Monetary-Fiscal Interactions and the Euro Area's Malaise*

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Abstract

When monetary and fiscal policy are conducted as in the euro area, output, inflation, and government bond default premia are indeterminate according to a standard general equilibrium model with sticky prices extended to include defaultable public debt. With sunspots, the model mimics the recent euro area data. We specify an alternative setup to coordinate monetary and fiscal policy in the euro area, with a non-defaultable Eurobond. Output and inflation become determinate in general and government bond yields in important cases. If this policy arrangement had been in place during the Great Recession and afterwards, output could have been much higher and inflation somewhat higher than in the data.

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1 Introduction

The euro area economy has been experiencing a period of malaise. Real GDP per capita declined by 5 percent in 2009 (the "Great Recession"). A moderate recovery took place in 2010 and 2011. Real GDP per capita then decreased again in 2012 and 2013. At the end of 2015 real GDP per capita was 2 percent lower than in 2008. See the top left panel in Figure 1.

Figure 1 also shows the evolution of selected nominal variables in the euro area over the same years. Inflation, whether measured in terms of the Harmonized Index of Consumer Prices or in terms of the core HICP (excluding energy and food), declined, rose, and fell again. The annual rate of inflation based on the HICP has decreased in each year since 2011 and stood at 0.1 percent in 2015. The annual rate of inflation based on the core HICP has not exceeded 1.5 percent since 2008. The interest rate effectively controlled by the European Central Bank, the Eonia, followed the same non-monotonic pattern as real GDP per capita and inflation: The Eonia decreased in 2009 and 2010, increased in 2011, and then declined again. Default premia on public debt have also followed a non-monotonic path. The bottom right panel of Figure 1 shows weighted averages of one-year government bond yields for Germany, France, and the Netherlands and for Italy and Spain. The spread between the two weighted averages used to be practically zero between the launch of the euro in 1999 and 2008, rose sharply in 2011 and 2012, and fell subsequently.

This paper formalizes the idea that the way monetary and fiscal policy are conducted in the euro area has been central to the outcomes depicted in Figure 1. If monetary and fiscal policy had been coordinated differently, the outcomes could have been very different. We begin with a model in which the specification of monetary and fiscal policy aims to capture the essential features of how each policy is actually conducted in the euro area. We show that this model mimics the recent euro area data. We then study a version of the model in which policies interact differently. This version of the model implies that output could have been much higher and inflation somewhat higher than in the data.

We consider a simple general equilibrium model with sticky prices. There are homogenous households and firms and a single monetary authority. The only non-standard features of the model are that there are N fiscal authorities corresponding to N imaginary member states of a monetary union ($N = 2$ for simplicity), and that debt of the fiscal authorities is defaultable. Each household is a "European" household that consumes a union-wide basket of goods and supplies labor to firms throughout the union. The household comprises some individuals who pay lump-sum taxes to the fiscal authority in one imaginary member state of the union and some individuals who pay lump-sum taxes to the fiscal authority in the other imaginary member state of the union. Each "national" fiscal authority issues single-period nominal bonds.

We suppose that the monetary authority pursues a standard interest rate reaction function subject to a lower bound on the interest rate. Each national fiscal authority seeks to stabilize its debt by adjusting its primary budget balance, in the standard way, but may default in adverse circumstances. Specifically, we assume that there is an upper bound on the sustainable amount of public debt and that default occurs if debt rises above the upper bound. We think that this simple specification captures the essential features of how monetary and fiscal policy are actually conducted in the euro area.

In the full nonlinear model, we consider the effects of an unanticipated disturbance to the households' discount factor. The disturbance temporarily decreases the value of current consumption relative to future consumption. The economy's response to the disturbance is indeterminate. The economy converges either to a steady state in which inflation is equal to the monetary authority's objective ("the intended steady state") or to a steady state in which the nominal interest rate is zero and inflation is below the objective ("the unintended steady state"). Furthermore, there are infinitely many ways in which the economy can converge to the unintended steady state. The default premia on bonds issued by a national fiscal authority can also be indeterminate. If agents do not expect default, bond yields are low and therefore debt and the probability of default are also low validating the agents' expectation. If agents expect default, bond yields are high and therefore debt and the probability of default are also high likewise validating the agents' expectation.

We introduce two sunspot processes, one of which determines to which steady state the economy converges while the other coordinates bondholders on a single interest rate on public debt. We find that the simulated model mimics the recent euro area data (the "baseline simulation"). Output, inflation, the central bank's interest rate, and the government bond spread in the model replicate the non-monotonic pattern from Figure 1. Moreover, the paths of the variables in the model are quantitatively similar to the data.

We use the model to conduct policy experiments in which we assume an alternative arrangement to coordinate monetary and fiscal policy. We introduce a new policy authority, a centrally-operated fund that can buy debt of the national fiscal authorities and can issue its own debt, single-period nominal bonds ("Eurobonds"). We suppose that Eurobonds are non-defaultable, i.e., backed by the monetary authority. The fund stands ready to purchase debt issued by each national fiscal authority so long as that authority follows an *ex ante* specified fiscal policy reaction function. In "normal" times each national fiscal authority is to stabilize its debt by adjusting its primary surplus in the standard way. If the central bank's interest rate reaches the lower bound, each national fiscal authority is to raise its primary surplus if its debt increases in relation to the sum of all public debt in the union. As we explain, this behavior amounts to active fiscal policy in the sense of Leeper (1991) at the level of the union as a whole. We also suppose that if the central bank's interest rate reaches the lower bound, monetary policy remains passive in the sense of Leeper (1991) after the lower bound ceases to bind.

With this configuration of policy, the model has a unique solution for output, inflation, and the central bank's interest rate, and the solution converges to the intended steady state. For plausible parameter values, output is much higher and inflation somewhat higher than in the baseline simulation that mimics the euro area data. The critical feature of the policy experiment is that the fund issues nominal non-defaultable debt. When primary surpluses backing nominal non-defaultable debt decrease permanently, households are wealthier at a given price level and they spend more. Inflation rises and, if prices are sticky, output also increases. This is an attractive outcome when inflation is too low and the economy is in a recession to begin with. When a fiscal authority with defaultable debt lowers primary surpluses permanently, the fiscal authority must default. Default produces a gain for households as taxpayers. However, default also imposes a loss of the same magnitude on households as bondholders. There is no wealth effect prompting households to spend more.

It is important to ask what would happen if a national fiscal authority deviated from the prescribed reaction function. We have in mind an institutional setup in which the fund would then refuse to purchase debt issued by that authority and the authority could default. We use the model to assess the consequences of default by a national fiscal authority for inflation in the euro area. Default by a national fiscal authority exerts upward pressure on inflation by lowering the stream of the primary surpluses flowing to the fund. We simulate two scenarios in which one of the two national fiscal authorities in the model defaults in equilibrium. In the "moderate default scenario," we assume that default causes a capital loss of about 420 billion euros. We find that the inflation rate jumps up by about 60 basis points at an annual rate due to the default. This is a non-trivial effect but it is difficult to think of the resulting transitory inflation rate of just above 2 percent as materially excessive. In the "severe default scenario," we suppose that default causes a capital loss of about 1 trillion euros and that prices become more flexible at the time when default takes place. The inflation rate jumps up to about 8 percent and subsequently declines to the intended steady state. We conclude that a "severe default scenario" like this one can produce excessive inflation for some time. At the same time, we point out that the effects of default on inflation diminish and can vanish completely if the fund can impose a tax directly on households conditional on default.

The model let us study how the presence of the fund affects the determinacy of bond yields in the market for debt issued by the national fiscal authorities. The following two cases seem important. First, when the fund purchases a sufficient fraction of debt at the price free of default premium, that price becomes the only equilibrium, although in the absence of the fund there are two other equilibria, each with a positive probability of default. Second, any bond purchases by the fund, or even an announced intention of the fund to buy bonds, at the price free of default premium can coordinate households on the equilibrium with the probability of default equal to zero when there are multiple equilibria in the absence of the fund.

Section 2 contains a literature review. Section 3 sets up the model. Section 4 presents the baseline experiment. Section 5 shows the policy experiments, and Section 6 concludes.

2 Contacts with the literature

[To be written.]

This work is related to the following papers: Leeper (1991), Sims (1994), Sims (1997), Sims (2012), Benhabib et al. (2001), Schmitt-Grohé and Uribe (2012), Bianchi and Melosi (2014).

3 Model

We consider a simple general equilibrium model with sticky prices. There are homogenous households and firms and a single monetary authority. The only non-standard features of the model are that there are N fiscal authorities corresponding to N imaginary member states of a monetary union, and that debt of the fiscal authorities is defaultable. For simplicity, we set $N = 2$ ("North" and "South").

3.1 Setup

Time is discrete and indexed by t. There is a continuum of identical households indexed by $j \in [0, 1]$. Household j consumes, supplies labor to firms, collects firms' profits, pays lump-sum taxes, and can hold three bonds: a claim on other households, a claim on the fiscal authority in North, and a claim on the fiscal authority in South. Each bond is a single-period nominal discount bond. The household maximizes

$$E_t \left[\sum_{\tau=t}^{\infty} \beta^{\tau-t} e^{\xi_\tau} \left(\log C_{j\tau} - L_{j\tau} \right) \right]$$

where

$$C_{jt} = \left(\int_0^1 C_{ijt}^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}.$$

C_{ijt} is consumption of good i by household j in period t, C_{jt} is composite consumption of the household, L_{jt} is labor supplied by the household, ξ_t is an exogenous disturbance, and $\beta \in (0, 1)$ and $\varepsilon > 1$ are parameters.

We interpret each household as a "European" household that consumes the union-wide basket of goods and supplies labor to firms throughout the union. The household comprises some individuals who pay taxes to the fiscal authority in one imaginary member state of the union, North, and some individuals who pay taxes to the fiscal authority in the other imaginary member state of the union, South. The budget constraint of household j in period t reads

$$C_{jt} + \frac{R_t^{-1} H_{jt} + \sum_n Z_{nt}^{-1} B_{jnt}}{P_t} = \frac{H_{j,t-1} + \sum_n \Delta_{nt} B_{jn,t-1}}{P_t} + W_t L_{jt} - \sum_n S_{jnt} + \Phi_{jt}. \quad (1)$$

H_{jt} denotes bonds issued by other households and purchased by household j in period t, and R_t is the gross interest rate on these bonds. B_{jnt} denotes bonds issued by fiscal authority n and purchased by household j in period t, Z_{nt} is the gross interest rate on these bonds, $n = 1, ..., N$, and $N = 2$. $\Delta_{nt} \in (0, 1]$ is the period t payoff from a bond of fiscal authority

n. P_t is the price level given by

$$P_t = \left(\int_0^1 P_{it}^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}},$$

where P_{it} is the price of good i. W_t is the real wage. S_{jnt} is a lump-sum tax paid by household j to fiscal authority n. Φ_{jt} is household j's share of the aggregate profit of firms. We make the standard assumption that bonds H do not default. The reason why we introduce bond H is that we want the model to contain a bond with yield free of any default premium. We suppose that $\int_0^1 H_{jt} dj = 0$. Furthermore, we assume that taxes and profits are shared equally by households in every period, i.e., $S_{jnt} = S_{nt}$ and $\Phi_{jt} = \Phi_t$ for each j, n, and t. In equilibrium households are identical and therefore most of the time we drop the subscript j.

There is a continuum of monopolistically competitive firms indexed by $i \in [0, 1]$. Firm i produces good i. In every period firm i sets the price of good i, P_{it}. The firm maximizes

$$E_t \left[\sum_{\tau=t}^{\infty} \beta^{\tau-t} \left(e^{\xi_\tau} / C_\tau \right) \Phi_{i\tau} \right]$$

where $\left(e^{\xi_t} / C_t \right)$ is the households' marginal utility of consumption in period t, and Φ_{it} is the real profit function given by

$$\Phi_{it} = \frac{P_{it} X_{it}}{P_t} - W_t L_{it} - \frac{\chi}{2} \left(\frac{P_{it}}{P_{it-1}} - \bar{\Pi} \right)^2 \frac{P_{it} X_{it}}{P_t}.$$

X_{it} is the quantity of good i produced in period t satisfying $X_{it} = L_{it}$, where L_{it} is the quantity of labor hired by firm i. The last term on the right-hand side is the cost of changing the price. Here $\chi \geq 0$ is a parameter and $\bar{\Pi} \geq 1$ is the inflation objective of the monetary authority. The firm supplies any quantity demanded at the chosen price, i.e., $X_{it} = C_{it}$, where C_{it} is aggregate consumption of good i in period t. The firm faces the demand function

$$C_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\varepsilon} C_t.$$

In equilibrium firms are identical and therefore we drop the subscript i.

In modeling monetary policy and fiscal policy we aim to capture the essential features of how each policy is actually conducted in the euro area. We suppose that the single monetary authority has inflation stabilization as its objective and pursues a standard interest rate reaction function subject to a lower bound on the interest rate. There are multiple fiscal authorities each of which seeks to stabilize its debt by adjusting its primary budget balance, in the standard fashion, but may default in adverse circumstances.

Specifically, we assume that the single monetary authority sets the interest rate on non-defaultable bonds H according to the reaction function

$$R_t = \max\left\{\frac{\bar{\Pi}}{\beta}\left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\phi}, 1\right\}, \tag{2}$$

where $\Pi_t \equiv (P_t/P_{t-1})$ and ϕ is a parameter satisfying $\phi > 1$. Since $\phi > 1$ monetary policy is active in the sense of Leeper (1991), so long as the interest rate is away from the lower bound.[1]

The budget constraint of fiscal authority n, $n = 1, 2$, in period t reads

$$\frac{B_{nt}}{Z_{nt}P_t} = \frac{\Delta_{nt}B_{n,t-1}}{P_t} - S_{nt}, \tag{3}$$

where S_{nt} is the real primary budget surplus of fiscal authority n in period t. Let Y_t denote aggregate output net of the cost of changing prices, $\tilde{S}_{nt} \equiv (S_{nt}/Y_t)$, and $\tilde{B}_{nt} \equiv (B_{nt}/P_tY_t)$. It is convenient to rewrite equation (3) as

$$\frac{\tilde{B}_{nt}}{Z_{nt}} = \frac{\Delta_{nt}\tilde{B}_{n,t-1}Y_{t-1}}{\Pi_tY_t} - \tilde{S}_{nt}. \tag{4}$$

We suppose that fiscal authority n sets its primary surplus according to the reaction function

$$\tilde{S}_{nt} = \psi_n + \psi_B\tilde{B}_{n,t-1} + \psi_{Yn}\,(Y_t - Y) + \psi_Z(Z_{n,t-1} - R_{t-1}), \tag{5}$$

where Y denotes output in the "intended" steady state (which we solve for below), and $\psi_n < 0$, $\psi_B > 1/\beta - 1$, $\psi_{Yn} \geq 0$, and $\psi_Z \geq 0$ are parameters. For the sake of realism, equation (5) allows for feedback to the primary surplus from the output gap $Y_t - Y$ and from the default premium $Z_{nt} - R_t$. Since $\psi_B > 1/\beta - 1$ (the primary surplus responds to public debt by more than $1/\beta - 1$), fiscal policy would be passive in the sense of Leeper (1991) if we ended its description here. However, we want to capture the idea that there

[1] For simplicity and following common practice, we do not model the monetary base. One can think of the monetary base as being in the background.

is a limit to economically or politically feasible primary surpluses, and therefore beyond some upper bound public debt becomes unsustainable. Furthermore, there is uncertainty about what the upper bound is in any period. We suppose that in any period $t \geq 1$ fiscal authority n defaults if $\tilde{B}_{n,t-1} \geq \tilde{B}_{nt}^{\max}$, where $\tilde{B}_{nt}^{\max}$ is an i.i.d. random variable uniform on the interval $\left[\tilde{B}_n^a, \tilde{B}_n^b\right]$. If fiscal authority n defaults in period t, the recovery rate in that period is $\Delta_{nt} = \Delta_n \in (0,1)$; otherwise, $\Delta_{nt} = 1$. Private agents determine the yield on bonds issued by fiscal authority n, Z_{nt}, taking into account the value of Δ_n and the probability of default in period $t+1$ given by $\Pr\left(\tilde{B}_{nt} \geq \tilde{B}_{n,t+1}^{\max}\right)$. Default then occurs or not in period $t+1$ based on the realization of $\tilde{B}_{n,t+1}^{\max}$.

In this simple model default by a fiscal authority has no effect on households' wealth. Default imposes a loss on households as bondholders. However, default also produces a gain of the same magnitude for households as taxpayers, because at default the present value of primary surpluses falls by the amount of the haircut. Moreover, default has no effect on output or inflation.

3.2 Equilibrium conditions

The first-order conditions of households and firms imply that the following equations hold in equilibrium: (i) the standard consumption Euler equation

$$E_t\left[\frac{\beta\left(e^{\xi_{t+1}}/C_{t+1}\right)}{\left(e^{\xi_t}/C_t\right)}\frac{R_t}{\Pi_{t+1}}\right] = 1, \tag{6}$$

(ii) the equation determining the default premia

$$E_t\left[\frac{\beta\left(e^{\xi_{t+1}}/C_{t+1}\right)}{\left(e^{\xi_t}/C_t\right)}\frac{\Delta_{n,t+1}Z_{nt}}{\Pi_{t+1}}\right] = 1, \tag{7}$$

and (iii) a nonlinear Phillips curve

$$\varepsilon - \varepsilon C_t - (\chi/2)(\varepsilon-1)\left(\Pi_t - \bar{\Pi}\right)^2 + \chi\left(\Pi_t - \bar{\Pi}\right)\Pi_t - \chi E_t\left[\beta e^{(\xi_{t+1}-\xi_t)}\left(\Pi_{t+1} - \bar{\Pi}\right)\Pi_{t+1}\right] = 1. \tag{8}$$

Furthermore, the following condition holds:

$$\lim_{k\to\infty} E_t\left[\frac{\beta^k\left(e^{\xi_{t+k}}/C_{t+k}\right)}{\left(e^{\xi_t}/C_t\right)}\left(\frac{\sum_n Z_{n,t+k}^{-1}B_{n,t+k}}{P_{t+k}}\right)\right] = 0. \tag{9}$$

We obtain this equation after we take the transversality condition of each household j and sum across j's using the relation $\int_0^1 H_{jt}dj = 0$. Finally, in equilibrium the resource constraint reads $C_t = Y_t$, where $Y_t \equiv X_t \left(1 - \frac{\chi}{2}\left(\Pi_t - \bar{\Pi}\right)^2\right)$ and $X_t \equiv \left(\int_0^1 P_{it}X_{it}di\right)/P_t$.

3.3 Steady states

Assume that $\xi_t = 0$ in every period t. Furthermore, suppose that Π, R, and all real variables including $\tilde{B}$ are constant. We refer to a solution of the model in this case as a steady state.

There are two steady states. In one steady state (the "intended" steady state), Π is equal to the monetary authority's target, $\bar{\Pi}$, and R is equal to $\bar{\Pi}/\beta$. In the other steady state (the "unintended" steady state), Π is equal to β and R is equal to one. It is straightforward to solve for the other variables in each steady state. The reason why the model has the two steady states is familiar from Benhabib et al. (2001).

3.4 A discount factor disturbance

We now introduce an assumption that we will maintain throughout the rest of the paper. In period zero, the economy is in the intended steady state. The economy is expected to remain in the intended steady state forever. In period one, agents realize that ξ will take particular negative values beginning in period one and ending in period $T > 1$, and afterwards ξ will be equal to zero again forever, i.e., $\xi_t = \bar{\xi}_t < 0$, $t = 1, ..., T$, $\xi_t = 0$, $t = T + 1, ...$

To gain intuition about how the model works, it is helpful solve it under the assumption stated in the previous paragraph, for some parameter values and for some increasing sequence of the $\bar{\xi}_t$'s. (For the moment it does not matter what the parameter values are.) From equation (6) note that the stochastic discount factor is equal to $\beta e^{(\xi_{t+1}-\xi_t)}C_t/C_{t+1}$. Since the $\bar{\xi}_t$'s are negative and increasing, the exogenous component of the stochastic discount factor, $\beta e^{(\xi_{t+1}-\xi_t)}$, rises on impact and eventually falls to β. Hence, the disturbance hitting the economy temporarily decreases the value of current consumption relative to future consumption.[2]

There are multiple equilibrium paths for output, inflation, and the central bank's interest rate. There is a unique solution that converges to the intended steady state. There are also infinitely many solutions that converge to the unintended steady state. Figure 2 shows the

[2] The exogenous shock used here has been popular following Eggertsson and Woodford (2003) as a simple way to model the kind of disturbance that triggered the financial crisis of 2008-2009.

unique solution converging to the intended steady state and an arbitrarily chosen solution converging to the unintended steady state.

In general, the default premia are also indeterminate. The number of solutions for Z_{nt} in any period depends on last period's debt, $\tilde{B}_{n,t-1}$. If last period's debt is low, there is a unique solution with the probability of default in period $t+1$ equal to zero and with $Z_{nt} = R_t$. If last period's debt is high, there is a unique solution with the probability of default in period $t+1$ equal to one and with the value of Z_{nt} pinned down by Δ_n. For intermediate values of last period's debt, there are multiple solutions for Z_{nt}. If agents do not expect default, Z_{nt} is low and therefore $\tilde{B}_{n,t}$ and the probability of default are also low validating the agents' expectation. If agents expect default, Z_{nt} is high and therefore $\tilde{B}_{n,t}$ and the probability of default are also high likewise validating the agents' expectation.

It is useful to observe that optimal policy in this model keeps output and inflation constant at their values in the intended steady state. Suppose that monetary policy is not subject to the lower bound, i.e., the interest rate reaction function is simply $R_t = \left(\bar{\Pi}/\beta\right)\left(\Pi_t/\bar{\Pi}\right)^{\phi}$ in every period with $\phi > 1$. There is then a unique steady state, the intended steady state, and there is a unique solution for output, inflation, and the central bank's interest rate following a disturbance to ξ. Furthermore, when ϕ is large, Y and Π remain constant in every period at their steady-state values after a shock to ξ (while R declines below one in period one and afterwards returns to the steady state). Thus in the absence of the lower bound the standard interest rate reaction function implements the optimal policy. However, in the presence of the lower bound the optimal policy cannot in general be implemented via reaction function (2) even if one assumes that the economy converges to the intended steady state following each disturbance. Furthermore, the economy is exposed to self-fulfilling fluctuations and it can fluctuate around the unintended steady state. When the economy fluctuates around the unintended steady state, a welfare loss results due to the fact that the central bank's interest rate cannot be lowered as is desirable after contractionary shocks to ξ.[3]

[3]The stochastic simulations in Arias et al. (2016) show how the presence of the lower bound changes the probability distribution of outcomes in a New Keynesian model: the ergodic mean of output ends up below the nonstochastic-steady-state value of output (unique in their analysis), and the probability distribution of output becomes negatively skewed.

4 Baseline simulation

We have set up a simple model in which the behavior of monetary and fiscal policy captures the essential features of how each policy is actually conducted in the euro area. Given this specification of policy, in this section we simulate the model (the "baseline simulation"). The main finding is that the baseline simulation mimics the recent euro area data.

Before simulating the model we add to it two sunspot processes. This allows us to solve for the unique response of the economy to the discount factor disturbance. As before, we assume in this section that: (i) in period zero the economy is in the intended steady state, and the economy is expected to remain in the intended steady state forever; and (ii) in period one agents realize that ξ will follow the process defined in Section 3.4.

4.1 Sunspot processes

Consider the following two sunspot processes, mutually independent and independent of all other variables in the model. A "confidence about inflation" shock occurs with probability $p \in (0, 1)$ in every period $t = 1, 2, ...$, so long as the shock has not already occurred. After the shock has occurred, the probability of it occurring in a subsequent period is zero. Let Π'_t denote inflation in period t if the shock has not occurred. We suppose that if the shock occurs in period t inflation in period t will be to equal to $\kappa_\pi \Pi'_t$, where $\kappa_\pi > 0$ is a parameter. Furthermore, if the shock occurs in period t we solve for the other variables in period t and we solve for all variables in subsequent periods assuming that the economy converges to the unintended steady state.

As the confidence-about-inflation shock fails to occur, the economy converges to what we refer to as the "stationary point." Π, R, and all real variables including $\tilde{B}$ are constant at the stationary point, like in any steady state described in Section 3.3. However, at the stationary point the variables generally assume different values than in either steady state from Section 3.3, because at the stationary point the confidence-about-inflation shock is expected to occur in every period with probability $p > 0$.

We refer to the other sunspot shock as "confidence about debt." If in any period $t = 1, 2, ...$ multiple values of Z_{nt} satisfy all equilibrium conditions for any n, the confidence-about-debt shock selects one of the values as the equilibrium outcome.

Given the two sunspot processes, the response of the economy to the discount factor disturbance is unique and we solve for the response numerically.[4]

4.2 Parameterization

One period in the model is one year. Period one in the model is the year 2009. We set $\beta = 0.995$. This value would be too high for the period before the financial crisis of 2008-2009, but it seems a distinct possibility for the post-crisis environment, at least in the medium run that we look at.[5] We suppose that the elasticity of substitution between goods, ε, is equal to 11, which is a common value in the literature. We choose a value of χ such that the slope of the Phillips curve in the model linearized around the intended steady state is 0.1. This flat Phillips curve is consistent with the dynamics of output and inflation in the recession accompanying the financial crisis of 2008-2009. We assume that $\bar{\xi}_{t+1} - \bar{\xi}_t$ is a linear function of time and that $T = 7$ (ξ returns to zero in period eight). We specify $p = 0.04$ (the annual probability of the confidence-about-inflation shock is 0.04), we suppose that the confidence-about-inflation shock occurs in 2012, and we assume that $\kappa_\pi = 0.983$ (which affects the magnitude of the fall in inflation in 2012). In the monetary policy reaction function we set $\bar{\Pi} = 1.019$ (the inflation rate target is 1.9 percent) and $\phi = 3$.

We define North as Germany, France, and the Netherlands together. South is Italy and Spain together. We assume that $\tilde{B}_{1,0} = 0.35$, i.e., in period zero debt of the fiscal authority in North, as a share of nominal output, is equal to 0.35. Public debt of Germany, France, and the Netherlands together, as a share of nominal GDP *of the euro area*, was equal to 0.35 in 2008. We set $\tilde{B}_{2,0} = 0.22$ based on the same reasoning and data for Italy and Spain. We suppose that $\psi_B = 0.025$. This value of ψ_B implies that the debt-to-output ratio in the model follows a persistent process, as is realistic. Given the selected values of ψ_B and $\tilde{B}_n$, for each n we compute ψ_n from the equation $\psi_n = -\tilde{B}_n(\psi_B - (1-\beta)/\bar{\Pi})$ which holds in period zero (since the economy is in the intended steady state in period zero). We assume that $\psi_{Y1} = 0.255$, $\psi_{Y2} = 0.295$, and $\psi_Z = 0.2$. With this parameterization the primary surpluses in the baseline simulation mimic the data, in the following sense: The average value of $\tilde{S}_{1t}$ in periods one through seven in the model matches the average primary surplus of Germany, France, and the Netherlands together (as a fraction of euro area GDP) in the

[4]The assumption that the sunspot processes are mutually independent and independent of all other variables in the model is made for simplicity. For example, in a model with government spending one could consider a specification in which the sunspot processes were correlated with that variable.

[5]A richer model could allow for the possibility of variation in β over time, e.g., so that β rises at the time of the financial crisis and falls thereafter.

period 2009-2015. Analogously, the average value of $\tilde{S}_{2t}$ in periods one through seven in the model matches the average primary surplus of Italy and Spain together in the period 2009-2015. We specify that $\tilde{B}_1^a = 0.5$, $\tilde{B}_1^b = 0.6$, $\tilde{B}_2^a = 0.26$, $\tilde{B}_2^b = 0.27$, and $\Delta_1 = \Delta_2 = 0.8$ (the recovery rate is 80 percent). In any period in which multiple values of either Z_{1t} or Z_{2t} satisfy all equilibrium conditions, we suppose that the confidence-about-debt shock selects the lowest values of Z_{1t} and Z_{2t}, except that in 2012 the shock selects the lowest value of Z_{1t} and the intermediate of the three admissible values of Z_{2t}.

4.3 Baseline simulation versus the data

Figure 3 shows the response of the model economy to the discount factor disturbance in the baseline simulation. Output, inflation, and the central bank's interest rate in the model replicate the non-monotonic pattern in the data. Moreover, the paths of the three variables in the model are quantitatively similar to the data. According to the model, the fall in output and the decline in inflation in 2009 were caused by the discount factor shock. The subsequent recovery was interrupted by the confidence-about-inflation shock in 2012, when output and inflation decreased again. Afterwards, output has been recovering but inflation has shown little tendency to return to the inflation objective of the monetary authority. The bond spread in the model, $Z_{2t} - Z_{1t}$, also mimics the bond spread in the data (the bottom right panel in Figure 3).[6] According to the model, the spike in the spread and the subsequent fall in the spread were self-fulfilling.

To conclude, when monetary and fiscal policy in the model behave as they do in the euro area, the model matches the essential features of the data in the period 2009-2015. This finding makes us confident about using the model for policy experiments.[7]

[6] Throughout the baseline simulation the interest rate on bonds issued by the fiscal authority in North is equal to the central bank's interest rate, i.e., $Z_{1t} = R_t$ in every period.

[7] Of course, the simple structure of the model and the fact that only two shocks hit the model economy imply that we cannot expect the model to replicate all features of the data. For example, the model predicts a rapid decline in inflation in 2012, whereas the fall in inflation in the data since 2012 has been slow. It is no surprise that a model in which inflation is purely forward-looking, different from more empirically realistic sticky price models that allow for a backward-looking component in inflation, makes this kind of counterfactual prediction.

5 Policy experiments

This section uses the model to conduct policy experiments. The experiments help us understand what could have happened under counterfactual policy configurations, as opposed to what we actually see in the data.

We continue to assume in this section that: (i) in period zero the economy is in the intended steady state, and the economy is expected to remain in the intended steady state forever; and (ii) in period one agents realize that ξ will follow the process defined in Section 3.4. We drop the confidence-about-inflation sunspot process from the model, because the assumptions about monetary and fiscal policy we are about to make guarantee in this section a unique solution for output, inflation, and the central bank's interest rate, as we will see.

We introduce a new policy authority, a centrally-operated fund that can buy debt of the two "national" fiscal authorities and can issue its own debt, single-period nominal discount bonds ("Eurobonds"). We suppose that debt issued by the fund is non-defaultable, i.e., the monetary authority backs Eurobonds, in the same way in which a real-world central bank guarantees that reserves that it has issued are convertible into currency at par (or that maturing reserve deposits at the central bank are convertible into currency at par). We maintain the assumption that debt issued by the fiscal authorities in North and in South is defaultable (i.e., the monetary authority does not back debt of either national fiscal authority). The fund stands ready to purchase debt issued by each national fiscal authority so long as that authority follows an *ex ante* specified fiscal policy reaction function.[8]

The prescribed behavior of the national fiscal authorities is as follows. Fiscal authority n is to set its primary surplus according to reaction function (5), except that if the central bank's interest rate reaches one, i.e., if $R_\tau = 1$ in some period τ, then in period τ and in subsequent periods (i.e., in periods $t = \tau, \tau + 1, ...$) fiscal authority n is to set its primary surplus according to the reaction function

$$\tilde{S}_{nt} = \bar{\psi}_n + \psi_B \left[\tilde{B}_{n,t-1} - \theta_n \left(\sum_n \tilde{B}_{n,t-1} \right) \right] + \psi_{Yn} \left(Y_t - Y \right), \tag{10}$$

where $\bar{\psi}_n$ and θ_n are *ex ante* specified parameters satisfying $\bar{\psi}_n > 0$, $\theta_n > 0$, and $\sum_n \theta_n = 1$.[9]

[8]The way we model the fund formalizes, possibly with some differences, an idea in Sims (2012).

[9]For the moment, we focus on the case in which the behavior of each fiscal authority is as prescribed.

It is important to observe that summing equation (10) across n's yields

$$\sum_n \tilde{S}_{nt} = \sum_n \bar{\psi}_n + \left(\sum_n \psi_{Yn} \right) (Y_t - Y) \,. \tag{11}$$

Equation (11) is an active fiscal policy reaction function, in the sense of Leeper (1991), for the union as a whole. In particular, the primary surplus of the union does not respond to public debt. At the same time, the primary surplus of an individual national fiscal authority reacts to public debt, in a particular way. To understand how, suppose that an adverse disturbance to ξ occurs and output declines. If $\psi_{Y2} > \psi_{Y1}$, which is what we assume, public debt in South rises relative to public debt in North. The second term in equation (10) then implies that the fiscal authority in South is to increase its primary surplus whereas the fiscal authority in North is to decrease its primary surplus. Thus a fiscal effort is required in South and a fiscal accommodation in North. Observe that North is to lower its primary surplus even if its own public debt has risen. Note also that as the effects of any disturbance die out, the share of fiscal authority n in the union-wide stock of public debt converges to a constant, $\tilde{B}_n = \theta_n \left(\sum_n \tilde{B}_n \right)$ where $\theta_n = \bar{\psi}_n / \left(\sum_n \bar{\psi}_n \right)$.[10]

The monetary authority sets R according to reaction function (2), except that if doing so implies that $R_\tau = 1$ in some period τ then in subsequent periods (i.e., in periods $t = \tau + 1, \tau + 2, ...$) monetary policy sets an exogenous path for R converging to the intended steady-state value $\bar{\Pi}/\beta$. An exogenous path for the central bank's interest rate is a simple specification of passive monetary policy in the sense of Leeper (1991).[11]

To sum up, we suppose that when the central bank's interest rate reaches the lower bound, monetary policy becomes passive – and remains passive after the lower bound ceases to bind – and fiscal policy becomes active at the level of the union as a whole.

[10] A reaction function similar to equation (10) appears in the discussion of options for Europe's monetary union in Sims (1997).

[11] The qualitative predictions of the model do not depend on whether we assume an exogenous path for the central bank's interest rate or the passive monetary policy reaction function given by equation (2) with $\phi < 1$. We choose the former assumption because it is easier to solve the model with it than with the latter assumption. Furthermore, the quantitative results of the policy experiment in Section 5.1 and of what we refer to as the "moderate default scenario" in Section 5.2 are identical if we assume that monetary policy sets the exogenous path for the interest rate stated here so long as the inflation rate remains below some threshold, say 2.5 percent, and monetary policy switches to the passive reaction function given by equation (2) with $\phi < 1$ if the inflation rate crosses the threshold.

5.1 Simulation with no default by member states in equilibrium

To build intuition it is helpful to begin by assuming that the fund holds all debt issued by each national fiscal authority; accordingly, households hold only debt issued by the fund.[12] We will relax this assumption in Section 5.2. With this assumption in place, the budget constraint of the fund in period t reads

$$\frac{F_t}{R_t P_t} = \frac{F_{t-1}}{P_t} - \left(\sum_n \frac{\Delta_{nt} B_{n,t-1}}{P_t} - \sum_n \frac{B_{nt}}{Z_{nt} P_t} \right), \tag{12}$$

where F_t denotes Eurobonds issued by the fund and purchased by households in period t. The term in parentheses on the right-hand side of equation (12) is the cash flow of the fund in period t, in real terms, equal to the revenue from the fund's maturing claims on the national fiscal authorities minus the current period lending of the fund to the national fiscal authorities. Equations (3) and (12) imply that

$$\frac{F_t}{R_t P_t} = \frac{F_{t-1}}{P_t} - \sum_n S_{nt}, \tag{13}$$

which tells us that Eurobonds are backed by the primary surpluses of the national fiscal authorities.

The following condition holds:

$$\lim_{k \to \infty} E_t \left[\frac{\beta^k \left(e^{\xi_{t+k}} / C_{t+k} \right)}{\left(e^{\xi_t} / C_t \right)} \frac{F_{t+k}}{R_{t+k} P_{t+k}} \right] = 0. \tag{14}$$

We obtain this equation after we take the transversality condition of each household j and sum across j's using the relation $\int_0^1 H_{jt} dj = 0$. Employing equations (6) and (14) we can solve equation (13) forward to obtain

$$\frac{F_{t-1}}{P_t} = \sum_{k=0}^{\infty} E_t \left[\frac{\beta^k \left(e^{\xi_{t+k}} / C_{t+k} \right)}{\left(e^{\xi_t} / C_t \right)} \left(\sum_n S_{n,t+k} \right) \right].$$

[12] The budget constraint of household j, initially given by equation (1), must be modified in a straightforward way.

Dividing both sides by Y_t and letting $\tilde{F}_t \equiv (F_t/P_tY_t)$, we have

$$\frac{\tilde{F}_{t-1}Y_{t-1}}{\Pi_t Y_t} = \sum_{k=0}^{\infty} E_t \left[\beta^k e^{\xi_{t+k}-\xi_t} \left(\sum_n \tilde{S}_{n,t+k} \right) \right], \tag{15}$$

In the model presented in Section 3, many paths of output and inflation were consistent with equilibrium. In this subsection, equation (15) lets us find the unique path of output and inflation consistent with equilibrium.

We must select values for the new parameters θ_n and $\bar{\psi}_n$. We set $\theta_n = \tilde{B}_{n,0}/(\tilde{B}_{1,0}+\tilde{B}_{2,0})$ for each n. To select $\bar{\psi}_n$ we assume that at the end of the simulation $\tilde{B}_1$ converges to a value 5 percent lower than $\tilde{B}_{1,0} = 0.35$ and $\tilde{B}_2$ converges to a value 5 percent lower than $\tilde{B}_{2,0} = 0.22$. This assumption pins down the values of $\bar{\psi}_1$ and $\bar{\psi}_2$, at $\bar{\psi}_1 = 0.0016$ (i.e., 0.16 percent of union's output) and $\bar{\psi}_2 = 0.001$. We suppose that if R reaches one in period τ, the monetary authority keeps R equal to one in periods $\tau + 1$,...,$\tau + 4$. Subsequently, the monetary authority raises R at a constant speed to reach $\bar{\Pi}/\beta$ in period $\tau + 7$. When solving the model, we guess and verify that in equilibrium the probability of default by each fiscal authority n in every period $t \geq 1$ is zero (i.e., given the assumed parameter values, we guess and verify that $\tilde{B}_{nt} < B_n^a$ for each n in every period $t \geq 0$).

The model has a unique solution. Output, inflation, and the central bank's interest rate converge to their values in the intended steady state. Figure 4 compares the outcome of this policy experiment with the baseline simulation. Monetary and fiscal policy stabilize output and inflation almost completely in the experiment. There is a small recession in 2009, followed by a small expansion and a shallow recession starting in 2013 as the interest rate begins to rise. Inflation never moves away much from its value in the intended steady state. The bond spread disappears reflecting the fact that the probability of default is zero throughout the simulation. To conclude, when monetary and fiscal policy interact as in this experiment, output is much higher and inflation somewhat higher than in the baseline simulation that mimics the euro area data.

Recall that the average primary surpluses in the baseline simulation match the average primary surpluses in the data in the period 2009-2015. In the present experiment the average primary surplus of each national fiscal authority is higher than in the baseline. However, the average *structural* primary surplus of each national fiscal authority, $\tilde{S}_{nt} - \psi_{Yn}(Y_t - Y)$ for each n, is *lower* in the experiment compared with the baseline. See Table 1. The results in Table 1 help understand in what sense fiscal policy is more accommodative in the experiment than the baseline. There are no fiscal policy shocks in the model. It is the *systematic component* of fiscal policy that is more accommodative in the experiment than in the baseline. In particular, in the experiment the second term on the right-hand side of equation (10) pushes South to increase its structural primary surplus somewhat and North to decrease its structural primary surplus somewhat, compared with the initial steady state, and hence the structural primary surplus of the union as a whole remains the same as in the initial steady state. By contrast, in the baseline the passive reaction function (5) requires material increases in the structural primary surpluses in North and in South, relative to the initial steady state. Consequently, the structural primary surpluses are lower in the experiment than in the baseline. At the same time, the actual primary surpluses rise in the experiment compared with the baseline, since output is higher in the former than in the latter and the effect of output on the primary surpluses dominates. Furthermore, the debt-to-output ratio in North and the debt-to-output ratio in South fall in the experiment relative to the baseline due to the improved outcomes for the primary surpluses and output.[13]

It is common to summarize the macroeconomic effects of fiscal policy by reporting multipliers. While the policy experiment analyzed here does not feature an exogenous fiscal policy disturbance, we can use the model to simulate the effects of an exogenous shock to lump-sum taxes. Using the setup of this subsection, we find that an exogenous decrease in lump-sum taxes, $\tilde{S}_{nt}$, by one percentage point (recall that $\tilde{S}_{nt}$ is defined as a share of output) increases output in the same period by 0.36 percent.

[13] Compared with the baseline, the average debt-to-output ratio in the period 2009-2015 decreases in the experiment, approximately, by 4 percentage points in North and by 4 percentage points in South. The average debt-to-output ratio in the baseline understates the average debt-to-GDP ratio in the data, despite the fact that the average primary surpluses in the baseline match the average primary surpluses in the data. The reasons are that: (i) the public debt in the data increased *inter alia* due to "stock-flow adjustments," e.g., asset purchases by the public sector, that are not recorded in the data on the primary surpluses and that we do not model, and (ii) the model assumes that public debt has a maturity of one year, while in the data government bonds have different maturities, often longer than one-year. When interest rates fall, as in the simulations, all debt in the model is rolled over at the new, lower rates, whereas in the data only a fraction of debt is rolled over at the new, lower rates. The quantitative implications can be large. For example, in the model bond yields are zero in 2009, and hence the debt-service costs in 2010 are zero. Italy actually spent 4 percent of its GDP on servicing its public debt in 2010.

Table 1: Average primary surplus as percent of euro area GDP, 2009-2015

	Data	Baseline	Simulation in Section 5.1
Fiscal authority in North			
Primary surplus	-0.39	-0.39	0.13
Structural primary surplus	-	0.22	0.16
Fiscal authority in South			
Primary surplus	-0.43	-0.43	0.06
Structural primary surplus	-	0.28	0.10

5.2 Simulations with default by a member state in equilibrium

So far we have assumed that each national fiscal authority follows the prescribed reaction function. It is important to ask what would happen if a national fiscal authority deviated from the prescribed reaction function. We have in mind an institutional setup in which the fund would then refuse to purchase debt issued by that authority and the authority could default. The fund would stand ready to resume debt purchases as soon as the authority complied with the prescribed reaction function again, including after having defaulted. The model is too simple for us to study the incentives of a national fiscal authority to deviate and to default, or the incentives of the fund to follow through on its promise not to purchase public debt of a recalcitrant member state. However, we can use the model to assess the consequences of default by a national fiscal authority for inflation and output in the euro area.

To do that we relax the assumption that the fund holds all debt issued by each national fiscal authority; now, both the fund and households hold bonds issued by the national fiscal authorities and, as before, households hold bonds issued by the fund.[14] With this assumption in place, the analogue of equation (13) is

$$\frac{F_t}{R_t P_t} = \frac{F_{t-1}}{P_t} - \sum_n S_{nt}^F, \tag{16}$$

where S_{nt}^F denotes the part of the primary surplus of fiscal authority n in period t flowing to

[14]Again, the budget constraint of household j, initially given by equation (1), must be modified in a straightforward way. Another such modification will be required below when we introduce a tax imposed directly by the fund.

the fund. Of course, if we let S_{nt}^{H} denote the part of the primary surplus going to households, we have $S_{nt}^{H}+S_{nt}^{F}=S_{nt}$ for each n in every period. Equation (16) shows that Eurobonds are backed by the part of the national primary surpluses flowing to the fund.

Let B_{nt}^{H} denote bonds issued by fiscal authority n purchased by households. Let B_{nt}^{F} denote bonds issued by fiscal authority n purchased by the fund. We suppose that if the central bank's interest rate reaches one, i.e., if $R_{\tau}=1$ in some period τ, then in period τ and in subsequent periods (i.e., in periods $t=\tau,\tau+1,...$) fiscal authority n is to set

$$\tilde{S}_{nt}^{H}=\psi_{n}+\psi_{B}\tilde{B}_{n,t-1}^{H}+\psi_{Yn}\left(Y_{t}-Y\right)+\psi_{Z}(Z_{n,t-1}-R_{t-1}) \tag{17}$$

and

$$\tilde{S}_{nt}^{F}=\bar{\psi}_{n}+\psi_{B}\left[\tilde{B}_{n,t-1}^{F}-\theta_{n}\left(\sum_{n}\tilde{B}_{n,t-1}^{F}\right)\right]+\psi_{Yn}\left(Y_{t}-Y\right), \tag{18}$$

where $\tilde{B}_{nt}^{H}\equiv\left(B_{nt}^{H}/P_{t}Y_{t}\right)$ and $\tilde{B}_{nt}^{F}\equiv\left(B_{nt}^{F}/P_{t}Y_{t}\right)$. Equation (17) is the analogue of (5), and equation (18) is the analogue of (10). We assume that if fiscal authority n defaults in period t, the value of $\bar{\psi}_{n}$ drops permanently. This imposes a capital loss on the fund relative to the prescribed fiscal policy reaction function. Furthermore, we suppose that in the period in which default occurs the recovery rate on bonds issued by fiscal authority n held by households is $\Delta_{n,t}=\left(\bar{\psi}_{n}^{new}/\bar{\psi}_{n}^{old}\right)<1$, where $\bar{\psi}_{n}^{old}$ denotes the prescribed value of $\bar{\psi}_{n}$ and $\bar{\psi}_{n}^{new}$ denotes the new value of $\bar{\psi}_{n}$.

Making use of equations (6) and (14) to iterate equation (16) forward yields

$$\frac{\tilde{F}_{t-1}Y_{t-1}}{\Pi_{t}Y_{t}}=\sum_{k=0}^{\infty}E_{t}\left[\beta^{k}e^{\xi_{t+k}-\xi_{t}}\left(\sum_{n}\tilde{S}_{n,t+k}^{F}\right)\right], \tag{19}$$

Analogously to equation (15) in Section 5.1, in this subsection equation (19) lets us find the unique path of output and inflation consistent with equilibrium.[15] It is apparent from (19) that default by a national fiscal authority exerts upward pressure on inflation and output by lowering the stream of the primary surpluses flowing to the fund. It is interesting to ask if under plausible assumptions default can cause what one would think of as excessive inflation.

[15]Equation (14) holds also in this subsection. To derive this equation in this subsection, we take the transversality condition of each household j, sum it across j's using the relation $\int_{0}^{1}H_{jt}dj=0$, and we notice that since equation (17) holds $\tilde{B}_{n,t}^{H}$ converges to a constant for each n as time goes to infinity.

We suppose that the fiscal authority in South defaults and, for simplicity, we assume that the default occurs in period one. To begin, we suppose that $\left(\bar{\psi}_2^{new}/\bar{\psi}_2^{old}\right) = 0.8$ (the recovery rate is 80 percent). We think of this specification as a "moderate default scenario." Since $\left(\bar{\psi}_2^{new}/\bar{\psi}_2^{old}\right)\tilde{B}_{2,0} = 0.8{*}0.22 = 0.176$, the capital loss from default in this case is about 4.5 percent of euro area GDP, or about 420 billion euros. The top row in Figure 5 shows the effects of the default on output and inflation. The most striking feature is that the inflation rate in 2009, the year in which default occurs, jumps up by about 60 basis points compared with the simulation without default from Section 5.1. This is a non-trivial effect but it is difficult to think of the resulting inflation rate of just above 2 percent at an annual rate as materially excessive.

Next, we suppose that $\left(\bar{\psi}_2^{new}/\bar{\psi}_2^{old}\right) = 0.5$ (the recovery rate is 50 percent), implying that the capital loss is about 11 percent of euro area GDP, or about 1 trillion euros. Furthermore, we assume that prices become more flexible when default occurs in such a way that the slope of the Phillips curve in the model linearized around the intended steady state increases from 0.1 to 0.4, and we suppose that the central bank's interest rate is constant at the intended-steady-state value throughout the simulation. We think of this specification as a "severe default scenario." As one can see in the bottom row of Figure 5, the inflation rate jumps to about 8 percent in the year in which default occurs and subsequently declines to the intended steady state. We conclude that a severe default scenario like this one can produce excessive inflation for some time.[16]

It is interesting to modify the model by giving to the fund the ability to tax households directly. Equation (16) becomes

$$\frac{F_t}{R_t P_t} = \frac{F_{t-1}}{P_t} - \sum_n S_{nt}^F - S_t^F,$$

where the new variable S_t^F denotes a lump-sum tax imposed by the fund in period t.

[16] In each of the two default scenarios in this subsection we assume that in steady state the fund holds a share λ of bonds issued by each national fiscal authority and households hold the remainder, $1-\lambda$. For a given λ, we select the value of ψ_n for each n using the same approach as in Section 4.2 and we select the value of $\bar{\psi}_n^{old}$ for each n using the same approach as in Section 5.1. In equation (17) we multiply ψ_{Yn} by $1-\lambda$ and in equation (18) we multiply ψ_{Yn} by λ. Given this rescaling, the solution of the model for output and inflation is invariant to the value of λ. The reason is that given this rescaling changing the value of λ amounts to multiplying the left-hand side and the right-hand side of equation (19) in period one by the same number. The other parameters have the same values as thus far.

Furthermore, equation (19) changes to

$$\frac{\tilde{F}_{t-1}Y_{t-1}}{\Pi_t Y_t} = \sum_{k=0}^{\infty} E_t \left[\beta^k e^{\xi_{t+k}-\xi_t} \left(\tilde{S}^F_{t+k} + \sum_n \tilde{S}^F_{n,t+k} \right) \right], \tag{20}$$

where $\tilde{S}^F_t \equiv \left(S^F_t / Y_t\right)$. If the fund imposes a tax conditional on default by a national fiscal authority, the effects of default on inflation and output diminish. Actually, the effects of default on inflation and output vanish *completely* if the tax is sufficient, e.g., if $\tilde{S}^F_t = \bar{\psi}^{old}_2 - \bar{\psi}^{new}_2$ in every period starting in the period in which default takes place.

5.3 The fund and determinacy of government bond yields

In Section 3.4 we explained that one of the following three cases can arise in the market for bonds of fiscal authority n in any given period: the case with a single equilibrium and the probability of default equal to zero, the case with a single equilibrium and the probability of default equal to one, and the case with multiple equilibria. In the case with multiple equilibria there are typically three equilibria: one with the probability of default equal to zero, one with the probability of default equal to one, and one with a probability of default in an intermediate range.[17]

How does the fund affect the determinacy of government bond yields? Let us make two observations. Figure 6 illustrates the equilibria in the bond market. The vertical axis measures the market price of a bond, $1/Z_t$ (we drop the subscript n for convenience). The horizontal axis measures the debt-to-output ratio, $\tilde{B}_t$. The grey curve represents the bond pricing equation (7): The bond price is equal to $1/R_t$ (i.e., the default premium is zero) when $\tilde{B}_t$ is smaller than $\tilde{B}^a$; the bond price is a decreasing function of $\tilde{B}_t$ between $\tilde{B}^a$ to $\tilde{B}^b$ (in which case the bond price incorporates a default premium increasing in $\tilde{B}_t$); and the bond price is equal to Δ/R_t when $\tilde{B}_t$ is greater than $\tilde{B}^b$ (in which case the probability of default is one). The solid black curve represents the government budget constraint in the absence of the fund, given by equation (4). Let a_t denote the fiscal authority's borrowing needs, given by the right-hand side of equation (4). The solid black curve is given by the equation $1/Z_t = a_t/\tilde{B}_t$. The figure assumes an intermediate value of a_t for which the bond pricing curve and the budget constraint curve cross three times, implying that in this case

[17] For example, in the baseline simulation we assume that the confidence-about-debt shock selects the intermediate outcome in South in 2012.

there are three equilibria.

Suppose that the fund buys a fraction λ_t of the debt at the price $1/R_t$. It can be shown that the budget constraint curve changes to $1/Z_t = a_t/((1-\lambda_t)\tilde{B}_t) - \lambda_t/((1-\lambda_t)R_t)$. Figure 6 plots this new budget constraint as a thin black line with circles, assuming a particular value of λ_t. With this new budget constraint curve only one equilibrium survives: the equilibrium in which the bond price is equal to $1/R_t$ and the probability of default is zero. The other two equilibria, the equilibrium with the probability of default equal to one and the intermediate equilibrium, disappear. Put differently, when the fund purchases a sufficient fraction of debt at the price free of default premium, that price becomes the only equilibrium, although there were two other equilibria in the absence of the fund, each with a positive probability of default. The intuition is as follows. As the fund purchases bonds charging the price free of default premium, the amount of bonds that a national fiscal authority needs to sell to households if they expect default falls and can become insufficient to validate the households' expectations of default.

The other observation also has to do with the case in which fundamentals allow multiple equilibria in the absence of the fund. Then any bond purchases by the fund, or even an announced intention of the fund to buy bonds, at the price free of default premium can coordinate households on the equilibrium with the probability of default equal to zero. We believe that both observations can be relevant empirically.

6 Conclusions

In a typical modern economy, the monetary authority supplies a fiat currency and the fiscal authority issues debt denominated in that currency. The authorities can coordinate so that when the fiscal authority lowers primary surpluses, households are wealthier at the given price level and they increase spending. Inflation and output rise. This is an attractive outcome when inflation is too low and the economy is in a recession to begin with. Although the euro is a fiat currency, the member states of the euro area have given up the ability to issue non-defaultable debt. One consequence is that the euro area economy has been exposed to self-fulfilling fluctuations. Another consequence is that no effective fiscal stimulus has been available to raise output and inflation between the financial crisis of 2008-2009 and today. This paper shows in a formal model that the recent macroeconomic outcomes in the euro area would have been very different if monetary and fiscal policy interacted differently than they do. The policy experiments in the paper are of practical relevance, we think, because the policy interactions they assume require only a modest degree of centralization of fiscal decision-making among the euro area member states.

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Figure 1: Euro area annual data, 2008-2015

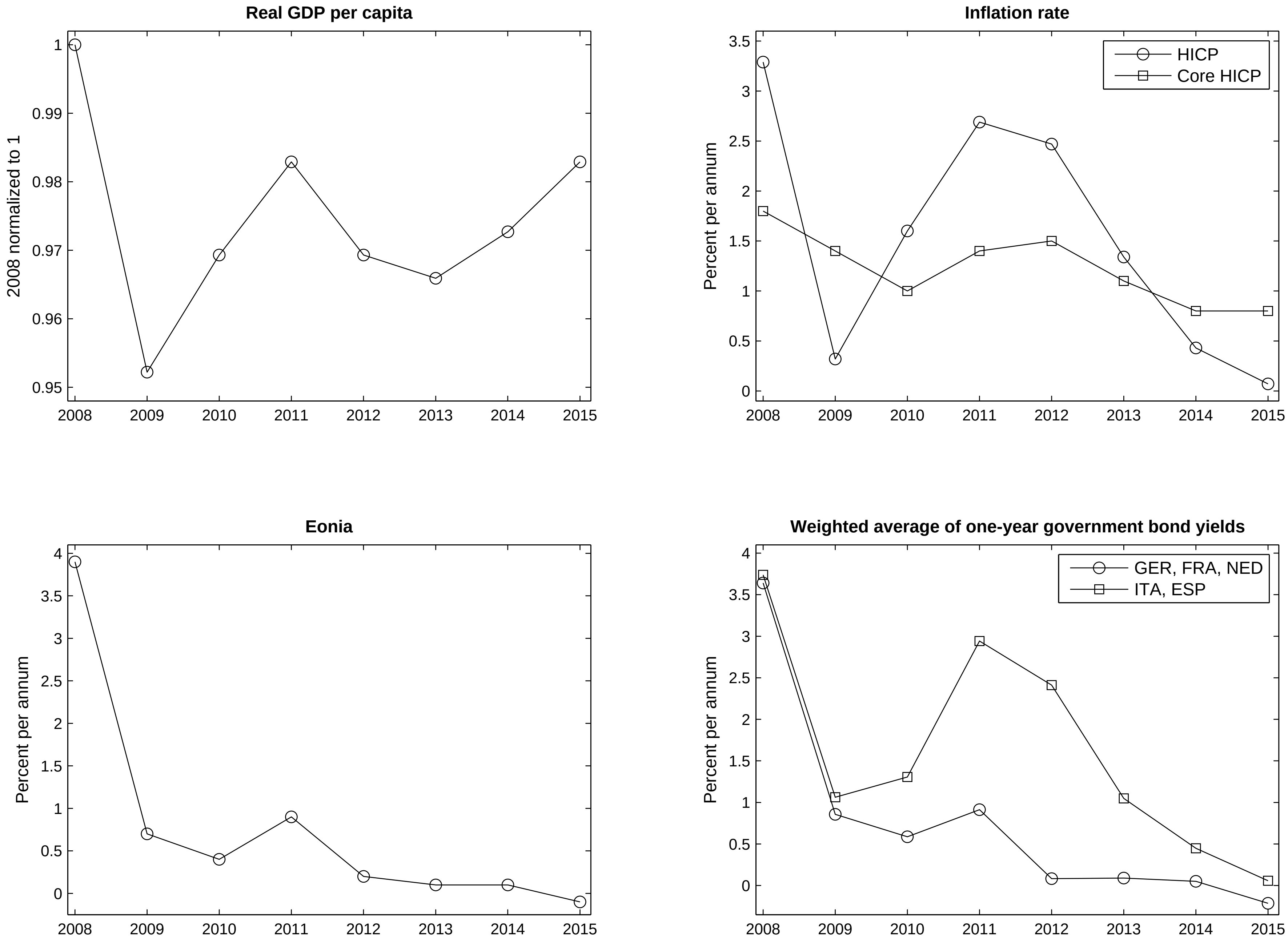


Figure 2: Two solutions of the model in Section 3

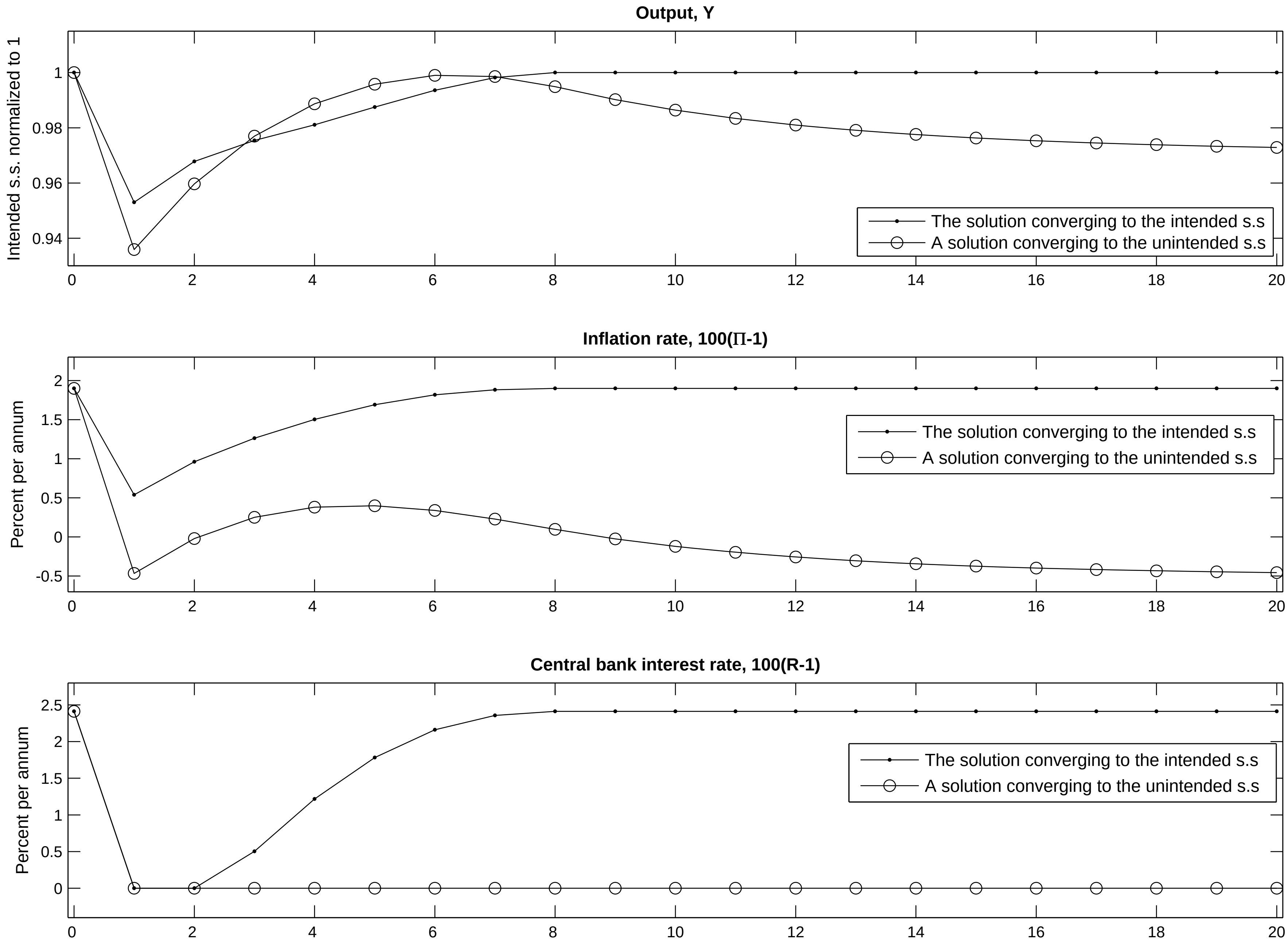


Figure 3: The baseline simulation versus the data

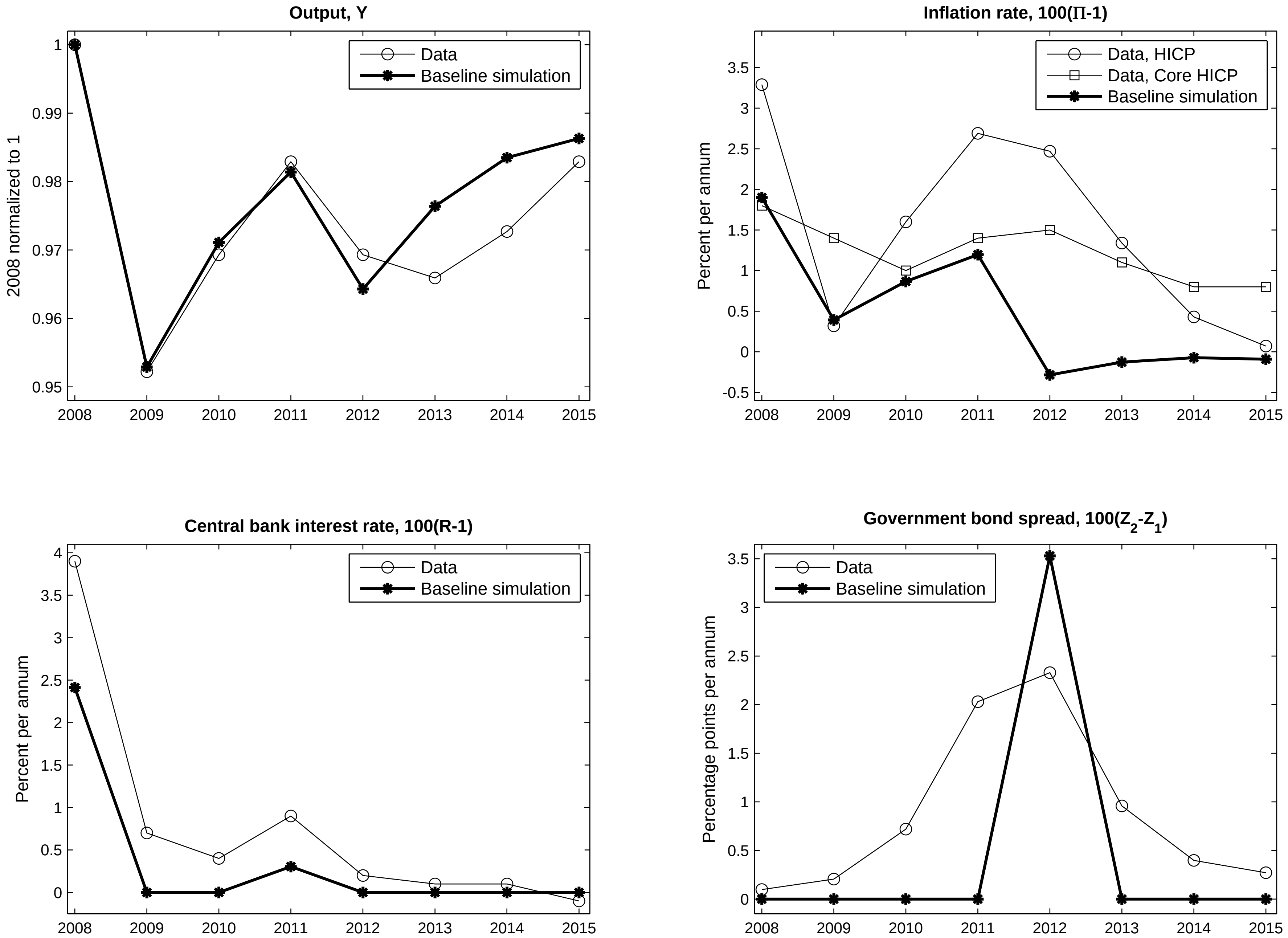


Figure 4: The policy experiment in Section 5.1 vs. the baseline simulation

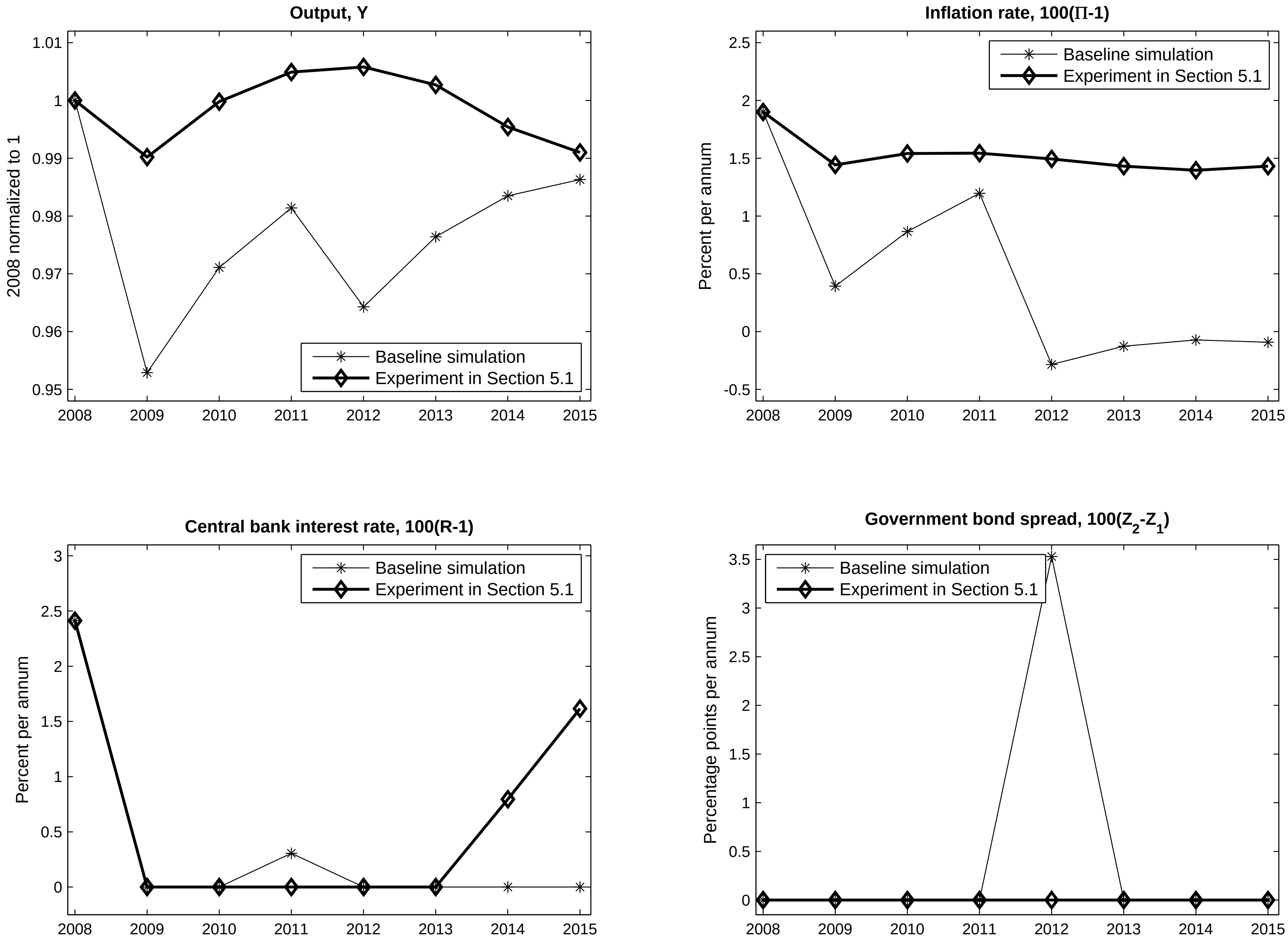
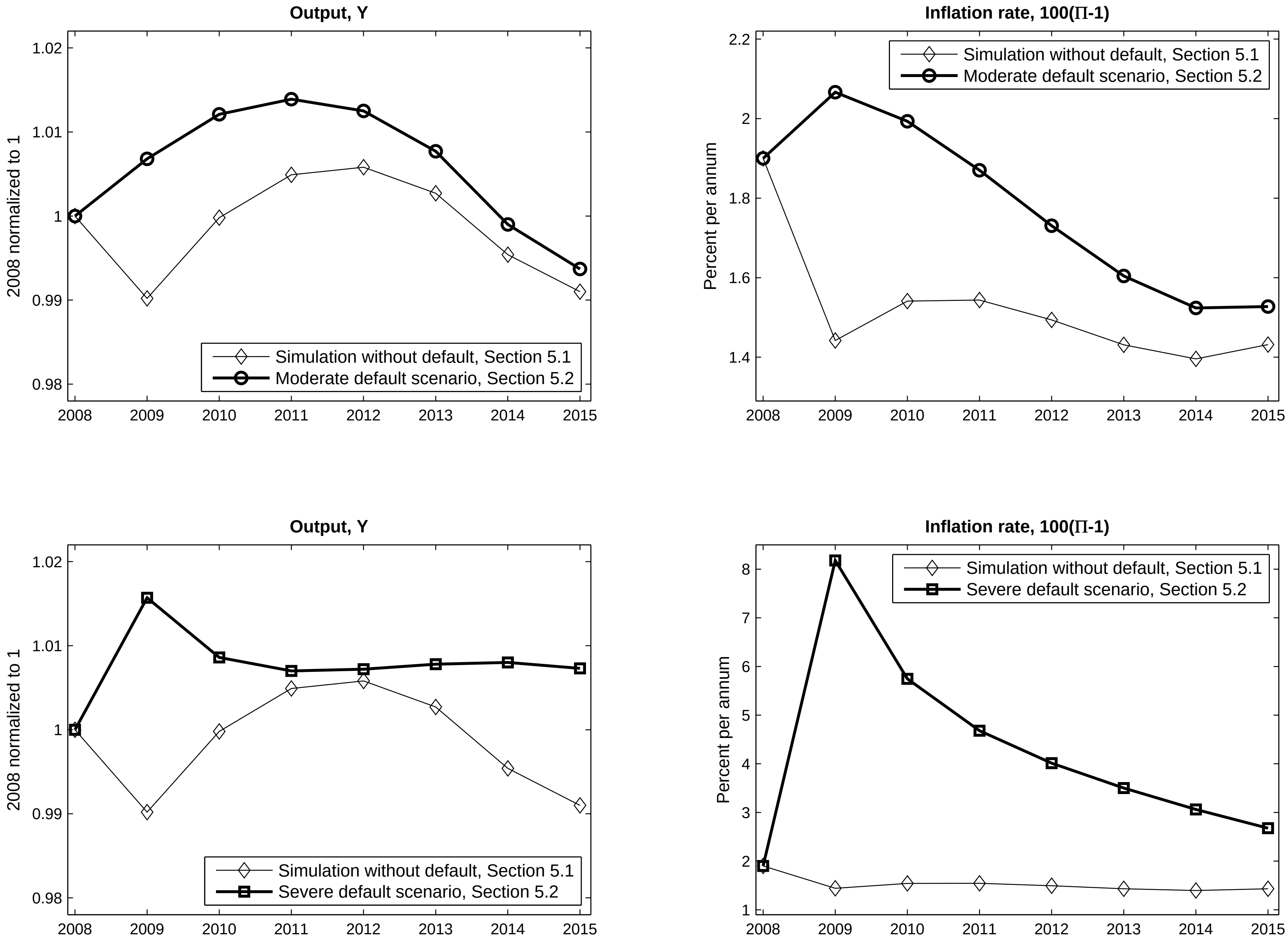
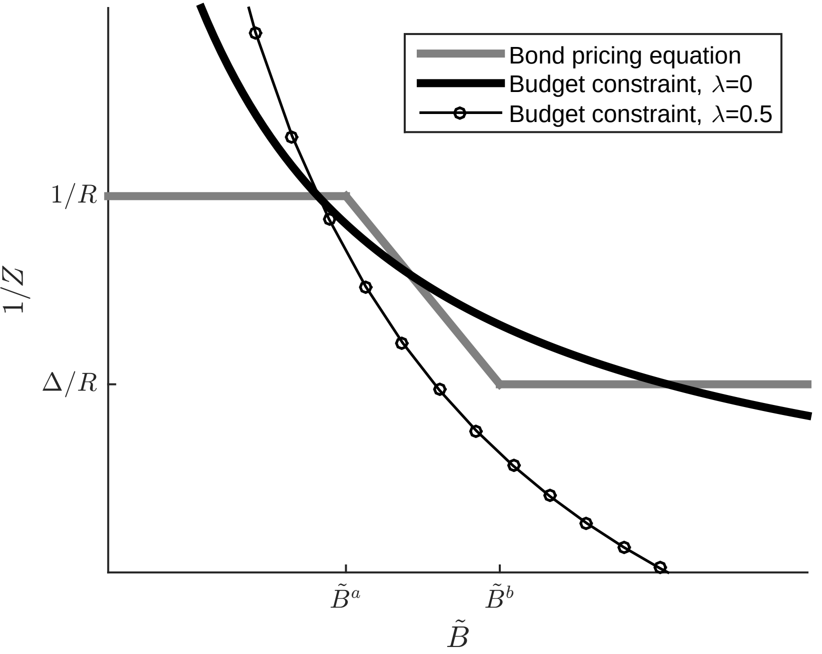


Figure 5: The effect of default on the policy experiment from Section 5.1





Bond pricing equation
Budget constraint, λ=0
Budget constraint, λ=0.5
$1/R$
Δ/R
$1/Z$
$\tilde{B}^a$
$\tilde{B}^b$
$\tilde{B}$