Same Spain, Less Pain?*

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We explore how the Spanish economy would have performed in the aftermath of the 2008 financial crisis if it had retained an independent monetary policy rather than joining the euro. A novel aspect of our approach is that we set up and estimate a structural model that takes account of the break in the conduct of monetary policy that occurred when Spain joined the euro, including anticipation effects. On average, Spanish economic growth would have been around 1.5 percentage points higher and consumption growth 0.5 percentage points higher between 2008 and 2014 if Spain had retained an independent monetary policy. But because euro entry led to a large boom prior to the crisis, the level of economic activity would have been similar by late 2014, regardless of Spain's monetary arrangements.

Keywords— Monetary Policy, Currency Union, Counterfactual Analysis, Spain.

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1 Introduction

In the aftermath of the 2008 Financial Crisis the Spanish economy experienced a deep and prolonged recession. Between 2008 and 2013 the level of GDP contracted by 9.3 per cent and at the time of writing remains well below its pre-crisis peak. The unemployment rate increased from an average rate of 9.7 per cent in the five years prior to the crisis to 26.2 per cent at its peak in mid-2013.

The poor performance of the Spanish economy in this episode is a puzzle. Many European economies experienced deep recessions. But unlike some of its counterparts, Spanish macroeconomic policy settings prior to the crisis appeared sound. In the decade prior to the crisis the central government ran small budget deficits (and on occasion surpluses), its public debt-to-GDP ratio was modest, employment was expanding rapidly and the sovereign yield spread was low.

Admittedly, with the benefit of hindsight some aspects of the Spanish economy look to have been unsustainable.[1] Spain experienced a residential property boom that featured a large run-up in house prices, rapid expansion of the residential construction sector and, in some segments of the market, imprudent lending practices. Spain also ran large current account deficits. Some form of correction may have been necessary to resolve these imbalances. Yet, even allowing for this fact, Spain's economic downturn was still unusually severe. The United States also experienced a large house price crash and saw a number of large financial institutions become insolvent. But by the end of 2014 per capita GDP in the United States was above its pre-crisis level and its labour market was on the road to recovery.

One explanation for the poor performance of the Spanish economy is that, as a member of the euro currency union, it lacked an independent monetary policy (Krugman (2011), Wolf (2011), De Grauwe (2015)). Euro membership may have depressed the Spanish economy in several ways. The European Central Bank (ECB)

[1] Ortega and Penalosa (2012) provide a comprehensive analysis of the Spanish economy in the years prior to the 2008 financial crisis.

targets economic conditions in the eurozone as a whole. Its monetary policy settings may have been tighter than optimal for Spain, whose economic conditions were particularly weak. Euro membership also meant that relative-price adjustment between Spain and its eurozone trading partners had to occur through changes in domestic wages and prices, which may be slower and more costly than a nominal exchange rate depreciation. And, had Spain retained an independent monetary policy, the shift in investor preferences away from Spanish assets that occurred between 2010 and 2013 may have translated into a weaker exchange rate rather than a rise in sovereign interest rates and firms' borrowing costs.

Our first contribution is to take these hypotheses to the data and quantitatively evaluate how the Spanish economy would have fared during the Great Recession if it had retained an independent monetary policy. To do this, we set up and estimate a two-country small open economy model of Spain and the euro area over the period 1988 - 2015. We use solution and estimation methods that account for Spain's entry into the euro in 1999, and the anticipation of future euro entry in the years prior. This model provides us with the economic shocks that explain the behaviour of the Spanish economy over our sample. We evaluate the performance of the Spanish economy outside the euro through counterfactual exercises in which we feed into the model the same economic shocks that we estimate but assume that Spain retained the monetary policy arrangements it had prior to 1999. Comparing these counterfactual exercises to actual economic outcomes tells us the extent to which Spain's poor economic outcomes were due to its membership of the euro.

We find some support for the idea that euro membership contributed to the poor performance of the Spanish economy in the years following 2008. If it had retained an independent monetary policy, Spanish economic growth would have been around 1.5 percentage points higher and consumption growth around 0.5 percentage points higher in average annualised terms between 2008 and 2014. Core inflation would have also been closer to target. In part, this improved economic performance reflects a substantial depreciation of the nominal exchange rate, of around 44 per cent.

These results come with two caveats. First, although Spain would have experienced faster economic growth since 2008, the estimated differences in the *level* of economic activity and consumption by the end of 2014 are modest. This reflects the fact that euro entry led to a boom in economic activity that Spain would not have experienced if it had retained an independent monetary policy.

Second, our results are only a first step towards addressing the broader question of whether euro membership is desirable for Spain. A complete answer would require one to account for the broader consequences of euro membership, including lower trade costs (Rose (2000), Frankel (2010) among many others) and the long-term productivity gains from realising economies of scale in a larger market (Balassa (2012), Baldwin (1989)). Instead we tackle the narrower question of the consequences of the loss of monetary policy autonomy and its implications for the Spanish economy during the Great Recession and its aftermath.

Our paper also contributes to the literature exploring the behaviour of the Spanish economy since its adoption of the euro. A number of these papers focus on the period prior 2008. For example, Rabanal (2009) explores the sources of persistent differences in trend inflation between Spain and eurozone, while Jimeno and Santos (2014), FEDEA (2010), Estrada et al. (2009) and Suarez (2010) have also sought to uncover the factors contributing to macroeconomic imbalances in Spain in the 2000s.

Like this earlier literature, Veld et al. (2014) and Veld et al. (2015) describe the factors behind the buildup of imbalances in Spain prior to 2008. These papers, however, also explore the reasons for the subsequent slump in economic activity. Both papers conclude that tightening collateral constraints and falling house prices were important contributors to the Spanish economy's weak recovery from the crisis. We extend this literature by quantifying the extent to which a loss of monetary autonomy affected Spanish economic outcomes in the lead-up to, and aftermath of, the 2008 crisis.

Our paper also makes a methodological contribution to the literature estimating DSGE models of eurozone economies. The transition from a system of individual monetary policies to a currency union represents a change in economic structure that standard solution methods can not account for. Reflecting this, euro-area DSGE models are typically estimated over short samples, over which the assumption of a single monetary regime is plausible (e.g. Andres et al. (2010), Rabanal (2009), Veld et al. (2014), Veld et al. (2015)). Others estimate over a longer sample and ignore the change in monetary policy regime associated with the transition to, and introduction of, the euro (e.g. Smets and Wouters (2005), Burriel et al. (2010)). Both approaches have drawbacks. The use of short samples may result in imprecise inference and overstate the importance of idiosyncratic aspects of recent economic episodes. And models estimated over longer samples, without accounting for the shift in monetary policy regime, are necessarily misspecified.

We show how to use solution and estimation methods that account for changes in the conduct of monetary policy associated with euro entry. Our methods also incorporate anticipation effects in the years prior to euro entry and endogenously account for the gradual shifts in inflation and interest rates observed in the data.

The rest of the paper is structured as follows. Section 2 lays out the model. Section 3 describes the estimation. In Section 4 we use the estimated model to explore the performance of the Spanish economy outside the euro zone. Section 5 concludes.

2 Model

We work with a New Keynesian small open economy model along the lines of Gali and Monacelli (2005). The model features two economies: a large economy (the euro-area) and a small economy (Spain). Economic developments in the large economy affect the small economy, but the reverse is not true.

The set-up of the large economy is standard; it features a household that chooses consumption and hours of work to maximize expected lifetime utility, firms that face pricing rigidities and a monetary authority that adjusts nominal interest rates to stabilize inflation and aggregate output.

The modelling of the small economy is richer since it is the focus of our analysis. In addition to consumption and hours worked, housing also enters the utility function of small economy households. And households have access to several alternative savings instruments, including bonds denominated in either domestic or foreign currency, housing and productive capital.

On the production side of the small economy, there are five sectors. An intermediate goods sector combines capital and labor into domestically-produced goods. A domestic final goods retailer aggregates these intermediate goods into a final domestic good. An exporting sector purchases a portion of the domestic final goods and differentiates them for sale to the large economy. An importing sector buys goods produced abroad and differentiates them for sale to domestic consumers and firms. And a final goods retailer purchases domestic and imported goods and aggregates them for sale to domestic consumers.

Prior to euro entry, Spanish monetary authorities follow a reaction function that responds to developments in inflation, output and the nominal exchange rate. After entering the euro, Spanish interest rates are equal to euro-area interest rates plus an exogenous risk premium.

In the remainder of this section we lay out the basic features of the model. Readers looking for more detail may consult Appendix A for the log-linearized equations and our online appendix for the full derivation.

2.1 The Large Economy

Households

The large economy features a representative household that maximizes its expected lifetime utility given by:

$$\sum_{t=0}^{\infty} \beta^t \left[\xi_t^* \left(\log(C_t^* - h^* C_{t-1}^*) - A_L^* \frac{N_t^{*\,1+\phi}}{1+\phi} \right) \right]$$

where C_t^* denotes consumption of the large economy's final good, N_t^* represents the household's labor supply and h^* parameterizes the degree of the household's habit formation. The term ξ_t^* is a consumption preference shock that evolves as an autoregressive process in logs:

$$\log(\xi_t^*) = \rho_{\xi^*} \log\left(\xi_{t-1}^*\right) + u_{\xi^*,t}$$

where $u_{\xi^*,t} \sim N(0, \sigma_{\xi^*}^2)$.

Utility maximization is subject to the budget constraint:

$$P_t^* C_t^* + Q_t^* D_{t+1}^* \leq D_t^* + W_t^* N_t^* + T_t^*$$

where P_t^* is the price of the final good, W_t^* is the nominal wage, and T_t^* denotes lump-sum taxes/transfers. Households have access to a risk-free one-period nominal bond, D_t^*, that pays a return of one unit of the large economy's currency. Q_t^* is the price of the bond and satisfies $Q_t^* = (R_t^*)^{-1}$, where R_t^* is the nominal interest rate in the large economy.

Firms

On the production side, each firm produces an intermediate good, indexed by $i \in [0, 1]$, using a technology linear in labor given by:

$$Y_t^*(i) = Z_t N_t^*(i)$$

where Z_t is total factor productivity. The growth rate of productivity, $z_t = \log(Z_t/Z_{t-1})$, follows a unit root with drift:

$$z_t = \mu + u_{z,t}$$

where $u_{z,t} \sim N(0, \sigma_z^2)$. Real marginal costs are equal across firms and given by:

$$MC^*_{R,t} = \frac{W^*_t}{P^*_t Z_t}$$

A competitive final good producer combines intermediate goods using the aggregator $Y^*_t = \left[\int_0^1 Y^*_t(i)^{1-\frac{1}{\epsilon^*_t}} dj\right]^{\frac{\epsilon^*_t}{\epsilon^*_t - 1}}$. Final good producer's profit maximization implies a demand function of the form:

$$Y^*_t(i) = \left[\frac{P^*_t(i)}{P^*_t}\right]^{-\epsilon^*_t} Y^*_t$$

where ϵ^*_t is the elasticity of substitution between intermediate goods which follows the process:

$$\log(\epsilon^*_t) = (1 - \rho_{\epsilon^*}) \log(\epsilon^*) + \rho_{\epsilon^*} \log\left(\epsilon^*_{t-1}\right) + u_{\epsilon^*,t}$$

where $u_{\epsilon^*,t} \sim N(0, \sigma^2_{\epsilon^*})$.

Price-setting

As standard in this literature, we assume Calvo pricing: each firm may reset its price with probability $1 - \theta^*$ each period, independently of the time of the last price readjustment. The firm's pricing problem is:

$$\max_{P^*_t(i)} \sum_{k=0}^{\infty} (\beta\theta^*)^k E_t \left\{ \frac{\Lambda^*_{t+k} P^*_t}{\Lambda^*_t} \left[\frac{P^*_t(i) \overline{\Pi}^{*k}}{P^*_{t+k}} Y^*_{t+k}(i) - MC^*_{R,t+k} Y^*_{t+k}(i) \right] \right\}$$

where $\overline{\Pi}^*$ is the steady-state level of inflation in the large economy and Λ^*_{t+k} measures the marginal utility value to the representative household of an additional unit of real profits at $t + k$.

Monetary Policy and Market Clearing

The large economy's monetary policy authority follows a reaction function that responds to the deviation of inflation from target as well as the level and growth rate of output:

$$\frac{R^*_t}{R^*} = \left[\frac{R^*_{t-1}}{R^*}\right]^{\rho^*_R} \left[\left(\frac{\Pi^*_t}{\overline{\Pi^*}}\right)^{\varphi^*_\pi} \left(\frac{Y^*_t}{Y^*_{t-1}\mu}\right)^{\varphi^*_g} (Y^*_t)^{\varphi^*_y} \right]^{1-\rho^*_R} e^{u^*_{R,t}}$$

where R^* is the steady-state nominal interest rate and $u_{R^*,t} \sim N(0, \sigma^2_{R^*})$ is a monetary policy shock.

Finally, goods market clearing requires that:

$$Y^*_t = C^*_t$$

2.2 The Small Economy

Households

The small economy is populated by a representative household that maximizes expected lifetime utility given by:

$$\sum_{t=0}^{\infty} \beta^t \left[\xi_t \left(\log(C_t - hC_{t-1}) - A_L \frac{N_t^{1+\phi}}{1+\phi} + A_S \log(K_{s,t}) \right) \right]$$

subject to the budget constraint:

$$P_t C_t + P_t I_{B,t} + P_t I_{S,t} + Q_{H,t} D_{H,t+1} + Q_{F,t} \mathcal{E}_t D_{F,t+1} \leq R_{B,t} K_{B,t} + D_{H,t} + \mathcal{E}_t D_{F,t} + W_t N_t + T_t$$

where ξ_t, P_t, C_t, W_t, T_t and N_t are the small economy counterparts of the starred variables for the large economy. $K_{s,t}$ denotes the stock of housing, A_L and A_S are normalizing constants, and $R_{B,t}$ is the rental rate of business capital paid by firms to households. At time t the household purchases domestic and foreign debt - denoted as $D_{H,t+1}$ and $D_{F,t+1}$ - and obtains a return of $D_{H,t+1}$ and of $\mathcal{E}_{t+1} D_{F,t+1}$ units of local currency at time $t+1$. $\mathcal{E}_t$ represents the nominal exchange rate which we define as the number of units of domestic currency to purchase one unit of foreign currency. The price of the domestic debt, $Q_{H,t}$, equals R_t^{-1}. The price of foreign debt, $Q_{F,t}$, is given by:

$$Q_{F,t} = \left[R^*_t e^{-\psi \mathcal{E}_t D_{F,t+1}} e^{\varepsilon_{RP,t}} \right]^{-1} \tag{1}$$

This term has three parts. First, the foreign interest rate, R^*_t. Second, a debt-elastic premium, $-\psi \mathcal{E}_t D_{F,t+1}$, which ensures the stationarity of foreign debt level. Third, a risk-premium shock which evolves as follows:

$$\log\left(\varepsilon_{RP,t}\right) = \rho_{\varepsilon_{RP}} \log\left(\varepsilon_{RP,t-1}\right) + u_{RP,t}$$

where $u_{RP,t} \sim N(0, \sigma^2_{RP})$.

$I_{B,t}$ and $I_{S,t}$ represent business and residential investment. The capital stock of each type evolves according to the law of motion:

$$K_{j,t+1} = (1-\delta)K_{j,t} + \Upsilon_{j,t}\left(1 - F_{j,t}\left(\frac{I_{j,t}}{I_{j,t-1}}\right)\right) I_{j,t}$$

where $j \in B, S$. $\Upsilon_{j,t}$ is a shock to the efficiency of investment of type j that follows a first order autoregressive process in logs, δ parametrizes depreciation, and the adjustment cost function $F_{j,t}$, which satisfies the Christiano et al. (2005) assumptions, is given by:

$$F_{j,t}\left(\frac{I_{j,t}}{I_{j,t-1}}\right) = \frac{\varphi_{K,j}}{2}\left(\frac{I_{j,t}}{I_{j,t-1}} - \mu\right)^2$$

where $\varphi_{K,j}$ controls the size of investment adjustment costs for capital of type j and μ is the growth rate of TFP in steady state.

Firms

There are five types of firms in the domestic economy: domestic intermediate producers, domestic final good producers, importers, exporters, and domestic final goods retailers. We describe each sector in turn.

Domestic Goods Producers

Intermediate producing firms have access to a Cobb-Douglas technology which combines labor and business capital:

$$Y_{H,t}(i) = (Z_t N_t(i))^a \left(K_{B,t}(i)\right)^{1-a}$$

Firms face Calvo price-stickiness, with the parameter θ denoting the degree of price rigidity. The firm's pricing problem is given by:

$$\max_{P_t(i)} \sum_{k=0}^{\infty} (\beta\theta)^k E_t \left\{ \frac{\Lambda_{t+k} P_t}{\Lambda_t} \left[\frac{P_{H,t}(i) Y_{t+k}(i) \Pi^k}{P_{t+k}} - \frac{MC_{t+k}}{P_{t+k}} Y_{t+k}(i) \right] \right\}$$

where MC_t denotes nominal marginal cost, which is equal across firms and given by $MC_t = a^{-a}(1-a)^{-(1-a)} \left(\frac{W_t}{Z_t}\right)^a \left(R_{B,t}\right)^{1-a}$.

Domestic Final Goods Retailers

The domestically-produced final good, $Y_{H,t}$ is assembled by a perfectly competitive domestic final good retailer that combines domestically-produced intermediate goods using the technology:

$$Y_{H,t} = \left[\int_0^1 Y_{H,t}(i)^{\frac{\varepsilon_t - 1}{\varepsilon}} di \right]^{\frac{\varepsilon_t}{\varepsilon_t - 1}}$$

where ε_t denotes the elasticity of substitution across varities that follows the process:

$$\log(\epsilon_t) = (1-\rho_\epsilon)\log(\epsilon) + \rho_\epsilon \log(\epsilon_{t-1}) + u_{\epsilon,t}$$

where $u_{\epsilon,t} \sim N(0, \sigma_\epsilon^2)$.

Importers

Importers bring in homogeneous products from abroad at price $\mathcal{E}_t P_t^*$ and differentiate them by branding them. The differentiated imports are combined into the imported consumption good using the CES technology:

$$Y_{F,t} = \left[\int_0^1 Y_{F,t}(i)^{\frac{\epsilon_{F,t} - 1}{\epsilon_F}} di \right]^{\frac{\epsilon_{F,t}}{\epsilon_{F,t} - 1}}$$

with the corresponding price index $P_{F,t} = \left[\int_0^1 P_{F,t}(i)^{1-\epsilon_{F,t}} di\right]^{\frac{1}{1-\epsilon_F}}$ and the elasticity of substitution $\epsilon_{F,t}$. The latter follows the process:

$$\log\left(\epsilon_{F,t}\right) = (1-\rho_{\epsilon_F})\log\left(\epsilon_F\right) + \rho_{\epsilon_F}\log\left(\epsilon_{F,t-1}\right) + u_{\epsilon_F,t}$$

where $u_{\epsilon_F,t} \sim N(0, \sigma^2_{\epsilon_F})$.

Consequently, each importer faces the demand curve:

$$Y_{F,t}(i) = \left(\frac{P_{F,t}(i)}{P_{F,t}}\right)^{-\epsilon_{F,t}} Y_{F,t}$$

Importers face standard Calvo pricing frictions. The probability of resetting the price for importers equals $1-\theta_m$. The problem is:

$$\max_{P_{F,t}(i)} \sum_{k=0}^{\infty} (\beta\theta_m)^k E_t \left\{ \frac{\Lambda_{t+1} P_t}{\Lambda_t} \left[\frac{P_{F,t}(i) Y_{F,t}(i) \Pi^k}{P_{t+k}} - \frac{\mathcal{E}_{t+k} P^*_{t+k} Y_{F,t+k}(i)}{P_{t+k}} \right] \right\}$$

subject to the demand constraint above.

Exporters

Exporters buy a bundle of domestically produced goods at price $P_{H,t}$ and differentiate it through branding for sale in the foreign economy. A retailer bundles these goods before selling them overseas according to the technology:

$$X_t = \left[\int_0^1 X_t(i)^{\frac{\epsilon_{X,t}-1}{\epsilon_{X,t}}} (i) \right]^{\frac{\epsilon_{X,t}}{\epsilon_{X,t}-1}}$$

with corresponding price index in foreign currency equal to $P^*_{X,t} = \left[\int_0^1 P^*_{X,t}(i)^{1-\epsilon_{X,t}} di\right]^{\frac{1}{1-\epsilon_{X,t}}}$ and elasticity of substitution between varieties of $\epsilon_{X,t}$. The latter follows the process:

$$\log\left(\epsilon_{X,t}\right) = (1-\rho_{\epsilon_X})\log\left(\epsilon_X\right) + \rho_{\epsilon_X}\log\left(\epsilon_{X,t-1}\right) + u_{\epsilon_X,t}$$

where $u_{\epsilon_X,t} \sim N(0, \sigma^2_{\epsilon_X})$.

The export retailer faces the following demand function:

$$X_t = \nu \left(\frac{P^*_{X,t}}{P^*_t} \right)^{-\eta} Y^*_t$$

where $P^*_{X,t}$ is the foreign-currency price of the bundle of exported goods, ν is a normalizing constant and η is the elasticity of demand for the small economy's goods in the large economy.

The demand for each exporter's goods are given by:

$$X_t(i) = \left(\frac{P^*_{X,t}(i)}{P^*_{X,t}} \right)^{-\epsilon_{X,t}} X_t$$

The firm's problem under sticky prices is:

$$\max_{P^*_{X,t}(i)} \sum_{k=0}^{\infty} (\beta\theta_x)^k E_t \left\{ \frac{\Lambda_{t+1} P_t}{\Lambda_t} \left[\frac{P^*_{X,t}(i) \Pi^k X_{t+k}(i) \mathcal{E}_{t+k}}{P_{t+k}} - \frac{P_{H,t+k} X_{t+k}(i)}{P_{t+k}} \right] \right\}$$

subject to the demand constraint given above.

Final Goods Retailers

Final goods retailers produce final goods using domestically-produced and imported consumption goods using the technology:

$$DFD_t = \left[(1-\nu)^{\frac{1}{\eta}} \left(Y^D_{H,t} \right)^{\frac{\eta-1}{\eta}} + \nu^{\frac{1}{\eta}} \left(Y_{F,t} \right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

where $Y^D_{H,t}$ denotes the home-produced goods consumed in the small economy -not exported- and $Y_{F,t}$ is the foreign good. The parameter η is the elasticity of substituion between both types of goods. The price index corresponding to this bundle is:

$$P_t = \left[(1-\nu) \left(P_{H,t} \right)^{1-\eta} + \nu \left(P_{F,t} \right)^{1-\eta} \right]^{\frac{1}{1-\eta}}$$

The final good retailer's demands for each good are given by:

$$Y_{H,t}^{D} = (1-\nu)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} DFD_t; \qquad Y_{F,t} = \nu\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} DFD_t$$

Market Clearing and the Current Account

Market clearing for the domestically-produced final good retailer requires that all production is sold either at home or abroad:

$$Y_{H,t} = Y_{H,t}^{D} + X_t$$

Market clearing for the final good retailer requires that all production is either consumed or invested:

$$DFD_t = C_t + I_{B,t} + I_{S,t}$$

The current account equation relates the accumulation of net foreign assets to the trade balance:

$$\frac{\mathcal{E}_t D_{F,t+1}}{R_t^{*} e^{-\psi \mathcal{E}_t D_{F,t+1}} e^{\varepsilon_{RP,t}}} = \mathcal{E}_t D_{F,t} + \mathcal{E}_t P_{X,t}^{*} X_t - \mathcal{E} P_t^{*} Y_{F,t}$$

Monetary Policy Before and After Euro Entry

Before adopting the euro, we assume that the Spanish monetary authorities follow a reaction function that responds to the Spanish CPI inflation rate, the level and growth rate of Spanish output, and the exchange rate:

$$\frac{R_t}{R} = \left[\frac{R_{t-1}}{R}\right]^{\rho_R} \left[\left(\frac{\Pi_t}{\overline{\Pi}}\right)^{\varphi_\pi} \left(\frac{Y_t}{Y_{t-1}\mu}\right)^{\varphi_g} (Y_t)^{\varphi_y} \left(\frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}\right)^{\varphi_{\mathcal{E}}}\right] e^{u_{R,t}} \tag{2}$$

where $\overline{\Pi}$ is the Spanish inflation target, R is the steady-state Spanish nominal interest rate and $u_{R,t}$ is a monetary policy shock.

After joining the euro, Spain no longer has an independent monetary policy. To implement this in the model, we replace the Spanish monetary policy reaction function with the restriction that the exchange rate must be constant:

$$\frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} = 1 \tag{3}$$

To understand the operation of monetary policy within the currency union note that, regardless of Spain's monetary policy arrangements, uncovered interest rate parity (UIP) must hold:

$$R_t = R_t^* E_t \left\{ \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} \right\} e^{\varepsilon_{RP,t}} \tag{4}$$

Before Spain joins the euro, monetary policy in Spain and abroad controls R_t and R_t^*. Conditional on these policy rates, the UIP condition then determines the expected change in the Spanish exchange rate. After euro entry the expected change in the exchange rate is zero and R_t is no longer under the control of the Spanish monetary authorities. Therefore, the UIP condition condition determines Spanish interest rates, which reflect two forces. The first is the policy rate in the euro area, R_t^*. The second is a time-varying risk premium that foreign investors demand when lending to Spanish borrowers, $e^{\varepsilon_{RP,t}}$.[2] Euro entry does not eliminate this risk premium. But whereas prior to euro entry the risk premium showed up largely as an exogenous movement in the nominal exchange rate, after euro entry it affects the Spanish economy primarily by altering the interest rate faced by Spanish borrowers.

2.3 Model Solution with Structural Change

We use the solution methods proposed in Kulish and Cagliarini (2013) and Kulish and Pagan (Forthcoming) and the estimation method of Kulish et al. (2014). Because these methods have more general application than the context we are considering, we discuss how the methods apply to our case.

In estimation, we allow for a break in Spain's monetary policy framework when Spain joins the euro in 1999Q1. We denote this date as T_b. Of course, the introduction

[2] The risk premium also contains a systematic response to foreign debt to ensure stationarity. However, this effect is very small.

of the euro was widely anticipated well before 1999. To account for this, and we allow agents to incorporate future euro entry into their expectations from some earlier date, $T_a < 1999Q1$. Unlike the date at which Spain joined the euro, which is a known parameter, we must estimate T_a.

From period $t = 1, 2, \ldots, T_a - 1$ Spanish monetary authorities operate an independent monetary policy and agents expect this regime to continue. The first order approximation to the equilibrium conditions around the initial steady state is a system of n equations that we will write as:

$$\mathbf{A}x_t = \mathbf{C} + \mathbf{B}x_{t-1} + \mathbf{D}Ex_{t-1} + \mathbf{F}w_t \tag{5}$$

where x_t is the state vector and w_t is the vector of structural shocks, which we take to be *iid* without loss of generality. If the rational expectations solution to Equation 5 exists and is unique it will be a VAR of the form:

$$x_t = \mathbf{J} + \mathbf{Q}x_{t-1} + \mathbf{G}w_t \tag{6}$$

where the matrices J, Q and G are constructed in the standard way by the method of undetermined coefficients. From period $t = T_b, T_b + 1, \ldots, T$ Spain is part of the euro area. The first order approximation to the equilibrium conditions around the final steady state is a system of n equations that we will write as:

$$\mathbf{A}^*x_t = \mathbf{C}^* + \mathbf{B}^*x_{t-1} + \mathbf{D}^*Ex_{t-1} + \mathbf{F}^*w_t \tag{7}$$

where the superscript $*$ denotes the matrices corresponding to the model equations when Spain is part of the euro zone.[3] The reduced form solution from this point on is simply $x_t = \mathbf{J}^* + \mathbf{Q}^*x_{t-1} + \mathbf{G}^*w_t$.

In the period $t = T_a, T_a+1, \ldots, T_b-1$ Equation 5 continues to describe the structure

[3] Note that in Equation 7 we account for the fact that entry to the euro alters the steady state around which we log-linearize the equations.

of the model solution. However, in constructing expectations one now has to account for the fact that Spanish residents expect to join the euro zone in period T_b. Following Kulish and Pagan (Forthcoming), the solution may be written as a time-varying VAR of the form:

$$x_t = \mathbf{J}_t + \mathbf{Q}_t x_{t-1} + \mathbf{G}_t w_t \tag{8}$$

Equation 8 implies that expectations are $Ex_{t+1} = \mathbf{J}_{t+1} + \mathbf{Q}_{t+1} x_t$. Substituting these expectations into Equation 5 implies that at period t:

$$\mathbf{A}x_t = \mathbf{C} + \mathbf{B}x_{t-1} + \mathbf{D}\left(\mathbf{J}_{t+1} + \mathbf{Q}_{t+1}x_t\right) + \mathbf{F}w_t \tag{9}$$

which implies by the method of undetermined coefficients the following recursions:

$$\begin{aligned}
\mathbf{J}_t &= \left[\mathbf{A}_t - \mathbf{D}_t\mathbf{Q}_{t+1}\right]^{-1}\left(\mathbf{C} + \mathbf{D}\mathbf{J}_{t+1}\right) \\
\mathbf{Q}_t &= \left[\mathbf{A}_t - \mathbf{D}_t\mathbf{Q}_{t+1}\right]^{-1}\mathbf{B} \\
\mathbf{G}_t &= \left[\mathbf{A}_t - \mathbf{D}_t\mathbf{Q}_{t+1}\right]^{-1}\mathbf{F}
\end{aligned}$$

The backward recursion of time-varying reduced form matrices, $\{\mathbf{Q}_t\}_{t=T_a}^{T_b-1}$ starts from the terminal condition $\mathbf{Q}_{T_b} = \mathbf{Q}^*$ and works its way back to T_a, yielding a system of time-varying reduced form matrices. From the sequence for $\mathbf{Q}_t$, the sequence for $\mathbf{G}_t$ may be computed as well. One can then compute the sequence for $\mathbf{J}_t$ using the sequence for $\mathbf{Q}_t$ and the terminal condition $\mathbf{J}_{T_b} = \mathbf{J}^*$.

2.4 Transition to a currency union

In this section, we illustrate the economic consequences of a pre-announced transition to a currency union and discuss features that aid identification of the structural parameters associated with this transition.

To construct the exercise, we first set all of the models' parameter values to the prior means listed in Table 1. We then simulate the model for 100 quarters, setting all stochastic shocks equal to zero. For the first 50 quarters, the small economy has an independent monetary policy. In quarter 50 it enters a currency union with the large economy. Agents first incorporate the future change in monetary arrangements into their expectations in quarter 26, that is six years before the small economy enters the currency union.

[Figure 1 about here.]

Figure 1 shows the result of the exercise. For the first 25 quarters all variables are at their initial steady state values. For the small economy, this corresponds to an annualised inflation rate of around 5 per cent and a nominal interest rate of around 8 per cent. As the small economy's steady state inflation rate is higher than that of the large economy, its nominal exchange rate depreciates at a rate that exactly offsets the inflation differential, ensuring that the real exchange rate is constant.

Entering into a currency union with the large economy leaves the steady state of the small economy's real variables, including the level of economic activity, the real interest rate and the real exchange rate, unchanged. But it does lower the small economy's steady-state inflation rate to the large economy's inflation target of 2 per cent in annualised terms. There is a corresponding decrease in the steady-state nominal interest rate. And, once the small economy enters the currency union it no longer has its own currency and the nominal exchange rate ceases to be an observable variable.

The anticipation of entering a currency union in the future induces a transition that has implications for the paths of the small economy's endogenous variables, including those whose steady state is unaffected by the change in monetary arrangements. The transition begins as soon as agents incorporate future currency union entry into their expectations. And the transition occurs even in the absence of stochastic shocks.

Because firms set prices in a forward-looking manner, the expectation of lower inflation in the future reduces inflation in the present. Rather than displaying a discrete break when the small economy enters the currency union, inflation starts to drift downwards as soon as agents learn of the future change in monetary policy arrangements. As the small economy's monetary authorities continue to follow their standard reaction function, the fall in inflation causes nominal interest rates to decrease. And lower inflation reduces the pace of nominal exchange rate depreciation in the years leading up to currency union entry.

On the real side of the economy, the anticipation of currency union entry induces a boom in economic activity. Export volumes increase by a particularly large amount, although all categories of domestic expenditure are above their steady-state values at the time the small economy enters the currency union.

The boom in activity occurs because the real interest rate decreases and the real exchange rate depreciates in the lead-up to currency union entry. The intuition for why the real interest rate must fall is as follows. Price stickiness means that inflation converges gradually to its new steady-state value. In the first few quarters after currency union entry, inflation in the small economy remains slightly above its new 2 per cent steady state. At the same time, once the small economy enters a currency union its nominal exchange rate is fixed. For uncovered interest rate parity to hold (in the absence of stochastic shocks) nominal interest rates in the small and large economies must be equal. That is, when the small economy enters the currency union its nominal interest rate is at its new steady state.

The steady states of the small economy's inflation and nominal interest rates change by the same amount. Hence, in the period in which the small economy enters the currency union the reduction in its nominal interest rate - relative to its initial steady state - must be larger than the decrease in expected inflation. But this means that the real interest rate must have fallen.

A similar logic applies in the quarters immediately before and after the small economy enters the currency union. That is, the real interest rate declines in the lead-up to currency union entry and returns to its original steady state subsequently.

To understand why the real exchange rate depreciates in the lead-up to currency union entry, recall that arbitrage in the foreign exchange market requires that a decrease in the small economy's real interest rate must be accompanied by an expected appreciation of its real exchange rate in the future. As the steady-state level of the real exchange rate is unaffected by monetary factors, the real exchange rate must depreciate in the lead-up to currency union entry and then appreciate later as the real interest rate differential disappears.

The existence of a transition across a range of observable variables allows our estimation procedure to identify the date at which Spanish households and firms first incorporated entry into the euro into their expectations. This date corresponds to the start of the transition. It also helps to identify some of the structural parameters, for example the Spanish inflation target prior to euro-entry, as these parameters influence the size and shape of the transition.

3 Estimation

We estimate our model using Bayesian methods, as is common in the DSGE literature. Our case, however is non-standard, because we allow for structural change and jointly estimate two sets of distinct parameters: the structural parameters of the model, ϑ, that have continuous support, and the date of the shift in agents' expectations, T_b, that has discrete support.

The joint posterior density of ϑ and T_b is:

$$p(\vartheta, T_b|\mathcal{Y}) \propto \mathcal{L}(\mathcal{Y}|\vartheta, T_b)\, p(\vartheta, T_b) \tag{10}$$

where $\mathcal{Y} \equiv \{y_t^{obs}\}_{t=1}^{T}$ is the data and y_t^{obs} is a $n^{obs} \times 1$ vector of observable variables.

$\mathcal{L}(\mathcal{Y}|\vartheta, T_b)$ is the likelihood. The priors of the structural parameters are taken to be independent, so that $p(\vartheta, T_b) = p(\vartheta)\, p(T_b)$. We use a flat prior for T_b so $p(T_b) \propto 1$, which is proper given its discrete support.

3.1 Priors and Data

Our estimation sample spans the period 1988Q1 to 2014Q4. The observable variables for the large economy are euro-area GDP growth, core inflation and the ECB policy rate.[4] The observable variables for Spain are the growth rates of GDP, consumption, residential construction investment and non-residential investment, core inflation, interest rates and, for the period before 1999Q4 the change in the Peseta-Deutsche mark nominal exchange rate. Until 1999Q4 our interest rate measure is the Spanish policy rate. After Spain enters the euro zone we use the the three month Spanish Treasury bill rate.[5]. The Spanish residential construction investment series begins in 1995Q1. For the period before this we treat aggregate investment (that is, the sum of residential and non-residential investment) as an observable variable. Figure 2 plots the data series that we use in estimation. All data are seasonally adjusted. GDP and its components are expressed in per capita terms.

[Figure 2 about here.]

[Figure 3 about here.]

We calibrate a number of parameters that are likely to be poorly identified using our observable data series. We set the parameter governing the elasticity of labour supply, ϕ , to 1.0, which is a standard value in the literature and is the same calibration used in Rabanal (2009) and Andres et al. (2010). We set the parameter ν to 0.27, the foreign asset position in steady state b to 5.0 and the quarterly investment depreciation rates to 0.01 to match various shares in the data. We set the elasticity of substitution between Spanish and euro-area goods, η, to 0.8, which is roughly the midpoint of the estimates in the literature (e.g. Rabanal (2009) and Veld et al. (2015)). We set the parameter controlling the elasticity of the risk premium to the foreign debt level,

[4]For the period before 1999 we use the German GDP, inflation and interest rate data.

[5]We account for the term premium present in the Spanish Treasury bill rate by subtracting a constant that is equal to the mean difference between this rate and the German / ECB policy rate over the period 1991Q1 - 2007Q4.

ψ, to 0.001. This is small enough to have little effect on the dynamics of the model while ensuring that foreign debt is stationary.

We estimate the remaining parameters using Bayesian methods. Most of our priors are standard in the literature. We center the prior on quarterly trend productivity growth, μ, at 0.35. This is roughly equal to the average growth rate of per capita GDP in Spain and the euro zone over our sample period. We center the euro area inflation target at 0.50 per cent in quarterly terms, consistent with the European Central Bank's stated inflation target. For the Spanish inflation target before its entry into the euro zone we use a higher mean of 1.25 per cent in quarterly terms, with a wider prior than for the ECB's inflation target, reflecting our uncertainty about the value of this parameter.

The domain of the prior over T_b spans the period 1991Q1 to 1998Q4. The start date coincides with the opening of the negotiations for the Maastricht Treaty, which led to the creation of the euro. The end date represents the quarter immediately prior to the formation of the euro in 1999Q1. We use the methods described in Kulish and Pagan (Forthcoming) to construct $\mathcal{L}(\mathcal{Y}|\vartheta, T_b)$.

3.2 Estimation Results

Figure 4 shows the probability density function of the posterior distribution of the break in Spanish agents' beliefs about their economy's future monetary policy arrangements. Each bar shows the probability that Spaniards first incorporated the expectation of future euro entry at that date. Almost the entire mass of the distribution occurs in 1992Q4. This date coincides with the breakdown of the European exchange rate mechanism, an event that revealed the fragility of existing European monetary policy arrangements and may have provided an impetus towards future monetary union (Buiter et al. (1998)). As such it is a plausible candidate for the date at which Spanish households and firms first incorporated future euro entry into their expectations.

[Figure 4 about here.]

Table 1 show the results for the structural parameters that we estimate.

We estimate an inflation target for the ECB of 0.5 per cent in quarterly terms, consistent with their stated inflation target. For Spain, we estimate a pre-euro inflation target of 1.4 per cent in quarterly terms. This is broadly in line with average inflation outcomes in Spain for the period 1988-1992, that is before the Spanish economy began its transition to euro entry.

Turning to the Spanish monetary reaction function, we estimate that Spanish monetary authorities displayed a relatively strong reaction to inflation and exchange rate movements. However, they showed little responsiveness to the level of output, with φ_y insignificantly different from zero. The estimated responsiveness to inflation in the ECB monetary reaction function is consistent with other estimates in the literature (e.g. Smets and Wouters (2005) and Rabanal (2009)). The responses to the growth rate and level of output that we estimate are, however, slightly higher than in other papers.

We find a high degree of price stickiness in the euro area as a whole, as well as in domestic and import prices in Spain. This is a common result in DSGE models of Europe (e.g. Smets and Wouters (2005)). Spanish export prices, however, appear to be relatively flexible.

For the other parameters, our results appear broadly consistent with other estimated DSGE models of the Spanish economy (Andres et al. (2010) and Burriel et al. (2010).) The estimation points to large adjustment costs in both business and housing investment. The standard deviations of the model's investment and intertemporal preference shocks are large compared to the markup and technology shocks. In contrast, the standard deviations of the monetary policy and risk premium shocks are small.

Table 1: Estimated parameters (*continued next page*)

	Prior			Posterior			
Parameter	Dist	Mean	Std Dev	Mode	Mean	5 percent	95 percent
h^*	B	0.60	0.20	0.43	0.45	0.29	0.61
κ^*	B	0.67	0.10	0.94	0.93	0.89	0.97
$100(\pi^* - 1)$	N	0.50	0.10	0.51	0.53	0.41	0.66
ρ_R^*	B	0.60	0.20	0.87	0.87	0.84	0.90
φ_π^*	N	1.75	0.20	1.49	1.48	1.14	1.81
φ_g^*	N	0.20	0.10	0.35	0.34	0.22	0.47
φ_y^*	N	0.20	0.10	0.26	0.26	0.13	0.38
100μ	N	0.35	0.05	0.28	0.28	0.21	0.35
$100(\beta - 1)$	G	0.50	0.10	0.43	0.43	0.31	0.56
h	B	0.60	0.20	0.86	0.86	0.80	0.91
κ	B	0.67	0.10	0.95	0.95	0.93	0.97
κ_F	B	0.67	0.10	0.97	0.97	0.94	0.98
κ_X	B	0.67	0.10	0.50	0.54	0.35	0.74
$100(\pi - 1)$	N	1.25	0.20	1.42	1.43	1.23	1.65
S_B''	N	5.00	2.00	7.47	7.79	5.40	10.36
S_S''	N	5.00	2.00	8.58	8.41	6.12	11.00
ρ_R	B	0.60	0.20	0.85	0.85	0.81	0.88
φ_π	N	1.75	0.20	1.95	1.91	1.62	2.21
φ_g	N	0.20	0.10	0.28	0.28	0.12	0.43
φ_y	N	0.20	0.10	−0.03	−0.03	−0.06	0.01
$\varphi_{\Delta e}$	N	0.00	0.20	0.33	0.36	0.17	0.58

4 How would Spain have performed outside the euro?

We evaluate the performance of the Spanish economy outside the eurozone through counterfactual exercises in which Spain experiences the same economic shocks but retains monetary autonomy. We construct these counterfactuals as follows. We take a draw from the posterior distribution of parameter values and use the Kalman smoother to extract the economic shocks the model uses to explain the observed data, conditional on those parameter values. We then feed these shocks back through an alternative model in which Spain retains its original monetary policy settings and does not join the eurozone.[6] We repeat this process for a large number of draws from the posterior distribution of parameters. This leaves us with a distribution of

[6]Specifically, we feed the shocks through the model holding all solution matrices at their initial values, rather than using the time-varying structure described in Section 2.3.

Table 1: Estimated parameters (*continued*)

	Prior			Posterior			
Parameter	Dist	Mean	Std Dev	Mode	Mean	5 percent	95 percent
ρ_ξ^*	B	0.60	0.20	0.89	0.88	0.81	0.94
ρ_p^*	B	0.50	0.15	0.53	0.53	0.38	0.67
ρ_ξ	B	0.60	0.20	0.79	0.77	0.65	0.87
ρ_p	B	0.50	0.15	0.75	0.71	0.50	0.88
ρ_{p_M}	B	0.50	0.10	0.55	0.55	0.38	0.71
ρ_{p_X}	B	0.50	0.15	0.32	0.40	0.18	0.81
ρ_{rp}	B	0.60	0.20	0.88	0.86	0.75	0.92
ρ_{Υ_B}	B	0.60	0.20	0.76	0.72	0.57	0.83
ρ_{Υ_S}	B	0.60	0.20	0.78	0.77	0.62	0.89
$100 \times \sigma_r^*$	IG	0.15	1.00	0.08	0.08	0.07	0.10
$100 \times \sigma_\xi^*$	IG	2.00	1.00	2.56	2.68	2.10	3.42
$100 \times \sigma_p^*$	IG	0.50	1.00	0.14	0.13	0.10	0.18
$100 \times \sigma_z$	IG	0.50	1.00	0.87	0.93	0.70	1.23
$100 \times \sigma_r$	IG	0.15	1.00	0.24	0.25	0.19	0.33
$100 \times \sigma_\xi$	IG	2.00	1.00	3.86	4.55	3.08	6.66
$100 \times \sigma_p$	IG	0.50	1.00	0.08	0.10	0.05	0.15
$100 \times \sigma_{p_M}$	IG	0.50	1.00	0.28	0.27	0.14	0.43
$100 \times \sigma_{p_X}$	IG	0.50	1.00	4.01	4.32	2.93	6.36
$100 \times \sigma_{rp}$	IG	1.00	1.00	0.14	0.15	0.13	0.18
$100 \times \sigma_{\Upsilon_B}$	IG	5.00	3.00	11.49	13.05	8.08	21.20
$100 \times \sigma_{\Upsilon_S}$	IG	5.00	3.00	5.87	7.49	4.69	11.50

counterfactual outcomes.

Figure 5 compares actual outcomes for the observed Spanish data series against the counterfactual distribution.[7] Our results confirm that the transition to euro entry raised Spanish economic growth in the late 1990s and early 2000s. Consistent with the parameter estimates in Table 1, nominal interest rates and inflation would have been higher for most of the past two decades if Spain did not join the euro.

[Figure 5 about here.]

Our primary interest, however, is in the period from 2008 - 2014. For the most part, the Spanish economy would have experienced stronger economic outcomes if it remained outside the eurozone. In particular, the economic recovery in 2010 would

[7]Actual outcomes for business and housing investment growth are not available before 1995Q1. The nominal exchange rate is not observed after Spain joins the eurozone in 1999Q1.

have been sharper and the subsequent recession less deep. The stronger recovery would have been supported by a larger fall in nominal interest rates and a substantial nominal exchange rate depreciation.

But by most metrics Spain's economic performance would still have been poor. Spain would still have experienced a double-dip recession in 2012. And the stronger recovery in 2010-2011 would largely have reflected faster growth in business and housing investment. The pattern of consumption growth, which is arguably a better measure of welfare, is similar to its actual path in most of the counterfactual draws.

Table 2 quantifies the estimated differences in Spanish economic outcomes if it had remained outside the euro. The first four rows compare the average growth rates of per capita output, consumption, business investment and housing investment between 2008 and 2014 in the data against moments of the counterfactual distribution. In the counterfactual, the mean outcome for Spanish GDP growth over the period was 0.3 per cent growth, with a 95 per cent confidence interval spanning -0.8 per cent to 1.6 per cent. Even the lower outcome represents a faster rate of growth than the Spanish economy, which shrank at an average rate of 1.2 per cent in annualised terms over this period, actually achieved. Other measures of economic activity show similar improvements in relative performance but remain weak in absolute terms. Consumption, for example, would still have declined over 2008-2014, albeit by less than it did in the data.

The fifth row of Table 2 compares inflation outcomes in the data against the counterfactuals. In this case we compute average deviations from the inflation target. For the counterfactuals we use the estimated inflation target from each draw. For the data we take an annualised rate of 2 per cent to be the inflation target. In the vast majority of draws, the faster pace of economic activity in the counterfactual does not come at the cost of larger deviations of inflation from target.

The final row of Table 2 shows the cumulated nominal exchange rate depreciation across the distribution of counterfactuals. The 95 per cent probability interval ranges

Table 2: Economic Outcomes: 2008Q1 - 2014Q4

Variable	Actual (%)	Counterfactual (%)		
		Mean	2.5 percent	97.5 percent
GDP Growth[1]	-1.2	0.3	−0.8	1.6
Consumption Growth[1]	-1.4	−0.8	−1.1	−0.5
Business Investment Growth[1]	-0.4	3.9	0.8	8.1
Housing Investment Growth[1]	-10.3	−5.3	−7.6	−2.7
Inflation[2]	-1.4	−0.9	−2.5	0.1
Exchange Rate Depreciation[3]	–	44.0	28.8	58.2

Note: 1. Annualised quarterly percentage change. 2. Average annualised percentage point deviation from estimated inflation target. 3. Cumulative estimated nominal exchange rate depreciation.

from 28.8 per cent to 58.2 per cent. This helps to illustrate an important mechanism through which maintaining an independent monetary policy could have aided the Spanish economy after 2008. Such large changes in relative prices would be difficult to achieve in such a short period of time given the estimated degree of price rigidity in Spain.

Our results suggest that euro entry raised Spanish economic growth rates in the 1990s and early 2000s, but depressed growth subsequently. To assess the net effect of euro entry, Figure 6 compares the *level* GDP and consumption in the data against the counterfactual distribution. The level of GDP in the data is above its counterfactual level until 2008. Subsequently, however, the gap closes and at the end of the estimation period the actual level of GDP lies around the middle of the counterfactual distribution. The pattern for consumption is similar, although by the end of the sample the actual level of GDP is in the bottom half of the counterfactual distribution.

[Figure 6 about here.]

4.1 Why are the differences so modest?

Although an independent monetary policy would have led to improved Spanish economic outcomes over recent years, the differences are modest. One possible explanation is that the Spanish economy received a sequence of economic shocks that monetary policy is not well placed to offset. To examine whether this is the case we use the Kalman smoother to extract the economic shocks that the model uses to fit the observed data series. We then explore how observed outcomes differ when we remove individual shocks.[8]

Figure 7 shows the contributions of two important sets of shocks. The top panel compares actual GDP growth to a counterfactual in which we exclude the model's technology shock. In the bottom panel we perform the same exercise but exclude the consumption preference and risk premium shocks. These can both be considered to be demand-type shocks, as they move prices and output in the same direction, and so it makes sense to examine their joint contribution.

The most relevant single shock in explaining the initial reduction in GDP growth in 2009 is the aggregate technology shock. Absent this shock, Spain's GDP contraction would have roughly halved; no other shock can explain as much of the slowdown in GDP growth in 2009 as the technology shock does.

This result helps to explain why the contraction in Spanish GDP in 2009 would have been similar even if Spain retained its own monetary policy (Figure 5). Monetary policy has limited effectiveness when faced with negative supply shocks. To illustrate this point, Figure 8 compares impulse responses to a negative technology shock for an economy inside (in red) and outside a currency union (in black).[9] Regardless of the economy's monetary arrangements, the negative technology shock induces a large, and permanent, reduction in output. If the economy is outside a currency union the nominal and real exchange rates depreciate after the technology shock. Relative to the currency union case, the exchange rate depreciation supports export volumes and delays the contraction in GDP. However, the differences here are modest and relate to the timing of the responses. Monetary policy cannot alter the fact that the negative

[8]Note that for these exercises we do not allow Spain to retain an independent monetary policy after 1999.

[9]We constructed these IRFs setting all parameters at their posterior mean values from Table 1.

technology shock has made the economy less productive.

[Figure 7 about here.]

[Figure 8 about here.]

We now turn to the timid recovery between 2011 and 2014. Figure 7 shows that in this period Spanish GDP growth would have been noticeably higher absent demand and risk-premium shocks. This is also congruent with our conclusion that the Spanish economy's recovery would have been stronger in 2010 and the subsequent recession not as deep, had it retained an independent monetary policy.

The reason behind this finding is that the shocks that hit the Spanish economy in the 2011 - 2014 period are shocks for which monetary policy is well equipped to offset. To illustrate this, Figure 9 plots impulse responses to a risk-premium shock. Outside of a currency union, an increase in the risk-premium on domestic borrowing shows up primarily as a depreciation of the nominal exchange rate. This is stimulatory for the domestic economy, leading to an increase in GDP growth and a rise in inflation. Although domestic interest rates increase, this is a standard reaction to the boom in the domestic economy. Within a currency union, the nominal exchange rate channel of adjustment is absent. Instead, an increase in the risk premium shows up as an increase in domestic borrowing costs. This has a large contractionary effect on domestic activity and causes inflation to fall. If the central bank targets average economic conditions across the entire currency union, and the domestic economy is small, interest rates may not respond to the contraction in domestic demand.

The importance of the risk-premium in the 2010-2015 recovery period is consistent with the results in Veld et al. (2014). This study concludes that the tightening on collateral constraints played an important role in slow recovery of the Spanish economy after the financial crisis. As Smets and Wouters (2007) point out risk-premium shocks have similar effects to the net-worth shocks that tighten collateral constraints and increase external finance premia in Bernanke et al. (1999).

[Figure 9 about here.]

4.2 Were better outcomes possible?

The previous section showed that part of the explanation for the modest improvement in Spanish economic outcomes in our counterfactual scenario lies in the nature of the shocks that affected the Spanish economy. But one might still wonder whether better outcomes were possible under an alternative policy framework.

We have explored this possibility in two ways. First, we re-calculated the counterfactual exercise assuming that Spain adopted the ECB's monetary policy reaction function but remained outside the eurozone. Compared to the estimated Spanish policy rule, the ECB reaction function features a lower inflation target, a smaller response to inflation, a larger response to output growth and no direct response to exchange rate movements. The ECB policy rule produces a similar - albeit somewhat less volatile - path for output than that generated by the estimated Spanish reaction function. However, the differences remain modest - remaining outside the euro but adopting the ECB policy rule would not have generated to large improvements in Spain's macroeconomic performance.

Of course, there may be other policy rules that would have led to substantially improved outcomes. To explore this possibility, our second exercise compares estimated output gaps in the data (black line) and the original counterfactual exercise in which Spain did not join the eurozone and retained its original policy rule (grey line). We calculate the output gap as the deviation of output from its estimated flexible price level, calculated with all parameters set at their posterior mode values.[10] Figure 10 shows the results.

The model suggests that in the lead-up to the crisis Spanish economic activity was running far above its natural level. However, the recession was sufficiently large to push output to around 8 per cent below its flexible-price level. In the counterfactual, output does not rise as far above potential before the crisis, or fall as far during

[10] In calculating the output gap we set all markup shocks equal to zero, although this choice does not meaningfully change the results.

the recession. However, an output gap, of around 4 per cent at its trough, still exists, suggesting some scope for alternative policies to have generated improved macroeconomic outcomes.

[Figure 10 about here.]

5 Conclusion

In this paper we have quantified the consequences for Spain of the loss of monetary policy independence following its entry to the eurozone. After entering the euro, Spain lost the ability to tailor monetary policy settings to Spanish economic conditions. And adjustment of relative prices between Spain and the rest of the eurozone could no longer occur through changes in nominal exchange rates.

We find that Spanish economic outcomes would have been poor in recent years, even if Spain had retained monetary autonomy. In common with other advanced economies, Spain would have still experienced a deep recession in 2009. And it would have endured a further downturn in 2011-12, although this episode would not have been as severe. Moreover, much of the increase in economic growth that would have occurred if Spain had retained an independent monetary policy would have come through increased investment; consumption outcomes would have been little changed.

Our analysis highlights two reasons for the modest improvements in economic outcomes resulting from monetary policy independence. The first is the nature of the economic shocks affecting the Spanish economy. Particularly in the early part of the crisis, these were supply-side in nature. There is little that monetary policy can do in response to these types of shocks other than smooth the transition to a lower level of potential output. The second is the nature of the estimated Spanish policy rule, which we find would have failed to fully offset demand-side shocks, leading to a negative output gap for much of the post-2011 period.

A further contribution of our work is to set up and estimate a structural model that explicitly accounts for the change in the conduct of monetary policy associated with joining the euro area. This feature could be built in to existing structural models of euro-area economies. It will also be useful for researchers analysing the economic consequences for other economies that are considering entering a currency union in the future.

The ongoing economic challenges facing the eurozone have led some to question whether the costs of euro membership outweigh the benefits. Our paper - by quantifying the effects of one aspect of euro membership - represents a first step to answering this question. The analysis of the benefits, and further costs, of euro membership we leave to further work.

A Log-linear System of Equations

A.1 Large Economy Log-linear Equations

$$(\mu-\beta h)(\mu-h)\lambda_t^* = \mu h y_{t-1}^* + \mu\beta h E_t\{y_{t+1}^*\} - \left(\mu^2+\beta h^2\right) y_t^* - \mu h(1-\beta\rho_z) z_t + (\mu-h)\left(\mu-\beta h\rho_\xi^*\right)\xi_t^* \tag{11}$$

$$0 = \lambda_t^* - E_t\left\{\lambda_{t+1}^*\right\} - \left(r_t^* - E_t\left\{\pi_{t+1}^*\right\}\right) + \rho_z z_t \tag{12}$$

$$\pi_t^* = \beta E_t \pi_{t+1}^* + \kappa^* \left[\xi_t^* + \phi\ y_t^* - (1+\phi\ )a_t^* - \lambda_t^*\right] \tag{13}$$

$$r_t^* = \rho_R^* r_{t-1}^* + (1-\rho_R^*)\left(\varphi_\pi^*(\pi_t^*-\pi^*) + \varphi_g^*(y_t^* - y_{t-1}^* + z_t)\right) + \varepsilon_{R,t}^* \tag{14}$$

A.2 Small Economy Log-linear Equations

Household First Order Conditions and Capital Law of Motion

$$(\mu-\beta h)(\mu-h)\lambda_t = \mu h c_{t-1} + \mu\beta h E_t\{c_{t+1}\} - (\mu^2+\beta h^2)c_t - \mu h(1-\beta\rho_z)z_t + (\mu-h)(\mu-\beta h\rho_\xi)\xi_t \tag{15}$$

$$\xi_t + \phi\ n_t = \lambda_t + w_t \tag{16}$$

$$\lambda_t = \lambda_{j,t}^k - \sigma_{k,j}\mu^2\left[(1+\beta)i_{j,t} - i_{j,t-1} - \beta i_{j,t+1} - \beta z_{t+1} + z_t\right] + \hat{\Upsilon}_{j,t} \tag{17}$$

$$\lambda_{B,t}^k = \left[\frac{\mu-\beta(1-\delta_B)}{\mu}\right]\left[E_t\lambda_{t+1} + E_t r_{B,t+1}\right] + \frac{\beta(1-\delta_B)}{\mu}E_t\lambda_{B,t+1}^k - E_t z_{t+1} \tag{18}$$

$$\lambda_{S,t}^K = \frac{\beta(1-\delta_S)}{\mu}(E_t\{\lambda_{S,t+1}^K\} - E_t\{z_{t+1}\}) - \left[\frac{\mu-\beta(1-\delta_S)}{\mu}\right]k_{S,t+1} \tag{19}$$

$$0 = \lambda_t - E_t\{\lambda_{t+1}\} - (r_t - E_t\{\pi_{t+1}\}) + \rho_z z_t \tag{20}$$

$$0 = r_t - E_t\{\Delta e_{t+1}\} - r_t^* + \psi b_{t+1} - \varepsilon_{RP,t} \tag{21}$$

$$k_{j,t+1} = \frac{1-\delta_j}{\mu}\left(k_{j,t} - z_t\right) + \frac{\mu-1+\delta_j}{\mu}(i_{j,t} + \hat{\Upsilon}_{j,t}) \tag{22}$$

Household Demand Functions

$$y^D_{H,t} = dfd_t - \eta\gamma_{H,t} \tag{23}$$

$$y_{F,t} = dfd_t - \eta_F\gamma_{F,t} \tag{24}$$

$$x_t = y^*_t + \eta_F(q_t - \gamma_{X,t}) \tag{25}$$

Relative Prices

$$\gamma_{F,t} = \gamma_{F,t-1} + \pi_{F,t} - \pi_t \tag{26}$$

$$\gamma_{X,t} = \gamma_{X,t-1} + \pi_{X,t} - \pi_t + \Delta e_t \tag{27}$$

$$\gamma_{H,t} = \gamma_{H,t-1} + \pi_{H,t} - \pi_t \tag{28}$$

Production Functions and Producers' First Order Conditions

$$y_{H,t} = a_t + \alpha n_t + (1-\alpha)z_t + (1-\alpha)k_{B,t} \tag{29}$$

$$\pi_t = (1-\nu)(\pi_{H,t} + \gamma_{H,t-1}) + \nu(\pi_{F,t} + \gamma_{F,t-1}) \tag{30}$$

$$\pi_{F,t} = \kappa_f(q_t - \gamma_{F,t}) + \beta E_t\{\pi_{F,t+1}\} + \varepsilon_{msM,t} \tag{31}$$

$$\pi_{X,t} = \kappa_z(\gamma_{H,t} - \gamma_{X,t}) + \beta E_t\{\pi_{X,t+1}\} + \varepsilon_{msX,t} \tag{32}$$

$$\pi_{H,t} = \kappa mc_t + \beta E_t\{\pi_{H,t+1}\} + \varepsilon_{ms,t} \tag{33}$$

$$mc_t = \alpha w_t + (1-\alpha)r_{B,t} - \gamma_{H,t} - a_t \tag{34}$$

$$n_t = k_{B,t} + r_{B,t} - w_t - z_t \tag{35}$$

Market Clearing, UIP, Monetary Policy, and Current Account Conditions

$$y_{H,t} = \frac{Y_{H,t}^D}{Y_H} y_{H,t}^D + \frac{X}{Y_H} x_t \tag{36}$$

$$dfd_t = \frac{C}{DFD} c_t + \frac{I_B}{DFD} i_{B,t} + \frac{I_S}{DFD} i_{S,t} \tag{37}$$

$$q_t = q_{t-1} + \Delta e_t + \pi_t^* - \pi_t \tag{38}$$

$$r_t = \rho_r r_{t-1} + (1 - \rho_r) \left[\varphi_\pi (\pi_t - \pi) + \varphi_g (y_{H,t} - y_{H,t-1} + z_t) \right] + \varepsilon_{r,t} \tag{39}$$

$$\frac{b_{t+1}}{R^*} = \frac{\Delta \mathcal{E} b_t}{\mu \Pi} + \frac{\Gamma_X X}{Y_H} (\gamma_{X,t} + x_t - y_{H,t}) - \frac{Q Y_F}{Y_H} (q_t + y_{F,t} - y_{H,t}) \tag{40}$$

B Data Sources

Euro area GDP: From 1988Q1 to 1998Q4 the growth rate of German real GDP per capita. This is constructed by dividing German real GDP (source: Datastream code BDGDP...D) by the German population (source: FRED code POPTTLDEA148NRUG). From 1999Q1 to 2014Q4 the growth rate of euro-area GDP per capita, excluding Spain. We calculate the growth rate of real euro-area GDP per capita by subtracting nominal Spanish GDP from euro-area nominal GDP and dividing the resulting series by the euro-area GDP deflator (source: eurostat). We construct the population series by subtracting the Spanish population (source: INE) from the euro-area population (source: Eurostat.)

Euro area inflation: From 1988Q1 to 1998Q4, the growth rate of the German consumer price index ex-energy (source: Datastream.) From 1999Q1 to 2014Q4, euro-area HICP inflation excluding energy and food (source: Eurostat.)

Euro area interest rates: Between 1998Q1 and 1998Q4 the quarterly average of the Deutsche Bundesbank discount rate (Source: FRED.) From 1999Q1 to 2014Q4 the ECB overnight deposit rate (source: ECB.)

Spain GDP growth: The growth rate of Spanish real GDP per capita. We construct GDP per capita by dividing Spanish real GDP (Source: Banco de España) by the Spanish population from 1988Q1 to 2004Q4 (Source: INE)

Spain consumption growth: The growth rate of Spanish real final consumption expenditure per capita. (Source: INE).

Spain investment growth: The growth rate of Spanish Gross Fixed Capital Formation (GFCF) per capita (Source: INE). We include this variable as an observable variable in estimation between 1988Q1 and 1994Q4.

Spain business investment growth: The growth rate of real Spanish business investment per capita. We construct business investment by multiplying real GFCF by one minus the share of dwelling investment in nominal investment (Source: INE). This data is available only from 1995Q1 and we treat the series as missing from 1988Q1 to 1994Q4.

Spain housing investment: The growth rate of housing investment per capita. Housing investment is GFCF in dwellings (Source: INE). This data is available only from 1995Q1 and we treat the series as missing from 1988Q1 to 1994Q4.

Spain inflation: The growth rate of the Spanish consumer price index excluding taxes, food and energy prices. Between 1988Q1 and 1995Q4 the data source is OECD. Between 1996Q1 and 2015Q4 the source is Eurostat.

Spain interest rates: Between 1988Q1 and 1998Q4 the quarterly average of the daily interest rate on deposits in the interbank market. (Source: Banco de Espana.) From 1999Q1 onwards, the Spanish three month treasury bill rate. (Source: St Louis Federal Reserve FRED database.) We adjust for the term premia between the Spanish Treasury bill rate and the euro-area policy rate by calculating the mean difference between these two series over the sample 1999Q1 - 2006Q4 and subtracting this value from the Spanish Treasury Bill rate over the period 1999Q1 onwards.

Spain exchange rate: Quarterly change in the log of the nominal Spanish Peseta / German Deutschemark exchange rate. The series is discontinued in 1999Q1 when Spain joins the euro. (Source: Banco de España.)

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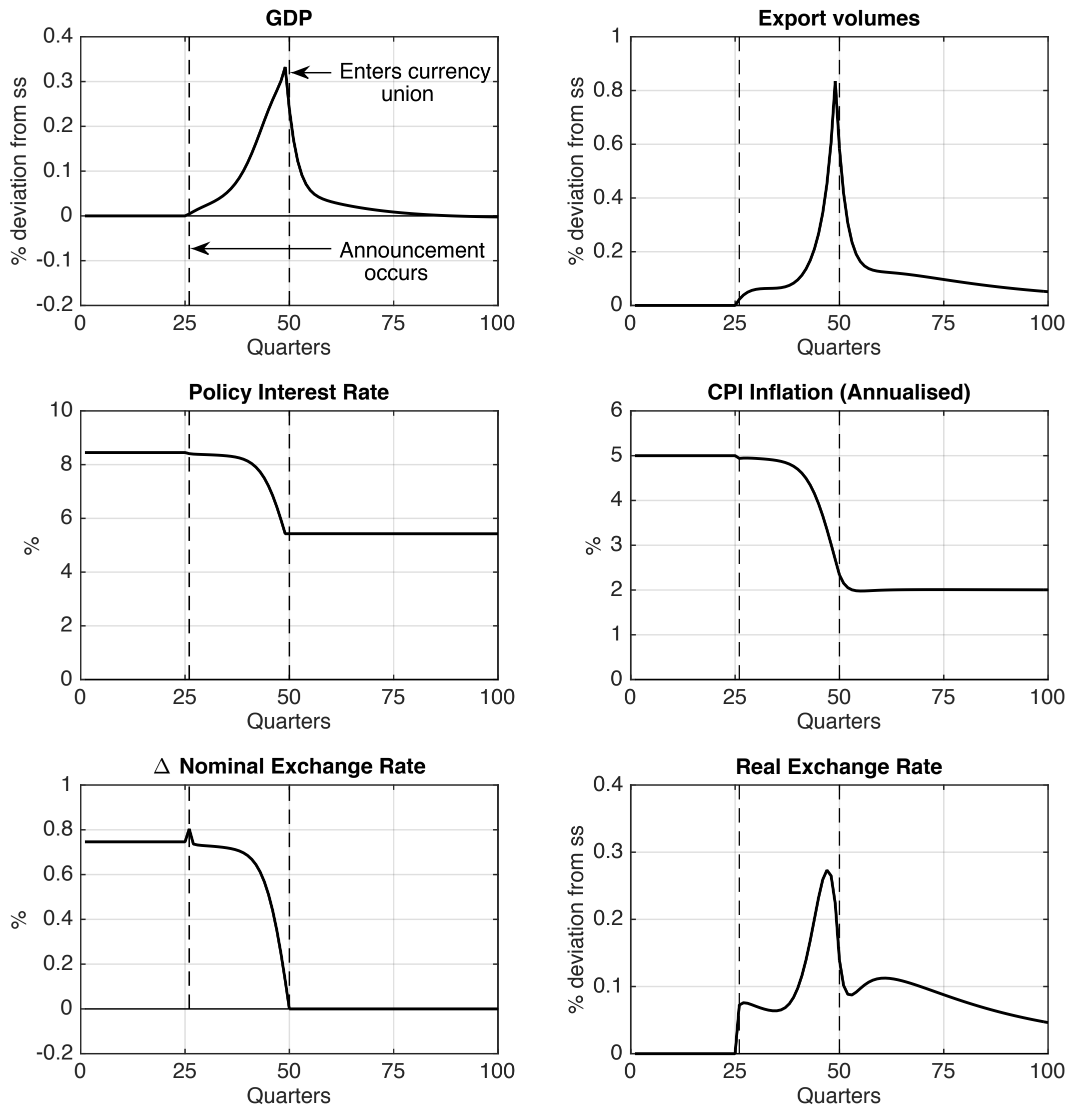

Figure 1: **Simulated transition to a currency union**. This figure plots a simulated transition to a currency union. The small economy enters the currency union in Quarter 50 and agents' first incorporate the change in monetary policy arrangements into their expectations in quarter 26.

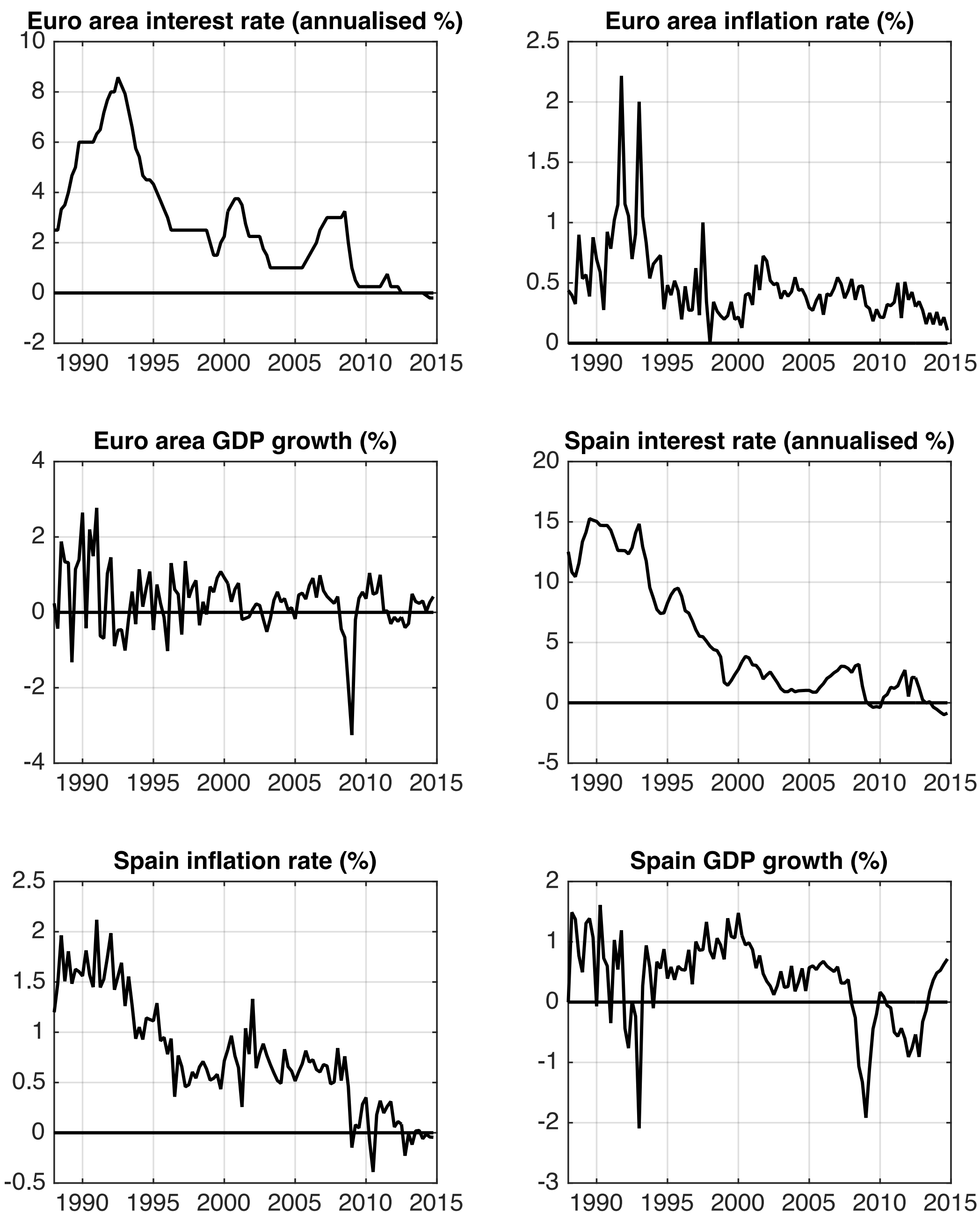

Figure 2: Data Used in Estimation (*continued on next page*).

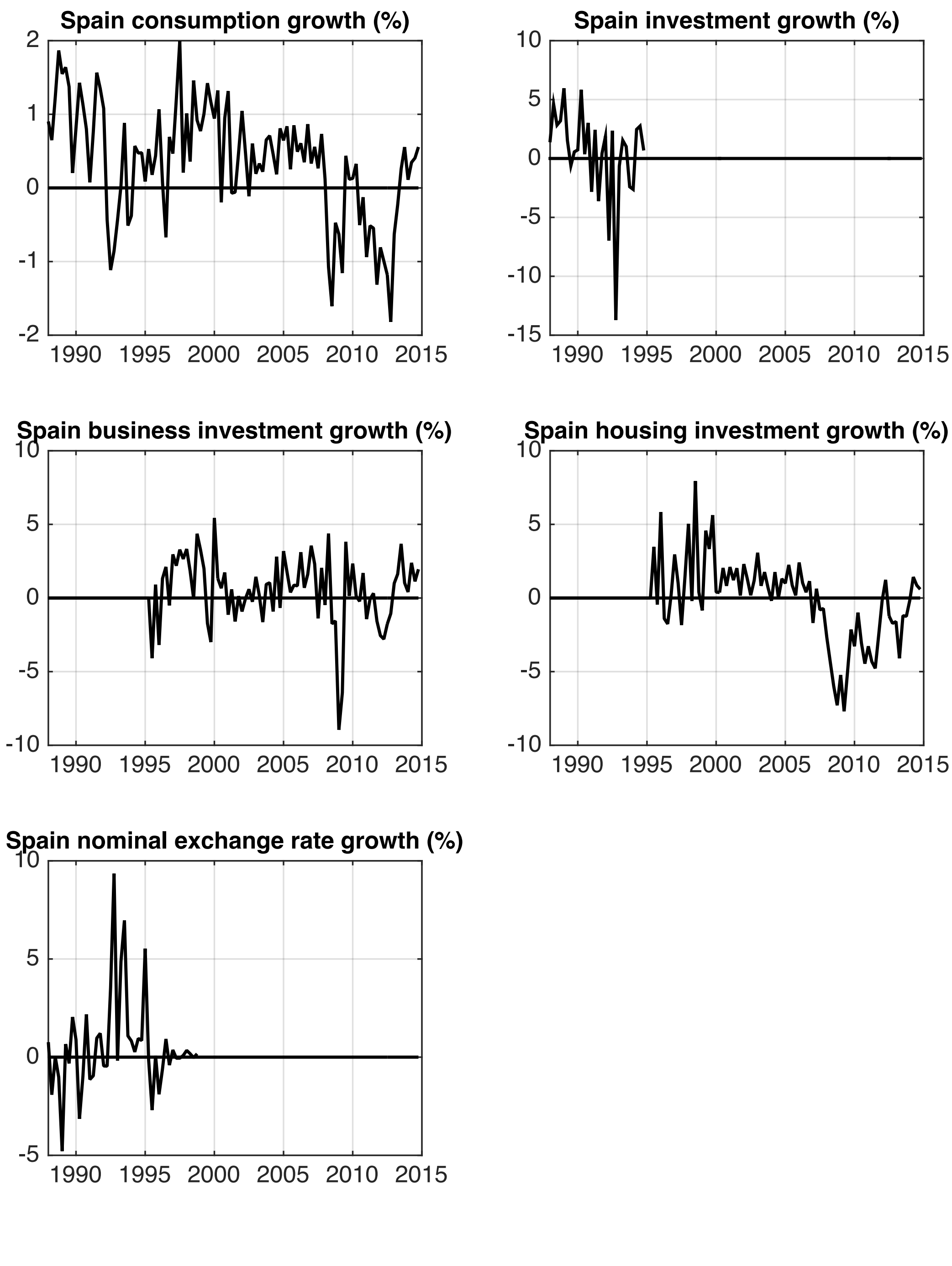

Figure 3: Data Used in Estimation (*continued*).

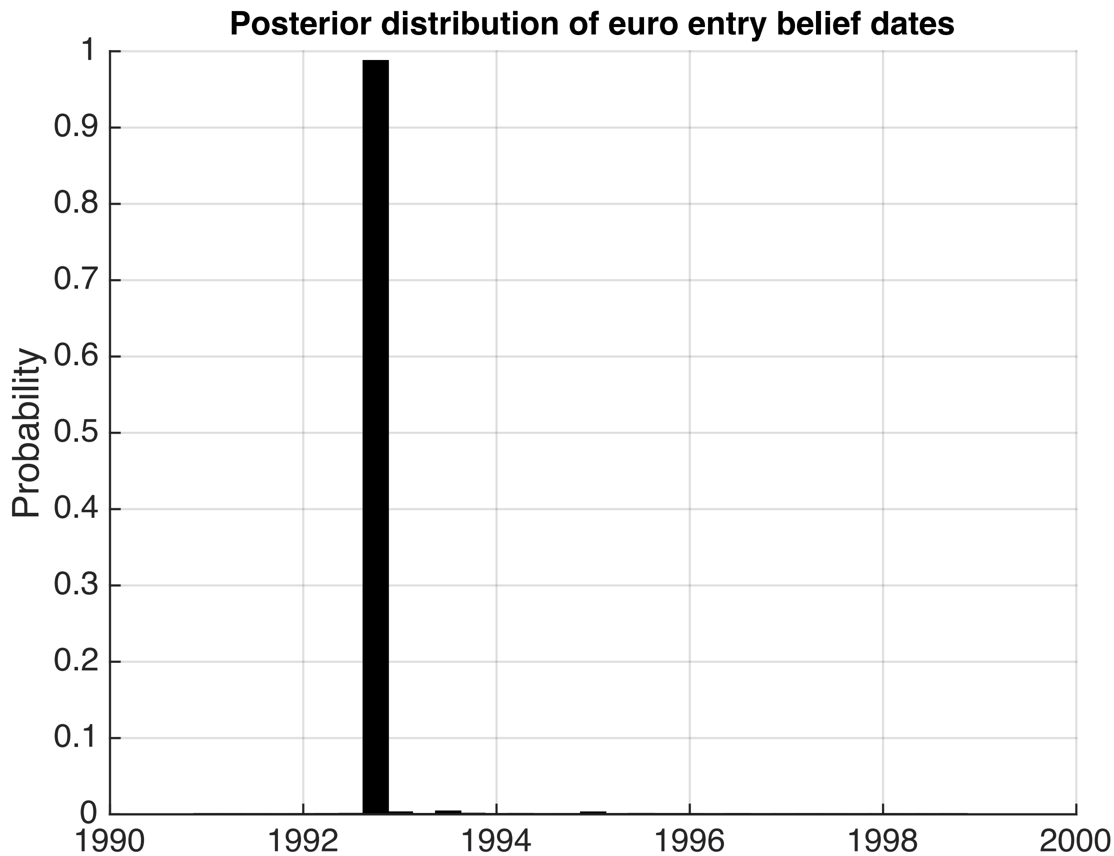

Figure 4: **Probability Density Function of Estimated Break in Expectations.** This figure plots estimated probability density function of the distribution of breaks in Spanish agents' beliefs about Spain's euro entry. Each bar shows the probability that agents began anticipating Spain's euro entry at that date.

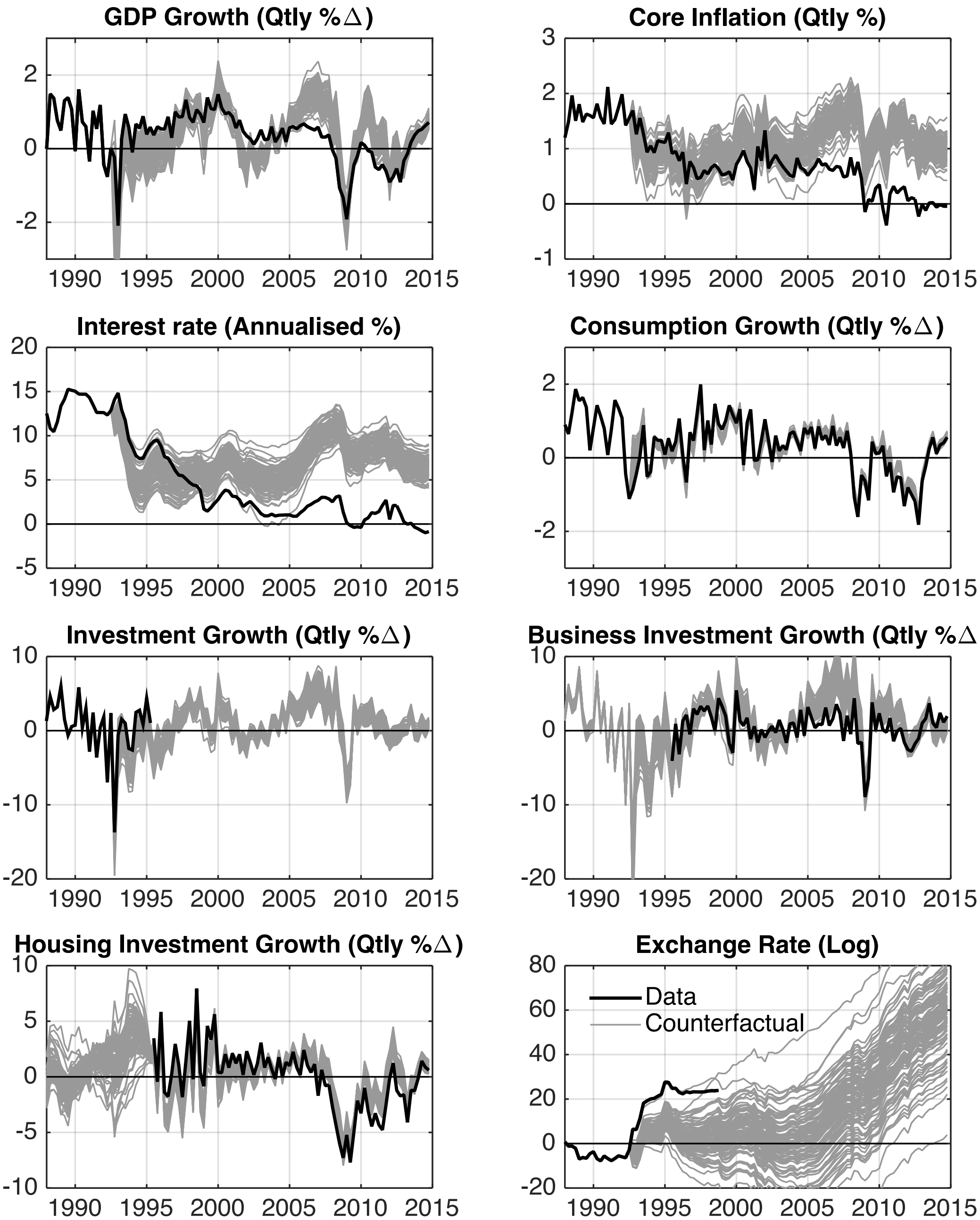

Figure 5: **Counterfactual Economic Outcomes**. This graph compares actual Spanish economic outcomes against counterfactuals in which Spain does not enter the eurozone. The black lines show actual data. Each grey line shows a counterfactual constructed for a single draw from the posterior parameter distribution.

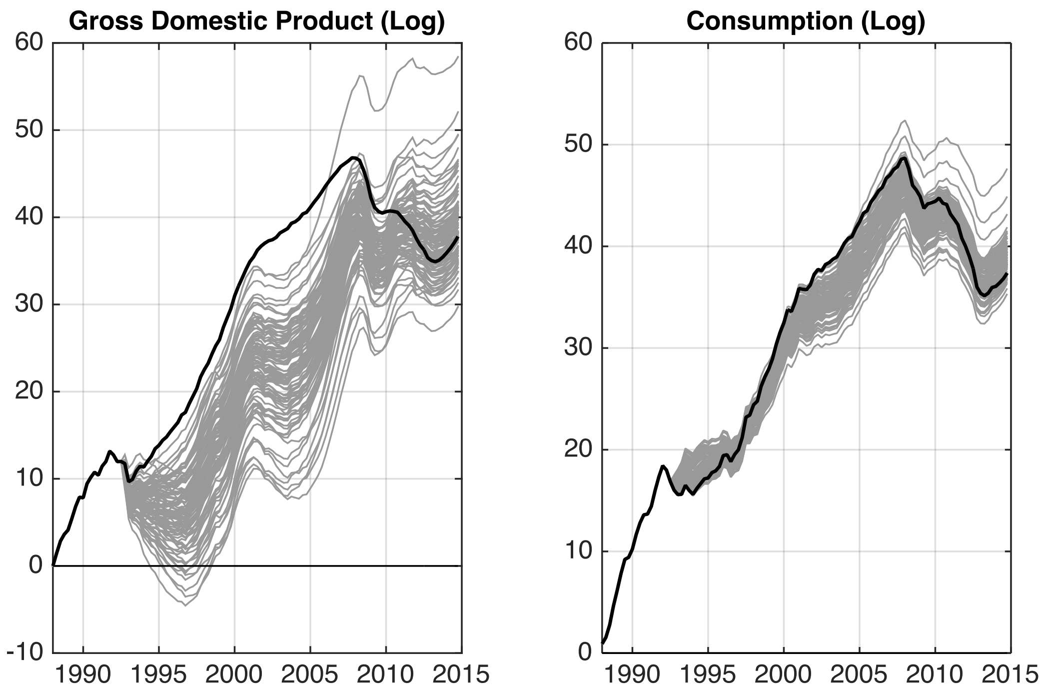

Figure 6: **Counterfactual Economic Outcomes**. This graph compares actual Spanish economic outcomes again counterfactuals in which Spain does not enter the eurozone. The black lines show actual data. Each grey line shows a counterfactual constructed for a single draw from the posterior parameter distribution.

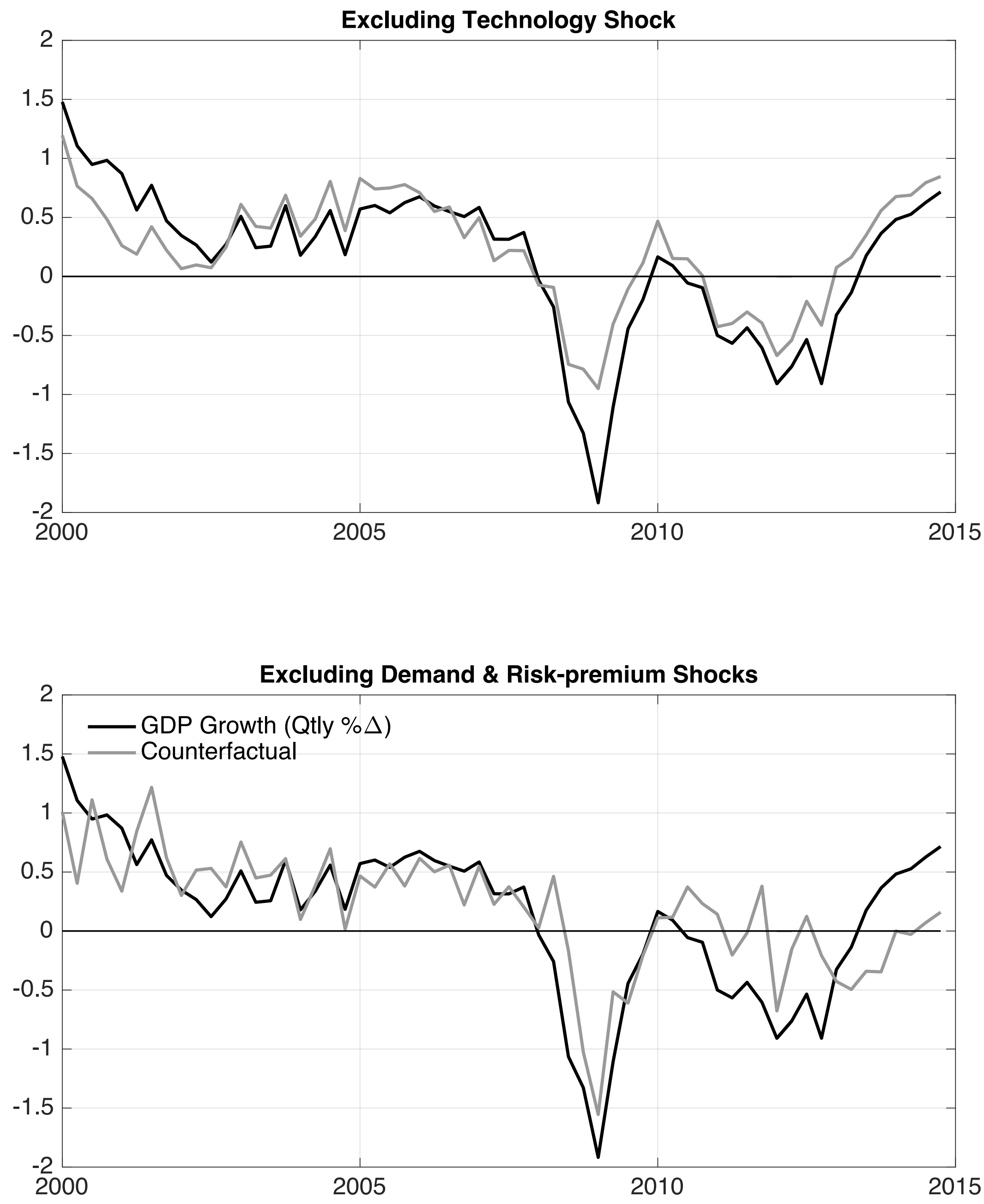

Figure 7: **Counterfactual Economic Outcomes when Excluding Shocks**. This graph compares actual Spanish GDP growth between 2000 and 2014 against counterfactual. The plot above shows the case in which Spain and the Euro area are not hit by the technology shock. The plot below shows the case when Spain is not hit by the demand and risk-premium shocks. The black lines show actual data. The grey lines show the counterfactual Spanish GDP growth.

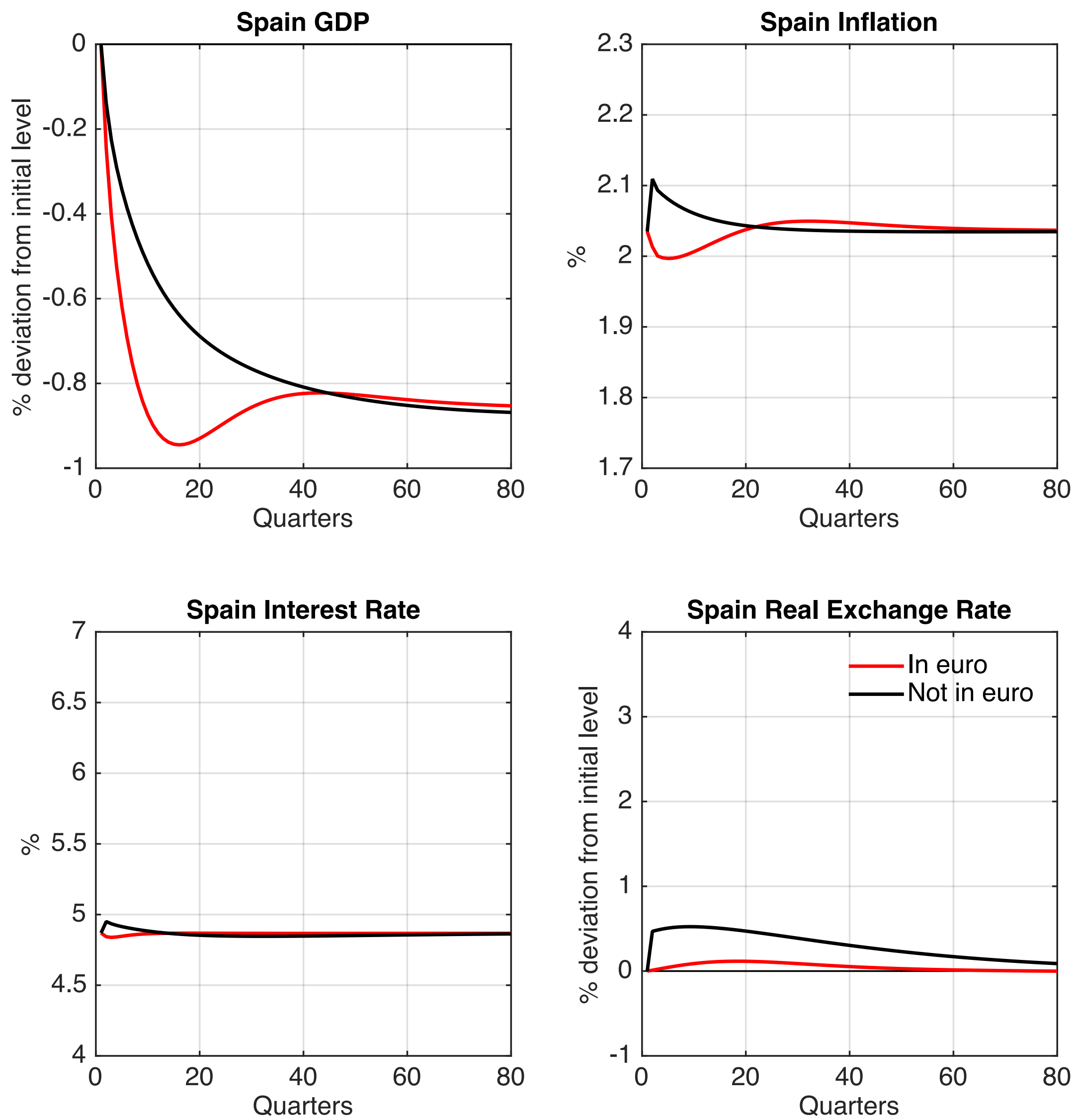

Figure 8: **Impulse response to a negative technology shock**. This figure plots the impulse responses to a one standard deviation technology shock in quarter 1.

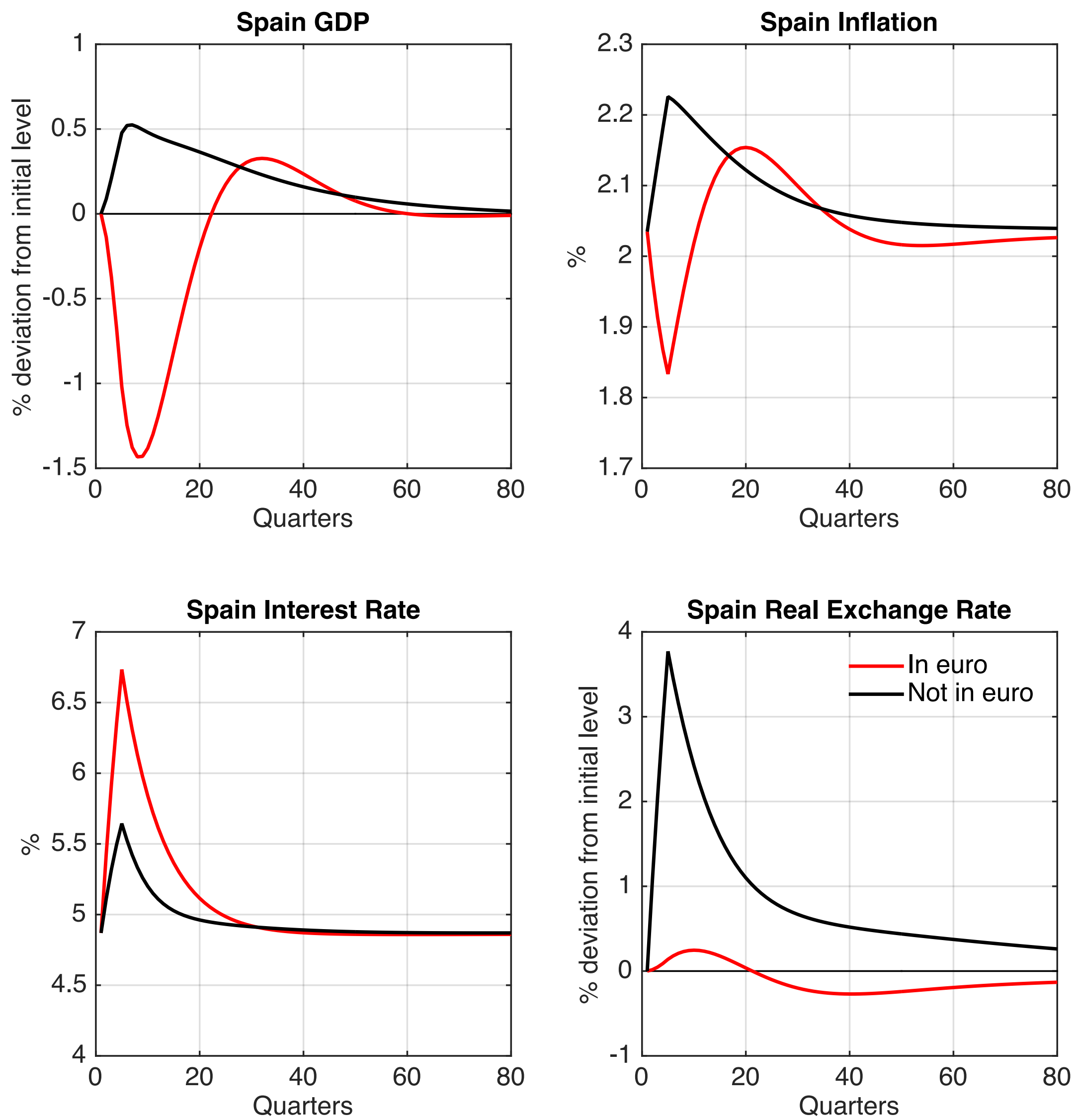

Figure 9: **Impulse response to a risk premium shock**. This figure plots the impulse responses to a one standard deviation risk premium shock in each of periods 1 to 4.

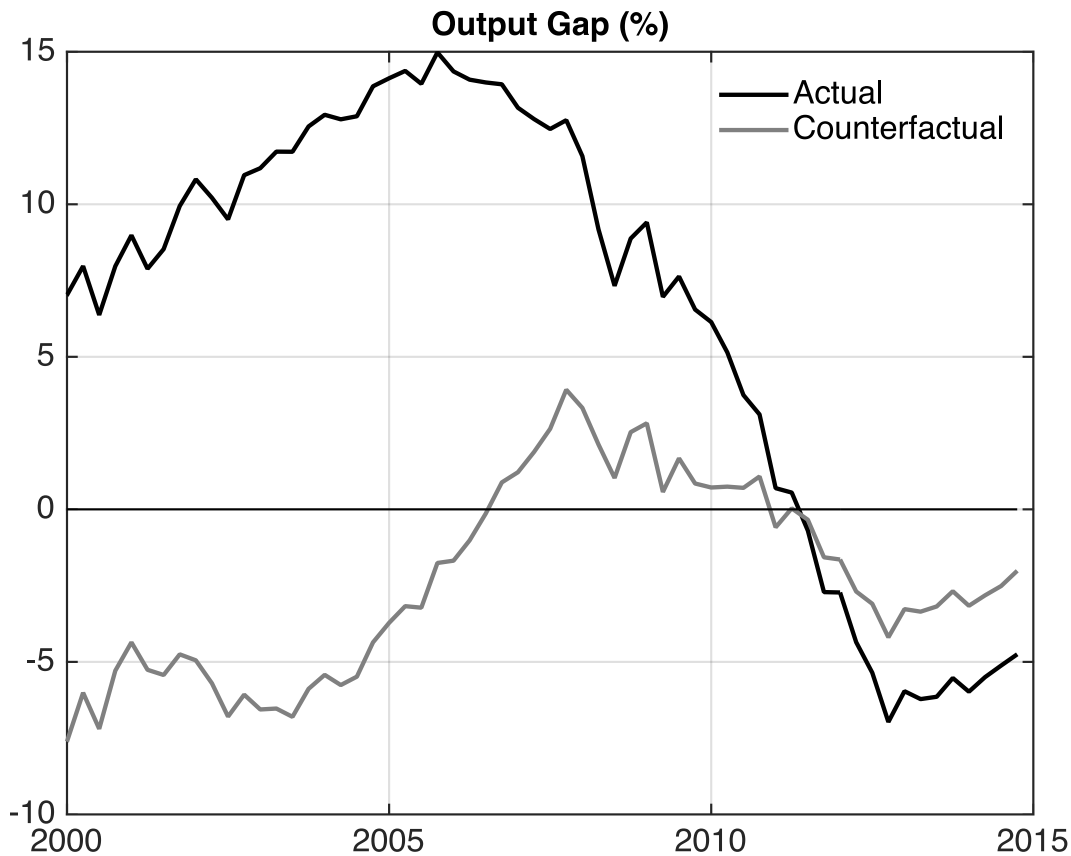

Figure 10: **Output Gap.** This graph shows estimated output gaps in the data (black line) and a counterfactual in which Spain does not join the eurozone (grey line).