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 configuration of monetary and fiscal policy, with a non-defaultable eurobond. If this policy arrangement had been in place since the onset of the Great Recession, output could have been much higher than in the data with inflation in line with the ECB's objective. (*Keywords:* self-fulfilling expectations, zero lower bound, fiscal theory of the price level, eurobond. *JEL:* E31, E32, E63.)

1 Introduction

The euro area recently experienced a period of malaise, with weak economic activity, inflation persistently short of the European Central Bank's objective of "below, but close to 2 percent," monetary policy interest rates near zero, and a sovereign debt crisis. In this paper, we propose a simple model – perhaps the simplest model – that speaks to all these phenomena together.

Figure 1 summarizes the euro area's malaise using annual data from the period 2008-2015. Real Gross Domestic Product per capita declined by 5 percent in the Great Recession of 2009. Output decreased again in 2012 and in 2013. In 2015, real GDP per capita was 1.6 percent lower than in 2008. Inflation, measured in terms of the Harmonized Index of Consumer Prices or in terms of the core HICP (excluding energy and food), decreased in the Great Recession, rose briefly, and declined again. The rate of inflation based on the core HICP has not exceeded 1.5 percent per annum since 2008. The Eonia, an interest rate effectively controlled by the ECB, followed the same non-monotonic path as inflation (down, up, and down again). From 2009, the Eonia remained near zero. Finally, default premia on public debt also followed a non-monotonic trajectory. 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, spiked in 2011-2012 during the sovereign debt crisis, and fell subsequently.

Public debt typically rises at the start of a recession.[1] As a recession continues, fiscal policy faces a trade-off between business cycle stabilization and debt sustainability. This trade-off is especially significant if monetary policy has become constrained by the lower bound on nominal interest rates. With a national fiat currency, the monetary authority and the fiscal authority can coordinate to ensure that public debt denominated in that currency will not default, i.e., maturing government bonds will be convertible into currency at par, just as maturing reserve deposits at the central bank are convertible into currency at par. With this arrangement in place, fiscal policy can focus on business cycle stabilization until a recovery has been achieved.[2] In particular, if the fiscal authority makes a lump-sum

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[1]The ratio of public debt to GDP computed for the euro area as a whole increased in 2008 and in 2009.

[2]By contrast, the primary budget balance in the euro area has increased as a fraction of GDP in every year since 2010, including in 2012 and 2013, two years in which output contracted.

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transfer to households, households are wealthier at a given price level and they increase spending. The price level rises and, if prices are sticky, output increases temporarily. This is an attractive outcome when inflation is too low and economic activity is weak to begin with. However, although the euro is a fiat currency, the fiscal authorities of the member states of the euro have given up the ability to issue non-defaultable debt.

Our model formalizes the idea that the way monetary and fiscal policy interact in the euro area was important for the outcomes depicted in Figure 1. If monetary and fiscal policy had interacted differently, the outcomes could have been very different. We begin with a specification of monetary and fiscal policy that aims to capture how policy is actually conducted in the euro area. With this policy configuration, our model reproduces the main features of the recent data. We then study a version of the model in which monetary and fiscal policy interact differently, around a non-defaultable public debt instrument (a "eurobond"). This version of the model implies that output could have been much higher than in the data with inflation in line with the ECB's objective.

The model is based on the standard three-equation general equilibrium model with sticky prices. As usual, there are price-setting firms, households who consume and supply labor, and a single monetary authority. We add to this familiar setting N fiscal authorities, corresponding to N imaginary member states of a monetary union (for simplicity $N = 2$, "North" and "South"). Each fiscal authority imposes lump-sum taxes, or makes lump-sum transfers, and issues bonds that can default. Each household is a "European" household that consumes a union-wide basket of goods, supplies labor to firms throughout the union, and pays taxes to the fiscal authority in North and to the fiscal authority in South.

We suppose that the monetary authority pursues a Taylor rule subject to a lower bound on the policy rate. Each "national" fiscal authority adjusts its primary budget balance in response to the business cycle and the debt-to-GDP ratio, via a standard reaction function, but can default in adverse circumstances, when the debt-to-GDP ratio reaches an upper bound (a "fiscal limit"). We believe that this simple specification captures the essential features of how monetary and fiscal policy are actually conducted in the euro area. Note that default in the model has no effect on households' wealth. Default imposes a loss on households as bondholders, but default also produces a gain of the same magnitude for households as taxpayers. Thus, fluctuations in the primary surplus do not affect households' wealth. Any decrease in the primary surplus is offset by a rise in future primary surpluses

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or an increase in the probability of default.

In the full nonlinear model, we consider the effects of a disturbance to the households' discount factor. The discount factor disturbance temporarily increases the value of future consumption relative to current consumption. The response of output, inflation, and the central bank's interest rate 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, the default premium on bonds issued by a national fiscal authority is generally also 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 after the discount factor disturbance, while the other coordinates bondholders. The simulated model reproduces the main features of the recent data ("the baseline simulation"). Output, inflation, the central bank's interest rate, and the government bond spread in the model replicate their respective non-monotonic trajectories seen in Figure 1. Furthermore, the paths of the variables in the model are quantitatively similar to the data. A key implication of the model is that macroeconomic outcomes in the euro area are indeterminate and subject to self-fulfilling fluctuations. The euro area is a "land of indeterminacy."

We use the model to conduct a policy experiment in which we assume an alternative configuration of monetary and fiscal policy. Inspired by the proposal in Sims (2012), we introduce a new policy authority, a centrally-operated fund that can buy from the national fiscal authorities their debt. The fund can sell to households its own nominal bonds ("eurobonds"). We suppose that the eurobonds are non-defaultable, i.e., the monetary authority and the fund agree that maturing eurobonds are convertible into fiat currency at par. We maintain the assumption that debt issued by the national fiscal authorities, now held in part by households and in part by the fund, can default. In this setup, the primary surplus of each national fiscal authority has two components: a part flowing to households and a part flowing to the fund and thus backing eurobonds. We assume that after the discount

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factor disturbance, the sum of the primary surpluses flowing to the fund does not react to any measure of debt. Hence, the eurobonds are backed by "active" fiscal policy in the sense of Leeper (1991). We also suppose that in the wake of the disturbance, the central bank's interest rate follows an exogenous path converging to the intended steady state. This is a simple specification of "passive" monetary policy as in Leeper (1991), i.e., an interest rate policy that does not satisfy the Taylor principle.

With this policy configuration, the response of output, inflation, and the central bank's interest rate to the discount factor disturbance is unique, and the economy converges to the intended steady state. For plausible parameter values, output is much higher than in the data and inflation is in line with the ECB's objective. Furthermore, as we will explain, favorable stabilization outcomes can be achieved irrespective of the quantity of the eurobonds.

The critical assumptions in the policy experiment are that the eurobonds are non-defaultable and the present value of the primary surpluses flowing to the fund falls after the discount factor disturbance. The discount factor disturbance exerts downward pressure on output and inflation. The primary surplus tends to decrease since it depends positively on output, through the fiscal reaction function. In the baseline simulation, fluctuations in the primary surplus do not affect households' wealth. The fall in the primary surplus is not expansionary, because it is offset by a combination of a rise in future primary surpluses and an increase in the probability of default. Things are different in the policy experiment. There, a part of the fiscal accommodation in the wake of the discount factor shock is *never undone*. The present value of the primary surpluses flowing to the fund falls relative to the value of the eurobonds, implying – since the eurobonds do not default – that households' wealth increases at a given price level. As households spend the extra wealth, "too many eurobonds are chasing too few goods," and output and inflation rise relative to the baseline simulation.

What if a national fiscal authority delivers smaller primary surpluses to the fund than promised? We use the model to analyze the consequences of a deviation by a national fiscal authority from the reaction function the fund expects the authority to follow. The deviation, which we simply refer to as default, results in a decrease in the stream of the primary surpluses flowing to the fund thereby exerting inflationary pressure. We calibrate the defaulting fiscal authority to match the sum of Italy and Spain. The other, non-defaulting

fiscal authority consists of Germany, France, and the Netherlands, taken together. The fund holds bonds of each fiscal authority. If we suppose that the defaulting fiscal authority delivers only 60 percent of the primary surpluses promised to the fund, the inflation rate in the model jumps temporarily by 120 basis points at an annual rate. While this is a non-trivial effect, we find it difficult to think of the resulting transitory inflation rate of 2.7 percent per year as materially excessive. One reason why the inflationary effect is moderate is that only Italy and Spain default, while the other countries represented in the fund's portfolio do not. Another reason is that the Phillips curve in the model is rather flat, consistent with recent data. We consider other examples implying that the inflationary effect of a default on the fund could become sizable. That said, the inflationary effect can diminish and disappear if the fund, in order to recoup its losses from default, can impose a tax on households directly. We report the magnitude of the fund's tax revenue necessary for the inflationary effect of a default on the fund to disappear.

The model lets us study how the presence of the fund affects the determinacy of the default premia on national bonds. In the baseline simulation, multiple solutions arise for the default premium of the fiscal authority calibrated to match the sum of Italy and Spain. In the policy experiment, the default premia are unique and equal to zero. The accommodative policy mix in the experiment, possible in the presence of the fund, actually lowers the debt-to-GDP ratio of that fiscal authority into the range implying a unique equilibrium with the probability of default equal to zero. Furthermore, suppose that in any period there are multiple solutions for the default premium of a given national fiscal authority, including a solution in which the probability of default is equal to zero. Then the zero-probability-of-default solution becomes the unique solution if the fund purchases a sufficient quantity of bonds. 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 falls and can become insufficient to validate expectations of default.

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

2 Contacts with the literature

This paper is related to two strands of macroeconomic literature that emphasize multiple equilibria.

Benhabib et al. (2001) show that the standard general equilibrium model with sticky prices has two steady states, once the analysis takes into account that the Taylor rule is constrained by the lower bound on nominal interest rates. Schmitt-Grohé and Uribe (2017) argue that the model with two steady states explains several features of the recent macroeconomic outcomes in Japan, the United States, and the euro area. Schmitt-Grohé and Uribe propose that the central bank set an exogenous path for the policy rate converging to the intended steady state, to ensure that this steady state is unique. Since Schmitt-Grohé and Uribe assume "passive" fiscal policy in the sense of Leeper (1991), the short-run trajectory of output and inflation in their model is indeterminate. We combine the passive monetary policy assumed by Schmitt-Grohé and Uribe with an active fiscal policy suitable for a monetary union to obtain a unique equilibrium outcome for output and inflation, both in the short run and in the long run. Aruoba et al. (2017) fit the full nonlinear version of the standard sticky price model, with a sunspot process that governs fluctuations between the two steady states, to the data from Japan and the United States. Mertens and Ravn (2014) describe how the size of the government spending multiplier in the model depends on whether the disturbance affecting the economy is fundamental or non-fundamental.

In addition, the paper is related to the literature on multiple equilibria in the market for defaultable public debt, starting with Calvo (1988), with recent contributions by Lorenzoni and Werning (2014), Ayres et al. (2015), and Corsetti and Dedola (2016). In Calvo (1988), the multiplicity arises from a two-way interaction between the probability of default and bond yields: A higher probability of default increases yields, and higher yields raise the probability of default. We obtain the same two-way interaction in a simple setup in which a fiscal authority sets the primary surplus as a function of the state of the economy and defaults when debt reaches an ex-ante uncertain upper bound. Lorenzoni and Werning (2014) and Ayres et al. (2015) show that similar multiple equilibria emerge when the fiscal authority is modeled as optimizing.

The paper also builds on the literature on the fiscal theory of the price level, initiated by Leeper (1991), Sims (1994), Woodford (1994), and Cochrane (2001). We borrow from that literature the definitions of passive and active policy. The analysis of Benhabib et al.

(2002) and Woodford (2003), chapter 2.4.2, implies that what we refer to as the intended steady state becomes unique if fiscal policy turns active in the face of deflation. We think of our model, with a once-and-for-all shift in the monetary and fiscal regimes after a one-time disturbance, as a simplified version of a model in which the policy regimes switch recurrently in a stochastic environment. Bianchi and Ilut (2017) interpret the U.S. postwar macroeconomic data using a model in which such recurrent policy regime fluctuations are exogenous. Bianchi and Melosi (2017) study how the macroeconomic outcomes at the lower bound depend on which policy configuration prevails once the economy exits the liquidity trap. One reason to use a fiscal theory setup is because it provides a simple way to model the role of fiscal policy in business cycle stabilization. In particular, one can focus on lump-sum taxes and transfers as the tool of fiscal policy. This focus is more than a matter of convenience. While in reality fiscal policy has multiple tools, a transfer policy can be implemented quickly reaching all households. Moreover, the evidence in Parker et al. (2013) concerning the U.S. tax rebate of 2008 indicates that a well-designed transfer policy can have sizable and swift effects on consumer spending, and therefore on output and inflation.

3 Model

The model is based on the standard simple general equilibrium model with sticky prices, consisting of the consumption Euler equation, the Phillips curve, and a Taylor rule. We add to this familiar setup $N > 1$ fiscal authorities, corresponding to N imaginary member states of a monetary union. Each fiscal authority imposes lump-sum taxes, or makes lump-sum transfers, and issues bonds that can default. 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 members who pay taxes to the fiscal authority in one imaginary member state of the union, North, and some members 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

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

where W_t is the real wage, Φ_{jt} is household j's share of the aggregate profits of firms, and S_{jnt} is a lump-sum tax paid by household j to fiscal authority n, $n = 1, ..., N$. 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. H_{jt} denotes bonds issued by other households in period t and purchased by household j, with a gross yield R_t. We make the usual assumption that bonds H do not default, and therefore R_t is the yield free of any default premium. Furthermore, we suppose that $\int_0^1 H_{jt} dj = 0$. The reason why we introduce bonds H is that we want to be able to refer to the yield free of any default premium. B_{jnt} denotes bonds issued by fiscal authority n in period t and purchased by household j, with a gross yield Z_{nt}. $\Delta_{nt} \in (0,1]$ is the payoff in period t from a bond of fiscal authority n issued in period $t-1$. The bond defaults if $\Delta_{nt} < 1$. We assume that taxes and profits are shared equally by households, i.e., $S_{jnt} = S_{nt}$ and $\Phi_{jt} = \Phi_t$ for each j, n, and t. In equilibrium, households

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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 Φ_{it} is real profit in period t 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, following Rotemberg (1982), where $\chi \geq 0$ and $\bar{\Pi} \geq 1$ are parameters. 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 and fiscal policy, we aim to capture in a simple way the essential features of how each policy is actually conducted in the euro area. We suppose that the single monetary authority follows a Taylor rule subject to a lower bound on the interest rate.[3] Furthermore, each fiscal authority seeks to stabilize its debt by adjusting its primary budget balance, in a standard way, but can default in adverse circumstances.

Specifically, we assume that the single monetary authority sets the interest rate on 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 Π_t is inflation, $\Pi_t \equiv P_t / P_{t-1}$, $\bar{\Pi}$ is the inflation objective of the monetary authority, and ϕ is a parameter satisfying $\phi > 1$. Henceforth, we refer to R_t as "the central bank's

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[3]We assume that the monetary authority supplies a fiat currency and, following common practice, we do not include the currency in the model.

interest rate." Following Leeper (1991), when the central bank's interest rate reacts more than one-for-one to inflation, monetary policy is said to be "active." The restriction $\phi > 1$ implies that monetary policy is active in a neighborhood of the inflation objective $\bar{\Pi}$. The lower bound on the central bank's interest rate implies that monetary policy is not active, i.e., it is "passive," globally.[4]

The budget constraint of fiscal authority n 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. Let Y_t denote aggregate output net of the cost of changing prices. Furthermore, let us express debt and the primary surplus as a share of output, $\tilde{B}_{nt} \equiv B_{nt}/P_tY_t$ and $\tilde{S}_{nt} \equiv S_{nt}/Y_t$. We can then rewrite equation (3) as

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

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

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

where Y denotes output in the "intended" steady state (which we solve for below), and $\psi_n > 0$, $\psi_B > 1/\beta - 1$, $\psi_{Yn} > 0$, and $\psi_Z > 0$ are parameters. The parameters ψ_{Yn} and ψ_Z measure the feedback to the primary surplus, respectively, from the output gap, $Y_t - Y$, and from the default premium, $Z_{nt} - R_t$, lagged by one period. The parameter ψ_B captures the feedback to the primary surplus from the lagged debt-to-GDP ratio. The restriction $\psi_B > 1/\beta - 1$ is standard and implies that the primary surplus reacts to debt by more than the steady-state real interest rate. With this restriction, the debt-to-GDP ratio $\tilde{B}_{nt}$ converges to a constant regardless of the path of the price level and output. (Specifically, $\tilde{B}_{nt}$ converges to $\psi_n/(\psi_B - (1-\beta)/\Pi)$, where Π denotes the inflation rate in steady state.) Moreover, fluctuations in the primary surplus have no effect on households' wealth. Any decrease in the primary surplus is offset by a rise in future primary surpluses. Following

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[4]Leeper (1991) studies a similar model, linearized around the steady state in which inflation is equal to the inflation objective of the central bank. He shows that if monetary policy is active and fiscal policy is passive, in the sense defined below, equilibrium is unique in a neighborhood of this steady state. The same result holds in this model.

Leeper (1991), when the primary surplus reacts to debt by more than the steady-state real interest rate, fiscal policy is said to be "passive."

While the assumption of passive fiscal policy is standard, we add the possibility of default. Equation (5) implies that in some periods debt and the primary surplus may be much larger than in steady state. We want to capture in a simple way the idea that in the real world there is a limit to economically or politically feasible primary surpluses, and therefore beyond some upper bound debt becomes unsustainable. Furthermore, there is uncertainty about the value of that upper bound. 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 drawn in period t from the uniform distribution on the interval $\left[\tilde{B}_n^a, \tilde{B}_n^b \right]$.[5] 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 default premium $Z_{nt} - R_t$, taking into account the value of Δ_n and the probability of default in period $t+1$ given by $\Pr\left(\tilde{B}_{nt} \geq \tilde{B}_{n,t+1}^{\max} \right)$.[6]

In this simple model, default by a fiscal authority has no effect on households' wealth, output, or inflation. Default imposes a loss on households as bondholders. Default also produces a gain of the same magnitude for households as taxpayers, because at default the present value of the primary surpluses falls by the amount of the haircut. Given the way we introduce default, fluctuations in the primary surplus continue to have no effect on households' wealth. Any decrease in the primary surplus is offset by a combination of a rise in future primary surpluses and an increase in the probability of default.

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

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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}
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[5] Let $\tilde{B}_n$ denote $\tilde{B}_{nt}$ in steady state. We assume that $\tilde{B}_n < \tilde{B}_n^a$ for each n.

[6] The way we model default is related to the idea of a "fiscal limit." See Davig et al. (2010), Bi (2012), and Lorenzoni and Werning (2014).

(ii) the equation determining the default premium $Z_{nt} - R_t$ for each n

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

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:

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

To obtain equation (9), we take the transversality condition of household j

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

and sum it 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_t, R_t, and all real variables including $\tilde{B}_{nt}$ for each n 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), inflation is equal to the monetary authority's objective, $\Pi = \bar{\Pi}$, and the central bank's interest rate R is equal to $\bar{\Pi}/\beta$. In the other steady state (the "unintended" steady state), $\Pi = \beta$ and $R = 1$. 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). In the absence of the lower bound, i.e., if the central bank's reaction function were simply $R_t = \left(\bar{\Pi}/\beta \right) \left(\Pi_t/\bar{\Pi} \right)^\phi$ with $\phi > 1$, the intended steady state would be the unique steady state. However, constrained by the lower bound, monetary policy cannot lower the interest rate to prevent the economy from converging to the unintended steady state.

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3.4 A discount factor disturbance

Suppose that in period zero the economy is in the intended steady state, and the economy is expected to remain in the intended steady state forever. In period one, agents realize that from period one through period $T > 1$ the variable ξ_t will assume negative values that form a strictly increasing sequence, i.e., $\xi_t = \bar{\xi}_t < 0$ for $t = 1, ..., T$, where $\{\bar{\xi}_t\}_{t=1}^{T}$ is a strictly increasing sequence, and $\xi_t = 0$ for $t \geq T + 1$.

To understand how this disturbance affects the economy, note that the stochastic discount factor is equal to $\beta e^{(\xi_{t+1} - \xi_t)} C_t / C_{t+1}$. Since $\{\bar{\xi}_t\}_{t=1}^{T}$ is a sequence of negative, increasing numbers converging to zero in finite time, the exogenous component of the stochastic discount factor, $\beta e^{(\xi_{t+1} - \xi_t)}$, rises on impact and falls to β in finite time. Hence, the disturbance temporarily increases the value of future consumption relative to current consumption.[7] In the rest of the paper, we study the response of the economy to this discount factor disturbance.

To begin, it is helpful to solve for the response of the economy to the disturbance given arbitrary parameter values. The response of output, inflation, and the central bank's interest rate to the disturbance is indeterminate. In other words, multiple paths of $\{Y_t, \Pi_t, R_t\}_{t=1}^{\infty}$ are consistent with equilibrium. There is a unique equilibrium path that converges to the intended steady state. There are also infinitely many equilibrium paths that converge to the unintended steady state. Figure 2 shows the unique path converging to the intended steady state and an arbitrarily chosen path converging to the unintended steady state.

In general, the default premia are also indeterminate. The number of solutions for the default premium $Z_{nt} - R_t$ in any period $t \geq 1$ depends on the financing needs of fiscal authority n, given by the right-hand side of equation (4), $\Delta_{nt} \tilde{B}_{n,t-1} Y_{t-1} / (\Pi_t Y_t) - \tilde{S}_{nt}$. If the financing needs are low, there is a unique solution in which the probability of default in period $t + 1$ is zero and $Z_{nt} = R_t$. If the financing needs are high, there is a unique solution in which the probability of default in period $t + 1$ is one and the value of $Z_{nt} - R_t$ is pinned down by Δ_n. For intermediate financing needs, there are multiple solutions for $Z_{nt} - R_t$. If agents do not expect default, $Z_{nt} - R_t$ is close to zero and therefore $\tilde{B}_{nt}$ and the probability of default are low, validating the agents' expectation. If agents expect default, $Z_{nt} - R_t$ is large and therefore $\tilde{B}_{nt}$ and the probability of default are high, likewise validating the

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[7]A similar specification due to Eggertsson and Woodford (2003) has been popular as a simple way to model the shock that caused the Great Recession.

agents' expectation.[8]

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 central bank's reaction function is $R_t = \left(\bar{\Pi}/\beta\right)\left(\Pi_t/\bar{\Pi}\right)^{\phi}$ with $\phi > 1$. Then there is a unique solution for output, inflation, and the central bank's interest rate following a disturbance to ξ_t, and this solution converges to the intended steady state. Furthermore, when ϕ is large, output and inflation remain constant in every period at their steady-state values after a shock to ξ_t (while R_t declines, possibly below one, assuming that the shock is "contractionary," and returns to the steady state). Thus, in the absence of the lower bound the standard interest rate reaction function can implement the optimal policy. By contrast, 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 any disturbance to ξ_t. The central bank's interest rate can react optimally to expansionary shocks to ξ_t, but the central bank's interest rate cannot react optimally to all contractionary shocks to ξ_t.[9]

4   Baseline simulation

We have set up a simple model in which the specification of monetary and fiscal policy captures the essential characteristics of how each policy is actually conducted in the euro area. In this section, we simulate the model with this specification of policy ("the baseline simulation"). We aim to show that the model reproduces the main features of the recent data for reasonable parameter values and to establish a benchmark with which to compare the outcome of the policy experiment in Section 5.

As before, we assume 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_t will follow the process defined in Section 3.4. In this section, we modify the model by adding to it two sunspot processes. Given the two sunspot processes, the response of the economy to the discount factor disturbance is unique, we can solve for it numerically and compare it with the data.

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[8]Section 5.4 provides more discussion of the determination of the default premia in the model.

[9]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 decreases and the probability distribution of output becomes negatively skewed.

4.1 Sunspot processes

Consider two sunspot processes, mutually independent and independent of all other variables. A "confidence-about-inflation" sunspot shock can occur with probability $p \in (0,1)$ in every period $t \geq 1$, so long as the shock has not yet occurred. If the shock has occurred, the probability of it occurring again is zero and the economy converges to the unintended steady state. Let Π'_t denote inflation in period t if the shock has not occurred. We assume that if the shock occurs in period t, inflation in period t is equal to $\kappa_\pi \Pi'_t$, where $\kappa_\pi \in (0,1)$ is a parameter. We find that as the shock fails to occur, the economy converges to what we refer to as the "stationary point." Inflation, the central bank's interest rate, and all real variables including the debt-to-output ratio of each fiscal authority 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 sunspot shock is expected to occur in every period with probability $p > 0$.[10]

The other sunspot shock, "confidence about debt," is a simple equilibrium selection device. If in any period $t \geq 1$ multiple values of the default premium $Z_{nt} - R_t$ satisfy all equilibrium conditions for a given n, the confidence-about-debt sunspot shock selects one of the values as the equilibrium outcome.

4.2 Parameterization

One period in the model is one year. Period one in the model is the year 2009. We choose a value of χ, the parameter governing the degree of price stickiness, and a process for the discount factor disturbance ξ_t such that output and inflation in period one in the baseline simulation match output and inflation in 2009 in the data.[11] This strategy implies that the Phillips curve in the model is rather flat, e.g., the slope of the Phillips curve in the model linearized around the intended steady state is equal to 0.1. We suppose that the

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[10] In other words, the confidence-about-inflation sunspot follows a two-state Markov process. The economy begins in the state "convergence to the stationary point" and the other state, "convergence to the unintended steady state," is absorbing. Mertens and Ravn (2014) specify a similar sunspot process. In their model, "convergence to the intended steady state" is the absorbing state. Both models can be thought of as simplified versions of the model in Aruoba et al. (2017), in which neither state of the sunspot process is absorbing and the economy fluctuates continuously between the intended steady state and the unintended steady state.

[11] In particular, we assume that $\bar{\xi}_1 = -0.113$, $T = 7$, and $\bar{\xi}_{t+1} - \bar{\xi}_t$ is a decreasing linear function of time, for $t = 1, ..., T$. Recall that $\bar{\xi}_t$ denotes a non-zero realization of ξ_t.

confidence-about-inflation sunspot shock occurs in 2012 and κ_π (the parameter affecting the magnitude of the fall in inflation due to the realization of this sunspot shock) is equal to 0.983. These assumptions imply that the baseline simulation produces a second recession in 2012. We specify $p = 0.04$, i.e., the annual probability of the confidence-about-inflation sunspot shock is 0.04. We set $\beta = 0.995$. A high value of β seems natural in a model of the Great Recession and the period immediately following the Great Recession.[12] We suppose that the elasticity of substitution between goods, ε, is equal to 11. In the monetary policy reaction function, we assume $\phi = 3$ and $\bar{\Pi} = 1.019$ (i.e., the inflation objective is an annual rate of 1.9 percent).

Turning to fiscal policy, recall that fiscal policy has no effect on households' wealth given the assumed specification of monetary and fiscal policy. This means that fiscal policy parameters do not affect the path of output, inflation, and the central bank's interest rate in the baseline simulation. Fiscal policy parameters *do* affect the primary surpluses, the probability of default, and the government bond yields. We define North as Germany, France, and the Netherlands taken together. South is Italy and Spain taken together. We set $\tilde{B}_{1,0} = 0.35$, i.e., in period zero the stock of debt of the fiscal authority in North is equal to 0.35, as a share of nominal output. The stock of government debt of Germany, France, and the Netherlands taken together was equal to 0.35 in 2008, as a share of nominal GDP of *the euro area as a whole*. We set $\tilde{B}_{2,0} = 0.22$, based on the same reasoning and data for Italy and Spain. We specify $\psi_B = 0.05$, which is the baseline estimate in Bohn (1998). Given the selected values of $\tilde{B}_n$ and ψ_B, we compute ψ_n for each n from the relation $\psi_n = \tilde{B}_n(\psi_B - (1 - \beta)/\bar{\Pi})$, which holds in period zero since the economy is in the intended steady state in period zero. We set $\psi_{Y1} = 0.278$, $\psi_{Y2} = 0.316$, and $\psi_Z = 0.2$. With this parameterization of equation (5), the primary surpluses in the baseline simulation match the data: the average value of $\tilde{S}_{1t}$ in periods one through seven in the model is equal to the average primary surplus of Germany, France, and the Netherlands taken together in the period 2009-2015, and the average value of $\tilde{S}_{2t}$ in periods one through seven in the model is equal to the average primary surplus of Italy and Spain taken together in the period 2009-2015. We set $\tilde{B}_1^a = 0.5$, $\tilde{B}_1^b = 0.6$, $\tilde{B}_2^a = 0.26$, $\tilde{B}_2^b = 0.27$, and $\Delta_1 = \Delta_2 = 0.8$ (i.e., the recovery rate is 80 percent). With this parameterization, the model has a unique solution for the default premium in North: $Z_{1t} = R_t$ in every period $t \geq 1$. In any period in which

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[12]Below we consider the effects of lowering the value of β. A richer model could allow for the possibility of low-frequency variation in β, in addition to the high-frequency variation in ξ_t that we focus on.

multiple values of $Z_{2t} - R_t$ (the default premium in South) satisfy all equilibrium conditions, we suppose that the confidence-about-debt sunspot shock selects the lowest value, except that in 2012 the shock selects the intermediate of the three admissible values.[13]

4.3 Baseline simulation versus the data

Figure 3 shows the response of the economy to the discount factor disturbance in the baseline simulation. Output, inflation, and the central bank's interest rate in the model replicate their respective non-monotonic paths in the data. Moreover, the simulated trajectories of the three variables are quantitatively similar to the data. According to the model, the fall in output and inflation in 2009 was caused by the discount factor disturbance. The recovery was interrupted in 2012, when output and inflation decreased again in the wake of the confidence-about-inflation sunspot shock. The simulated government bond spread, $Z_{2t} - Z_{1t} = Z_{2t} - R_t$, also mimics the spread in the data. The model tells us that both the spike in the spread and the subsequent fall in the spread were self-fulfilling, i.e., in the simulation each of the two outcomes reflects a realization of the confidence-about-debt sunspot shock.[14]

To conclude, when monetary and fiscal policy in the model behave as in the euro area, the model reproduces the main features of the data in the period 2009-2015. Furthermore, a key implication of the model is that macroeconomic outcomes in the euro area are indeterminate and subject to self-fulfilling fluctuations. The euro area is a "land of indeterminacy."

Table 1 compares the primary surpluses in the baseline simulation and in the data. By construction, in the baseline the average primary surplus of each fiscal authority in the period 2009-2015 matches the data. Specifically, the primary budget in North and in South is in deficit, on average in the period 2009-2015, by about an equal amount as a share of euro area GDP (0.39 in North and 0.43 in South), in the model and in the data. The deficits in that period can be compared with a primary surplus of 0.74 in North and a primary surplus of 0.04 in South in the data in 2008. The deficits in the baseline simulation are not expansionary, because they fail to make households wealthier. Any decrease in the primary

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[13]When we find multiple solutions for $Z_{nt} - R_t$, we always find three solutions: with the probability of default next period equal to zero, with the probability of default equal to one, and with the probability of default in an intermediate range.

[14]In the absence of the confidence-about-debt sunspot shock, there would be multiple solutions for the default premium in South in 2012 and in 2013. The baseline simulation assumes that the sunspot shock selects the intermediate solution in 2012 and the zero-probability-of-default solution in 2013. See Section 5.4 for more discussion of the outcomes in the government bond markets in the model.

surplus is offset by a rise in future primary surpluses or an increase in the probability of default (in South in 2012).

We can use the model to compute the structural primary surplus of a fiscal authority, defined as the difference between the primary surplus and its cyclical component, $\tilde{S}_{nt} - \psi_{Yn}(Y_t - Y)$. As Table 1 shows, the structural primary surplus is much larger than the primary surplus (i.e., the cyclical component of the budget moves into a large deficit) both in North and in South. The reason is the negative and sizable output gap in the baseline simulation.

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

	Data	Baseline	Experiment in Section 5.2
Fiscal authority in North			
Primary surplus	-0.39	-0.39	0.07
Structural primary surplus	-	0.27	0.10
Fiscal authority in South			
Primary surplus	-0.43	-0.43	0.03
Structural primary surplus	-	0.33	0.06

Notes: To express the primary surplus in North as percent of North's GDP, one must multiply the numbers reported in the table by 1.8, e.g., $-0.39 * 1.8 = -0.70$. To express the primary surplus in South as percent of South's GDP, one must multiply the numbers reported in the table by 3.7, e.g., $-0.43 * 3.7 = -1.59$. The number 1.8 (3.7) is the average ratio of euro area nominal GDP to North's (South's) nominal GDP in the years 2009-2015.

Since the model is simple (e.g., only two disturbances, the discount factor shock in 2009 and the confidence-about-inflation sunspot shock in 2012, affect the paths of output and inflation in the baseline simulation), we cannot expect to replicate all features of the data. For instance, the model produces a discrete decline of inflation in 2012, whereas the fall of inflation in the data starting in 2012 was gradual. Adding a backward-looking component to the inflation process in the model, common in the empirical literature, could help the model match this aspect of the data. As another example, the model predicts a discrete decline in long-term inflation expectations in 2012 by 160 basis points.[15] In the data, the five-year

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[15]The inflation rate expected on average between 5 and 10 years in the future drops in 2012 from 1.3 percent to -0.3 percent in the model. The main reason why the first number is smaller than $100(\bar{\Pi} - 1)$, or 1.9 percent, is that the economy will converge to the unintended steady state with probability p. The reason why the second number is larger than $100(\beta - 1)$, or -0.5 percent, is that convergence to the unintended steady state takes time.

five-year forward inflation swap rate, a popular indicator of long-term inflation expectations, declined gradually by about 100 basis points between 2012 and the summer of 2016.[16] A version of the model in which "convergence to the unintended steady state" was not an absorbing state would produce a smaller drop in long-term inflation expectations compared with the baseline simulation, more in line with the data.[17] Finally, the assumption that the sunspot processes are independent of all other variables has been made for simplicity. In a version of the model with government spending, the confidence-about-inflation sunspot shock could be correlated with government spending. One could then explain the recession of 2012-2013 mainly as the consequence of the decline in government spending that took place in the euro area at that time, while attributing to the confidence-about-inflation sunspot shock the tendency of inflation not to return to the objective of the central bank.[18]

5 Policy experiment

This section uses the model to conduct a policy experiment. The experiment helps us understand what could have happened under a counterfactual policy configuration after the same discount factor disturbance. The experiment is motivated by the observation that if debt is denominated in a fiat currency, monetary and fiscal policy can coordinate to make debt non-defaultable. With this arrangement in place an effective fiscal stimulus is available, since a decrease in the primary surplus need not be offset by a rise in future primary surpluses or an increase in the probability of default.

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_t will follow the process defined in Section 3.4. We drop from the model the two sunspot processes used in Section 4.

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[16]From 2.6 percent in 2009 to 2.3 percent in 2012 and to 1.3 percent in the summer of 2016.

[17]Furthermore, to produce a more gradual decline in long-term inflation expectations than in the baseline simulation, one could model the probability that the economy will revert toward the intended steady state as a function of the realized inflation rate.

[18]The sum of government consumption and government investment in the euro area as a whole, measured in real terms, decreased in 2012.

5.1 Setup of the experiment

Inspired by the proposal in Sims (2012), we introduce a new policy authority, a centrally-operated fund that can buy from the two "national" fiscal authorities their debt. The fund can sell to households its own debt, single-period nominal discount bonds ("eurobonds").[19] We suppose that the fund's debt is non-defaultable, i.e., the monetary authority and the fund agree that maturing eurobonds are convertible into fiat currency at par. We maintain the assumption that debt issued by the national fiscal authorities, now held in part by the fund and in part by households, can default.

We suppose that in period one, coincident with the arrival of the discount factor disturbance, the monetary authority abandons reaction function (2). Instead, in every period $t \geq 1$, the central bank sets an exogenous path for R_t that converges in finite time 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).[20]

In the presence of the eurobonds, the primary surplus of each national fiscal authority has two components: a part flowing to households and a part flowing to the fund and thus backing the eurobonds. We assume that in period one, coincident with the arrival of the disturbance, the national fiscal authorities abandon reaction function (5). Instead, each national fiscal authority adopts a reaction function implying that the eurobonds are backed by active fiscal policy as in Leeper (1991). At the same time, there is fiscal discipline in the sense that the share of each national bond in the fund's assets is constant in the long run. Furthermore, national bonds held by households continue to be backed by the passive fiscal policy from Sections 3-4. To specify the details of the new fiscal policy, we need some notation. Let B_{nt}^F denote bonds issued by fiscal authority n and purchased by the fund, and let B_{nt}^H denote bonds purchased by households ($B_{nt}^F + B_{nt}^H = B_{nt}$). Let S_{nt}^F denote the part of the primary surplus of fiscal authority n flowing to the fund, and let S_{nt}^H denote the part flowing to households ($S_{nt}^F + S_{nt}^H = S_{nt}$). Define $\tilde{B}_{nt}^F \equiv \left(B_{nt}^F/P_t Y_t\right)$, $\tilde{B}_{nt}^H \equiv \left(B_{nt}^H/P_t Y_t\right)$, $\tilde{S}_{nt}^F \equiv \left(S_{nt}^F/Y_t\right)$, and $\tilde{S}_{nt}^H \equiv \left(S_{nt}^H/Y_t\right)$. Suppose that in period zero the

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[19]Households now hold bonds issued by each national fiscal authority and eurobonds. The budget constraint of household j, initially given by equation (1), must be modified in a straightforward way. Another straightforward modification of the budget constraint of household j is required below after we introduce a tax imposed directly by the fund.

[20]The qualitative predictions of the model do not depend on whether we assume an exogenous path for the central bank's interest rate or an alternative passive monetary policy allowing the central bank's interest rate to react less than one-for-one to inflation. The former assumption facilitates the solution of the model.

fund holds a share $\lambda \in (0, 1]$ of bonds issued by each national fiscal authority and households hold the remainder, $1 - \lambda$. In every period $t \geq 1$, fiscal authority n sets the two components of its primary surplus according to the reaction functions

$$\tilde{S}_{nt}^H = -\psi_n + \psi_B \tilde{B}_{n,t-1}^H + \psi_{Yn} (1 - \lambda) (Y_t - Y) + \psi_Z (Z_{n,t-1} - R_{t-1}) \qquad (10)$$

and

$$\tilde{S}_{nt}^F = \bar{\psi}_n + \psi_B \left[\tilde{B}_{n,t-1}^F - \theta_n \left(\sum_n \tilde{B}_{n,t-1}^F \right) \right] + \psi_{Yn} \lambda (Y_t - Y), \qquad (11)$$

respectively, where $\bar{\psi}_n$ and θ_n are parameters satisfying $\bar{\psi}_n > 0$, $\theta_n > 0$, and $\sum_n \theta_n = 1$. Equation (10) is simply analogous to equation (5). In particular, since we maintain the restriction $\psi_B > 1/\beta - 1$, the debt-to-GDP ratio of each national fiscal authority exclusive of the holdings of the fund, $\tilde{B}_{nt}^H$, converges to a constant regardless of the path of the price level and output. By contrast, equation (11) is non-standard.[21] This equation implies that

$$\sum_n \tilde{S}_{nt}^F = \sum_n \bar{\psi}_n + \left(\sum_n \psi_{Yn} \right) \lambda (Y_t - Y), \qquad (12)$$

which says that the sum of the primary surpluses flowing to the fund, $\sum_n \tilde{S}_{nt}^F$, *does not* react to any measure of debt. Hence, the eurobonds are backed by active fiscal policy as in Leeper (1991). However, the part of the primary surplus flowing to the fund from an individual national fiscal authority, $\tilde{S}_{nt}^F$, *does* react to debt. Suppose that $\theta_n = \tilde{B}_{n,0}^F / \left(\sum_n \tilde{B}_{n,0}^F \right)$ and consider the response of the fiscal variables to the discount factor disturbance, assuming that output falls on impact. If $\psi_{Y2} > \psi_{Y1}$, as we maintain, the debt-to-GDP ratio in South rises relative to the debt-to-GDP ratio in North. The second term on the right-hand side of equation (11) implies that the fiscal authority in South increases its primary surplus ("fiscal effort"). At the same time, the fiscal authority in North decreases its primary surplus ("fiscal accommodation"), even if the debt-to-GDP ratio in North has risen in absolute terms. Consequently, as the effects of any disturbance die out, the share of fiscal authority n in the fund's assets converges to a constant, θ_n.

In sum, after the discount factor disturbance the central bank's interest rate follows an exogenous path that converges to the intended steady state (passive monetary policy) and

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[21] A reaction function similar to equation (11) appears in the discussion of options for Europe's monetary union in Sims (1997). Sims refers to his reaction function as a "politically robust fiscal rule."

the sum of the primary surpluses flowing to the fund does not react to debt (the eurobonds are backed by active fiscal policy).

With this policy configuration, we find that the response of output and inflation to the discount factor disturbance is unique and the economy converges to the intended steady state. To see why, note that the budget constraint of the fund in period t reads

$$\frac{F_t}{R_t P_t} = \frac{F_{t-1}}{P_t} - \left(\sum_n S_{nt}^F \right), \tag{13}$$

where F_t denotes the eurobonds issued by the fund and purchased by households in period t.[22] Furthermore, the following equation holds:

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

To derive this equation, we take the transversality condition of household j

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

sum it across j's using the relation $\int_0^1 H_{jt} dj = 0$, and notice that, given equation (10) with $\psi_B > 1/\beta - 1$, B_{nt}^H / P_t for each n converges to a constant regardless of the path of the price level and output. Employing equations (6) and (14), we solve equation (13) forward to obtain

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

The real value of the eurobonds is equal to the present value of the primary surpluses flowing to the fund, evaluated with the stochastic discount factor. Dividing both sides by Y_t and letting $\tilde{F}_t$ denote the eurobonds as a share of nominal output, $\tilde{F}_t \equiv (F_t / P_t Y_t)$, we arrive at

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

Given the policy configuration in this section, equation (15) lets us find the unique equi-

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[22]The term in parentheses on the right-hand side of equation (13) is equal to the revenue from the fund's claims on the national fiscal authorities maturing in period t minus the period t lending of the fund to the national fiscal authorities, in real terms. This simply equals the sum of the primary surpluses flowing to the fund in period t.

librium path of output and inflation. Just as in Section 3, infinitely many paths satisfy equilibrium conditions (6) and (8), i.e., the consumption Euler equation and the Phillips curve. Given the active fiscal policy assumed here, $\tilde{F}_t$ converges only along one of those paths. The paths that start with "low" output and inflation imply that $\tilde{F}_t$ explodes, in violation of equation (14), while the paths that start with "high" output and inflation imply that $\tilde{F}_t$ implodes, also in violation of equation (14). Furthermore, the passive monetary policy ensures that in the long run inflation converges to $\bar{\Pi}$.

5.2 Outcome of the experiment

We now analyze the response of the economy to the discount factor disturbance given the assumptions about policy made in Section 5.1.

We must select values for the new parameters λ, θ_n, and $\bar{\psi}_n$.[23] We set $\lambda = 0.2$, implying that in period zero the fund holds 20 percent of bonds issued by each national fiscal authority and households hold 80 percent. We discuss below the effect of the value of λ on the solution. We assume $\theta_n = \tilde{B}_{n,0}/(\tilde{B}_{1,0} + \tilde{B}_{2,0})$, arriving at $\theta_1 = 0.61$ and $\theta_2 = 0.39$. To set $\bar{\psi}_n$, we suppose that in the long run $\tilde{B}_{nt}^F$ converges to a number 5 percent lower than $\tilde{B}_{n,0}^F$ (i.e., $\tilde{B}_{1t}^F$ converges to $0.95 * \lambda * \tilde{B}_{1,0} = 0.95 * 0.2 * 0.35 = 0.0665$ and $\tilde{B}_{2t}^F$ converges to $0.95 * \lambda * \tilde{B}_{2,0} = 0.95 * 0.2 * 0.22 = 0.0418$).[24] Hence, by design of the experiment, the part of the primary surplus in North and the part of the primary surplus in South flowing to the fund *decrease* in the long run, by 5 percent, compared with the initial steady state. In this sense, the response of fiscal policy to the discount factor disturbance is expansionary. As to monetary policy, we suppose that the central bank's interest rate satisfies $R_t = 1$ in periods $t = 1, 2, 3, 4$. Subsequently, the monetary authority raises the interest rate at a constant speed to reach $\bar{\Pi}/\beta$ in period $t = 8$ and holds the interest rate at $\bar{\Pi}/\beta$ thereafter.

Figure 4 compares the outcome of the 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 there is a shallow recession starting in 2013 when the central bank's interest rate begins to rise. Inflation never moves away much from the central bank's objective. The government bond

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[23]The values of all other parameters, given in Section 4.2, are unchanged except that now we compute ψ_n from the relation $\psi_n = (1 - \lambda) \tilde{B}_n (\psi_B - (1 - \beta)/\bar{\Pi})$.

[24]This assumption and equation (15) evaluated in the intended steady state imply that $\bar{\psi}_1 = 3.26\text{e-}4$ and $\bar{\psi}_2 = 2.05\text{e-}4$.

spread disappears, as the debt-to-GDP ratio in South falls sufficiently so that there is a unique equilibrium with the probability of default in South equal to zero.[25] To conclude, when monetary and fiscal policy interact as in this experiment, output is much higher than in the baseline simulation and inflation is in line with the ECB's objective.

The following intuition helps understand the outcome of the experiment. When the contractionary discount factor disturbance arrives, the primary surplus tends to fall because it depends positively on output. In the baseline, the initial decrease in the primary surplus is offset by a combination of a rise in future primary surpluses and an increase in the probability of default. However, in the presence of non-defaultable public debt there would have been no need to undo the initial fiscal accommodation, and in the experiment a part of the initial fiscal accommodation is *never undone*. The present value of the primary surpluses flowing to the fund falls relative to the value of the eurobonds, implying – since the eurobonds do not default – that households' wealth increases at a given price level. As households spend the extra wealth, "too many eurobonds are chasing too few goods," and output and inflation rise relative to the baseline.

To see by how much fiscal policy affects output and inflation in the policy experiment, note from equation (15) that the elasticity of *nominal* output with respect to the present value of the primary surpluses flowing to the fund is simply minus one. The degree of price stickiness determines the elasticity of *real* output. In other words, the degree of price stickiness determines how a given change in nominal output is divided between real output and inflation. With our parameterization, the elasticity of real output with respect to the present value of the primary surpluses flowing to the fund is -0.6.[26]

We now comment on the measure of the size of the fund, $\lambda \in (0, 1]$. The response of output, inflation, and the central bank's interest rate to the discount factor disturbance, i.e., the equilibrium path of $\{Y_t, \Pi_t, R_t\}_{t=1}^{\infty}$, is *invariant* to the value of λ. The reason is that the key equilibrium condition is equation (15) in period one, and changing the value of λ amounts to multiplying each side of this equation by the same number. For instance,

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[25]In the experiment, we find that $\tilde{B}_{nt} < B_n^a$ for each n in every period $t \geq 1$, implying that in every period there is a unique equilibrium in the government bond markets with the probability of default by each national fiscal authority equal to zero, $Z_{1t} = Z_{2t} = R_t$.

[26]We prefer to think of the effects of fiscal policy in this model in terms of the elasticity of output with respect to the present value of the primary surpluses flowing to the fund. This quantity is independent of the initial stock of debt and the size of the fund, measured by the parameter λ. By contrast, a standard multiplier in this model depends both on the initial stock of debt and the value of λ. Define the multiplier as the change in output per one euro change in the primary surplus flowing to the fund. With the policy configuration in this section and $\tilde{B}_{1,0} + \tilde{B}_{2,0} = 0.57$, the multiplier is approximately $-0.4/\lambda$.

lowering λ means that there are fewer eurobonds and that they are being backed by a smaller fraction of the primary surpluses of the national fiscal authorities, in such a way that the equilibrium value of a eurobond is unchanged. The following analogy may be useful. Think of a simple monetarist model, in which the central bank controls money supply and in equilibrium nominal output is proportional to money supply. If the central bank wants to raise nominal output by x percent, the central bank needs to increase money supply by x percent, irrespective of the initial size of the money stock. The policy implication is that favorable stabilization outcomes can be achieved irrespective of the quantity of the eurobonds.

Let us take a closer look at the behavior of the primary surpluses and debt. By design of the experiment, the primary surplus of each national fiscal authority falls in the long run. Specifically, since $\lambda = 0.2$ and the part of each primary surplus flowing to the fund decreases by 5 percent in the long run, each primary surplus falls by 1 percent. Next, consider the short run. In the period 2009-2015, the average structural primary surplus of each national fiscal authority is lower in the experiment than in the baseline (see Table 1). At the same time, the average primary surplus of each national fiscal authority overall is higher in the experiment than in the baseline (see Table 1). The primary surpluses rise in the experiment compared with the baseline, because output is much higher in the former than in the latter. Finally, note that in the long run the national debt-to-GDP ratios decline relative to the baseline, by design of the experiment. We find that the national debt-to-GDP ratios decrease also in the short run, on average by 4 percentage points both in North and in South in the period 2009-2015, compared with the baseline. The national debt-to-GDP ratios fall in the short run because nominal output rises and because the primary surpluses improve in the short run relative to the baseline.[27]

Since we assume that the discount factor, β, is equal to 0.995 and a higher discount factor increases the present value of a given stream of primary surpluses, one could be concerned that the primary surpluses in the policy experiment are unrealistically small. Indeed, the

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[27]The debt-to-GDP ratios in the baseline understate the debt-to-GDP ratios in the data, despite the fact that the average primary surpluses in the baseline match the average primary surpluses in the data. One reason is that in the data government debt increased in the wake of the Great Recession inter alia due to "stock-flow adjustments," e.g., asset purchases by the public sector, unrecorded in the data on the primary surpluses. Another reason is that in the model all debt has a maturity of one year. Due to this assumption, the model overstates the effect of interest rate changes on the cost of debt service. For example, in the model bond yields are zero in 2009, and hence the cost of debt service in 2010 is zero. Italy actually spent 4 percent of its GDP on government debt service in 2010.

primary surpluses required to achieve favorable stabilization outcomes, similar to those in Figure 4, would have to be larger with a lower β. The question is how much larger. We reconsider the policy experiment having lowered β. We continue to suppose that the part of each primary surplus flowing to the fund falls by 5 percent in the long run compared with the initial steady state. If $\beta = 0.99$ and all other parameters are unchanged, the long-run primary surplus in the experiment doubles to 0.34 percent of output of the union in North and 0.21 percent of output of the union in South (see Table 2). If $\beta = 0.98$, the long-run primary surplus doubles again, to 0.68 and 0.43, respectively. The key point is that these outcomes for the primary surplus in the model are comparable with the pre-Great Recession averages in the data. For example, in the data the average primary surplus in the period 1999-2008 was equal to 0.38 percent of euro area GDP in North and 0.62 percent of euro area GDP in South (see Table 2).[28]

Table 2: Long-run primary surplus in Section 5.2, as percent of euro area GDP

	Fiscal authority in North	Fiscal authority in South
$\beta = 0.995$	0.17	0.11
$\beta = 0.99$	0.34	0.21
$\beta = 0.98$	0.68	0.43
Memo: Average primary surplus in the data, 1999-2008	0.38	0.62

Notes: To express the primary surplus in North as percent of North's GDP, one must multiply the numbers reported in the table by 1.8, e.g., $0.38 * 1.8 = 0.68$. To express the primary surplus in South as percent of South's GDP, one must multiply the numbers reported in the table by 3.6, e.g., $0.62 * 3.6 = 2.23$. The number 1.8 (3.6) is the average ratio of euro area nominal GDP to North's (South's) nominal GDP in the years 1999-2008.

5.3 If things go wrong

What would happen if a national fiscal authority deviated from reaction function (11)? We have in mind an institutional setup in which the fund would then refuse to purchase debt

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[28]Members of the Federal Open Market Committee forecast the federal funds rate and the U.S. inflation rate in "the longer run." One can use these forecasts to compute the expected long-run real interest rate. For instance, at the December 2015 FOMC meeting, the long-run real interest rate was forecast to be in the range of 0.5-1.8 percent per annum, corresponding to a value of β between 0.98 and 0.995.

issued by that authority, and the authority could default.[29] 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 refuse to purchase debt issued by a national fiscal authority that has deviated. However, we can use the model to quantify the inflationary consequences of a deviation by a national fiscal authority.

We model a deviation from reaction function (11) by fiscal authority n as a permanent fall in the value of $\bar{\psi}_n$, from the prescribed value that we denote as $\bar{\psi}_n^{old}$ to a new value $\bar{\psi}_n^{new} < \bar{\psi}_n^{old}$. As is apparent from equations (11) and (15), a decrease in $\bar{\psi}_n$ exerts upward pressure on inflation by lowering the stream of the primary surpluses flowing to the fund. We assume that only the fiscal authority in South deviates, i.e., $\bar{\psi}_1$ remains unchanged and $\bar{\psi}_2$ falls. A decline in $\bar{\psi}_2$ produces a gain for households as taxpayers in South, while the ensuing inflation imposes a loss on households as holders of the eurobonds. We suppose that, coincident with the deviation, the fiscal authority in South also defaults on its bonds held by households, with a recovery rate given by $\bar{\psi}_2^{new}/\bar{\psi}_2^{old}$. For simplicity, the deviation and the default occur in period one, and we refer to this event simply as "default."[30]

To begin, we assume $\bar{\psi}_2^{new}/\bar{\psi}_2^{old} = 0.8$. The capital loss from the default, to households and the fund taken together, amounts to about 4.5 percent of euro area GDP (or 450 billion euros, if we round off euro area GDP to 10 trillion euros). The top panel in Figure 5 shows the effect of the default on inflation in the experiment from Section 5.2. The inflation rate jumps to 2.1 percent in the year in which the default occurs, 2009, or by 60 basis points compared with the outcome in Section 5.2. As another example, we suppose that $\bar{\psi}_2^{new}/\bar{\psi}_2^{old} = 0.6$, implying that the capital loss is about 9 percent of euro area GDP, or 900 billion euros.[31] The bottom panel in Figure 5 shows the effect of this larger default on inflation. This time the inflation rate jumps to 2.7 percent, or by 120 basis points compared with the experiment from Section 5.2. While the inflationary consequences of each scenario are non-trivial, we find it difficult to think of the resulting inflation rates as materially excessive.

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[29]See Sims (2012) and Corsetti et al. (2016) for more discussion of the institutional reform that we have in mind.

[30]As equation (15) shows, what matters for the backing of the eurobonds is the present value of the primary surpluses flowing to the fund, not whether a given decline in that present value represents default from a legal viewpoint.

[31]For comparison, Zettelmeyer et al. (2013) estimate a recovery rate of about 35-41 percent in the Greek debt restructuring of 2012. The Greek debt restructuring of 2012 applied only to private creditors, whereas in the model we assume a uniform haircut on all households and the fund.

Why are the inflationary effects of South's default moderate here? For one thing, the fund holds fewer South's bonds than North's bonds, and North does not default. The share of South in the fund's assets is 39 percent, $\tilde{B}_{2,0}/(\tilde{B}_{1,0} + \tilde{B}_{2,0}) = 0.39$. Hence, a haircut of even 50 percent on South's bonds amounts to a much smaller loss, about 20 percent, for the portfolio of the fund. Furthermore, the Phillips curve in the model is rather flat, consistent with the recent data (see the first paragraph of Section 4.2). If prices were less sticky, default would be more inflationary. To investigate how the inflationary consequences of South's default depend on the degree of price stickiness, we resolve the model assuming a steeper Phillips curve than so far. Specifically, we select a value for the parameter governing the degree of price stickiness, χ, so that the slope of the Phillips curve in the model linearized around the intended steady state is equal to 0.5, instead of 0.1. With a recovery rate of 80 percent, the inflation rate in 2009 jumps from 2.1 to 2.5 percent per annum. With a recovery rate of 60 percent, the inflation rate in 2009 rises from 2.7 percent to 5.1 percent. Thus if prices were to become less sticky following an extreme event such as a sovereign default in the euro area, the inflationary consequences of the default could be sizable. Table 3 summarizes the effects of South's default on inflation in the experiment. The table reports, inter alia, the results of an exercise in which we use the version of the model with completely flexible prices to compute an upper bound for the inflation rate in the year in which South defaults. With a recovery rate of 80 percent, the upper bound for the inflation rate is 8 percent. As another example, with a recovery rate of 60 percent the upper bound rises to 18 percent.

Table 3: Effects of South's default on inflation in the experiment from Section 5.2

Recovery rate, $\bar{\psi}_2^{new}/\bar{\psi}_2^{old}$	Capital loss, billions of euros	Inflation rate	Inflation rate if the PC steeper	Inflation rate if prices flexible
0.8	450	2.1	2.5	8
0.7	675	2.4	3.7	13
0.6	900	2.7	5.1	18

Notes: Default occurs in period one (2009). The inflation rate in the same period is reported, in percent per annum. The "capital loss" is the sum of the loss to households and the loss to the fund. The column "inflation rate if the PC steeper" refers to the case in which the slope of the Phillips curve computed in the model linearized around the intended steady state is five times greater than in Section 5.2.

Next, we modify the model by giving to the fund an ability to tax households directly.

Suppose that the fund can impose a lump-sum tax uniformly throughout the union. Equation (13) becomes

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

where the new variable S_t^F denotes a lump-sum tax imposed by the fund in period t. Furthermore, equation (15) changes to

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

where $\tilde{S}_t^F \equiv \left(S_t^F / Y_t \right)$. If the fund imposes a tax conditional on South's default, the effect of the default on inflation diminishes and *disappears* if the tax is sufficient (e.g., if $\tilde{S}_t^F = \bar{\psi}_2^{old} - \bar{\psi}_2^{new}$ in every period starting in the period in which the default takes place). By dampening the inflationary consequences of a default, a tax imposed by the fund produces a gain for households as holders of the eurobonds, while constituting a loss for households as taxpayers.

The magnitude of the fund's tax revenue required for a default to have no impact on inflation decreases with the recovery rate, $\bar{\psi}_2^{new} / \bar{\psi}_2^{old}$, and increases with the fund's exposure, λ. Table 4 reports numerical examples. Suppose that the recovery rate is 80 percent. Assuming the same parameterization as before including $\lambda = 0.2$, the present value of the fund's tax revenue must be equal to approximately 0.9 percent of output of the union as a whole (or 90 billion euros) for the default to have no effect on inflation. If the recovery rate falls to 60 percent, the required tax revenue doubles. If the fund's exposure rises to 40 percent, the necessary tax revenue doubles again. If the fund incurs a large loss (i.e., the recovery rate is low and the fund's exposure is large), the fund may find it politically impossible to impose a tax sufficient to prevent the default from causing inflation. The euro area economy would then face the inflationary outcomes shown in Table 3.[32]

Could the euro area's central bank, the ECB, act as the fund described here? Could the non-defaultable, interest-bearing reserve deposits at the ECB act as the eurobonds? The policy experiment from Section 5.2 *can be* replicated if the central bank issues interest-

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[32]For comparison, Corsetti et al. (2016) estimate that the present value of a 0.5 percentage point euro-area-wide VAT surcharge is equal to 1.2-1.7 trillion euros. The member states of the euro could also decide to direct to the fund seigniorage revenue of the Eurosystem. Corsetti et al. (2016) estimate that the present value of non-inflationary seigniorage revenue in the euro area is equal to 1.6-1.7 trillion euros.

Table 4: The fund's tax revenue required for South's default to have no impact on inflation

Recovery rate, $\bar{\psi}_2^{new}/\bar{\psi}_2^{old}$	Fund's exposure, λ		
	0.2	0.4	0.6
0.8	0.9	1.8	2.6
0.6	1.8	3.5	5.3
0.4	2.6	5.3	7.9

Note: The tax revenue is reported in present value as percent of euro area GDP.

bearing reserves to purchase national public debt, *so long as* the interest rate policy and fiscal policy are as assumed in that section. In particular, the critical features of the experiment are that the eurobonds are non-defaultable *and* the present value of the primary surpluses backing the eurobonds falls. Both features must be present for the experiment to produce favorable stabilization outcomes. That said, an important difference between the fund and a central bank is that a central bank cannot tax. A central bank earns seigniorage revenue that can be used to recoup a loss, e.g., from a default by a fiscal authority, but the non-inflationary seigniorage revenue may be insufficient to cover a central bank's loss. Moreover, most people would probably agree that an institution such as the fund ought to be subject to more direct democratic control than a central bank.[33]

5.4 The fund and determinacy of the government bond yields

How does the presence of the fund affect the determinacy of the default premia? In Section 5.2, there is a unique equilibrium in the government bond market in South in each year from 2009 to 2015, with the probability of default equal to zero. The reason is that South's debt-to-GDP ratio falls relative to the baseline, into the range implying a unique equilibrium with zero probability of default. South's debt-to-GDP ratio declines because nominal output rises and because South's primary surplus improves in the short run relative to the baseline. Moreover, the magnitude of the increase in nominal output is independent of the size of the fund measured by λ.

Another effect of the fund on the government bond markets does depend on the quantity

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[33]See Del Negro and Sims (2015) for a model of the relation between a central bank's balance sheet and inflation. Note also that in the real world only banks hold reserves at a central bank, whereas the eurobonds envisaged here could be held by many different agents. In a model with heterogenous agents, the effects of the policy experiment studied in this paper could depend on who owns the non-defaultable debt instrument.

of purchases made by the fund. Figure 6 illustrates the equilibria in the market for bonds of a national fiscal authority. 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-GDP 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 financing 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 there are three equilibria.

Suppose that the fund purchases a fraction λ_t of the debt at the price $1/R_t$. 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 the new budget constraint as a thin black line with circles, assuming a particular value of λ_t. Only one equilibrium survives with the new budget constraint, 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. In other words, if the fund purchases a sufficient fraction of bonds at the price free of default premium (i.e., λ_t is large enough), 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.[34] 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 falls and can become insufficient to validate expectations of default.[35]

When we find multiple equilibria in the government bond market, we always find one equilibrium in which the probability of default is equal to zero. Suppose that there are multiple equilibria in the absence of the fund. Then any bond purchases by the fund, or

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[34]Formally, one can prove the following result. Suppose that in period t there exists an equilibrium with the probability of default equal to zero. Then there exists a $\bar{\lambda}_t < 1$ such that if the fund purchases a fraction $\lambda_t \geq \bar{\lambda}_t$ of the debt at the price $1/R_t$, the equilibrium with the probability of default equal to zero is the unique equilibrium.

[35]Corsetti and Dedola (2016) obtain a similar result in a model in which a monetary authority can issue non-defaultable reserves to purchase defaultable bonds issued by a fiscal authority, and the authorities optimize.

even an announced intention of the fund to buy bonds at the price free of default premium, can act as a sunspot to coordinate households on the equilibrium in which the probability of default is equal to zero. One can interpret the announcement of the Outright Monetary Transactions program of the ECB in 2012 as a sunspot of this kind.

6   Conclusions

According to our model, the way monetary and fiscal policy interact has consequences for macroeconomic stability. With the current policy configuration, the euro area economy has been exposed to self-fulfilling fluctuations. Furthermore, effective fiscal stimulus has been unavailable since the onset of the Great Recession. The recent macroeconomic outcomes in the euro area could have been very different if monetary and fiscal policy had interacted differently, around a non-defaultable public debt instrument. The experiment in the paper is of practical relevance, we think, because the policy interactions it assumes require only a fairly modest degree of centralization of fiscal decision-making among the euro area member states. Moreover, in effect, a non-defaultable eurobond already exists in the form of interest-bearing reserve deposits at the ECB.

The model is simple and can be extended in a number of ways. For instance, it would be worthwhile to specify monetary and fiscal policy as subject to recurrent regime switches, with monetary policy becoming passive and fiscal policy active, as in Section 5, only in adverse macroeconomic circumstances. In addition, it would be interesting to allow for country heterogeneity, and to study the incentive problems of the fund and the national fiscal authorities. With respect to the latter, it would seem important to recognize that incentive problems presumably arise also in the current environment, in which the ECB is expected to purchase 2.3 trillion euros of securities, mostly national public debt, through the end of 2017. Finally, the effects of spikes in government bond yields and of government default on the real economy, abstracted from in this paper, require further study.

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Figure 1: Euro area annual data, 2008-2015
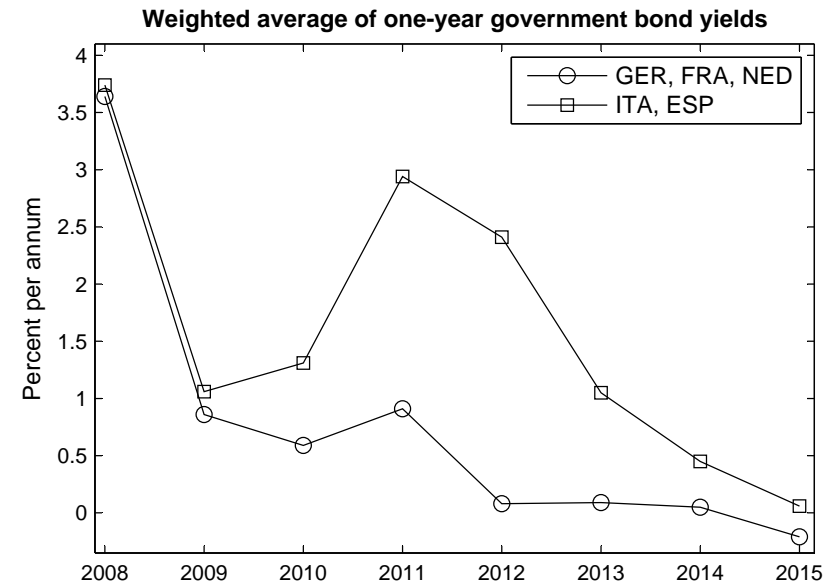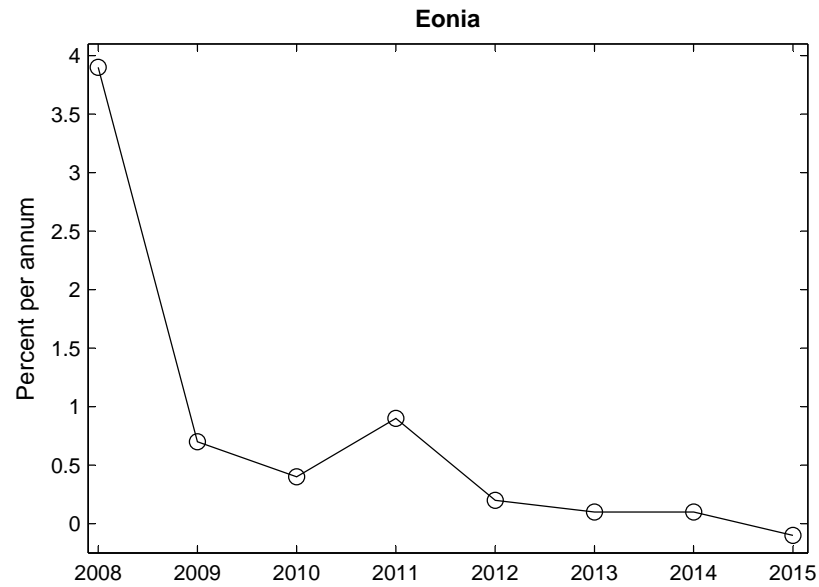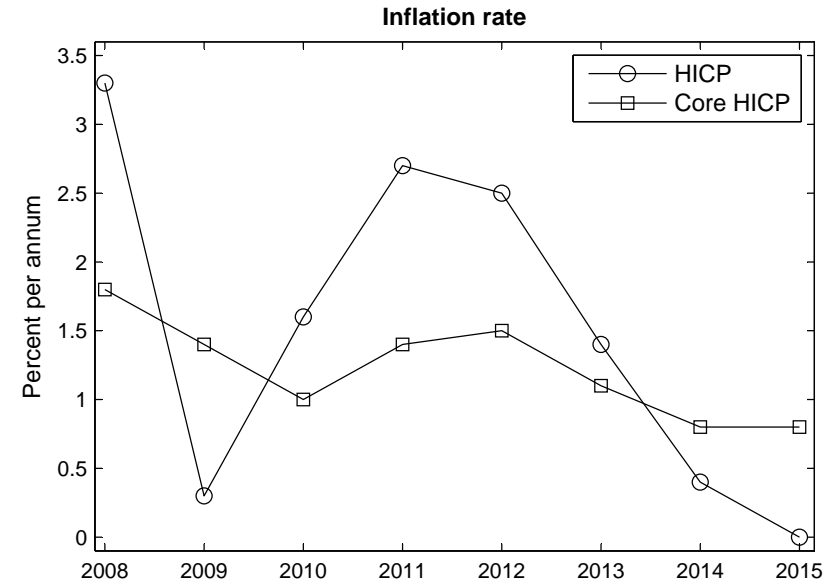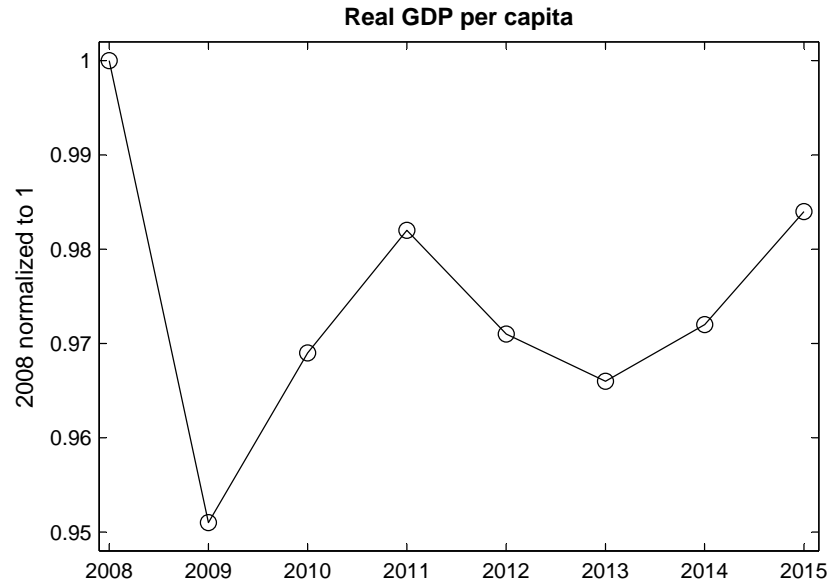
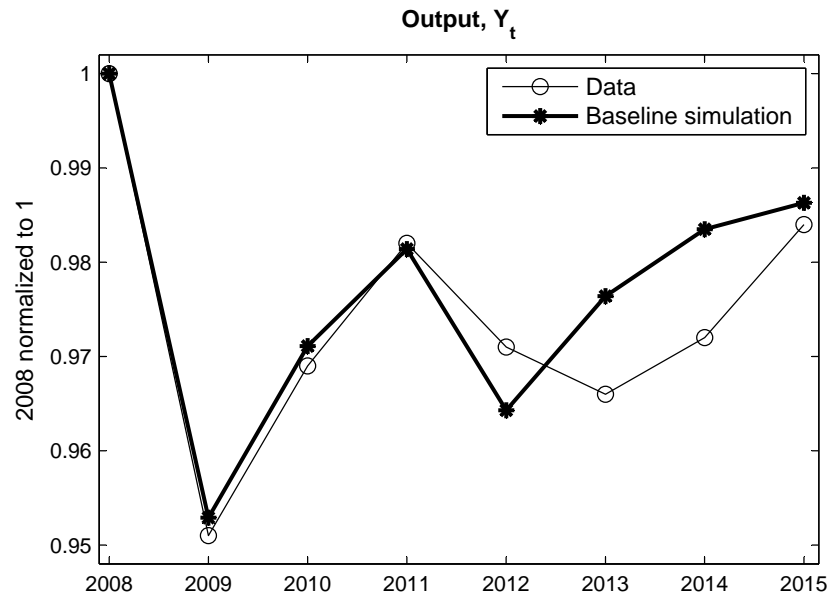**Figure 2: Two solutions of the model in Section 3**
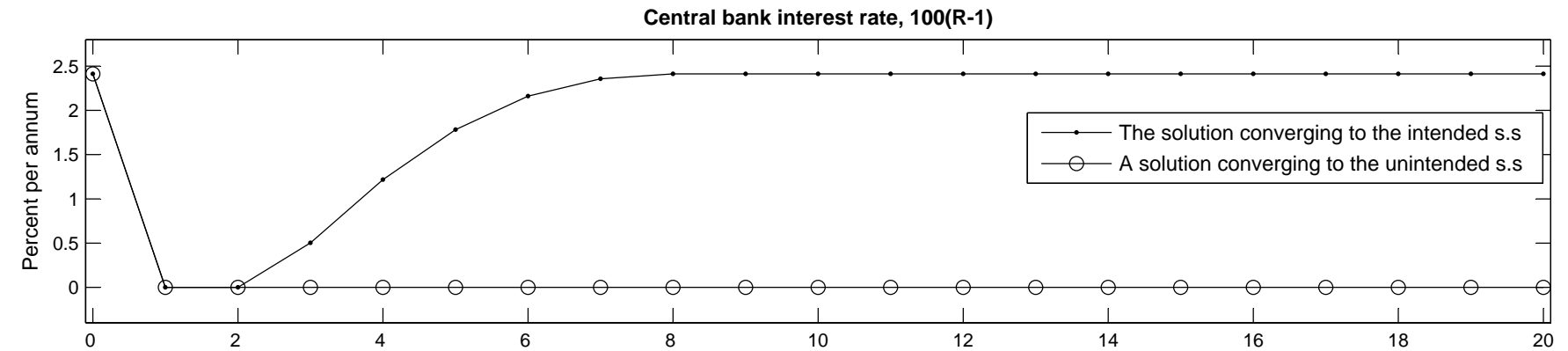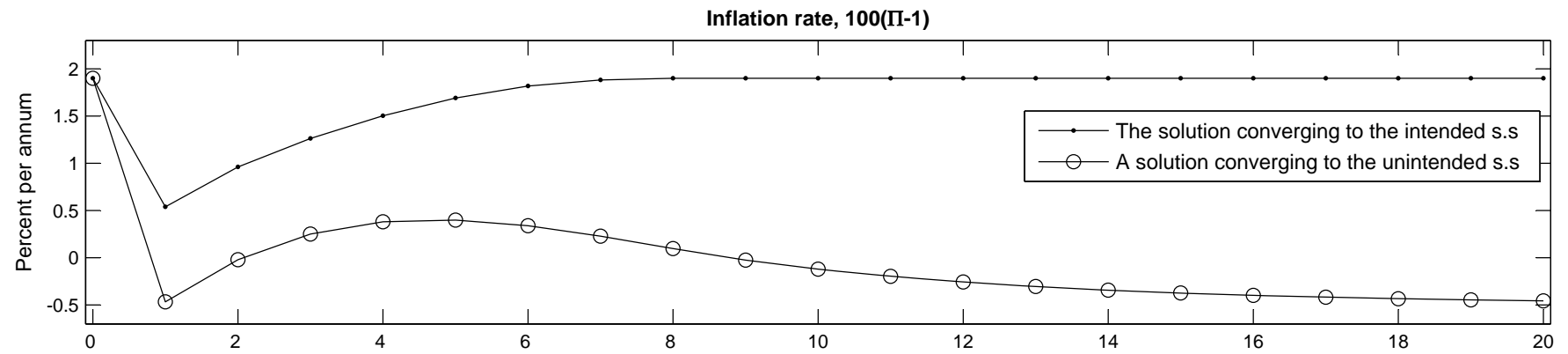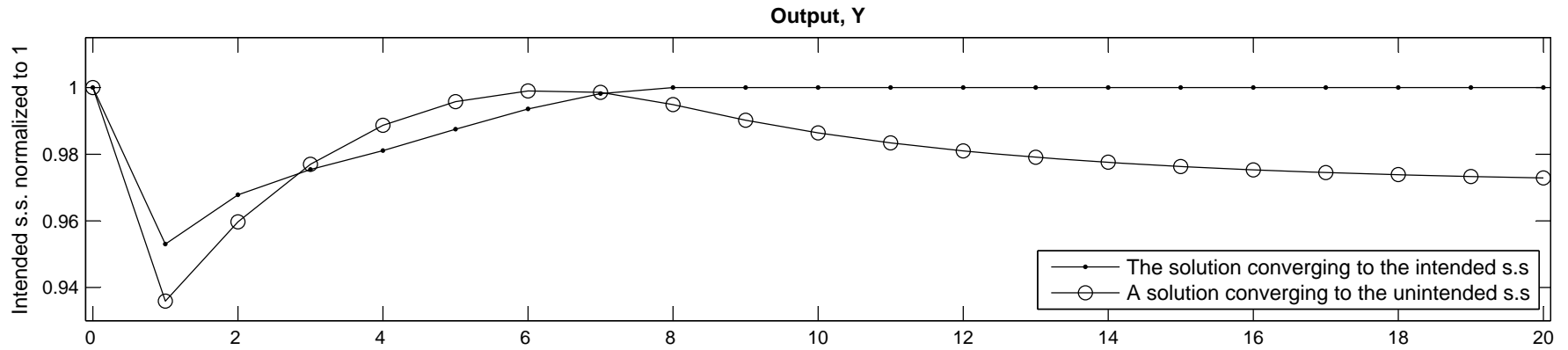
Figure 3: The baseline simulation versus the data
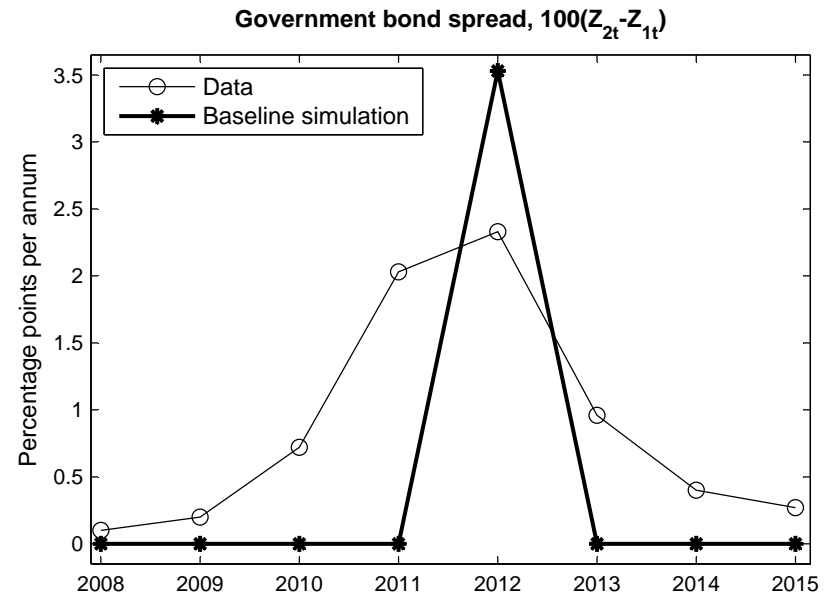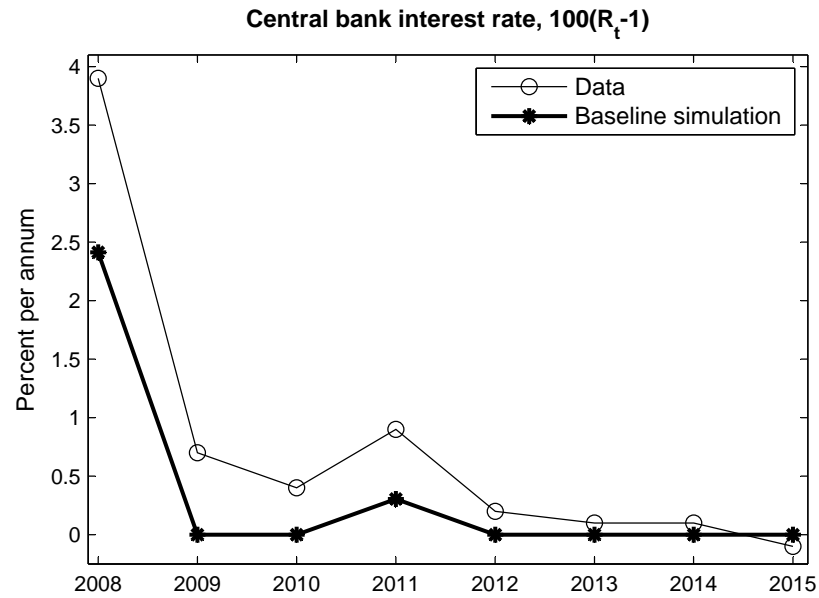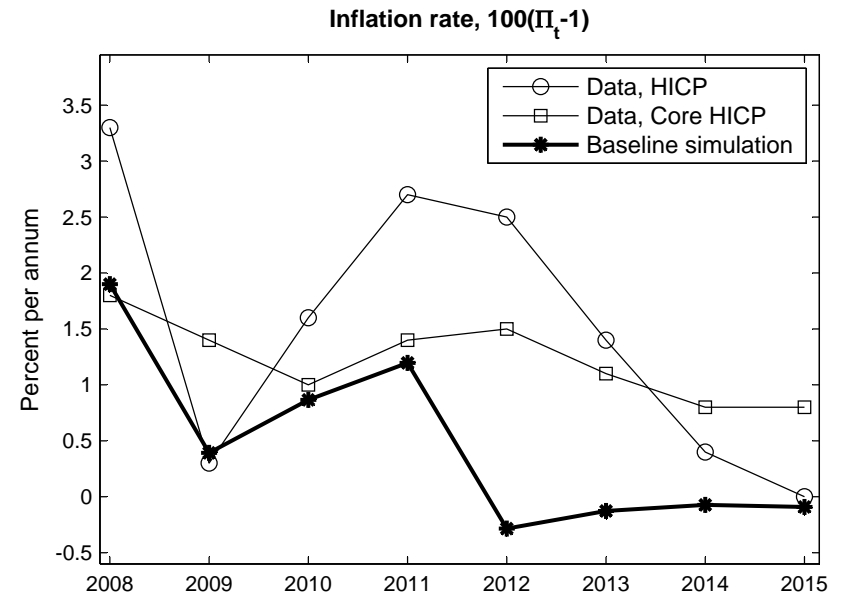
Figure 4: The policy experiment in Section 5.2 vs. the baseline simulation

Output, Y_t

Inflation rate, $100(\Pi_t - 1)$

Central bank interest rate, $100(R_t - 1)$
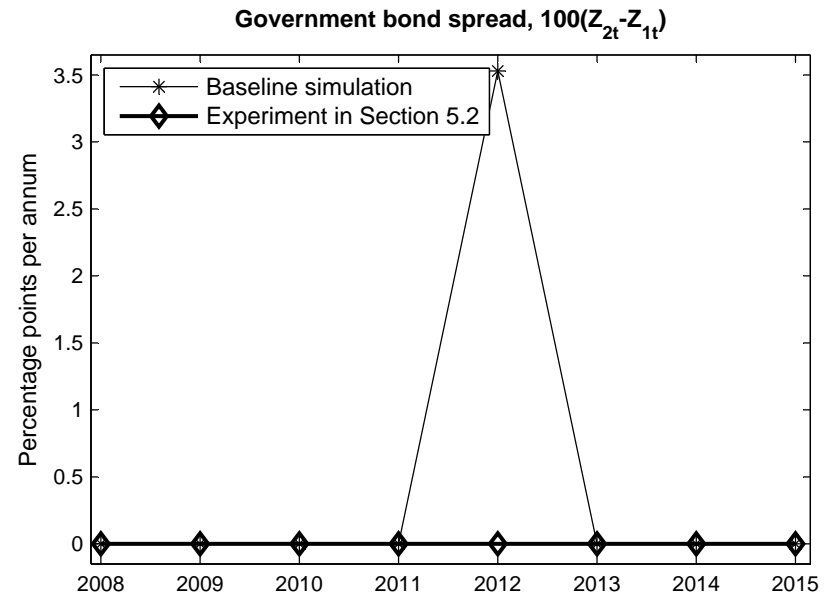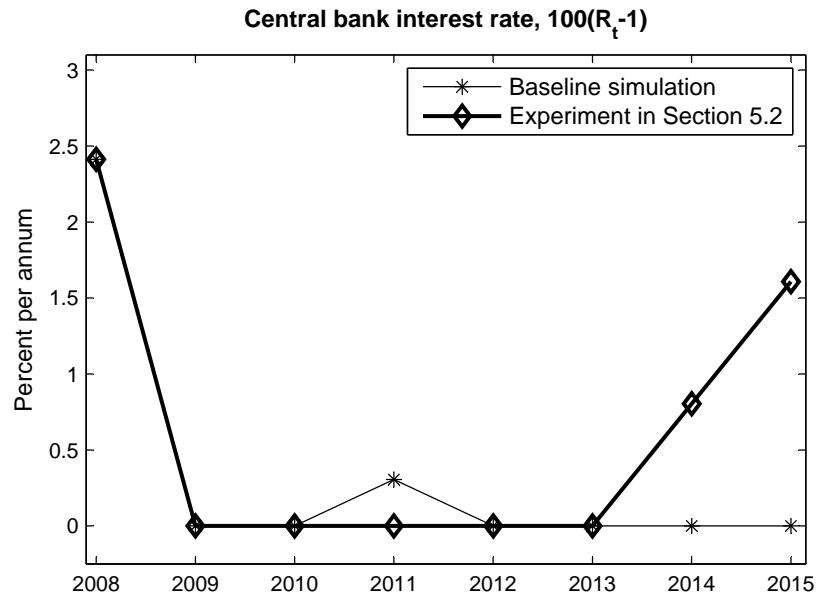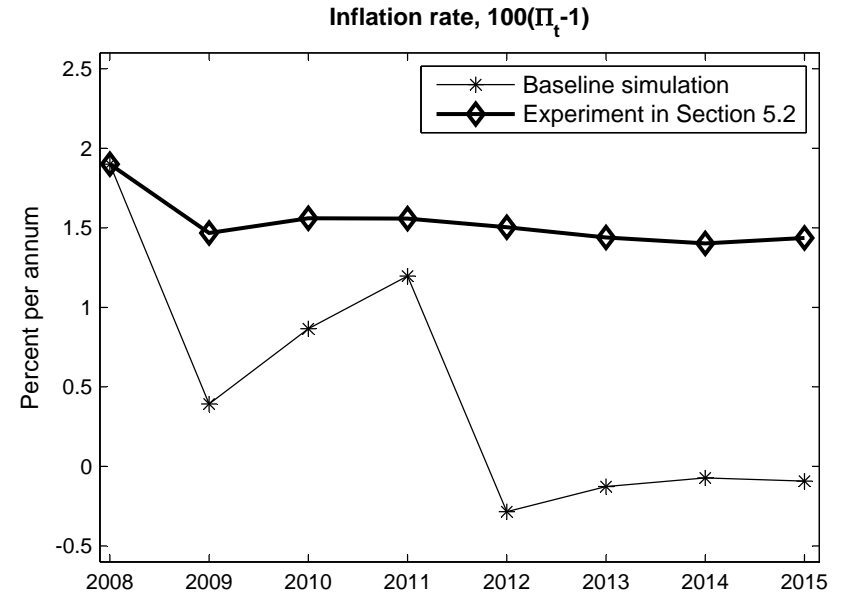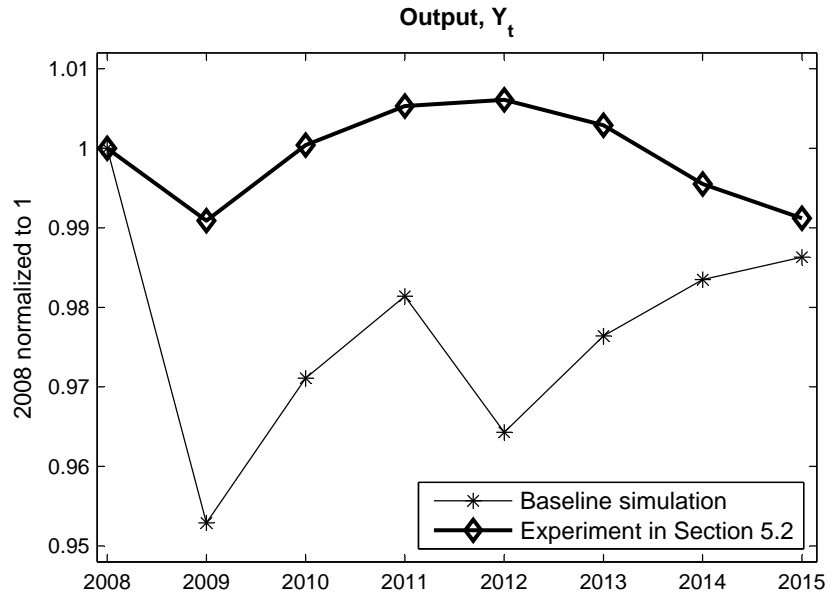
Government bond spread, $100(Z_{2t} - Z_{1t})$

Figure 5: The effect of default on inflation in the policy experiment

Inflation rate, $100(\Pi_t - 1)$

Legend:
- Experiment in Section 5.2
- Default with recovery rate 0.8, Section 5.3

Inflation rate, $100(\Pi_t - 1)$

Legend:
- Experiment in Section 5.2
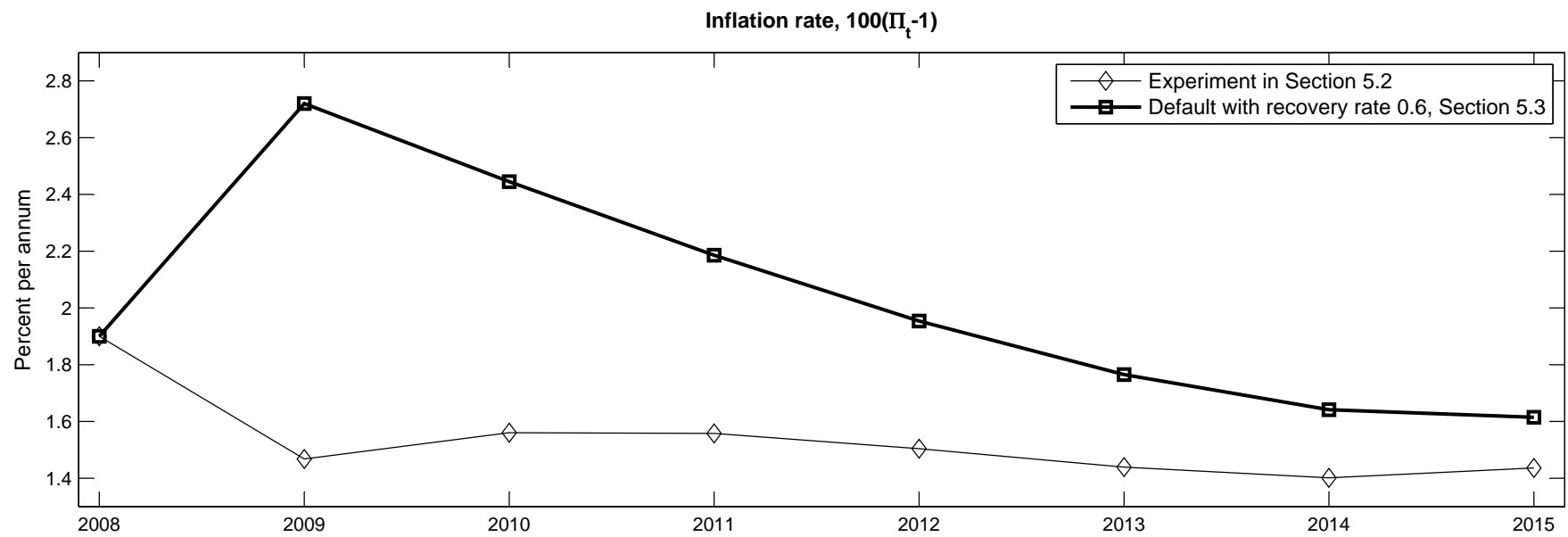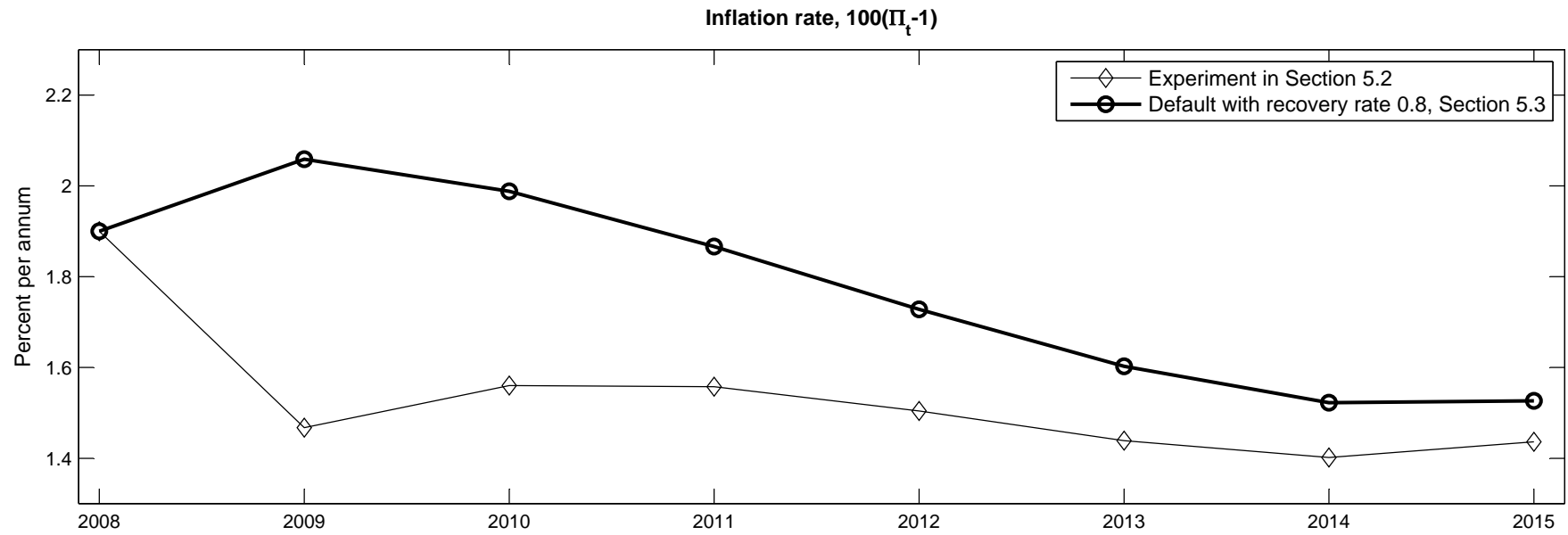- Default with recovery rate 0.6, Section 5.3

Figure 6: The equilibria in the market for government debt

Legend:
- Bond pricing equation
- Budget constraint, $\lambda_t = 0$
- Budget constraint, $\lambda_t = 0.5$

Axes: $1/Z_t$ (vertical), $\tilde{B}_t$ (horizontal)

Vertical axis markings: $1/R_t$, Δ/R_t

Horizontal axis markings: $\tilde{B}^a$, $\tilde{B}^b$