growth	3.2710	1.7757	0
Short-term rate	1.3670	1.2097	1.0275
Long-term rate	1.5118	0.9275	1.5494
Term premium	0.7845	0.8917	1.0196
Welfare gains	-	0.2920	0.5212

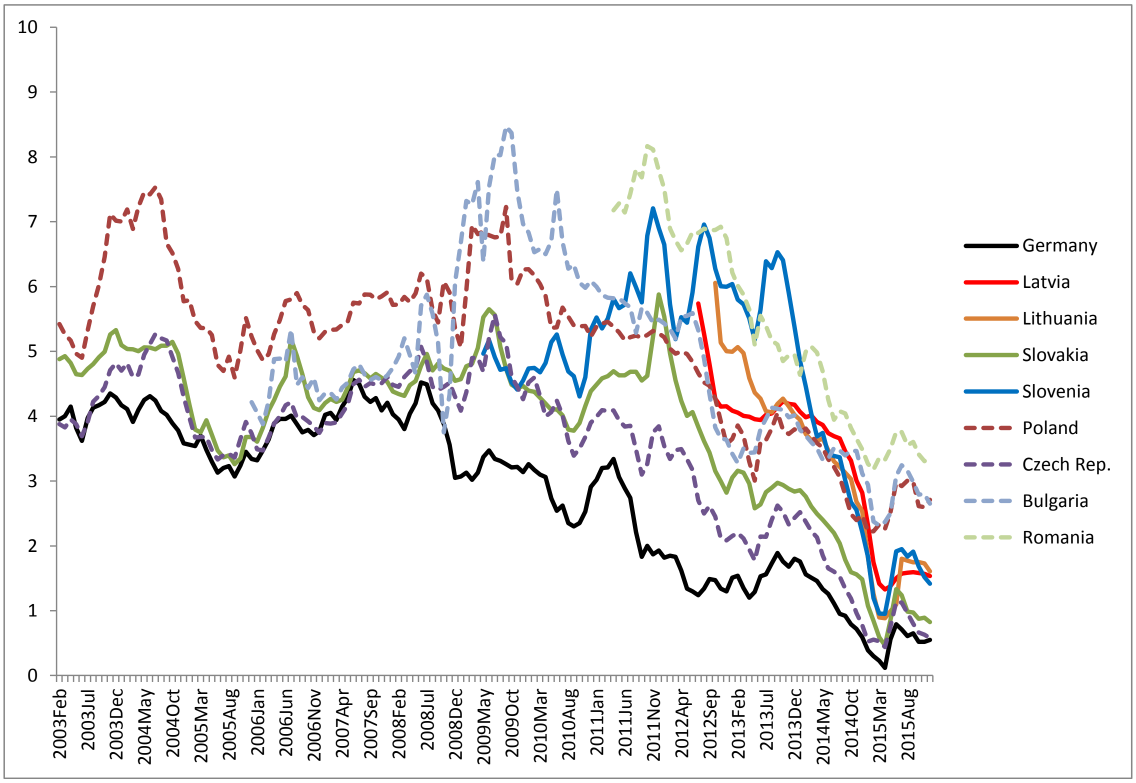
Note: All variables are in percent. Inflation, the interest rates, term premium and exchange rate growth are annualized. Output, consumption and investment are normalized by technological progress, and their means are expressed relative to the case of independent monetary policy. Welfare gains are expressed in percent of steady state consumption and relative to the case of independent monetary policy.

Figure 1: 10-year bond yields in the euro area



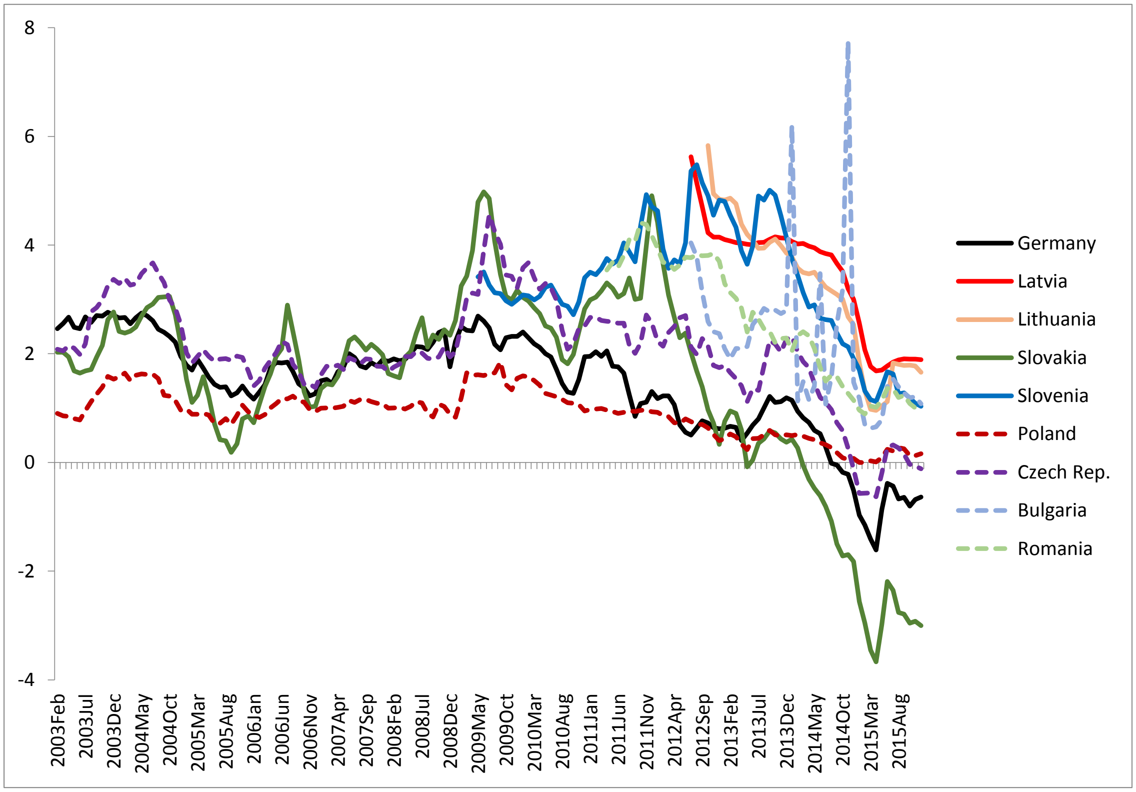
Note: The figure presents yields on 10-year government bonds of the euro area member states, obtained with the Nelson-Siegel procedure using Bloomberg data.

Figure 2: 10-year bond yields in CEE countries



Note: The figure presents yields on 10-year government bonds of the CEE countries and Germany, obtained with the Nelson-Siegel procedure using Bloomberg data.

Figure 3: Term premium on 10-year bonds in CEE countries



Note: The figure presents the term premium on 10-year government bonds of the CEE countries, estimated with the Adrian-Crump-Moench model using the yield curve obtained with the Nelson-Siegel procedure.