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

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Abstract

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

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1 Introduction

The euro area economy has been experiencing a period of malaise. Real GDP per capita declined by 5 percent in 2009 during the Great Recession. A moderate recovery took place in the subsequent two years. Output decreased again in 2012 and in 2013. In 2015, after two years of growth, real GDP per capita was 1.6 percent lower than in 2008. See the top left panel in Figure 1.

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

In a typical modern economy, the monetary authority supplies a fiat currency and the fiscal authority issues debt denominated in that currency. The two authorities can coordinate to ensure that public debt is non-defaultable, i.e., maturing government bonds are convertible into currency at par, just as maturing reserve deposits at the central bank are convertible into currency at par. With this policy coordination in place, if the fiscal authority lowers its primary budget surpluses, households are wealthier at a given price level and they increase spending. Inflation and output rise. This is an attractive outcome when inflation is too low and the economy is in a recession to begin with. However, although the euro is a fiat currency, the fiscal authorities of the member states have apparently given up the ability to issue non-defaultable debt.

This paper formalizes the idea that the way monetary and fiscal policy are conducted in the euro area has been central to the outcomes depicted in Figure 1. If monetary and fiscal policy had been coordinated differently, around a non-defaultable public debt instrument, the outcomes could have been very different. We begin with a model in which the specification of monetary and fiscal policy aims to capture the essential characteristics of how each policy is actually conducted in the euro area. This model reproduces the main features of the recent euro area data. We then study a version of the model in which policies interact differently. This version of the model implies that output could have been much higher and inflation somewhat higher than in the data in the period 2009-2015.

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 ($N = 2$ for simplicity). Each fiscal authority imposes lump-sum taxes and issues bonds that can default. Each household is a "European" household that consumes a union-wide basket of goods and supplies labor to firms throughout the union. The household comprises some individuals who pay taxes to the fiscal authority in one imaginary member state of the union and some individuals who pay taxes to the fiscal authority in the other imaginary member state of the union.

We suppose that the monetary authority pursues a Taylor rule subject to a lower bound on the interest rate. Each "national" fiscal authority seeks to stabilize its debt by adjusting its primary budget balance, in a standard way, but can default in adverse circumstances, when the stock of debt 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.

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"). There are infinitely many ways in which the economy can converge to the unintended steady state. Furthermore, the default premia on bonds issued by a national fiscal authority are 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 euro area data ("the baseline simulation"). Output, inflation, the central bank's interest rate, and the government bond spread in the model replicate the non-monotonic pattern from Figure 1. The paths of the variables in the model are quantitatively similar to the data. Furthermore, a key implication of the baseline simulation is that inflation can display no tendency to return to the objective of the monetary authority.

We use the model to conduct a policy experiment in which we assume an alternative arrangement to coordinate monetary and fiscal policy. We introduce a new policy authority, a centrally-operated fund that can buy from the national fiscal authorities their debt. The fund can also sell to households its own debt, single-period nominal bonds ("eurobonds"). We suppose that 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 factor disturbance the sum of the primary surpluses flowing to the fund does not react to any measure of public debt. Following Leeper (1991), we can say that fiscal policy of the union as a whole is "active." 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 in the sense of Leeper (1991), i.e., monetary policy that fails 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 and inflation somewhat higher than in the baseline simulation. Furthermore, as we will explain, favorable stabilization outcomes can be achieved irrespective of the quantity of eurobonds outstanding at the time when a disturbance arrives. The critical features of the policy experiment are that eurobonds are non-defaultable and the present value of the primary surpluses flowing to the fund falls after the discount factor disturbance. Thus households who hold eurobonds are wealthier at a given price level, and they increase their spending. As "too many eurobonds are chasing too few goods," the price level rises and, since prices are sticky, output also increases temporarily. By contrast, if a fiscal authority with defaultable debt lowers the present value of the primary surpluses, the fiscal authority must default. Default produces a gain for households as taxpayers. However, default also imposes a loss of the same magnitude on households as bondholders. There is no wealth effect prompting households to increase their spending.

We employ the model to quantify the inflationary consequences of a deviation by a national fiscal authority from the reaction function the fund expects the authority to follow. The deviation results in a decrease in the stream of the primary surpluses flowing to the fund. We calibrate the deviating fiscal authority to match the sum of Italy and Spain. The other, non-deviating fiscal authority consists of Germany, France, and the Netherlands, taken together. The fund holds bonds of each fiscal authority. For example, if we suppose that the deviating fiscal authority delivers only 60 percent of the primary surpluses promised to the fund, the inflation rate in the model jumps by about 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 between 2.5 and 3 percent per year as materially excessive. One reason why the inflationary effects are moderate is that only Italy and Spain deviate in this example, 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. If we imagine instead that prices are close to perfectly flexible, the inflation rate can jump to more than 10 percent in the same example. The inflationary effects diminish and can vanish completely if the fund imposes a tax directly on households to recoup any losses. We employ the model to compute the size of a per period lump-sum tax, imposed by the fund on households uniformly throughout the union, necessary for the inflationary effects of a deviation by a national fiscal authority to disappear.

The model lets us study how the presence of the fund affects the determinacy of yields in the market for bonds issued by the national fiscal authorities. Let us emphasize the following insights here. When the fund purchases a sufficient quantity of bonds at the price free of default premium, that price becomes the only equilibrium, although in the absence of the fund there are two other equilibria, each with a positive probability of default. Moreover, whereas in the baseline experiment multiple equilibria in the government bond market arise, equilibrium is unique in every period in the policy experiment. The reason is that the accommodative fiscal policy in the experiment, possible in the presence of the fund, lowers the debt-to-output ratio into the range implying a unique equilibrium with zero probability 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. Benhabib et al. (2002) and Woodford (2003), chapter 2.4.2, observe that what we refer to as the intended steady state becomes unique if fiscal policy turns active in the face of deflation. Schmitt-Grohé and Uribe (2016) argue that a version of the model with two steady states explains several features of the macroeconomic outcomes in the United States and the euro area in the last several years as well as in Japan in the 1990s. Schmitt-Grohé and Uribe (2016) 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 (2016) assume "passive" fiscal policy in the sense of Leeper (1991), the short-run trajectory of output and inflation in their model (and thus the stabilization outcomes) are indeterminate. We combine the passive monetary policy assumed by Schmitt-Grohé and Uribe (2016) 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. (2016) fit the full nonlinear version of the standard model, with a sunspot process that governs fluctuations between the two steady states, to the data from the United States and Japan. 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.

The paper is also related to the literature on multiple equilibria in the market for defaultable public debt, starting with Calvo (1988), with recent contributions by, e.g., 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 the 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 its primary surplus as a function of the state of the economy and defaults when its 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.[1]

Finally, the paper is related to the literature on the fiscal theory of the price level, initiated by Leeper (1991), Sims (1994), Woodford (1994), and Cochrane (2001). We borrow from the theory the definitions of passive and active policy. Although in the real world fiscal policy may have a number of different macroeconomic effects, we follow the theory by focusing on the wealth effect of fiscal policy. We think of the model in this paper, with a one-time disturbance and a once-and-for-all shift in monetary and fiscal policy after the disturbance, as a simplified version of a model in which monetary policy switches recurrently between active and passive and fiscal policy switches recurrently between passive and active. Bianchi and Ilut (2016) interpret the U.S. postwar macroeconomic data using a model in which such recurrent policy regime fluctuations are exogenous. Bianchi and Melosi (2016) study how the macroeconomic outcomes at the zero lower bound depend on which policy configuration prevails once the economy exits the liquidity trap.

3 Model

The model is based on the standard three-equation general equilibrium model with sticky prices, consisting of the consumption Euler equation, the Phillips curve, and a Taylor rule. We add to this familiar setting N fiscal authorities, corresponding to N imaginary member states of a monetary union. Each fiscal authority imposes lump-sum taxes and issues bonds

[1] See Section 5.4 for a comparison with Corsetti and Dedola (2016).

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 individuals who pay taxes to the fiscal authority in one imaginary member state of the union, North, and some individuals who pay taxes to the fiscal authority in the other imaginary member state of the union, South. The budget constraint of household j in period t reads

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

where W_t is the real wage, Φ_{jt} is household j's share of the aggregate profit 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 standard 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 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, 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.[2] 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.

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

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 $\Pi_t \equiv P_t/P_{t-1}$, $\bar{\Pi}$ 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 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.[3]

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

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

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

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

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

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

where Y denotes output in the "intended" steady state (which we solve for below), and $\psi_n > 0$, $\psi_B > 1/\beta - 1$, $\psi_{Yn} \geq 0$, and $\psi_Z \geq 0$ 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, $Z_{nt} - R_t$. The restriction $\psi_B > 1/\beta - 1$ implies that the primary surplus reacts to the stock of public debt by more than the steady-state real interest rate. Following Leeper (1991), when the primary surplus reacts to the stock of public debt by

[3] Leeper (1991) studies a model similar to this one, 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.

more than the steady-state real interest rate, fiscal policy is said to be "passive."

With this specification of fiscal policy, $\tilde{B}_{nt}$ converges to $\psi_n/(\psi_B - (1-\beta)/\Pi)$ after any disturbance, where Π denotes Π_t in steady state. At the same time, though, equation (5) implies that the stock of public debt and the primary surplus may in some periods 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 public 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 $\left[\tilde{B}_n^a, \tilde{B}_n^b\right]$.[4] 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 Z_{nt}, taking into account the value of Δ_n and the probability of default in period $t+1$ given by $\Pr\left(\tilde{B}_{nt} \geq \tilde{B}_{n,t+1}^{\max}\right)$. Default then occurs or not in period $t+1$ based on the realization of $\tilde{B}_{n,t+1}^{\max}$. $\tilde{B}_{nt}$ still converges to $\psi_n/(\psi_B - (1-\beta)/\Pi)$ following any disturbance, but now default can take place along the convergence path.[5]

In this simple model default by a fiscal authority has no effect on output or inflation. The reason is that default has no effect on households' wealth. Default imposes a loss on households as bondholders. However, default also produces a gain of the same magnitude for households as taxpayers, because at default the present value of lump-sum taxes falls by the amount of the haircut.

3.2 Equilibrium conditions

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

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

(ii) the equation determining the default premia

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

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

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

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:

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

To obtain equation (9), we take the transversality condition of each household j and sum across j's using the relation $\int_0^1 H_{jt}dj = 0$. Finally, in equilibrium the resource constraint reads $C_t = Y_t$, where $Y_t \equiv X_t\left(1 - \frac{\chi}{2}\left(\Pi_t - \bar{\Pi}\right)^2\right)$ and $X_t \equiv \left(\int_0^1 P_{it}X_{it}di\right)/P_t$.

3.3 Steady states

Assume that $\xi_t = 0$ in every period t. Furthermore, suppose that Π_t, R_t, and all real variables including the debt-to-output ratio $\tilde{B}_{nt}$ 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.

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 the variable ξ_t will assume negative values that form an increasing sequence, i.e., $\xi_t = \bar{\xi}_t < 0$, $t = 1, ..., T > 1$, $\left\{\bar{\xi}_t\right\}_{t=1}^{T}$ is an increasing sequence, and $\xi_t = 0$, $t \geq T + 1$.

To understand how this disturbance affects the economy, note in equation (6) 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.[6] 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 Z_{nt} 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} is pinned down by Δ_n. For intermediate financing needs, there are multiple solutions for Z_{nt}. If agents do not expect default, Z_{nt} is low and therefore $\tilde{B}_{nt}$ and the probability of default are also low, validating the agents' expectation. If agents expect default, Z_{nt} is high and therefore $\tilde{B}_{nt}$ and the probability of default are also high, likewise validating the agents' expectation.[7]

Note that optimal policy in this model keeps output and inflation constant at their values in the intended steady state. Suppose that monetary policy is not subject to the lower bound, i.e., the 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

[6] 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.

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

their steady-state values after a shock to ξ_t (while the central bank's interest rate declines below one in period 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.[8]

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 given this specification of policy ("the baseline simulation"). We find that the baseline simulation reproduces the main features of the recent euro area data.

As before, we assume in this section that: (i) in period zero the economy is in the intended steady state, and the economy is expected to remain in the intended steady state forever; and (ii) in period one agents realize that ξ_t will follow the process defined in Section 3.4.

4.1 Sunspot processes

We now modify the model by adding to it two sunspot processes, "confidence about inflation" and "confidence about debt," mutually independent and independent of all other variables. Given the two sunspot processes, the response of the economy to the discount factor disturbance is unique, and thus we can solve for the response numerically and compare it with the data.

The confidence-about-inflation shock can occur with probability $p \in (0,1)$ in every period $t \geq 1$, so long as the shock has not yet occurred. After the shock has occurred, the probability of it occurring in a subsequent period is zero. Let Π_t' denote inflation in period

[8] 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.

t if the shock has not occurred. We suppose that if the shock occurs in period t inflation in period t is equal to $\kappa_\pi \Pi_t'$, where $\kappa_\pi > 0$ is a parameter. Furthermore, if the shock occurs in period t, we solve for the other variables in period t and we solve for all variables in subsequent periods assuming that the economy converges to the unintended steady state. In other words, the confidence-about-inflation sunspot follows a two-state Markov process. The economy begins in the state "convergence to the intended steady state" and the other state, "convergence to the unintended steady state," is absorbing.[9]

As the confidence-about-inflation 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 ratios are constant at the stationary point, like in any steady state described in Section 3.3. However, at the stationary point the variables generally assume different values than in either steady state from Section 3.3, because at the stationary point the confidence-about-inflation shock is expected to occur in every period with probability $p > 0$.

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

4.2 Parameterization

One period in the model is one year. Period one in the model is the year 2009. In the monetary policy reaction function we set $\bar{\Pi} = 1.019$ (the inflation objective is an annual inflation rate of 1.9 percent) and $\phi = 3$. We suppose that the elasticity of substitution between goods, ε, is equal to 11, which is a common value in the literature. We set $\beta = 0.995$. This value seems natural in a model of the Great Recession and the period immediately following the Great Recession. In Section 5 we discuss the consequences of assuming a lower value of β.[10] We choose a value of χ and values of $\bar{\xi}_t$ (the non-zero realizations of the variable ξ_t in periods one through T) such that output and inflation in period one in the

[9] Mertens and Ravn (2014) use a similar specification. In their model, the economy begins in the state "convergence to the unintended steady state" and the other state is absorbing. Both models can be thought of as simplified versions of the model in Aruoba et al. (2016) 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.

[10] 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 model.

baseline simulation match output and inflation in 2009 in the data.[11] This strategy yields the result 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 0.1. We specify $p = 0.04$ (i.e., the annual probability of the confidence-about-inflation shock is 0.04). We suppose that the confidence-about-inflation shock occurs in 2012, and we assume that $\kappa_\pi = 0.983$ (this number affects the magnitude of the fall in inflation due to the realization of the confidence-about-inflation shock).

We define North as Germany, France, and the Netherlands taken together. South is Italy and Spain taken together. We assume that $\tilde{B}_{1,0} = 0.35$, 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 public 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*. We set $\tilde{B}_{2,0} = 0.22$ based on the same reasoning and data for Italy and Spain. We choose $\psi_B = 0.05$, which is the baseline estimate in Bohn (1998). Given the selected values of $\tilde{B}_n$ and ψ_B, we compute ψ_n from the relation $\psi_n = \tilde{B}_n(\psi_B - (1-\beta)/\bar{\Pi})$, which holds in period zero because the economy is then in the intended steady state. 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 in the following sense: 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. The model then has a unique solution for the yield on bonds issued by the fiscal authority in North throughout the baseline simulation; in particular $Z_{1t} = R_t$ in every period $t \geq 1$. In any period in which multiple values of Z_{2t} (the yield on bonds issued by the fiscal authority in South) satisfy all equilibrium conditions, we suppose that the confidence-about-debt shock selects the lowest value, except that in 2012 the shock selects the intermediate of the three admissible values.

[11] In particular, we assume: $\bar{\xi}_1 = -0.113$, $\bar{\xi}_{t+1} - \bar{\xi}_t$ is a decreasing linear function of time, and $T = 7$ (i.e., ξ_t returns to zero in period eight).

4.3 Baseline simulation versus the data

Figure 3 shows the response of the model economy to the discount factor disturbance in the baseline simulation. Output, inflation, and the central bank's interest rate in the model replicate the non-monotonic pattern in the data. Moreover, the paths of the three variables in the baseline simulation are quantitatively similar to the data. According to the model, the fall in output and the decline in inflation in 2009 were caused by the discount factor disturbance. Afterward, when the confidence-about-inflation shock hit in 2012, output decreased for the second time. Inflation also decreased again in the wake of the confidence-about-inflation shock, and thereafter inflation has shown little tendency to return to the objective of the monetary authority. The bond spread in the model, $Z_{2t} - Z_{1t} = Z_{2t} - R_t$, also mimics the bond spread in the data (the bottom right panel in Figure 3). According to the model, both the spike in the spread and the subsequent fall in the spread were self-fulfilling.[12]

To conclude, when monetary and fiscal policy in the model behave as they do in the euro area, the model reproduces the essential features of the data in the period 2009-2015. Furthermore, a key implication of the baseline simulation is that inflation can display no tendency to return to the objective of the monetary authority.

Since the model economy is simple and only two shocks affect the paths of output and inflation in the baseline simulation, we cannot expect to replicate all features of the data. For example, 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 about 160 basis points.[13] In the data, the five-year five-year forward inflation swap rate, a popular indicator of long-term inflation expectations, declined gradually by 100 basis points between 2012 and the summer of 2016.[14]

[12]See Section 5.4 for more discussion of the outcomes in the government bond markets in the baseline simulation.

[13]The inflation rate expected on average between 5 and 10 years in the future drops in 2012 from about 1.3 percent to about -0.3 percent. The main reason why the first number is smaller than $100\left(\bar{\Pi} - 1\right)$, 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 $100\left(\beta - 1\right)$, or -0.5 percent, is that convergence to the unintended steady state takes time.

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

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 economy, more in line with the data.[15] 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 shock could be correlated with government spending. One could then explain the recession of 2012-2013 and the initial deflationary impulse mainly as the consequence of the decrease in government spending that took place in the euro area at that time, while attributing to the confidence-about-inflation shock the tendency of inflation not to return to the objective of the central bank.

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.

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.

5.1 Setup of the experiment: eurobonds and coordination of fiscal policy

We introduce a new policy authority, a centrally-operated fund that can buy from the two "national" fiscal authorities their debt. The fund can also sell to households its own debt, single-period nominal discount bonds ("eurobonds").[16] We suppose that the fund's debt is non-defaultable, i.e., the monetary authority and the fund agree that maturing eurobonds

[15] Furthermore, to produce a gradual decline in long-term inflation expectations, one could model the probability of a switch from the state "convergence to the unintended steady state" to the state "convergence to the intended steady state" as a decreasing function of the realized inflation rate. Notice also that the fact that long-term interest rates in the data, e.g., the 10-year German government bond yield, dropped to about zero by the beginning of 2016 is quantitatively in line with the baseline economy.

[16] Thus, 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.

are convertible into fiat currency at par. We maintain the assumption that debt issued by the national fiscal authorities 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).[17]

We assume that in period one, coincident with the arrival of the disturbance, each fiscal authority n abandons reaction function (5). To specify 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 ($S_{nt}^F + S_{nt}^H = S_{nt}$). Finally, let $\tilde{B}_{nt}^F \equiv \left(B_{nt}^F / P_t Y_t\right)$, $\tilde{B}_{nt}^H \equiv \left(B_{nt}^H / P_t Y_t\right)$, $\tilde{S}_{nt}^F \equiv \left(S_{nt}^F / Y_t\right)$, and $\tilde{S}_{nt}^H \equiv \left(S_{nt}^H / Y_t\right)$. Suppose that in period zero the fund holds a share $\lambda \in (0, 1]$ of bonds issued by each national fiscal authority and households hold the remainder, $1 - \lambda$. We assume that in every period $t \geq 1$ fiscal authority n sets the two components of its primary surplus according to the reaction functions

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

and

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

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 reaction function (5). Equation (11) is non-standard, and we now comment on it.[18] First of all, this equation implies that

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

which says that the component of the primary surpluses that is backing eurobonds does not

[17] 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.

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

react to any measure of public debt. Following Leeper (1991), we can say that fiscal policy of the union as a whole is active. Next, observe that the primary surplus of an individual national fiscal authority does react to public debt, via the second term on the right-hand side of equation (11). Suppose that $\theta_n = \tilde{B}^F_{n,0} / \left(\sum_n \tilde{B}^F_{n,0} \right)$ 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 have supposed, the debt-to-output ratio in South rises relative to the debt-to-output ratio in North. The second term on the right-hand side of equation (11) then 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-output ratio in North has risen in absolute terms. Finally, as the effects of the disturbance die out, the share of fiscal authority n in the fund's assets converges back to θ_n.

In sum, we assume that 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 the component of the primary surpluses that is backing eurobonds does not react to public debt (active fiscal policy).

With this policy combination, 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 can be written as

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

where F_t denotes eurobonds issued by the fund and purchased by households in period t.[19] Observe also that 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 each household j, sum it across j's using the relation $\int_0^1 H_{jt} dj = 0$, and we notice that equation (10) implies that

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

$\tilde{B}^H_{n,t}$ converges to a constant for each n as time goes to infinity. Employing equations (6) and (14), we solve equation (13) forward to obtain

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

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

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

In Section 3.4, infinitely many paths of output and inflation were consistent with equilibrium. The debt-to-output ratio converged to the same constant along any of those paths, because fiscal policy followed the passive reaction function (5). Given the specification of policy in this section, equation (15) lets us find what turns out to be the unique equilibrium path of output and inflation. In this section, just as in the version of the model studied in Section 3.4, infinitely many paths of output and inflation satisfy equilibrium conditions (6) and (8), i.e., the consumption Euler equation and the Phillips curve. However, with active fiscal policy the paths that start with "low" prices and output imply that $\tilde{F}_t$ explodes, in violation of equation (14), while the paths that start with "high" prices and output 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 $\bar{\psi}_n$.[20] We set $\lambda = 0.2$, and we discuss below the effect of the value of λ on the solution. We assume that $\theta_n = \tilde{B}_{n,0}/(\tilde{B}_{1,0} + \tilde{B}_{2,0})$, i.e., $\theta_1 = 0.61$ and $\theta_2 = 0.39$. To set $\bar{\psi}_n$ we suppose that in the long run $\tilde{B}^F_{nt}$ converges to a number 5 percent lower than $\tilde{B}^F_{n,0}$. Thus, $\tilde{B}^F_{1t}$ converges to $0.95 * \lambda * \tilde{B}_{1,0} = 0.95 * 0.2 * 0.35 = 0.0665$, and $\tilde{B}^F_{2t}$ converges to $0.95 * \lambda * \tilde{B}_{2,0} = 0.95 * 0.2 * 0.22 = 0.0418$. This assumption and equation (15) evaluated in the intended steady state imply that $\bar{\psi}_1 =$

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

(0.0326/100) and $\bar{\psi}_2 = (0.0205/100)$. We emphasize that 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, each 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 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 bond spread disappears, reflecting the fact that the probability of default in South is zero throughout the simulation.[21] To conclude, when monetary and fiscal policy interact as in this experiment, output is much higher and inflation somewhat higher than in the baseline simulation.

The following intuition helps understand the outcome of the policy experiment. When the contractionary shock hits in period one, the primary surplus tends to fall because the primary surplus depends positively on output. In the baseline simulation, fiscal policy is passive, implying that the present value of the primary surpluses will be the same in the long run as in the initial steady state. Hence, there is no wealth effect that would prompt households to change their spending. In the policy experiment, fiscal policy is active and the present value of the primary surpluses flowing to the fund falls, implying that households experience a positive wealth effect. Households know that the current fiscal accommodation will *not* be undone in the future. As households spend the extra wealth, "too many eurobonds are chasing too few goods," and output and inflation rise relative to the baseline.

Let us examine the behavior of the fiscal variables in the model. With our parameterization, in period zero the primary surplus in North is equal to 0.17 percent of output of the union and the primary surplus in South is equal to 0.11 percent of output of the union. By the end of the policy experiment each primary surplus falls, by design. Specifically, since $\lambda = 0.2$ and the part of each primary surplus flowing to the fund decreases by 5 percent in

[21] In the policy experiment, the probability of default by each fiscal authority n is zero in every period $t \geq 1$: we find that $\tilde{B}_{nt} < B_n^a$ for each n in every period $t \geq 1$.

the long run, each primary surplus falls by 1 percent by the end of the experiment. Next, consider the short run. In the period 2009-2015, the average primary surplus of each fiscal authority is higher in the experiment than in the baseline. In the same period, the average *structural* primary surplus of each fiscal authority, $\tilde{S}_{nt} - \psi_{Yn}(Y_t - Y)$ for each n, is *lower* in the experiment than in the baseline. See Table 1. In the baseline, passive fiscal policy requires material increases in the structural primary surplus, starting in 2010, relative to the initial steady state. Meanwhile, the actual primary surpluses rise in the experiment compared with the baseline, because output is higher in the former than in the latter.

Since the primary surplus in North and the primary surplus in South fall by the end of the policy experiment, the debt-to-output ratio in North and the debt-to-output ratio in South must also decrease in the long run. After all, the value of public debt is equal to the present value of the primary surpluses backing it. The debt-to-output ratio falls in the experiment compared with the baseline also in the period 2009-2015, on average by 4 percentage points both in North and in South, due to the improved outcomes for the primary surpluses, output, and inflation.[22]

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

We now comment on the measure of the size of the fund, $\lambda \in (0, 1]$. A strong result arises: The response of output, inflation, and the central bank's interest rate to the discount

[22]The debt-to-output ratio in the baseline understates the debt-to-GDP ratio in the data, despite the fact that the average primary surpluses in the baseline match the average primary surpluses in the data. One reason is that in the data public debt increased 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 public 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 public debt service in 2010.

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, lowering λ means that there are fewer eurobonds and that they are being backed by a smaller part of the primary surpluses of both 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 equal 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 eurobonds outstanding at the time when a disturbance arrives.

We resolve the policy experiment with lower values of the discount factor β than 0.995. We continue to suppose that the part of each primary surplus flowing to the fund falls by 5 percent in the long run. Assuming a lower value of β implies that larger primary surpluses are required to achieve a path for output and inflation similar to the path obtained with $\beta = 0.995$. For instance, if $\beta = 0.99$ and all other parameters are unchanged, the long-run primary surplus in the policy experiment doubles to 0.34 percent of output of the union in North and 0.21 percent of output of the union in South. If $\beta = 0.98$, the long-run primary surplus doubles again. As β falls, the necessary primary surpluses can become larger than the primary surpluses have been in the data. 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, for example.

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 issued by that authority, and the authority could default. 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 $\bar{\psi}_n$. 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. 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 $\left(\bar{\psi}_2^{new}/\bar{\psi}_2^{old}\right) \in (0,1)$, where $\bar{\psi}_2^{old}$ is the prescribed value of $\bar{\psi}_2$ and $\bar{\psi}_2^{new}$ is the new value of $\bar{\psi}_2$. For simplicity, the deviation and the default occur in period one, and we refer to this event simply as "default."[23]

To begin, we specify that $\left(\bar{\psi}_2^{new}/\bar{\psi}_2^{old}\right) = 0.8$. The capital loss from the default, to households and the fund taken together, amounts to about 4.5 percent of euro area GDP, or roughly 420 billion euros in 2009. The top panel in Figure 5 shows the effects of the default on inflation. The inflation rate jumps to about 2.1 percent in the year in which the default occurs, 2009, or roughly by 60 basis points compared with the simulation from Section 5.2. As another example, we suppose that $\left(\bar{\psi}_2^{new}/\bar{\psi}_2^{old}\right) = 0.6$, implying that the capital loss is about 9 percent of euro area GDP, or roughly 840 billion euros in 2009. The bottom panel in Figure 5 shows the effects of this larger default on inflation. This time the inflation rate jumps to about 2.7 percent, or roughly by 120 basis points compared with the simulation from Section 5.2. While the effects of each scenario on inflation are non-trivial, we find it difficult to think of the resulting inflation rates as materially excessive.

Why are the two examples only moderately inflationary? For one, only South deviates and the share of South's bonds in the fund's portfolio is 39 percent, $\tilde{B}_{2,0}/(\tilde{B}_{1,0}+\tilde{B}_{2,0}) = 0.39$. Thus, 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. If prices were less sticky, default would be more inflationary. We use the version of the model in which prices are perfectly flexible 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. With a recovery rate of 60 percent, the upper bound for the inflation rate is 18 percent. If prices become much less sticky following an extreme event such as a sovereign default in the euro area, these are the maximum inflation rates the economy could experience.

[23] As equation (15) shows, what matters for the backing of 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.

Next, we modify the model by giving to the fund the 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 a default by a national fiscal authority, the effect of the default on inflation diminishes and vanishes *completely* 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. The size of the tax required for a default to have no impact on inflation depends on the value of λ. Suppose that the recovery rate is 80 percent. Assuming the same parameter values as before including $\lambda = 0.2$, $\tilde{S}_t^F$ must be equal to $0.2 * 0.0002$ for the default to have no impact on inflation. If $\lambda = 0.4$, the required tax is $0.4 * 0.0002$. A fall in the recovery rate and a decrease in β each raise the necessary size of the tax. For example, if $\lambda = 0.5$, the recovery rate is 50 percent, and $\beta = 0.98$, the required tax is 0.001 or 0.1 percent of output of the union as a whole per period, forever. If the fund incurs a large loss (i.e., λ is high and the recovery rate is low), the fund may find it politically impossible to impose a tax sufficient to prevent the default from causing inflation.

The preceding discussion pinpoints one difference between the fund and a central bank that issues non-defaultable, interest-bearing reserves: A central bank cannot tax. A central bank earns seigniorage revenues that can be used to recoup a central bank's loss, stemming for instance from a default by a fiscal authority. However, the non-inflationary revenue from seigniorage may be insufficient to cover all or most of a central bank's loss. Furthermore, the central bank's ability to earn seigniorage depends on the public's willingness to hold the currency supplied by the central bank.[24]

Let us also emphasize that the critical features of the policy experiment in Section 5 are

[24] See Del Negro and Sims (2015) for a model of the relation between a central bank's balance sheet and inflation.

that eurobonds are non-defaultable and *fiscal policy changes*, in such a way that the present value of the primary surpluses flowing to the fund falls. Both conditions must be satisfied for the experiment to produce favorable stabilization effects. Issuing a non-defaultable debt instrument to purchase government bonds – which a central bank that creates interest-bearing reserves can do – would have no effect on output or inflation in the model if fiscal policy was passive, or if the present value of the primary surpluses remained unchanged.[25]

5.4 The fund and determinacy of the government bond yields

In Section 3.4, we explained that one of the following statements describes the market for bonds of fiscal authority n in any period $t \geq 1$, depending on the fiscal authority's financing needs: there is a single equilibrium in which the probability of default next period is zero, there is a single equilibrium in which the probability of default is one, or there are multiple equilibria. In the case of multiple equilibria we typically find three equilibria: one in which the probability of default next period is zero, one in which the probability of default is one, and one with a probability of default in an intermediate range. When comparing the baseline simulation with the data in Section 4.3, we noted that the spike in the government bond yield in South in 2012 and the subsequent decline of the yield were self-fulfilling events according to the model. In particular, in the baseline simulation there are three equilibria in the government bond market in South in 2012 and in 2013. Furthermore, the simulation assumes that the confidence-about-debt shock selects the intermediate equilibrium in 2012 and the zero-probability-of-default equilibrium in 2013.

How does the fund affect the determinacy of government bond yields? First of all, we know from Section 5.2 that in the policy experiment there is a unique equilibrium in the government bond market in South in every period, with zero probability of default. The reason is that the accommodative fiscal policy in the experiment, possible in the presence of the fund, lowers the financing needs of the fiscal authority in South into the range implying a unique equilibrium with zero probability of default. Moreover, this outcome is independent of the size of the fund, because the path of $\tilde{B}_{2t}$ in the experiment is invariant to the value of λ.

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

[25]Finally, note 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 from Section 5 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-output ratio, $\tilde{B}_t$. The grey curve represents the bond pricing equation (7): The bond price is equal to $1/R_t$ (i.e., the default premium is zero) when $\tilde{B}_t$ is smaller than $\tilde{B}^a$; the bond price is a decreasing function of $\tilde{B}_t$ between $\tilde{B}^a$ to $\tilde{B}^b$ (in which case the bond price incorporates a default premium increasing in $\tilde{B}_t$); and the bond price is equal to Δ/R_t when $\tilde{B}_t$ is greater than $\tilde{B}^b$ (in which case the probability of default is one). The solid black curve represents the government budget constraint in the absence of the fund, given by equation (4). Let a_t denote the fiscal authority's 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 in this case there are three equilibria.

Suppose that the fund purchases a fraction λ of the debt at the price $1/R_t$. The budget constraint curve changes to $1/Z_t = a_t/((1-\lambda)\tilde{B}_t) - \lambda/((1-\lambda)R_t)$. Figure 6 plots this new budget constraint as a thin black line with circles, assuming a particular value of λ. With this new budget constraint curve only one equilibrium survives: the equilibrium in which the bond price is equal to $1/R_t$ and the probability of default is zero. The other two equilibria, the equilibrium with the probability of default equal to one and the intermediate equilibrium, disappear. When the fund purchases a sufficient fraction of bonds at the price free of default premium (i.e., if λ 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. The intuition is as follows. As the fund purchases bonds charging the price free of default premium, the amount of bonds that a national fiscal authority needs to sell to households if they expect default falls and can become insufficient to validate the households' expectations of default.[26]

Another observation to make here also concerns the case in which fundamentals allow multiple equilibria in the absence of the fund. Then any bond purchases by the fund, or even an announced intention of the fund to buy any quantity of bonds at the price free of default premium can coordinate households on the equilibrium in which the probability of

[26] 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.

default is equal to zero.

6 Conclusions

In a typical modern economy, the monetary authority supplies a fiat currency and the fiscal authority issues debt denominated in that currency. The two authorities can coordinate to ensure that public debt is non-defaultable. If the fiscal authority lowers the primary surpluses, households are wealthier at a given price level and they increase spending. Inflation and output rise. This is an attractive outcome when inflation is too low and the economy is in a recession to begin with. Although the euro is a fiat currency, the fiscal authorities of the member states have apparently given up the ability to issue non-defaultable debt. One consequence is that the euro area economy has been exposed to self-fulfilling fluctuations. Another consequence is that effective fiscal stimulus has been unavailable to raise output and inflation between the Great Recession and the present time. This paper shows in a formal model that the recent macroeconomic outcomes in the euro area could have been very different if monetary and fiscal policy had interacted differently. 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.

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Figure 1: Euro area annual data, 2008-2015

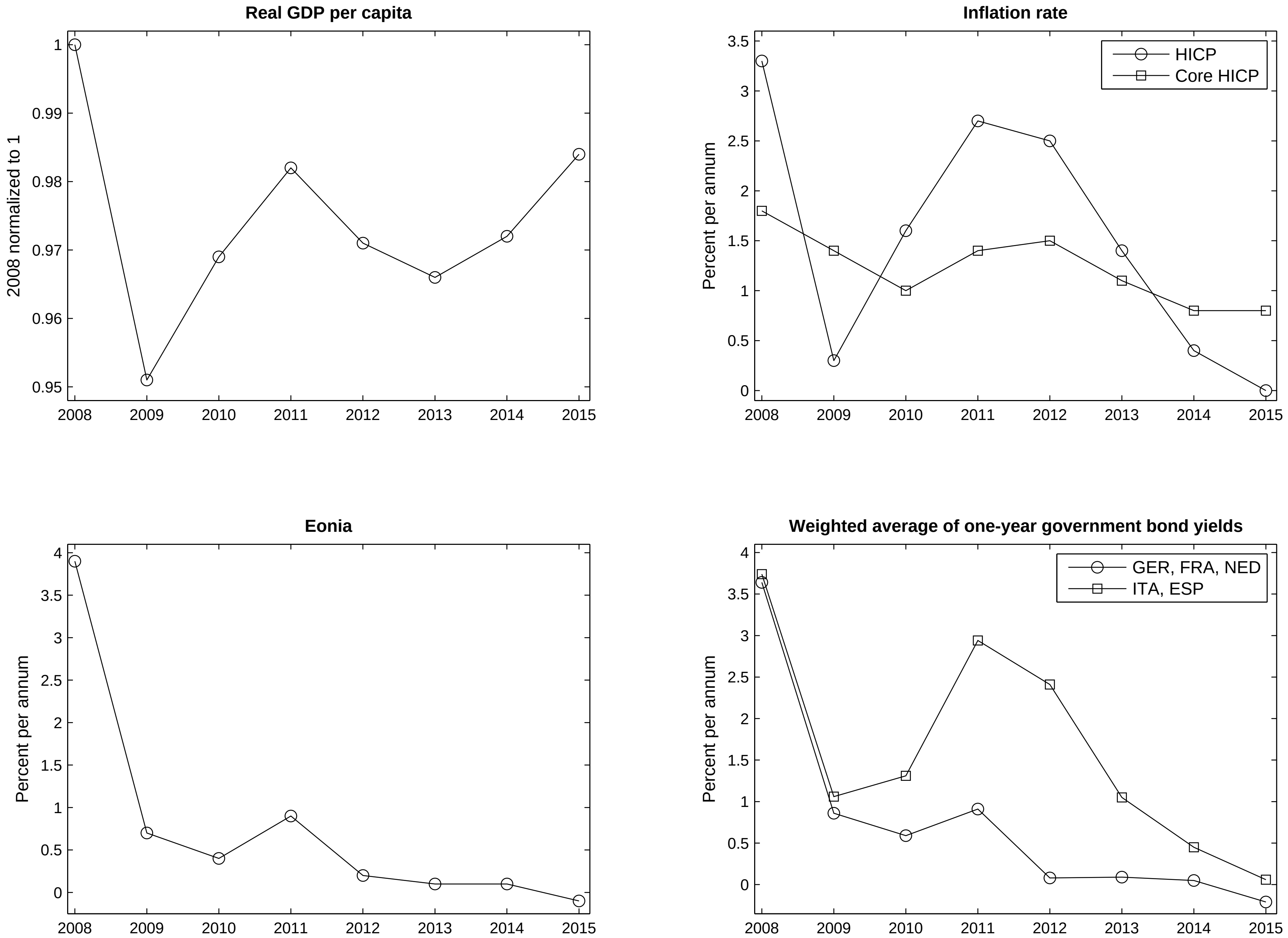


Figure 2: Two solutions of the model in Section 3

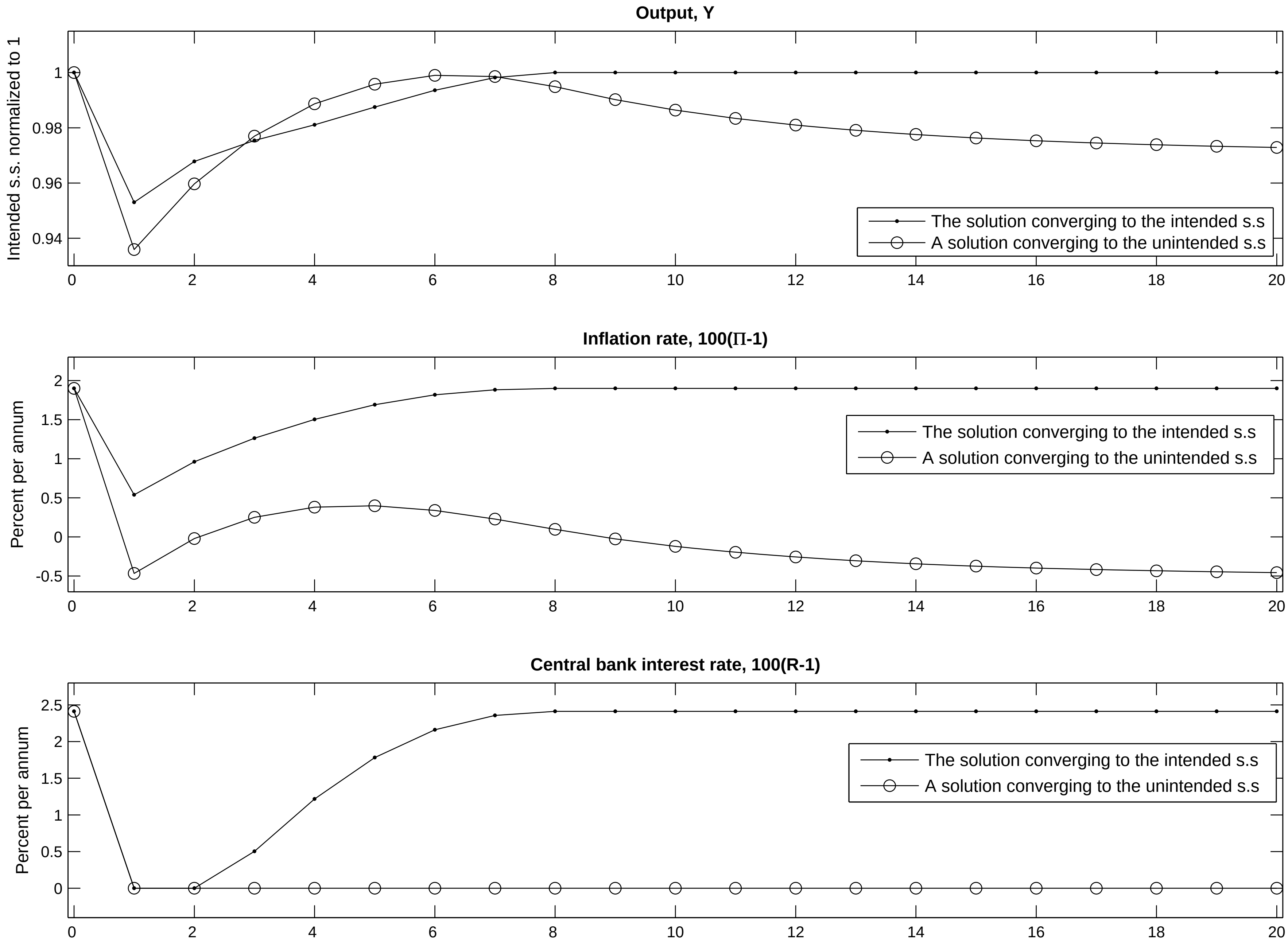


Figure 3: The baseline simulation versus the data

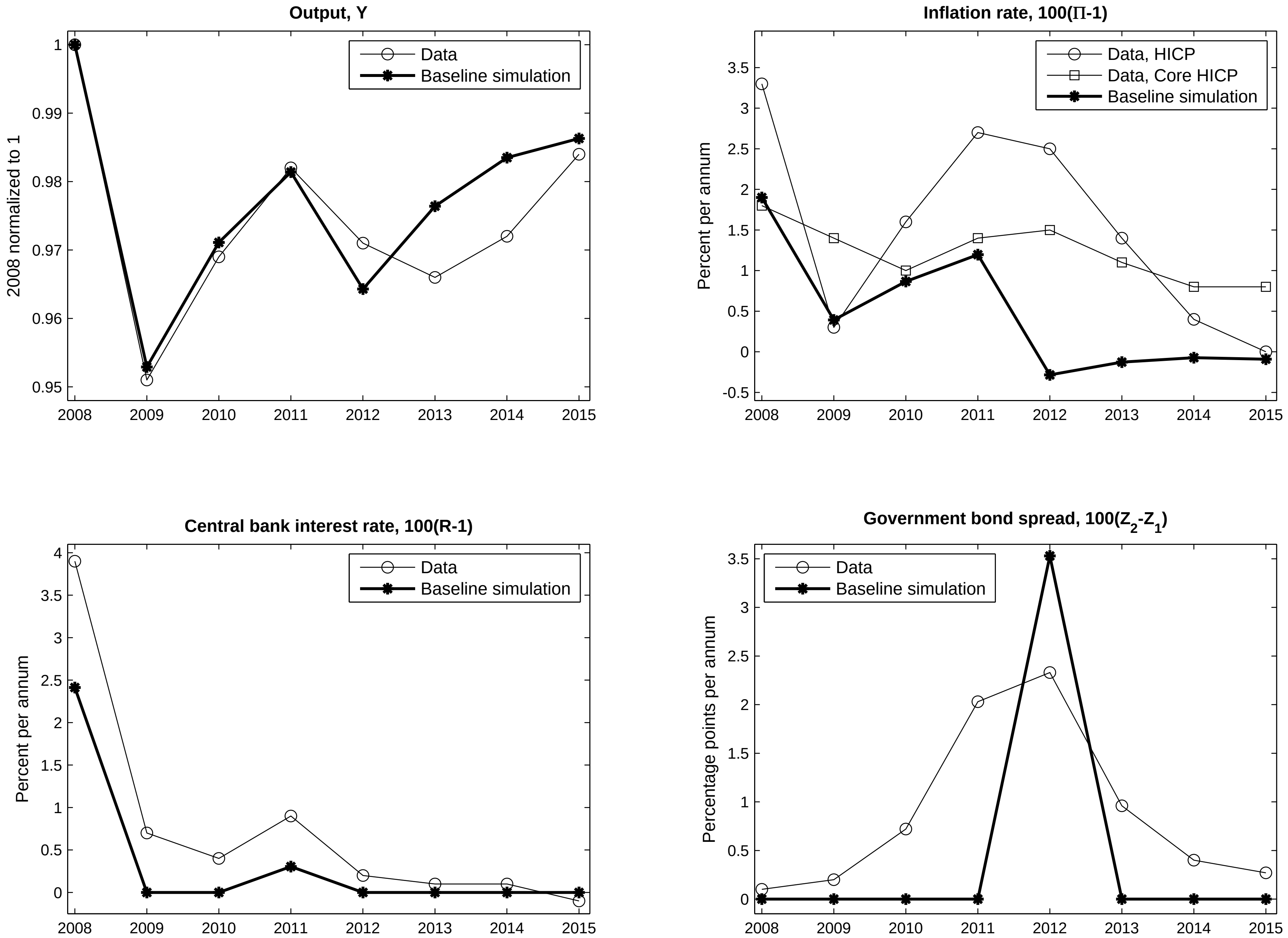


Figure 4: The policy experiment in Section 5.2 vs. the baseline simulation

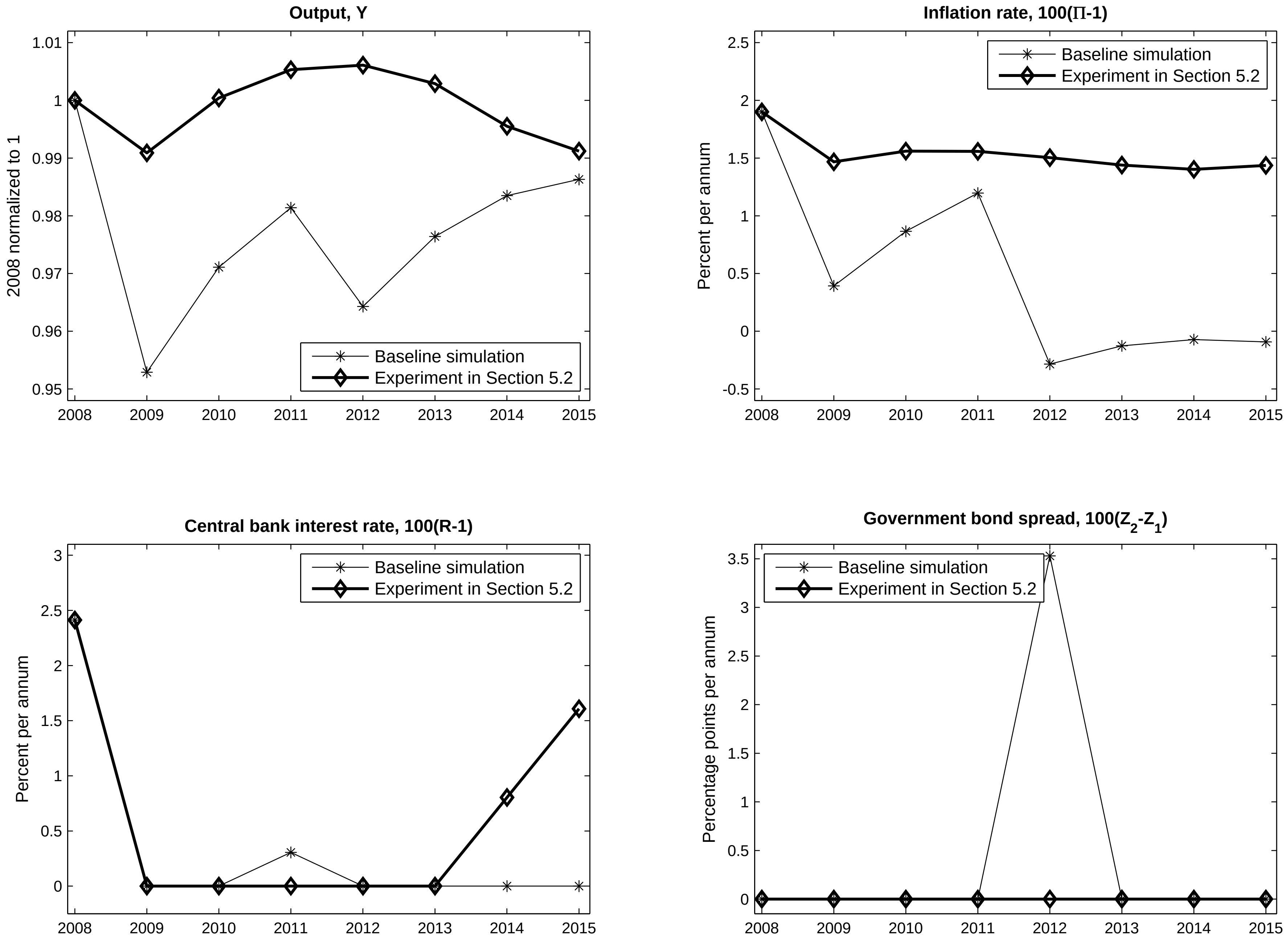
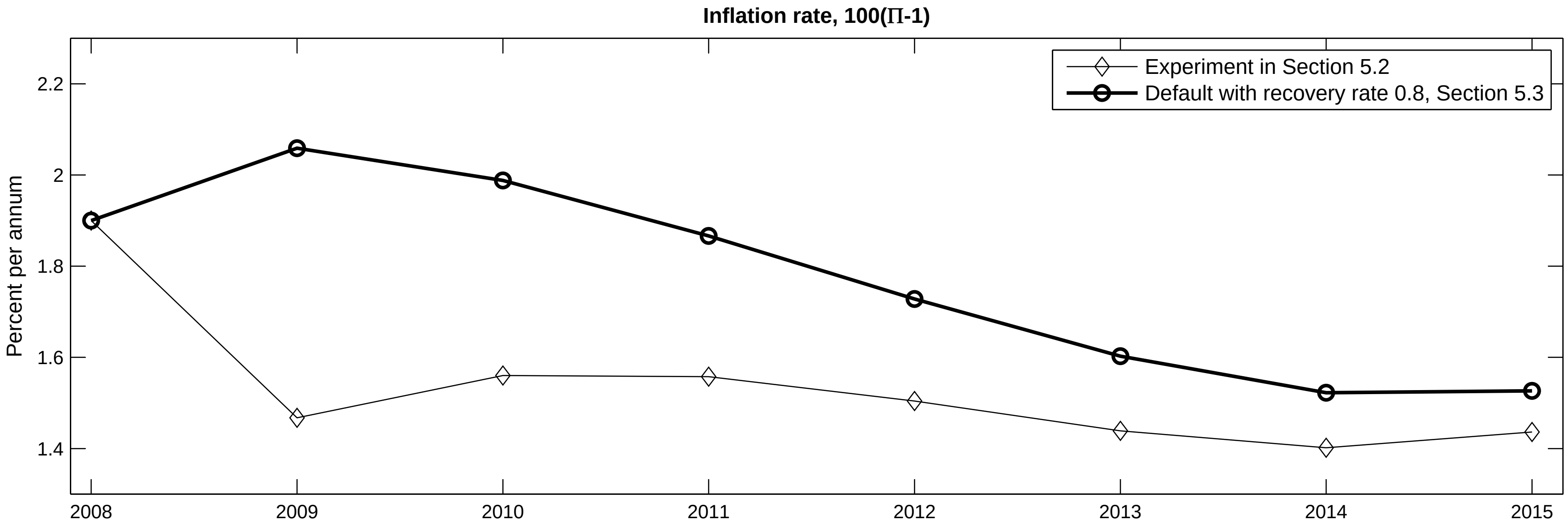


Figure 5: The effect of default on inflation in the policy experiment



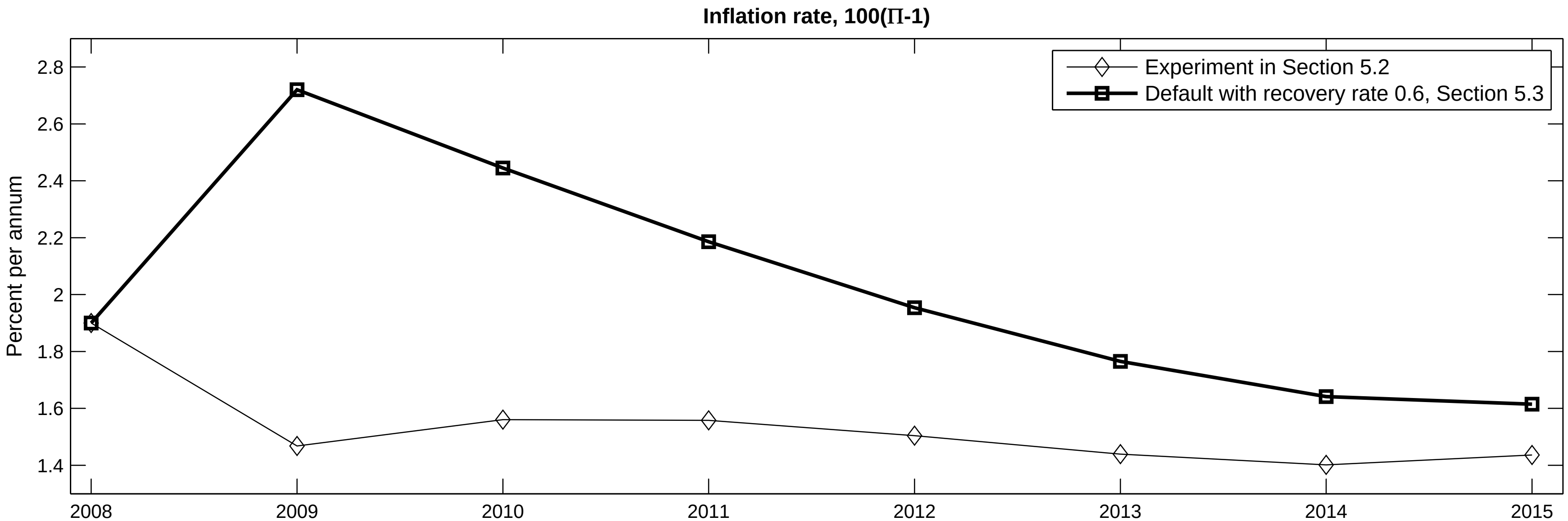


Figure 6: The equilibria in the market for government debt