On the Quantitative Effects of Unconventional Monetary Policies in Small Open Economies*

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This paper quantitatively evaluates the effects of several unconventional monetary policies for small open economies. In particular, a New Keynesian model is extended to include a liquidity premium, deviations from uncovered interest rate parity, and a premium in the term structure of interest rates, allowing the central bank to choose, in addition to its policy rate, the size and composition of its balance sheet. The model is calibrated to the case of Chile. We find that policies affecting the liquidity channel can potentially have large effects, but these depend on expectations about the future policy rate. On the other hand, alternatives working through the term premium have smaller effects, but they are less dependent on the expected path of the reference rate. We also study the possibility of undoing the unconventional policy as a possible exit strategy, with results indicating that this alternative may induce a significant slowdown, particularly if it is anticipated. Finally, we also consider the alternative of driving down the policy rate to its lower bound and maintaining it there for a prolonged period. While this policy can also be greatly expansionary, particularly after contractionary shocks, credibility issues regarding the promise of keeping the rate low for some time can severely undermine these effects.

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1. Introduction

In normal times, many central banks use the nominal interest rate as the policy instrument to achieve their inflation goals. However, when the policy rate reaches its lower bound, the monetary authority has to look for alternative (or unconventional) policies. What are the different tools that a central bank can use in such a situation? What are the quantitative effects of these policies? Although there is a significant branch of the literature that has evaluated the virtues of different options,[1] the analysis of the quantitative impact of different unconventional policies is much less frequent. Moreover, while until recently the experience of Japan (having a near-zero interest rate since the mid-1990s) was almost the only case of study, nowadays the aggressive response of many central banks aimed at dampening the effects of the 2008–09 crisis—taking the interest rate to its lower bound—further emphasizes the need for a quantitative assessment of different policy alternatives.

This paper is an attempt in this direction, presenting a quantitative exploration of different alternatives based on a dynamic and stochastic general equilibrium (DSGE) model, focusing on the small open-economy case.[2] In particular, we extend a simple New Keynesian model of a small open economy to include three frictions: a liquidity premium that introduces a gap between the policy rate and that of short-term debt, which depends on the velocity of base money; a portfolio-balance effect for the determination of the nominal exchange rate (implying deviations from the uncovered interest rate parity, UIP); and a premium in the term structure of interest rates that depends on the relative stock of short and long maturity of debt. These frictions, albeit introduced in an ad hoc fashion, allow the central bank to choose not only the interest rate as its policy tool but the composition of its balance sheet as well (the stock of money, short- and long-term debt, and foreign assets).

[1]See, for instance, Svensson (2001), Eggertsson and Woodford (2003), and Bernanke and Reinhart (2004), among many others.

[2]There are some quantitative studies in the literature for developed economies using DSGE models. An early example is Coenen and Wieland (2003), who analyze several alternatives for the case of Japan. More recently, Cúrdia and Woodford (2009), Gertler and Karadi (2009), and Eggertsson et al. (2010), among others, present studies for the recent experience in the United States.

We use this model to evaluate the dynamics generated by different changes in the central bank's balance sheet, taking into account the expected path for the policy rate, alternative "exit strategies," the possibility of (exogenous) lack of credibility in the policy announcements, and the role of the zero lower bound. The model is calibrated to the case of Chile, which is one of the countries that have driven the policy rate down to its lower bound during the 2008–09 crisis. In addition, from a methodological perspective, we present an algorithm, based on the idea of backward induction, to perform these types of exercises in the context of linear rational expectations models.

The results appear to indicate that policies working through the liquidity channel can potentially have important expansionary effects, which are generated not by the direct effect that a monetary expansion has in reducing this premium but rather through the expected future inflation that the increase in base money generates. However, these effects greatly depend on the perception about the future path of the interest rate and its credibility. On the other hand, policies aimed at reducing the term premium, while generating smaller expansions, are less dependent on the expected behavior of the policy rate and on credibility issues. The channel associated with the deviations from UIP seems to be of minor importance. We also consider the possibility of undoing the original change in the balance sheet as a possible exit strategy. This exercise shows that reversing the unconventional policy can generate important contractions, particularly if these changes are anticipated.

We also study the virtues of a temporary departure from the Taylor rule by which the central bank drops the policy rate down to the zero bound and keeps it there for an extended period of time. We find that this policy can be highly expansionary as well, and particularly useful after a contractionary shock that makes the zero limit binding endogenously. However, the issues regarding the credibility of the announcement are also relevant in this case.

In terms of the related literature, several reasons explain the lack of studies quantifying the effect of unconventional policies. First, it is difficult to estimate the impact of these policies directly from the data, for, at least until recently, the lower bound episodes were almost exceptional, limiting the power of direct econometric inference. The alternative is to use a model to tackle these issues, which is the route taken in this paper. However, this is not a trivial task either. On one hand, allowing for the interest rate to have a lower limit entails considering non-linearities in the model, which are generally difficult to handle computationally. On the other hand, even assuming that we can circumvent the computational issues, most models (particularly in the New Keynesian tradition) are not rich enough to allow for the monetary authority to use several different instruments. For instance, the role of money and liquidity is generally absent in these models, as well as the role of financial frictions.[3] In this work, we tackle the non-linearity by allowing the interest rate to be fixed at an arbitrary value (possibly zero) for some time as a way to capture deviations from the linear Taylor rule,[4] and we introduce frictions, although in an ad hoc way, in order to consider different policy tools.[5]

Before turning to the analysis, a caveat is in order concerning the type of policies analyzed and the kind of country analyzed in this paper. The term "unconventional policy" has been used somewhat vaguely, referring to a number of alternative tools that simply depart from the usual management of the monetary policy rate (e.g., in terms of a model, an unconventional policy could be any departure from the Taylor rule). One such alternative implemented during the recent crisis was the purchase by central banks of risky financial assets that were not part of the usual portfolio of these institutions, a type of policy that is generally labeled as credit policy. These alternatives were aimed at reducing a financial distortion that had widened due to the drop in the price of assets used as collateral (e.g., mortgage-backed securities). Moreover, it is likely that these central

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[3]Some recent studies attempt to expand the basic framework along these lines—for instance, Cúrdia and Woodford (2009) and Gertler and Karadi (2009).

[4]Although we allow for non-linearities, we are still focusing on a local solution, as most studies in this topic do. A different branch of the literature characterizes global solutions, showing that important differences may arise—most remarkably, the possibility of converging to a liquidity trap (see, for instance, Benhabib, Schmitt-Grohe, and Uribe 2001, 2002). This alternative, however, is not explored in this paper.

[5]The fact that frictions are not micro-founded is clearly a drawback of the analysis. However, given that the literature has not yet arrived at a consensus on which are the relevant frictions or how to model them, this analysis can provide some insight on which are the relevant parts of the model (or "wedges") that should be the focus of this research agenda.

banks would have implemented this same type of strategy regardless of the policy rate reaching its lower bound.

Although these alternatives are relevant to discuss as well, we do not analyze them in this paper for several reasons. First, these are not the only types of policies that have been evaluated and/or implemented, for many countries did not have to deal with a situation of deep financial distress. For instance, Céspedes, Chang, and García-Cicco (2011) compile a list of fifty-six policy announcements regarding unconventional policies, in the period from September 2008 to October 2009, for a group of thirteen central banks that generally implement (explicit or implicitly) inflation targets, finding that only twelve of these announcements were related to assets purchase programs or direct lending to (non-banks) financial firms, which were implemented by four central banks (Canada, Switzerland, England, and the United States). Moreover, this distinction seems particularly relevant for emerging countries. For instance, Ishi, Stone, and Yahoue (2009) document that for thirty-four emerging countries, most of the unconventional policies pursued between September 2008 and May 2009 were related to exchange rate interventions and to providing liquidity domestically, while only 3 out of 205 measures implemented according to their classification were related to credit-easing policies. This paper is then more representative of the situation faced by countries like Chile, Sweden, and Australia, among others, that drove the policy rate to its lower limit and had to look for other alternatives to stimulate the economy.

The rest of the paper is organized as follows. Section 2 presents the frictions introduced as well as the alternative policy tools that the central bank has available. We also show there the estimation exercise using Chilean data. In section 3 we present the quantitative results, where we analyze the role of different expected paths for the policy rate, lack of credibility, possible exit strategies, the role of the zero bound, and the response to contractionary shocks, as well some robustness exercises. Finally, section 4 concludes.

2. Model and Calibration

The structure of the model corresponds to a standard New Keynesian framework for a small open economy with incomplete asset markets, modified to introduce ad hoc frictions (or wedges in the usual equilibrium conditions), allowing the central bank (CB) to decide over the different elements in its balance sheet, in addition to its policy rate. In particular, we consider a structure with households having separable preferences in consumption and leisure and that can transfer resources over time using an internationally traded bond, money, and bonds of different maturities issued by the CB. They consume a combination of domestic and foreign goods. There is also an infinite number of monopolistic intermediate goods firms that use labor to produce, with a constant returns to scale technology, and that are subject to a Calvo-type problem in setting prices, with full indexation to past inflation. Finally, with the goal of simplifying the analysis, we abstract from capital as a productive input (and therefore investment), as well as from fiscal policy.

In this section we first describe the optimality conditions associated with households' assets decisions in the standard model and then describe the modifications we introduce.[6] Then, we characterize the CB and the several policy alternatives we consider. Finally, we discuss the estimation of the parameters describing the frictions we introduce. Appendix 1 contains a description of the other equilibrium conditions of the model. Appendix 2 contains the figures referred to in the paper.

2.1 Assets and Monetary Policy in the Standard Model

We begin by describing the budget constraint and the optimality conditions in the frictionless model to see how they reduce the CB policy alternatives to only one instrument (generally, the interest rate associated with short-term bonds). Consider the following budget constraint faced by households:

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\begin{aligned}
&P_t C_t + \frac{S_t B_t^*}{1 + i_t^* + cp_t} + \frac{D_{1,t}}{1 + i_{1,t}} + \frac{D_{2,t}}{1 + i_{2,t}} + \frac{M_t}{1 + i_t^M} \\
&\quad \leq W_t L_t + S_t B_{t-1}^* + D_{1,t-1} + \frac{D_{2,t-1}}{1 + i_{1,t}} + M_{t-1} + T_t.
\end{aligned}
$$

[6] As we mentioned in the introduction, these modifications are introduced ad hoc, with no microfoundations. Nevertheless, we discuss alternative mechanisms (introduced in the related literature) that may produce such departures from the standard model.

Here, C_t denotes consumption, S_t is the nominal exchange rate, P_t is the price level, W_t stands for nominal wages, L_t is hours worked, and T_t is lump-sum transfers from the CB. In terms of assets, households have access to an internationally traded bond B_t^* that has a price given $1/(1 + i_t^* + cp_t)$ (where i_t^* is the world interest rate and cp_t is the country premium that "closes" this small open-economy model), bonds issued by the CB ($D_{k,t}$ is a bond of maturity k with rate $i_{k,t}$),[7] and money, M_t, which has an acquisition price equal to $1/(1 + i_t^M)$ (we discuss the role of this rate below).

In the frictionless model, the first-order conditions associated with asset decisions can be written, after a log-linear approximation, as[8]

$$\hat{\lambda}_t = E_t\{\hat{\lambda}_{t+1}\} + i_{1,t} - E_t\{\hat{\pi}_{t+1}\}, \tag{1}$$

$$i_{2,t} = i_{1,t} + E_t\{i_{1,t+1}\}, \tag{2}$$

$$i_{1,t} = i_t^* + cp_t + E_t\{\hat{s}_{t+1}\} - \hat{s}_t, \tag{3}$$

$$i_{1,t} - i_t^M = -\varphi_m(\hat{m}_t - \hat{p}_t - \hat{y}_t), \tag{4}$$

where λ_t is the marginal utility of consumption and the parameter φ_m will depend on the specific assumption about the role of money.[9]

In the usual treatment of this model, it is also assumed that $i_t^M = 0$ and that the policy rate, i_t^{MP}, equals the short-term rate $i_{1,t}$. Therefore, in the standard model there is only one monetary policy instrument available (usually i_t^{MP}, which is determined by a Taylor-type rule) and the different elements in the CB balance sheet are irrelevant for the determination of other asset prices: the demand

[7] We only consider two-period bonds here to ease the notation, while in the estimation we allow for maturities in line with those available in our empirical case, Chile.

[8] We use small-caps hatted variables to denote log-deviations from the steady state.

[9] Here we are implicitly assuming that, in the absence of price stickiness, money is neutral, as it is generally assumed by the "cashless limit" modeling strategy. Additionally, it is worth mentioning that in a fully micro-founded model (particularly in one of a small open economy) consumption should appear in equation (4) instead of output. However, because in our estimation we use monthly data to overcome a short available sample, we use output because we do not have available a monthly consumption series, but we do have a monthly series for aggregate economic activity. Finally, we are implicitly assuming that money demand has a unitary elasticity with respect to output.

for real balances (4) determines the stock of money for a given i_t^{MP}, the expectations hypothesis (2) determines interest rates at different horizons, and equation (3) (the uncovered interest parity, UIP) pins down the exchange rate. To overcome this impossibility, in what follows we redefine the monetary policy rate and introduce wedges in these familiar conditions, in such a way that the stock of different assets will show up in equilibrium.

2.2 Modifying the Standard Framework

The first departure from the standard framework is to modify the assumption $i_t^M = 0$ and to consider this to be the policy rate (i.e., $i_t^{MP} = i_t^M$). The motivation behind this choice is that usually the target for the policy rate is not that of a short-term bond but, instead, that of a monetary market, such as the overnight or the repo rate. These are the types of markets that CBs actually use to introduce money into the economy through open-market operations and, although in those markets Treasuries and/or CB bonds are generally exchanged for money, the interest rates charged for these operations do not need to (and generally they actually do not) coincide with that of these assets, for the latter may generally include a liquidity premium.[10]

We are not the first, however, to use this type of assumption. For instance, Reynard and Schabert (2009) introduce a framework explicitly modeling the market for money where only short-term bonds are eligible for money acquisitions. In their framework monetary policy targets the rate prevailing in that market, which is generally different from that of other assets in the economy. Sims (2009) also considers a model with two policy rates, although his interpretation for the rate i_t^M is rather different, for he considers this to be the interest rate paid on reserves as a way to capture the policy recently implemented in the United States by the Federal Reserve.

This assumption introduces an additional degree of freedom for monetary policy, which can now be implemented by choosing two instruments—in our case, i_t^M and the stock of money M_t—leaving

[10]Such a premium does not need to be high (as it doesn't seem to be in the data) for this mechanism to work, but as long as it exists, this mechanism will generate the results presented below.

the short-term rate $i_{1,t}$ to be determined by equation (4). From a technical point of view, this assumption has also been considered in some textbook treatments such as Woodford (2003, chap. 2). In particular, Woodford shows (in the context of a flexible-price model) that a monetary policy specified by exogenous paths for both i_t^M and M_t will deliver a determinate equilibrium.[11] This result is relevant because, although we will consider a familiar Taylor-type rule for i_t^M satisfying the Taylor principle as the "normal times" policy rule (see below), we can also assume that i_t^M is fixed at a given value forever without facing indeterminacy issues, a feature that we will exploit to consider unconventional monetary policies.

From a qualitative point of view, given this friction, a permanent increase in the stock of M_t will have, ceteris paribus, two effects. On one hand, the reduction of $i_{1,t}$ will increase desired consumption. On the other hand, the rise in M_t will increase the price level which, in the presence of price rigidities, will generate expectations of future inflation, reducing the real interest rate and further expanding consumption demand.

The second difference with the standard framework is that we also consider deviations from the uncovered interest rate parity (UIP) such that

$$\hat{s}_t - E_t\{\hat{s}_{t+1}\} - i_t^* - cp_t + i_{1,t} = \varphi_s\left(\Delta \hat{b}_t^{*BC}\right), \tag{5}$$

where Δ denotes the first-difference operator and B_t^{*BC} denotes the holdings of foreign assets by the CB (described below). In this way, changes in the CB holdings of foreign assets will have a direct effect (ceteris paribus) on the nominal exchange rate.[12]

Finally, we modify equations (1) and (2) to consider a term premium in the yield-curve structure that affects intertemporal allocations. In particular,

$$\hat{\lambda}_t = E_t\{\hat{\lambda}_{t+1}\} + i_{1,t} - E_t\{\hat{\pi}_{t+1}\} + \Delta \hat{tp}_t, \tag{6}$$

[11] See proposition 2.11. This result is also present in the model of Reynard and Schabert (2009), which additionally features price rigidities.

[12] A similar deviation from the UIP gap can be obtained in a model with costly adjustment of the international portfolio. See, for instance, Sierra (2008).

where

$$\hat{tp}_t \equiv i_{2,t} - i_{1,t} - E_t\{i_{1,t+1}\} = \varphi_k(\hat{d}_{2,t} - \hat{d}_{1,t}). \tag{7}$$

Therefore, different combinations of long- and short-term debt will have first-order effects in consumption decisions.[13] In particular, either increases in $D_{1,t}$ or drops in $D_{2,t}$ will shift consumption demand upward.[14]

2.3 Monetary Policy

In each period t, the CB decides on four types of assets: base money (M_t), foreign reserves (B_t^{*CB}), and domestic debt of both short and long maturity ($D_{1,t}^{CB}$ and $D_{2,t}^{CB}$).[15] Additionally, it chooses the monetary policy rate i_t^{MP} and lump-sum transfers to households (T_t).

The CB resource constraint in any given period is given by[16]

$$\frac{S_t B_t^{CB*}}{1 + i_t^* + cp_t} + D_{1,t-1}^{CB} + \frac{D_{2,t-1}^{CB}}{1 + i_{1,t}} + M_{t-1}$$
$$= S_t B_{t-1}^{CB*} + \frac{D_{1,t}^{CB}}{1 + i_{1,t}} + \frac{D_{2,t}^{CB}}{1 + i_{2,t}} + \frac{M_t}{1 + i_t^M} + T_t.$$

[13]In principle, we could consider the possibility of $\Delta\hat{tp}_t$ entering the Euler equation with a coefficient different than one. However, to estimate such a coefficient will be difficult, for there is no monthly data on consumption. Nevertheless, in the robustness section we check the robustness with respect to the parameter φ_k, which can be seen also as a robustness check in terms of modifying this assumption.

[14]A similar modification of the Euler equation and the expectation hypothesis can be obtained, for instance, in line with Andres, López-Salido, and Nelson (2004), by assuming imperfect assets substitution between long- and short-term bonds.

[15]That a CB can issue its own debt is not a commonly observed characteristic, but it is the case for Chile. More generally, thinking of a CB that does not share this characteristic, we can interpret $D_{1,t}^{CB}$ and $D_{k,t}^{CB}$ as the negative of the CB holdings of Treasury bonds.

[16]In the absence of the frictions previously introduced, this equation is irrelevant in equilibrium.

It is further assumed that the CB uses transfers in such a way to rebate any capital gain/loss to households,[17] implying that the bank's total net worth is kept constant in nominal terms, i.e.,

$$\begin{aligned}&\left(S_t B_t^{*CB} - S_{t-1} B_{t-1}^{*CB}\right)\\&\quad = (M_t - M_{t-1}) + \left(D_{1,t}^{CB} - D_{1,t-1}^{CB}\right) + \left(D_{2,t}^{CB} - D_{2,t-1}^{CB}\right). \qquad (8)\end{aligned}$$

In normal times, policy is conducted through a familiar Taylor rule,

$$i_t^{MP} = \rho_i i_{t-1}^{MP} + (1 - \rho_i)(\alpha_\pi \hat{\pi}_t + \alpha_y \hat{y}_t). \qquad (9)$$

On the other hand, the unconventional policies that we will consider have two components: first, the policy rate is fixed at some value (either its steady-state level or zero) for some time and, second, the CB changes the position of an asset in its balance sheet, compensated by a change in another asset such that the bank's total net worth is kept constant in nominal terms (i.e., equation (8) holds).

2.4 Estimating the Frictions

Given the frictions previously introduced, different changes in the CB balance sheet may have different expansionary effects. To quantify these effects we need to assign values to the parameter describing these frictions (φ_m, φ_s, and φ_m), which we will obtain by estimating equations (4) to (7) using monthly Chilean data from January 2003 to May 2009.[18] Before presenting the results, it is relevant to mention several data limitations. First, even though there is data available on the total stock of bonds of the Central Bank of Chile (CBCh) on circulation, the data is not rich enough to obtain a long series for the stock of bonds at different maturities. In addition, although nowadays the CBCh has available a rich maturity structure for its

[17] Reynard and Schabert (2009), in a closed-economy model, make a similar assumption. In principle, this is not the only possibility one can consider. But allowing for a change in the CB net worth would require setting a rule for the evolution of this variable, and it is not clear how this rule should be specified (nor is there guidance in the literature on these issues). This exercise, on the other hand, is simpler and will allow us to obtain a cleaner intuition.

[18] The calibration of the other parameters in the model follows the related literature and is described in appendix 1.

bonds, this has not been always the case, and only the two-year bond in pesos (BCP2) has a long enough series of interest rates.

In terms of equation (4), i_t^{MP} is measured by the monetary policy rate set by the CBCh, $i_{1,t}$ is the ninety-day deposit rate,[19] M_t is the monetary base, output is the monthly index of economic activity (IMACEC), and the price level is the core consumer price index (IPCX1).[20] The equation was estimated by GMM, using as instruments five lags of the regressors, the JP Morgan Emerging Markets Bond Index Global (EMBI Global), the federal funds rate, the rate on a five-year bond in pesos (BCP5), and the ninety-day lending rate, and allowing also for an AR(1) error term.[21] The result obtained was[22]

$$\begin{aligned} i_{1,t} - i_t^{MP} &= \underset{(0.0017)}{-0.0025} - \underset{(0.0007)}{0.0014}(\hat{m}_t - \hat{p}_t - \hat{y}_t) + u_t, \\ u_t &= \underset{(0.0416)}{0.8056}\, u_{t-1} + e_t, \\ R^2(Adj) &= 0.587, J - stat = 0.175, Obs = 60. \end{aligned}$$

For equation (5), the foreign interest rate is the federal funds rate, and the country premium is measured by the EMBI, the stock of government foreign assets B_t^{*CB} was measured by the net foreign asset element in the CBCh balance sheet, and the three-month-ahead expectation of the nominal exchange rate comes from the Expectations Survey collected by the CBCh. The equation was estimated by GMM using the same instruments as in the previous equations and allowing also for an AR(1) error term. The results were

$$\begin{aligned} \hat{s}_t - E_t\{\hat{s}_{t+1}\} - i_t^* - cp_t + i_{1,t} &= \underset{(0.001)}{-0.0037} + \underset{(0.036)}{0.2047}\left(\Delta\hat{b}_t^{*BC}\right) + u_t, \\ u_t &= \underset{(0.0307)}{0.2615} u_{t-1} + e_t, \\ R^2(Adj) &= 0.014, J - stat = 0.115, Obs = 76. \end{aligned}$$

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[19] All rates are quarterly to be consistent with the calibration of the model.

[20] These two series have been seasonally adjusted. The source for all the series is the Central Bank of Chile. Variables are measured in logs.

[21] Adding lags of the dependent variable as regressors did not improve the goodness of fit.

[22] Newey-West robust standard errors are in parentheses.

Several studies have used this type of deviation from UIP for their analysis, and it is useful to compare their calibration with the results obtained here.[23] For instance, in an application for Japan, Orphanides and Wieland (2000) and Coenen and Wieland (2003) calibrate a parameter that governs the relation between deviation from UIP with respect to the level of foreign reserves to 0.025. On the other hand, in an empirical study for the United States and Germany by Baillie and Osterberg (2000), they find an elasticity with respect to deviations from UIP to foreign exchange interventions between 0.01 and 0.02. While these numbers are significantly smaller than what we obtained for the case of Chile, we should remember that these alternative figures come from studies of developed countries, and it is therefore reasonable to believe that this elasticity should be bigger for an emerging country.

Finally, for equation (7) the rate of nominal two-year bonds was used as a measure for $i_{k,t}$, and the expectations about the future short rate also come from the Expectations Survey. Because, as we commented before, there is no data on the stock of bonds at different maturities, we measure $\hat{d}^{BC}_{k,t} - \hat{d}^{BC}_{1,t}$ as the difference between the total stock of bonds in pesos and the stock of ninety-day commercial and consumer deposits. The equation was estimated by GMM using the same instruments as in the previous equations and allowing also for an AR(1) error term. The estimation yields

$$i_{k,t} - \sum_{j=0}^{k-1} E_t\{i_{1,t+j}\} = \underset{(0.001)}{-0.001} + \underset{(0.001)}{0.017}\left(\hat{d}^{BC}_{k,t} - \hat{d}^{BC}_{1,t}\right)u_t,$$

$$u_t = \underset{(0.0307)}{0.2615}\, u_{t-1} + e_t,$$

$$R^2(Adj) = 0.671, J - stat = 0.179, Obs = 76.$$

We can also compare this result with some papers that try to assess the effect of the composition of the Treasury holdings by the Federal Reserve. For instance, Bernanke, Reinhart, and Sack (2004) analyze

[23]There is a larger literature that addresses the effect of foreign exchange interventions on the exchange rate. This is, however, different from the parameter that we need to calibrate because we need the influence of changes in the CB foreign reserves on deviations from UIP.

the effect of two refunding episodes, finding an effect of 10 basis points in the Treasuries spread between five and two years of maturity. More recently, Gagnon et al. (2011) uses a time-series approach to measure the elasticity of the ten-year Treasury rate to changes in the supply of long-term Treasuries, finding that a 1-percent-of-GDP increase in long-term debt produces a drop in this rate between 4 and 10 basis points. While the elasticities computed in these exercises are not exactly the same as those we measured here, the results seem to be in line with these related studies.

Finally, it is relevant to highlight that these equations are not meant to represent a full theory explaining these gaps observed in the data (e.g., not all deviations from UIP are due to exchange rate interventions). Actually, the share of the variance of the left-hand-side variables explained by the proposed regressors is generally low. Nevertheless, the fact that the coefficients display the correct sign and appear to be statistically different from zero suggests that some explanatory power can be attributed to the proposed regressors.

3. The Effect of Unconventional Policies

We proceed with the numerical exercises in several steps. First, we study the effects of a given change in the CB balance sheet assuming that i_t^{MP} remains fixed in its steady-state value forever. Although this is clearly not a realistic assumption, it will be useful to grasp the intuition behind the dynamics implied by the different alternatives. Second, we analyze what happens if the CB promises to keep i_t^{MP} fixed at its steady-state value only for a limited amount of time, using the Taylor rule afterward. Additionally, we allow people to assign an exogenous probability to the event that the CB returns to the Taylor rule before it was promised. Third, the possibility of undoing the unconventional policy (either by a surprise or with an anticipated announcement) as a possible exit strategy is considered. Fourth, we evaluate the virtues of driving the policy rate down to zero and maintaining it there for some time as an additional unconventional policy alternative. Fifth, we hit the economy with a contractionary shock and study how these policies can be used to ameliorate the recession. Finally, we check the robustness of the results to several perturbations to the model.

3.1 Fixing i_t^{MP} Forever

The exercise we consider first is to fix i_t^{MP} at its steady-state value forever and to permanently change two components of the CB balance sheet in such a way that equation (8) is satisfied. In particular, we assume that the change in the balance sheet is equivalent to 10 percent of nominal GDP in steady state.

Figure 1 shows the effect of a purchase of foreign assets financed with an increase in the stock of money. (All figures referred to in this paper can be found in appendix 2.) This policy generates an increase of 6.1 percent in inflation and a rise in GDP of 3.7 percent on impact, and these positive effects last for several quarters. The fact that the response of inflation lies always above zero indicates, in line with the discussion before, that the price level experiences a permanent change in the long run.[24] This change does not fully materialize in the first quarter due to the price rigidities, generating, in particular, an increase in expected inflation. This rise in expectations reduces the ex ante real interest rate, $r_t \equiv i_{1,t} - E_t \pi_{t+1}$, which has an expansionary effect. In principle, this rate is also reduced by the drop in $i_{1,t}$. However, as can be seen in the figure, $i_{1,t}$ decreases by little compared with the increase in $E_t \pi_{t+1}$.

This alternative also has an effect through the exchange rate channel in equation (5). To see how important this mechanism is, the dashed-dotted line in figure 1 displays the same response assuming $\varphi_s = 0$. As can be seen, the responses are quite similar compared to the benchmark case, which further emphasizes the role of the increase in expected inflation as the relevant channel.

Monetary expansions can also be used to purchase either type of CB debt. In this case, the channel in equation (5) will play no role, but we may have an additional expansionary effect if long debt is acquired, for it reduces the term premium in equation (7). Figure 2 displays the dynamics under both alternatives. We can observe effects on impact on GDP and inflation similar to the previous exercise, with a slightly bigger effect in the case of a purchase of $D_{k,t}^{CB}$.

[24] Actually, given that equation (4) depends on velocity, and given that the stock of money increases by 10 percent of GDP, the integral of the response of inflation should be 10 percent, which can be verified numerically.

There is a somewhat smaller response on the real exchange rate in this case (the impact response in the previous case was a real depreciation of near 5.3 percent, while in this case it is around 4.7 percent), but in general the dynamics are similar, indicating that this alternative also creates an expansionary effect through the rise of inflation expectations.

In terms of policies that do not involve monetary expansions, figure 3 plots the responses to a purchase of long debt financed by new short debt, a policy that has a direct effect through the term premium channel in equation (7). This alternative generates a milder expansion of GDP and inflation on impact, 0.3 percent and 0.05 percent, respectively. While the nominal exchange rate depreciates in this case, there is a real appreciation on impact, which partially explains this smaller response. Moreover, given the shape of the inflation path, the real interest rate actually rises and therefore the expectations channel is not present in this case.

Finally, figure 4 shows the effect of a purchase of foreign assets financed with either long or short new debt. In this case, both the friction affecting the UIP condition, equation (5), and the yield curve, equation (7), are in place. However, we can see that the effect on output is only positive when the operation involves an increase in $D_{1,t}^{CB}$, which appears to indicate that the second channel is relatively more important. Additionally, while the increase in output is smaller compared with the case in figure 3, the response of inflation (at least on impact) brought about by the nominal depreciation is bigger in this case, although this change is reversed in the second quarter.

Overall, these exercises highlight that policies working through the liquidity channel may have significant effects, while other alternatives can also have expansionary effects but of a smaller magnitude. However, the maintained assumption so far was that the monetary policy rate is expected to remain fixed forever. In what follows, we relax this important assumption.

3.2 A Temporary Fix of i_t^{MP}

We consider the following exercise. At time t_0, the CB announces that the policy rate is going to stay fixed until period $T-1$, and from

T onward it will be determined according to the Taylor rule in equation (9). Additionally, it announces an unconventional policy, which also takes place at t_0 but that will never be reversed (an alternative that we consider in the next subsection). Everybody believes that, beginning at period T, the Taylor rule will be in place and that it will stay for any $t \geq T$. However, for $t \in [t_0, T-2]$, while the interest rate is fixed, people assign an exogenous probability sequence p_t to the CB breaking its promise and setting the nominal interest rate according to the Taylor rule starting at $t+1$. Moreover, if this is the case, they believe that the Taylor rule will stay forever. Finally, regardless of people not trusting the CB, we assume that (ex post) it fulfills its promises and actually waits until T to use the Taylor rule. Appendix 1 presents an algorithm, based on the idea of backward induction applied to linear rational expectations models, that can be used to compute the equilibrium trajectories under these assumptions. The algorithm also constrains the equilibrium path to satisfy the non-negativity constraint on the policy rate.

We begin with the case of a purchase of foreign assets financed by a monetary expansion. Figure 5 shows the dynamics for different T's, assuming full credibility (i.e., $p_t = 0$). As can be seen, allowing the Taylor rule to return after some time significantly dampens the expansionary effects of this alternative. For instance, if the policy rate is fixed for eight quarters, the impact response of output is near 0.9 percent, dropping to close to 0.2 percent for $T = 2$, while these figures for inflation are, respectively, close to 2 percent and 0.7 percent. These are significantly smaller than the rise of 3.7 percent in GDP and 6.1 percent in inflation that is generated if i_t^{MP} stays fixed ad infinitum.

In part, this smaller effect is due to the qualitatively different response of inflation: while before it used to lie completely above zero, now it increases on impact, decreases to a negative value in the second quarter, and then becomes positive and converges to zero from above.[25] This different path for inflation translates into a

[25]The cumulative response of inflation (i.e., the price level) is the same in the long run in both cases (equal to 10 percent as we dicussed before). However, while in the case of i_t^{MP} fixed forever the convergence was after just a few periods, it now takes more than 3,000 quarters to reach this value.

less expansionary path for the real interest rate, which now actually increases on impact and then becomes negative, converging to zero from below. Although the infinite sum of the real interest rate (i.e., the relevant measure for the determination of consumption according to the IS curve) is still negative (close to –0.6 percent when $T = 8$), it is significantly smaller than before (almost –4 percent), which explains why the response of output has dampened in this case.

However, this is only a part of the explanation, for the shape of the inflation path changes in this case because inflation is more affected by the dynamics of the nominal exchange rate than before, which explains why it decreases below zero in the second quarter.[26] In particular, if $\varphi_s = 0$, the response of inflation lies completely above zero. However, it is still the case that the convergence of the price level to its new steady state is much slower.

The difference in terms of the speed of convergence of the price level is clearly due to the expected rise in the policy rate. In particular, although this increase is small (less than 3 basis points when $T = 2$), the path of the interest rate also lies above zero for a significant period of time (until the price level converges to its new steady-state value).[27] Of course, this description cannot be interpreted causally, for both inflation and interest rates are jointly determined in equilibrium. However, it is clear that the anticipation of the return to the Taylor rule significantly limits the expansionary effect that this policy alternative may have.

We consider next the effect of lack of credibility. Figure 6 shows the same unconventional policy, fixing $T = 6$, and setting $p_t = p^t$ for different values of p (this implies that, as times goes by and people see that the CB has actually kept its promise, the assigned probability of an anticipated return to the Taylor rule decreases). This lack of credibility also dampens the expansionary effect that this policy

[26] Actually, as can be seen in figure 1, the response of inflation also displayed a small negative bump in the second quarter even with the policy rate fixed forever. However, the response of inflation in that case was so large that this had a minor impact.

[27] Taken together, while the infinite sum of the real interest rate is more negative if $\varphi_s = 0$ (close to –1.2 percent when $T = 8$), it is still significantly smaller than what it was in the case of the policy rate fixed forever.

may have. In particular, for $p = 0$ the impact increase in GDP is close to 0.5 percent, but with $p = 0.9$ it drops to almost 0.3 percent. The response of inflation is also milder the higher this probability is, although the difference is relatively smaller. Overall, the patterns are similar to those described for the case of $p_t = 0$.[28]

We can also consider how the results are affected if the unconventional policy implemented is a purchase of long-term debt financed with new short-term debt. Figure 7 shows the dynamics for different T's, keeping $p_t = 0$. Compared with the case of a monetary expansion, here the responses of output and inflation are not that sensitive to changes in T. Actually, the effects seem to be slightly bigger than the case of i_t^{MP} fixed forever, and the responses of both variables now lie completely above zero. This different shape particularly generates a drop in real interest rate, and although the policy rate rises once the Taylor rule returns, the increase is quite small and the real rate remains below zero for several periods.[29] Finally, we analyze the effect of this policy when people assign a positive but decreasing probability to the early return of the Taylor rule, a case described in figure 8. It appears that the dynamics are not significantly affected either when we allow for p_t to vary.

3.3 Undoing the Unconventional Policy

Part of the current discussion about unconventional policies refers to possible "exit strategies," which is clearly a broad term. In principle, one can consider a return to the usual Taylor rule being, in itself, an exit strategy. However, the discussion appears to focus on undoing the unconventional policy initially implemented. For instance, one might be worried about the effects that the excess of liquidity introduced. As an example, we described before how a policy that entails increases in M can generate significant persistence in the inflation

[28] Other policies that entail an increase in M also show results similar to those obtained in this case.

[29] This actually suggests that, for this type of policy, the responses vary nonmonotonically with changes in T. In the case of a monetary expansion, the bigger the T, the bigger and closer to the case of i_t^{MP} fixed forever the responses were. In this case, on the contrary, there seems to be a value for T (in the numerical exercises it is close to 25) such that the responses are bigger at that point, becoming closer to the case in figure 3 afterward.

process once the Taylor rule is reintroduced. In what follows, we present several exercises that help to sharpen this discussion.[30]

A first alternative is to consider the same policies as before (i.e., the CB announces an unconventional policy and that i_t^{MP} will be fixed until $T-1$, and the Taylor rule will be used for $t > T$) and to additionally assume that the CB also announces that in period $T-k$ (with $k \in [0, T-t_0+1]$) the unconventional policy will be completely reversed (assuming, for the moment, full credibility).[31] For instance, if at t_0 the CB buys foreign assets using base money, at $T-k$ it sells the same amount of dollars in exchange for currency. This alternative is considered in figure 9, which displays the equilibrium paths for different values of k. To clarify the exercise, the figure also displays the paths for M_t and B_t^{*BC}. It is clear that the anticipation of the reversal further dampens the expansion, actually generating a recession in most cases. In particular, the smaller the value of k, the more negative the responses of output and inflation are. This is because the policy reversal is contractionary and the effect is partially mitigated if the nominal rate remains fixed for more time.

These responses can be rationalized by realizing that the mechanism generating the expansion with a policy that expands M (i.e., the expected rise in the price level) disappears when the reversal is anticipated. Figure 10 actually shows that gradually undoing the unconventional policy is even worse when the change is anticipated, while figure 11 illustrates that if people believe that the change can occur earlier, the economy contracts even further.

We also explore the possibility of undoing the unconventional policy unexpectedly. Figure 12 displays the dynamics for different values of k, for the case of full reversal at $T-k$. Evidently, the impact response is the same we described in the previous subsection, and when the policy is undone we have a contraction, with output dropping slightly below zero at that time and inflation also becoming negative. What actually mitigates the negative effect on output is the fact that the shock is unanticipated: although inflation

[30]To simplify the exposition, we will just show the case of a purchase of foreign currency financed by a monetary expansion. The other alternatives yield qualitatively similar results.

[31]As shown in appendix 1, the algorithm can be generalized to consider this alternative.

drops on impact at $T-k$, it is expected to be positive in the next period (partly due to the dynamics of the nominal exchange rate), making the real interest rate negative and generating an increase in consumption demand. However, it is relevant to highlight that when the Taylor rule returns, the policy rate displays a minor drop (of less than a basis point) because both output and inflation converge to zero from below slowly. Finally, the case of a gradual reversal starting at $T-k$ is considered in figure 13. This reversal produces a bigger drop in output and inflation. However, inflation now converges from above zero and, consistently, the policy rate rises after period T.

3.4 Driving i_t^{MP} to the Lower Bound

So far we have kept the policy rate fixed at its steady-state level for some time as a way to complement the effects of changes in the CB balance sheet. However, we can alternatively consider the possibility of the CB driving the policy rate all the way down to its lower bound, which is also in line with the recent experience. For instance, Céspedes, Chang, and García-Cicco (2011) document that in a group of twenty countries with (implicit or explicit) inflation targets, thirteen of them drove the policy rate down to a lower bound at some point after September 2008 and have maintained it there for an extended period of time. Additionally, while maintaining the rate at its lower bound can be seen as a complementary action to enhance the effects of movements in the balance sheet, driving the policy rate to zero and leaving it there for some time also implies a departure from the usual Taylor rule. Therefore, we can consider this action an unconventional policy in itself, regardless of its potential role in complementing movements in the balance sheet.

Figure 14 shows the responses associated with a decrease (from its steady-state value) of the policy rate down to zero, leaving it at that value for alternative horizons, and assuming that afterward this rate is determined by the Taylor rule.[32] As can be seen, this policy alternative has important expansionary effects: for instance, if the rate drops to zero and remains at this value for one quarter,

[32]Notice that because the figure plots log-deviations from steady state, the lower bound in the graph corresponds to a value close to −1.6 percent (given that the steady state of this rate is, in annual terms, 6.5 percent).

output increases by nearly 5 percent while inflation rises by almost 7 percent. In addition, we can see that the key channel for this effect is the reduction in the ex ante real interest rate. To put these numbers in context, in order to obtain a similar response (on impact) for both inflation and output with an expansionary monetary shock to the Taylor rule, we would require a disturbance generating a drop on impact in the policy rate to −17 percent (in annual terms).

We can also analyze as before the role of (exogenous) credibility in the announcement of the policy rate staying at zero for some time. Figure 15 displays the response for the case in which it is announced that the Taylor rule will return after six quarters, but with people assigning a probability $p_t = p^t$ to the anticipated return of the Taylor rule in $t + 1$. In line with the results obtained previously, the effects of lack of credibility can be pervasive in this case as well, significantly dampening the expansionary effects brought about by the zero bound.

3.5 Contractionary Shocks and the Lower Bound

The analysis up to this point has focused on studying the alternative policies in isolation, a strategy followed to better understand the mechanics behind each of the alternatives. Nevertheless, probably the most interesting case is to study how these policies can be used after the economy is hit by a recessionary shock. In addition, this case will allow us to distinguish the role played by the zero bound when it is attained endogenously or exogenously. The first alternative refers to the situation in which a negative shock is big enough that it makes the policy rate indicated by the Taylor rule negative. In this case, the rate will remain at zero until the effect of the shock vanishes enough so that the Taylor rule prescribes to rise the rate. The second alternative, on the other hand, considers the possibility that the CB chooses to temporarily depart from the rule and keep the interest rate at zero even after the time in which the Taylor rule would have indicated to raise the policy rate.[33]

[33] In addition, it is also important to highlight that, because the equilibrium we compute is non-linear due to the presence of the zero bound, the response to a negative shock that drops the policy rate to zero is not the same as adding to the figures in the previous subsection the response that would have been obtained with this shock but without considering the lower bound.

The disturbance we consider is a preference shock that temporarily lowers the real interest rate in the flexible-price equilibrium, in line with Eggertsson and Woodford (2003) and much of the following literature.[34] In particular, the log-linearized Euler equation (6) now includes a variable $\hat{v}_t$ that follows an autoregressive process with a coefficient in its first and only lag of 0.7, which is in line with the estimates of Medina and Soto (2007) for Chile. In order to calibrate the size of the shock, we use a result from the empirical investigation of Céspedes, Chang, and García-Cicco (2011). They computed (for a group of CBs that decreased the policy rate to its lower bound during the 2008–09 period) the path of the interest rate that would have been implied by a Taylor rule if the interest rate was allowed to go below zero. In particular, for the small open economies in their sample—Canada, Chile, Sweden, and Switzerland—the average maximum difference (across countries and across several specifications for the Taylor rule) between their respective lower bound and the rate implied by the rule was 450 basis points (around 110 basis points at quarterly frequency). Therefore, we choose the value of the shock so that, in the alternative in which the policy rate is allowed to go below zero, the minimum value of the reference rate after the shock is around -1.1 percent at a quarterly frequency.[35]

As a first step, figure 16 displays the responses to the shock under two specifications for the Taylor rule, without including any

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[34] In terms of the recent episodes, to consider this type of shock for developed economies in which the crisis originated can be a strong reduced-form representation of a shock that propagated from a severe financial distortion, although it has been used anyway for the analysis, for instance, by Cúrdia and Woodford (2009) and many that followed their work. This is a controversial strategy because, if a financial friction was what originated a preference toward more savings, to analyze it in a reduced form will likely have non-trivial consequences for the analysis of monetary policy. On the other hand, thinking about the impact of the crisis in many small open economies, this disturbance seems a more appropriate way of capturing what happened in many of these countries. Most of these economies did not suffer a deep financial stress as in developed economies like the United States or the United Kingdom, and the shock more likely propagated from a precautionary saving motive which can be more properly captured by this type of disturbance.

[35] Given the calibration, this shock represents a drop close to 1,400 basis points in the real interest rate of the flexible-price equilibrium—i.e., in the baseline calibration, the steady-state real rate is 0.84 percent and the shock lowers it on impact to a value of -13.6 percent (all these figures are quarterly).

complementary policy. The solid line shows the case when the policy rate is allowed to be negative, as indicated by equation (9), while the dashed-dotted line considers a truncated Taylor rule, i.e., $i_t^{MP} = max\{-i, i_t^{target}\}$ where i is the steady-state value of the policy rate and $i_t^{target} = \rho_i i_{t-1}^{MP} + (1-\rho_i)(\alpha_\pi \hat{\pi}_t + \alpha_y \hat{y}_t)$. Therefore, the second alternative represents the case in which the zero bound is attained endogenously. As can be seen, when the zero bound is not accounted for, the shock produces a strong contraction on output,[36] a significant reduction in inflation, and both real and nominal depreciations.[37] The policy rate drops on impact and goes below the zero bound after the first period, remaining at a negative value for six quarters.

On the other hand, with the truncated Taylor rule the results are quite different: output drops even more, the deflation experienced is larger and starts on impact, and the nominal exchange rate displays an appreciation. It is also interesting to notice that the policy goes down to zero on impact, while in the previous case the rate was negative only after one quarter. This happens because agents internalize the presence of the zero bound, which—combined with the persistence of the shock—yields this equilibrium response.[38] Notice also that this anticipation generates that, in equilibrium, the policy rate under the truncated rule starts to rise earlier than the point in which the rate is positive in the equilibrium with no lower limit. Finally, the behavior of the ex ante real rate is also markedly different: at the zero bound, the shock increases the real rate, a result in line with the closed-economy analysis in Eggertsson and Woodford (2003) and akin to Keynes' Paradox of Thrift. In addition, in the open-economy case the negative effect generated by the appreciation seems to also contribute to this more severe recession.

The first unconventional policy we consider in this context is a temporary departure from the truncated Taylor rule in which the CB announces, right after the shock hits the economy, a decrease of

[36]In the robustness section we consider a model with habits, which significantly dampens the effect on output.

[37]Inflation does not drop on impact due to the presence of indexation in the Phillips curve and because of the nominal depreciation.

[38]Notice that the algorithm allows for the possibility that the zero bound is not attained on impact, but at a later period. However, this alternative does not correspond to an equilibrium in this case.

the policy rate down to zero and that it will be maintained there for a given number of periods (which is the same exercise considered in the previous subsection). Figure 17 displays this alternative for five, six, and seven quarters, and it also replicates the previous two cases for comparison. The results indicate that keeping the rate at zero for a longer period significantly reduces the problem originated by the zero bound, and if kept fixed long enough, it can even improve the responses obtained when the policy rate is allowed to be negative. The key channel for this result is the reaction of the real rate: as the policy rate is lower for a longer period of time, inflation expectations will rise. Nevertheless, while not shown for this case, the warnings regarding the credibility of the announcement analyzed in the previous subsection (figure 15) continue to apply here as well: the effect of the announcement will be milder if agents assign a positive probability to an earlier return to the truncated rule.

We analyze next the virtues of a purchase of foreign assets financed by money creation that is announced right after the shock materializes, and we consider the alternative only in the case of a truncated Taylor rule.[39] This is analyzed in figure 18. While the effect of absorbing the negative impact on output is only moderate, this policy helps to reduce (relative to the truncated rule) the deflation on impact by almost a half. The channel playing a relevant role in this case seems to be the wedge in the UIP equation: on one hand, it helps by almost eliminating the nominal appreciation on impact while, on the other hand, it worsens the situation by generating an expected appreciation (and therefore also a further deflation) which increases the real rate on impact.[40]

Finally, we consider the alternative of purchasing long-term debt financed by new short-term debt, which is displayed in figure 19.

[39] Because the size of the responses obtained after a negative shock are much larger than those explored when analyzing these alternative before, we increased the size of the operations analyzed to represent 50 percent of nominal GDP in steady state.

[40] In particular, if we set $\varphi_s = 0$, the nominal appreciation would be on impact smaller but, because no further appreciation would be expected, the increase in the real rate would be milder. Overall, the negative response of inflation would be reduced by just 2 percentage points, compared with almost 4 percentage points when φ_s takes the estimated value.

As expected given the results in subsection 3.2, although this operation improves the situation, its impact is of an order of magnitude smaller and therefore the differences are not noticeable. Nevertheless, we should stress the point highlighted also in that section: this alternative will probably not suffer the problems associated with the future expected behavior of the policy rate that are indeed relevant for alternatives that act through the liquidity channel.

3.6 Robustness

As a final exercise, we check the robustness of the results with respect to some parameter values. In particular, we first explore how the analysis presented in subsection 3.2 is affected by alternative values for the parameter describing the estimated frictions (plausible according to their estimated confidence bands) and also in terms of the coefficient in the Taylor rule that is assumed to follow after the temporary fix in i_t^{MP}.

Figure 20 shows the case of a purchase of foreign assets financed by a monetary expansion when the policy rate is fixed for six periods, presenting the case of the original value for φ_m (-0.0014), as well as two other alternatives representing plus and minus one standard error of the estimated parameter (-0.0007 and -0.0021). As can be seen, these differences in the coefficient affecting the liquidity channel significantly change the impact of this policy, particularly in terms of the responses of output and the real exchange rate and, to a lesser extent, in terms of inflation and nominal depreciation.

On the other hand, figure 21 presents the alternative of a purchase of long debt financed with new short debt under different values of the parameter φ_k (0.017, the point estimate, as well as 0.019 and 0.015—i.e., plus and minus two standard errors, respectively). In this case, changes in this parameter within its confidence range do not significantly affect the original responses.

We also check the robustness regarding the parameters describing the Taylor rule that will be in place after the temporary fix in the policy rate. Because agents anticipate the contractionary policy that will follow once the Taylor rule returns, the expansion generated by the unconventional policy will be smaller the more aggressive the response is with respect to inflation and output deviations, and the less important the smoothing part of the rule is. Accordingly, figure 22 displays the result of a purchase of foreign assets financed by a monetary expansion when the policy rate is fixed for six periods, considering the original Taylor rule as well as three alternative coefficients: half the response to the previous interest rate, and double the reaction to either inflation or output. As can be seen, it appears that these alternative rules affect mainly the response of output and, to a lesser extent, those of inflation and the real exchange rate.

Similarly, figure 23 shows the impact that considering the same alternative rules has on the evaluation of purchasing long debt financed with new short debt, also fixing the policy rate for six periods. In this case, the different specifications of the rule had little impact on the responses of output and inflation, while affecting more the responses of the real exchange rate and the ex ante real interest rate.

In addition, figure 24 evaluates the role of the Taylor rule's parameters for the experiment of driving the policy rate to zero for some time (subsection 3.4). For this case, what appears to generate significant difference is the smoothing coefficient, particularly for output and the real exchange rate, which was expected because this parameter will dictate how fast the interest rate can rise once the lower bound is abandoned.

As a final exercise related to subsection 3.5, we consider a model that includes exogenous habit formation in consumption. We do this for two reasons. First, this alternative will dampen the size of the recession, which (particularly in terms of GDP) seems excessive in the benchmark model. Second, the persistence of all variables will increase and therefore the zero limit will likely bind for a longer period. In particular, we set a habit parameter to 0.7, in line with previous estimates for Chile (e.g., Medina and Soto 2007). Figure 25 is analogous to figure 17 using this alternative model. Comparing both figures, the effects on output and inflation in the baseline case of no zero bound are indeed quantitatively smaller and more persistent. In terms of the policy rate, in this case it goes below zero after the third quarter. Nevertheless, it is still the case that the anticipation in the truncated-rule case generates a more severe recession and deflation, implying an equilibrium where the policy rate drops to zero right after the shock hits and then stays there endogenously for six quarters. Finally, in terms of policies that keep the rate at zero for a longer period, we can observe a qualitatively similar ranking of the responses; however, the quantitative differences between each of them are larger.

4. Conclusions

This paper uses a New Keynesian model of a small open economy to provide a quantitative evaluation of different policy alternatives that a CB can use when the nominal interest rate is fixed. In particular, we have analyzed the effects of different changes in the CB balance sheet, such as movements in the holdings of foreign assets, base money, and debt at different maturities. To allow for the possibility of the CB changing these assets, the standard model was extended to include several frictions—namely, a liquidity premium, deviations from the UIP condition, and a premium in the term structure of interest rates. Additionally, we introduced an algorithm that allows us to take into account issues like the anticipation of future policies, the (exogenous) lack of credibility in the announcements, and the role of the zero bound.

The results show that policies working through the liquidity channel can potentially have important expansionary effects, although their impact greatly depends on the perception about the future path of the interest rate and its credibility. On the other hand, policies aimed at reducing the term premium, while generating smaller expansions, are less dependent on the expected behavior of the policy rate and on credibility issues. Additionally, it seems that reversing the unconventional policy as a possible exit strategy might not be beneficial, particularly if these changes are anticipated. Finally, we described how driving the policy rate down to its lower bound and maintaining it at that value for some time can be highly expansionary as well, although the issues regarding the credibility of the announcement are also relevant in this case.

It is useful to compare these results with those in Eggertsson and Woodford (2003). Using a simpler model (in particular, a closed economy), their analysis suggests that the channel that is relevant to escape from a zero-bound situation is to affect the expectations about future inflation. Moreover, they show that the optimal policy in such a situation is a price level target. In our case, although we are not characterizing the optimal policy, we have described that the potentially big effect generated by policies affecting the liquidity premium is due to the increase in the future price level brought about by the permanent increase in base money, resembling the channel emphasized by these authors. Additionally, they also highlight that the effectiveness of this policy depends on the credibility of the announcement.[41]

It is also worth mentioning that, although in our setup money is what helps reduce the liquidity premium, there is nothing exclusively special about money. Actually, in more general settings where other assets can affect this premium (for instance, it might be the case that short-run debt provides liquidity as well), a permanent increase in such an asset can also generate the same effect, and its importance will also be subject to the same caveats about the expected path of interest rates and credibility that we have analyzed.

Additionally, it is worth mentioning that unconventional monetary strategies might not necessarily be the only (nor the most effective) policy alternatives available to use in a zero-bound situation. In particular, there are several fiscal tools that can be used as well. For instance, Christiano, Eichenbaum, and Rebelo (2009) describe that the government-expenditure multiplier is actually quite large when the nominal interest rate is at its lower bound. Additionally, Eggertsson (2006) highlights that government debt can be used as a commitment device to ameliorate the credibility issues associated with the optimal monetary policy. Our goal, however, was to analyze the virtues of these monetary alternatives, and we left the interaction with fiscal tools for future research.[42]

Finally, an important extension that is left for future research is to rank the different alternatives from the point of view of optimal policy. However, as we have argued, this is the kind of exercise in which having a more precise microfoundation of the different channels is most relevant. Nevertheless, this study shed light on the aspects of the model that might be more relevant to consider.

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[41] Eggertsson (2006) formally discusses the issues of credibility arising from this optimal policy.

[42] Moreover, in terms of the country we chose for the application, Chile has had a fiscal rule in place since 2001, limiting the fiscal deficits according to the revenues from copper exports. This characteristic places a bound on the type of fiscal tools that can be implemented, which further emphasizes the importance of analyzing the monetary alternatives.

Appendix 1. Technical Appendix

The Lower Bound, Anticipating Policy Changes, and Credibility in Linear Rational Expectations Models

Here we describe the algorithm to compute the policy exercises in the paper.[43] In a contemporaneous work, Bodenstein, Erceg, and Guerrieri (2009) present a similar algorithm, considering how to compute impulse responses when, given an initial shock, the interest rate reaches the lower bound endogenously through the Taylor rule. Here, we additionally consider the possibility that the central bank chooses (exogenously, as a policy) to fix the interest rate, deviating from the Taylor rule, to a given value (possibly zero) for a certain period of time. Moreover, we allow agents to assign an exogenous probability to the central bank breaking its promise and returning to the usual rule before it was announced. We also show how to compute the equilibrium trajectories when the unconventional policy is reversed, either surprisingly or anticipated.

The first exercise we want to consider is when the central bank announces, at time t_0, that the interest rate is going to stay at the lower bound until period $t_1 - 1$, and starting at t_1 the rate will be determined by the Taylor rule. The Taylor rule in "normal times" is constrained by the lower bound, so that the policy rate (measured as deviations from steady state) is

$$i_t = max\{-i, i_t^{target}\}, \tag{10}$$

where i is the steady-state value of the policy rate and the targeted policy rate is a linear function of any variable in the model (for instance, $i_t^{target} = \phi_i i_{t-1} + \phi_\pi \pi_t + \phi_y y_t$).[44] In particular, this implies that, even though the central bank can guarantee to keep the interest rate at the lower bound up to period $t_1 - 1$, the state of the economy could be such that the target rate is below $-i$ at t_1. Therefore, because the algorithm works with the idea of backward induction, we first describe how to compute the equilibrium for a given initial value of the state variables and the exogenous process

[43] Although we focus on applying the technique for the case analyzed in the paper, notice that this method is quite general and can accommodate many examples in these lines.

[44] It is, however, assumed that the constraint doesn't bind at the steady state.

when the policy rate is determined by the rule (10) (i.e., when the zero bound binds endogenously), and then we explore the solution for the period in which the government sets the policy rate at the lower bound (i.e., when the zero bound is imposed exogenously, as a policy choice).

At any point in time in which the $i_t = i_t^{target}$ endogenously, the conditions characterizing a linear rational expectations equilibrium can be written as

$$AE_t\{z_{t+1}\} = Bz_t + Cz_{t-1} + De_t, \tag{11}$$

where z_t is a vector collecting endogenous variables (including i_t and i_t^{target}), e_t is exogenous driving forces following the process $e_t = \rho e_{t-1} + u_t$, u_t is a vector of i.i.d random disturbances with zero mean, and A, B, C, and D are conformable matrices describing the linearized equilibrium conditions. In particular, if n_1 denotes the position in the vector z_t of the variable i_t and n_2 is analogous to the variable i_t^{target}, there is an equation j in the system such that (using Matlab notation) $A(j,:) = C(j,:) = D(j,:) = 0$ while $B(j,n_1) = -1$, $B(j,n_2) = 1$, and $B(j,l) = 0$ for $l \neq \{n_1,n_2\}$. On the other hand, when $i_t = -i$, the equilibrium is characterized by the system

$$AE_t\{z_{t+1}\} = \tilde{B}z_t + Cz_{t-1} + De_t + c, \tag{12}$$

where $\tilde{B}$ differs from B only in that $\tilde{B}(j,n_2) = 0$ and c is a column vector full of zeros except in position j where $c(j) = -i$.

The algorithm works under the assumption (which we later discuss) that if, starting at any given period t_1, there is a period $t \geq t_1$ such that $i_t = i_t^{target}$, then $i_{t+j} = i_{t+j}^{target}$ for $j > 0$ (i.e., if at some point the constraint on the interest rate ceases to bind, it will not bind again after that). Let T denote the minimum $t \geq t_1$ such that the constraint is no longer binding (i.e., $i_t = i_t^{target}$ for $t \geq T$ and $i_{T-1} = -i$) and assume for the moment that T is known. Therefore, the solution characterizing the equilibrium for $t \geq T$—obtained using the usual techniques—can be written as

$$z_t = F_T z_{t-1} + G_T e_t. \tag{13}$$

At period $T-1$ the policy rate is at the lower bound and the equilibrium is characterized by (12). Moreover, because agents know at T, $i_T = i_T^{target}$, they will use (13) to form expectations, i.e., $E_{T-1}\{z_T\} = F_T z_{T-1} + G_T \rho e_{T-1}$. Therefore, we can write the equilibrium conditions at $T-1$ as

$$A(F_T z_{T-1} + G_T \rho e_{T-1}) = \tilde{B} z_{T-1} + C z_{T-2} + D e_{T-1} + c, \tag{14}$$

which can be rearranged to obtain

$$\begin{aligned} z_{T-1} &= (AF_T - \tilde{B})^{-1} C z_{T-2} + (AF_T - \tilde{B})^{-1}(D - AG_T \rho) e_{T-1} \\ &\quad + (AF_T - \tilde{B})^{-1} c, \\ &\equiv F_{T-1} z_{T-2} + G_{T-1} e_{T-1} + H_{T-1} c, \end{aligned} \tag{15}$$

provided $AF_T - \tilde{B}$ is invertible. Working in this same way backwards until t_1, we can compute the equilibrium for $t \in [t_1, T-1]$, which will have the form

$$z_t = F_t z_{t-1} + G_t e_t + H_t c,$$

where

$$\begin{aligned} J_t &\equiv (AF_{t+1} - \tilde{B})^{-1}, \\ F_t &\equiv J_t C, \\ G_t &\equiv J_t (D - AG_{t+1} \rho), \\ H_t &\equiv J_t(-AH_{t+1} + I) \text{ for } t \in [t_1, T-2], \;\; H_{T-1} \equiv (AF_T - \tilde{B})^{-1}. \end{aligned} \tag{16}$$

Therefore, using these matrices, for initial values of z_{t_1-1} and e_{t_1-1} we can obtain the perfect foresight path (impulse response) for a given shock u_{t_1}, under the assumption that T is known. To find T, we can just run a progressive search starting on t_1 and find the first period for which $i_T = i_T^{target}$ and $i_{T-1} = -i$.

Before moving to the case in which the central bank imposes the lower bound, two comments are in order. First, notice that once T is found, the assumption that $i_t = i_t^{target}$ for $t \geq T$ can be verified numerically by simulating the path for the variables for many periods beyond T (by construction, the assumption will hold in steady state). Second, the extension for the case in which, given values z_{t_1-1} and u_{t_1}, the lower bound is expected to be reached in a period after t_1 is straightforward, which in our case is particularly relevant to check when analyzing the response of a contractionary shock in subsection 3.5.

To consider the case in which the central bank announces, at time t_0, that the interest rate is going to stay at the lower bound until period $t_1 - 1$, and starting at t_1 the rate will be determined by the Taylor rule, notice that the matrices in (17) characterize any backward induction problem in which the policy rate is expected to be at the lower bound for a certain period of time. Therefore, given an announced period t_1 and an initial shock u_{t_0}, we can proceed as follows. First, assuming that $T = t_1$ (i.e., that after the period the central bank has announced the state of the economy is such that the constraint on the policy rate is not binding), compute the matrices characterizing the equilibrium according to (17) and numerically verify whether $i_t = i_t^{target}$ for $t \geq t_1$ or not. If that is not the case, increase the candidate value for T until the condition is satisfied.[45]

We can also consider the role of exogenous credibility. In particular, we assume that in every period $t \in [t_0, t_1 - 2]$ when the interest rate is fixed, people assign a probability sequence p_t to the event that the central bank breaks its promise and sets the nominal interest rate according to the Taylor rule starting at $t + 1$. Moreover, if this is the case, they believe that the Taylor rule will stay forever. Additionally, regardless of people not trusting the central bank, we assume that (ex post) it fulfills its promises.

This possibility is accommodated by simply modifying the equations in (17) to obtain

$$\begin{aligned}
J_t &\equiv [A(p)tF_{t_1} + (1 - p_t)F_{t+1}) - \tilde{B}]^{-1}, \\
F_t &\equiv J_t C, \\
G_t &\equiv J_t[D - A(p_t G_{t_1} + (1 - p_t)G_{t+1})\rho], \\
H_t &\equiv J_t[-A(1 - p_t)H_{t+1} + I] \text{ for } t \in [t_0, t_1 - 2], \\
H_{t_1 - 1} &\equiv (AF_{t_1} - \tilde{B})^{-1}.
\end{aligned}$$

Finally, to consider an unconventional policy in t_0, we just assign values at t_0 for the shocks affecting the different instruments in the

[45] Notice that if we want to consider fixing the interest rate not at zero but to any arbitrary value, this can be done by setting an appropriate value for the constant c.

central bank's balance sheet. Additionally, the alternative of undoing these policies is also considered by placing appropriate values for the sequence u_t: if the change is not pre-announced we just change the value in the corresponding period, and if the change is pre-announced we can expand the exogenous vector e_t to consider anticipated shocks.

The Model

Here we present the equilibrium conditions of the model, as well as the calibration of the parameters. It is a standard New Keynesian model for a small open economy with incomplete asset markets. Households have separable preferences in consumption and leisure and can transfer resources over time using an internationally traded bond, as well as the debt created by the central bank. They consume a combination of domestic and foreign goods. There is an infinite number of monopolistic intermediate goods firms that use labor to produce using a constant returns to scale technology. They are subject to a Calvo-type problem in setting prices, with full indexation to past inflation. The equilibrium conditions associated with household optimization are[46]

$$\lambda_t = (c_t - bc_{t-1})^{-\sigma}, \tag{17}$$

$$w_t = \phi_0 l_t^{\phi_1} c_t^{\sigma}, \tag{18}$$

$$\lambda_t = \beta v_t i_{1,t} E_t \left\{ \frac{\lambda_{t+1}}{\pi_{t+1}} \right\} \left(\frac{D_{k,t}^{BC} / D_k^{BC}}{D_{1,t}^{BC} / D_1^{BC}} \right)^{\varphi_k}, \tag{19}$$

$$\lambda_t = \beta v_t i_t^* cp_t E_t \left\{ \frac{S_{t+1}\lambda_{t+1}}{S_t \pi_{t+1}} \right\} \left(\frac{B_t^{*BC}}{B_{t-1}^{*BC}} \right)^{\varphi_s}, \tag{20}$$

$$c_t = \left[(1-a)^{\frac{1}{\eta}} \left(c_t^H\right)^{\frac{\eta-1}{\eta}} + (a)^{\frac{1}{\eta}} \left(c_t^F\right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}. \tag{21}$$

[46]Variables without time subscripts denote steady-state values. Prices have been rescaled by the price index. Recall that in the case of (19), (20), and (24), which display the deviations from the standard model, these are imposed ad hoc over the usual equilibrium conditions and are not derived from microfoundations.

$$c_t^F = a\left(p_t^F\right)^{-\eta} c_t, \tag{22}$$

$$c_t^H = (1-a)\left(p_t^H\right)^{-\eta} c_t, \tag{23}$$

$$\frac{i_{1,t}}{i_t^{MP}} = \left(\frac{M_t}{P_t y_t}\frac{Py}{M}\right)^{-\varphi_m}. \tag{24}$$

Those related to firms' choices are[47]

$$y_t^H = z_t l_t - \kappa, \tag{25}$$

$$mc_t = \frac{w_t}{p_t^H z_t}, \tag{26}$$

$$f_t^1 = mc_t\left(\tilde{p}_t^H\right)^{-\epsilon} y_t^H + \theta\beta E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\pi_t}{\pi_{t+1}}\right)^{-\epsilon}\left(\frac{\tilde{p}_t^H}{\tilde{p}_{t+1}^H}\right)^{-\epsilon}\left(\frac{p_t^H}{p_{t+1}^H}\right)^{-1-\epsilon} f_{t+1}^1\right\}, \tag{27}$$

$$f_t^2 = \left(\tilde{p}_t^H\right)^{1-\epsilon} y_t^H\left(\frac{\epsilon-1}{\epsilon}\right) + \theta\beta E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\pi_t}{\pi_{t+1}}\right)^{1-\epsilon}\left(\frac{\tilde{p}_t^H}{\tilde{p}_{t+1}^H}\right)^{1-\epsilon}\left(\frac{p_t^H}{p_{t+1}^H}\right)^{-\epsilon} f_{t+1}^2\right\}, \tag{28}$$

$$f_t^1 = f_t^2. \tag{29}$$

The conditions associated with rest-of-the-world variables are

$$cp_t = \psi_d\left(e^{-p_t^F b_{t+1}^* + \bar{b}} - 1\right), \tag{30}$$

$$\frac{p_t^F}{p_{t-1}^F} = \frac{S_t \pi_t^*}{S_{t-1}\pi_t}, \tag{31}$$

[47]The assumption of full indexation to past inflation yields that, up to first order, the distortion that, in principle, price stickiness introduces (i.e., a gap between production and absorption) is not relevant even if steady-state inflation is different from zero.

Table 1. Calibration

σ	1	ϕ_1	0.84	a	0.34
η	1.12	ϵ	11	η^*	0.79
θ	0.74	ψ_d	0.01	μ_m	0.2
ρ_i	0.74	α_π	1.67	α_y	0.39
i^*	1.0025	i	1.016	π	1.0074
l	0.2	$\frac{D_1^{CB}+D_k^{CB}}{M}$	1.8	$\frac{D_k^{CB}}{D_1^{CB}}$	0.8

$$c_t^{H*} = \left(\frac{p_t^H}{p_t^f}\right)^{-\eta^*} y_t^*. \tag{32}$$

Market clearing conditions are

$$1 = \theta\left(\frac{p_{t-1}^H \pi_{t-1}}{p_t^H \pi_t}\right)^{1-\epsilon} + (1-\theta)\left(\tilde{p}_t^H\right)^{1-\epsilon}, \tag{33}$$

$$y_t^H = c_t^H + c_t^{H*}, \tag{34}$$

$$y_t = c_t + p_t^H c_t^{H*} - p_t^F c_t^F, \tag{35}$$

$$tb_t = p_t^H c_t^{H*} - p_t^F c_t^F, \tag{36}$$

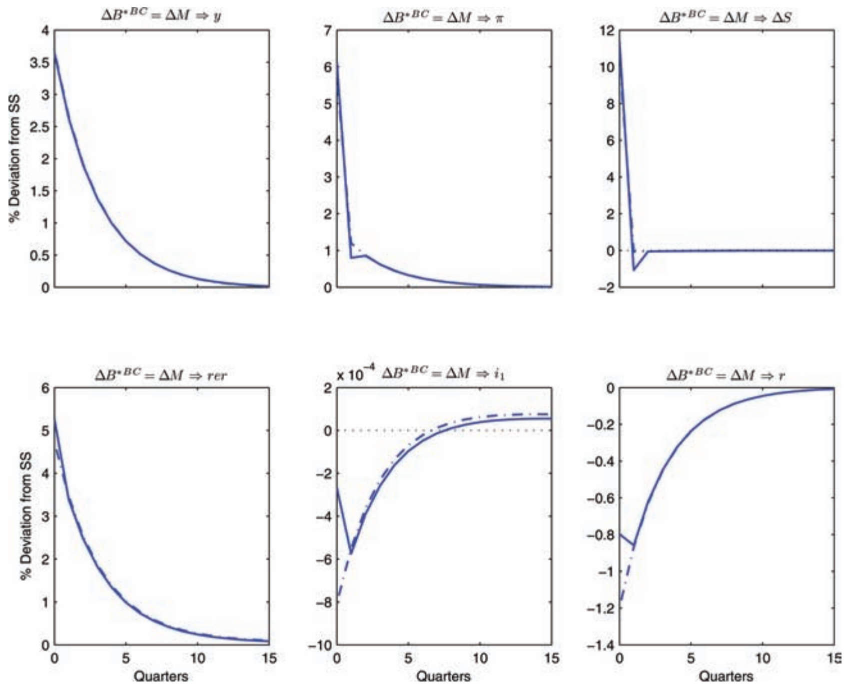
$$p_t^F b_{t+1}^* = p_t^F \frac{b_t^*}{\pi_t^*} i_{t-1}^* cp_{t-1} + tb_t. \tag{37}$$

Finally, monetary policy is as described in the text.

We calibrate the parameters following the structural estimation for Chile performed by Medina and Soto (2007), and the steady-state ratios of the variables in the CB balance sheet are taken from the average of the series used for estimation described in the text. The time period is meant to be a quarter. Table 1 presents the parameters and steady-state variables that were calibrated. Also, in the baseline version we consider no habits ($b = 0$) while in the robustness section we set $b = 0.7$. Finally, we assume that the frictions disappear in steady state. This implies that we need to introduce a demand for real balances in steady state, which we choose to be $M/P = y(i)^{-\mu_m}$.

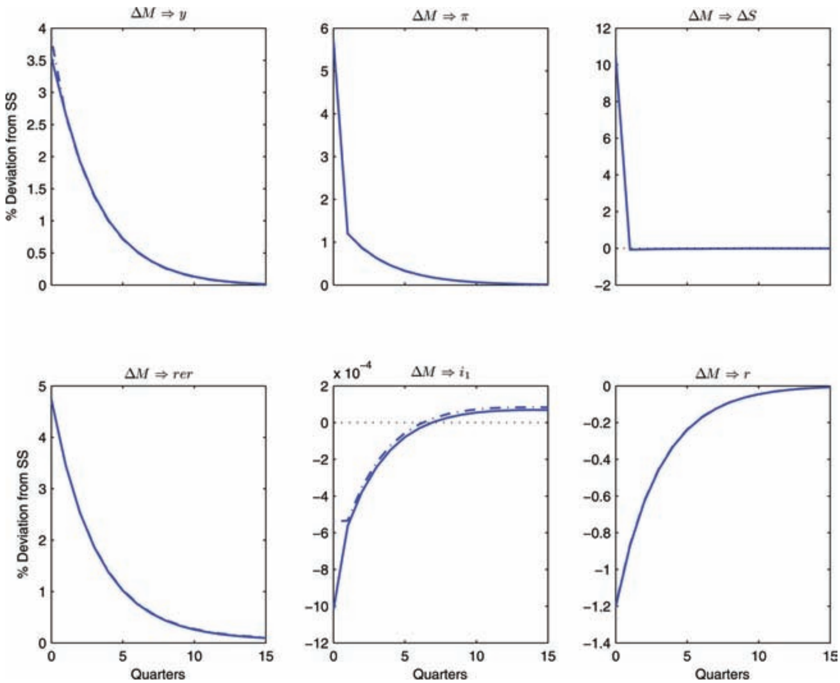
Appendix 2. Figures

Figure 1. Purchase of Foreign Assets Financed with a Monetary Expansion



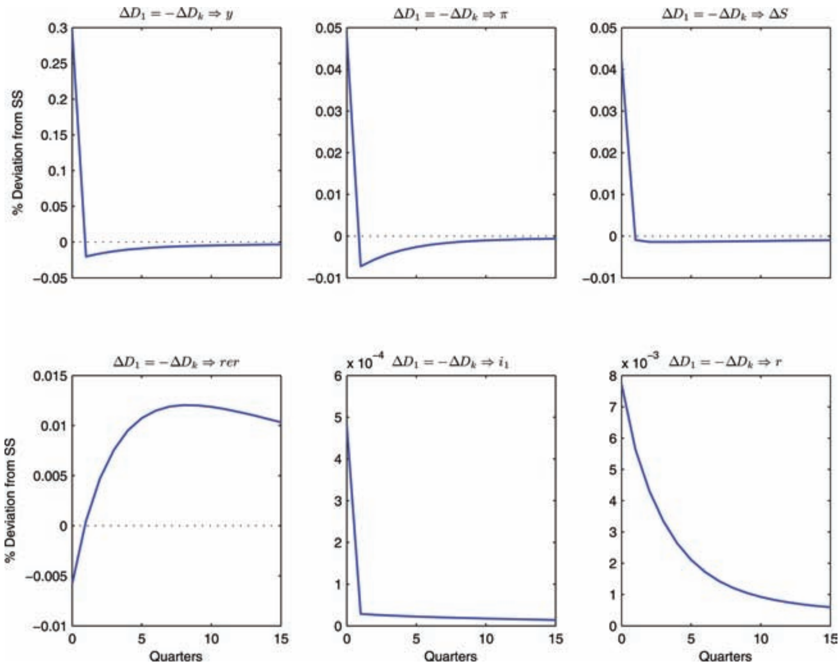
Note: y is real GDP, π is inflation, ΔS is nominal depreciation, rer is the real exchange rate, and $r_t \equiv i_{1,t} - E_t\pi_{t+1}$ is the ex ante real interest rate. All variables are in log-deviations from steady state. The shock is a permanent increase in B_t^{*CB} equivalent to 10 percent of nominal GDP in steady state, while i_t^{MP} remains in its steady-state value forever. The solid line is the benchmark case, while the dashed-dotted line is the case with $\varphi_d = \varphi_s = 0$.

Figure 2. Purchase of Debt Financed with a Monetary Expansion



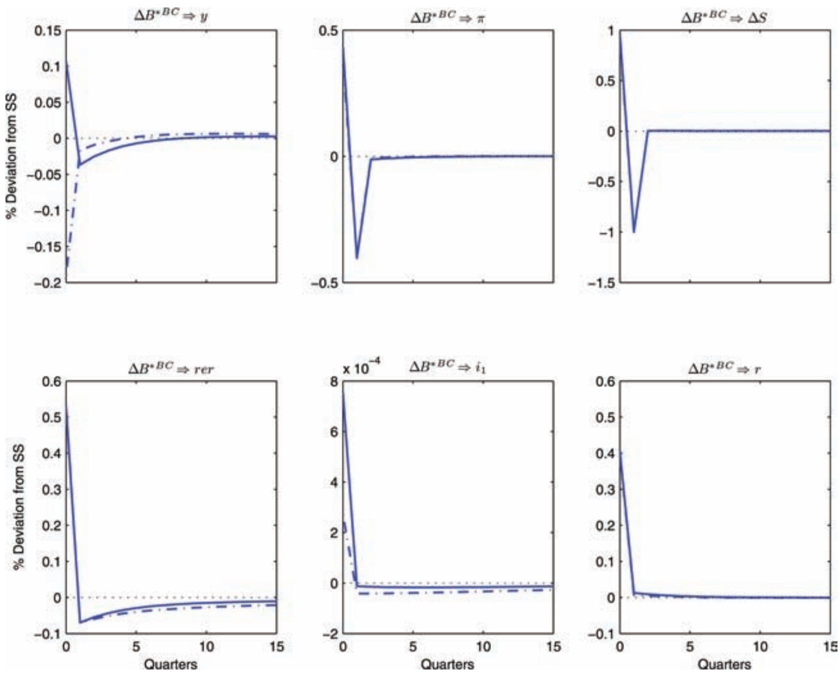
Note: The solid line corresponds to a purchase of short debt, $D_{1,t}$, and the dashed-dotted line is purchase of long debt, $D_{k,t}$. The shock is a permanent increase in M_t equivalent to 10 percent of nominal GDP in steady state, while i_t^{MP} remains in its steady-state value forever.

Figure 3. Purchase of Long Debt Financed with New Short Debt



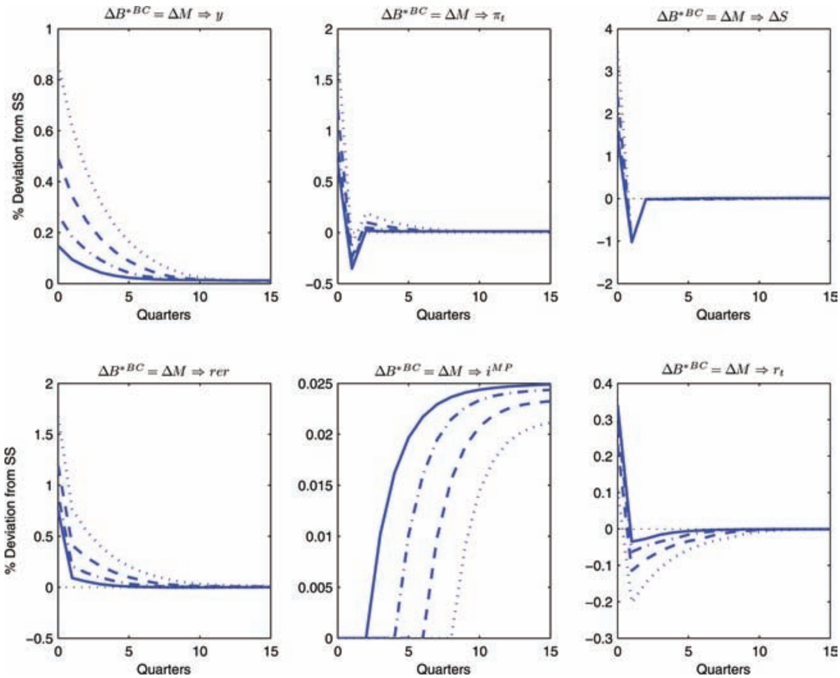
Note: The shock is a permanent increase in $D_{1,t}$ equivalent to 10 percent of nominal GDP in steady state, while i_t^{MP} remains in its steady-state value forever.

Figure 4. Purchase of Foreign Assets Financed with New Debt



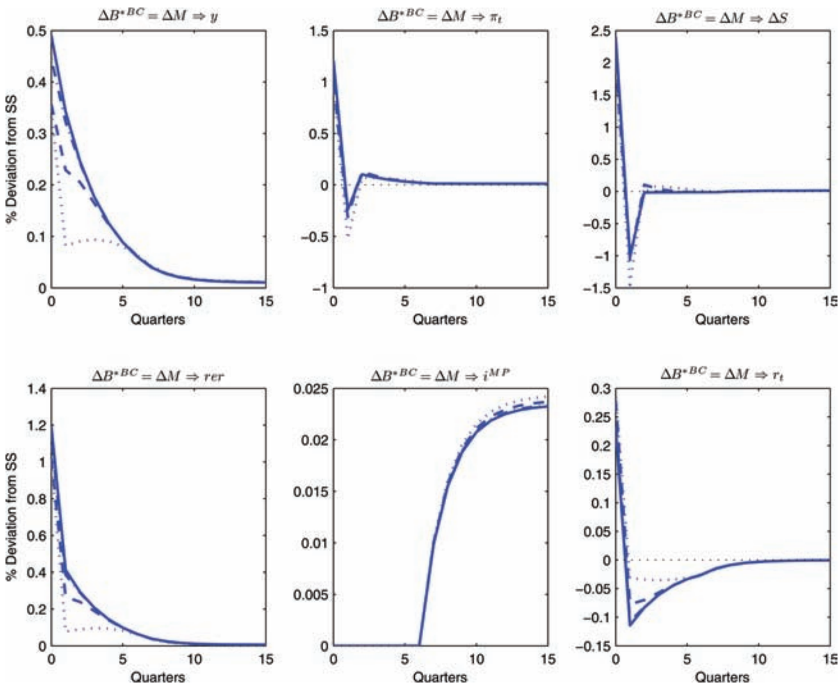
Note: The solid line corresponds to new short debt, $D_{1,t}$, and the dashed-dotted line is new long debt, $D_{k,t}$. The shock is a permanent increase in B_t^{*CB} equivalent to 10 percent of nominal GDP in steady state, while i_t^{MP} remains in its steady-state value forever.

Figure 5. Purchase of Foreign Assets Financed with a Monetary Expansion: Different T's, $p_t = 0$



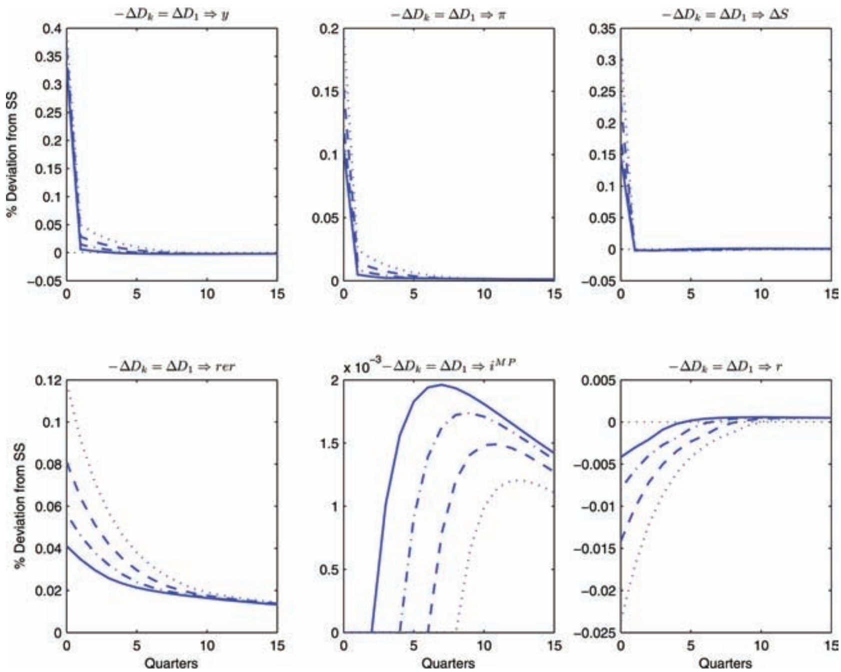
Note: The solid, dashed-dotted, dashed, and dotted lines correspond, respectively, to $T = 2, 4, 6, 8$. The shock is a permanent increase in B_t^{*CB} equivalent to 10 percent of nominal GDP in steady state, while i_t^{MP} remains in its steady-state value until T.

Figure 6. Purchase of Foreign Assets Financed with a Monetary Expansion: $T = 6$, $p_t = p^t$, Different p's



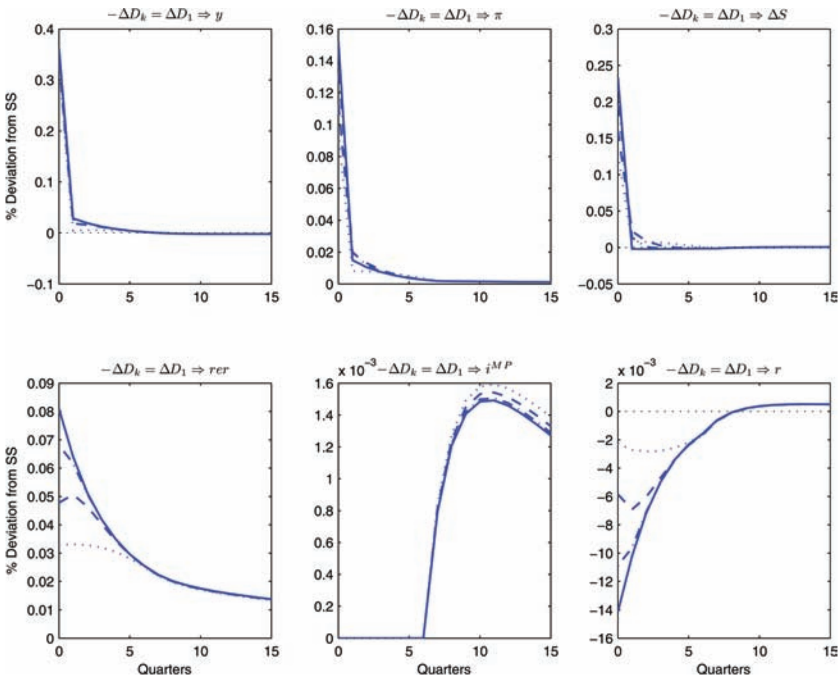
Note: The solid, dashed-dotted, dashed, and dotted lines correspond, respectively, to $p = 0, 0.3, 0.6, 0.9$. The shock is a permanent increase in B_t^{*CB} equivalent to 10 percent of nominal GDP in steady state, while i_t^{MP} remains in its steady-state value until T.

Figure 7. Purchase of Long Debt Financed with New Short Debt: Different T's, $p_t = 0$



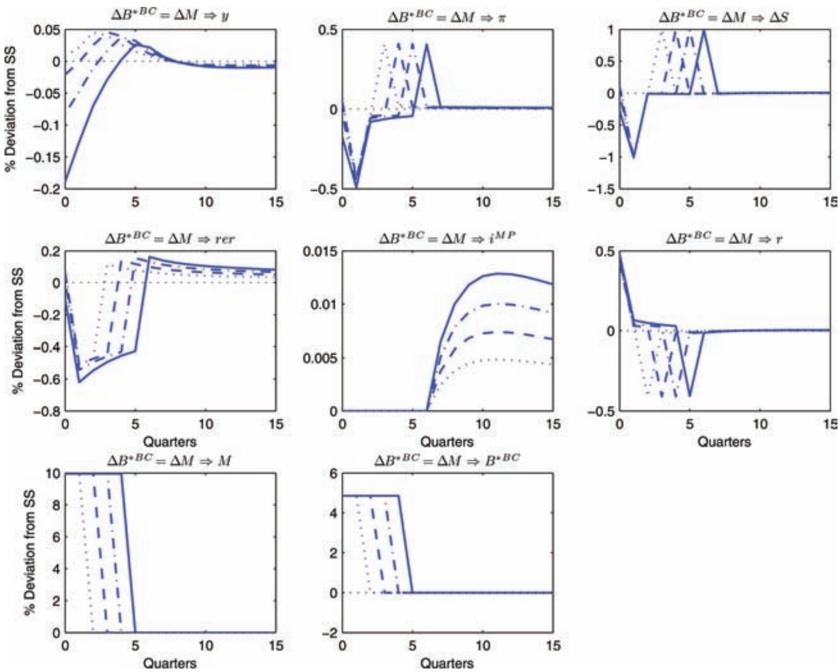
Note: The solid, dashed-dotted, dashed, and dotted lines correspond, respectively, to $T = 2, 4, 6, 8$. The shock is a permanent increase in B_t^{*CB} equivalent to 10 percent of nominal GDP in steady state, while i_t^{MP} remains in its steady-state value until T.

Figure 8. Purchase of Long Debt Financed with New Short Debt: $T = 6$, $p_t = p^t$, Different p's



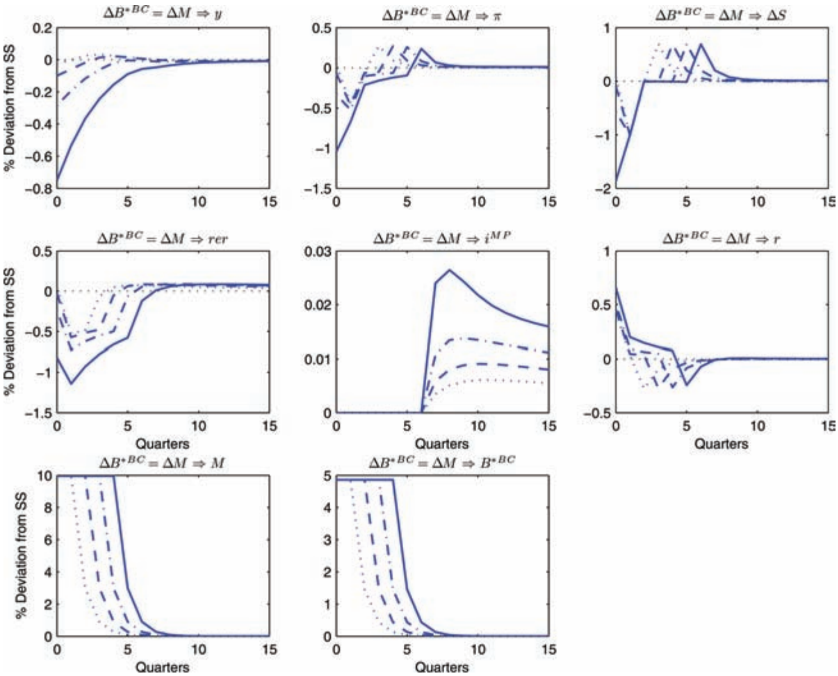
Note: The solid, dashed-dotted, dashed, and dotted lines correspond, respectively, to $p = 0, 0.3, 0.6, 0.9$. The shock is a permanent increase in B_t^{*CB} equivalent to 10 percent of nominal GDP in steady state, while i_t^{MP} remains in its steady-state value until T.

Figure 9. Purchase of Foreign Assets Financed with a Monetary Expansion, Pre-Announced Reversal, Different k's



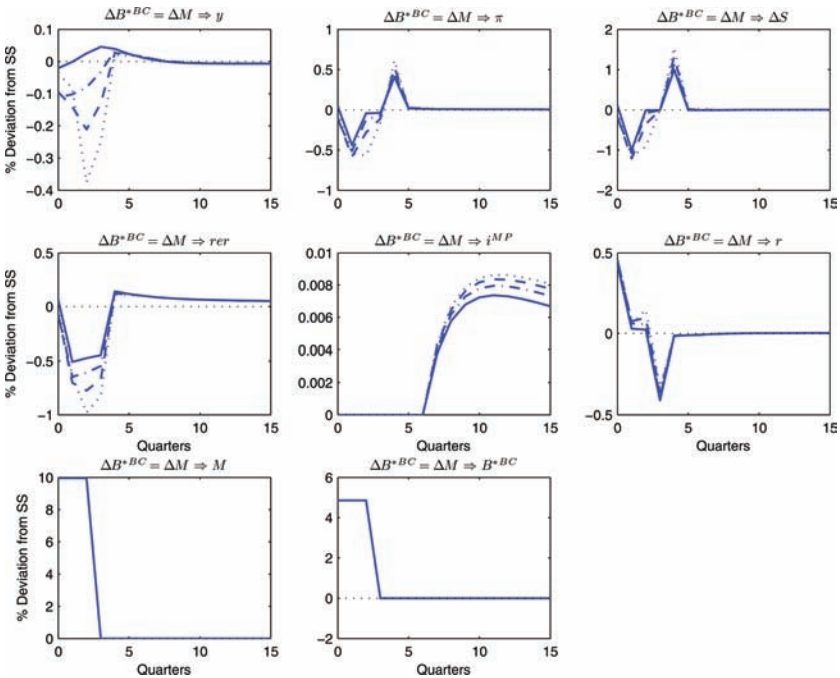
Note: The solid, dashed-dotted, dashed, and dotted lines correspond, respectively, to $k = 2, 3, 4, 5$, with $T = 6$. The shock is a permanent increase in B_t^{*CB} equivalent to 10 percent of nominal GDP in steady state, which is fully reversed in $T - k$, while i_t^{MP} remains in its steady-state value until T.

Figure 10. Purchase of Foreign Assets Financed with a Monetary Expansion, Pre-Announced Gradual Reversal, Different k's



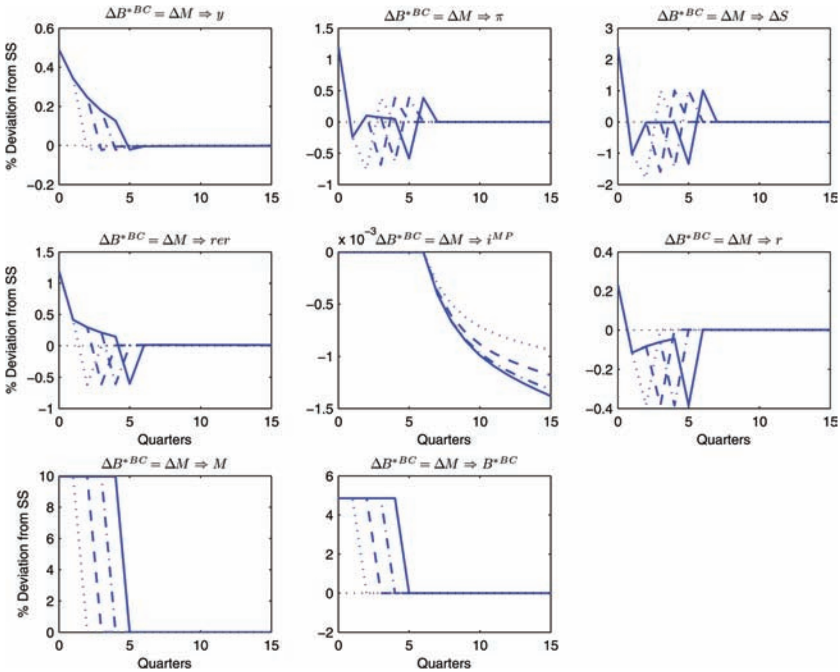
Note: The solid, dashed-dotted, dashed, and dotted lines correspond, respectively, to $k = 2, 3, 4, 5$, with $T = 6$. The shock is a permanent increase in B_t^{*CB} equivalent to 10 percent of nominal GDP in steady state, which is reversed slowly starting at $T - k$, while i_t^{MP} remains in its steady-state value until T.

Figure 11. Purchase of Foreign Assets Financed with a Monetary Expansion, Pre-Announced Reversal, $p_t = p^t$, Different p's



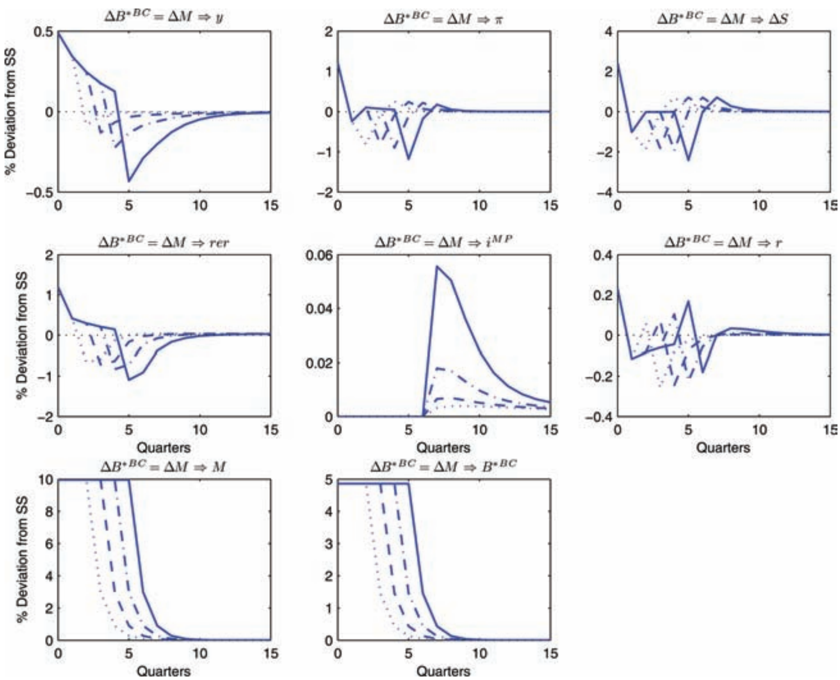
Note: The solid, dashed-dotted, dashed, and dotted lines correspond, respectively, to $p = 0, 0.3, 0.6, 0.9$. The shock is a permanent increase in B_t^{*CB} equivalent to 10 percent of nominal GDP in steady state, which is fully reversed in $T - k$, with $T = 6$ and $k = 4$, while i_t^{MP} remains in its steady-state value until T.

Figure 12. Purchase of Foreign Assets Financed with a Monetary Expansion, Unexpected Reversal, Different *k*'s



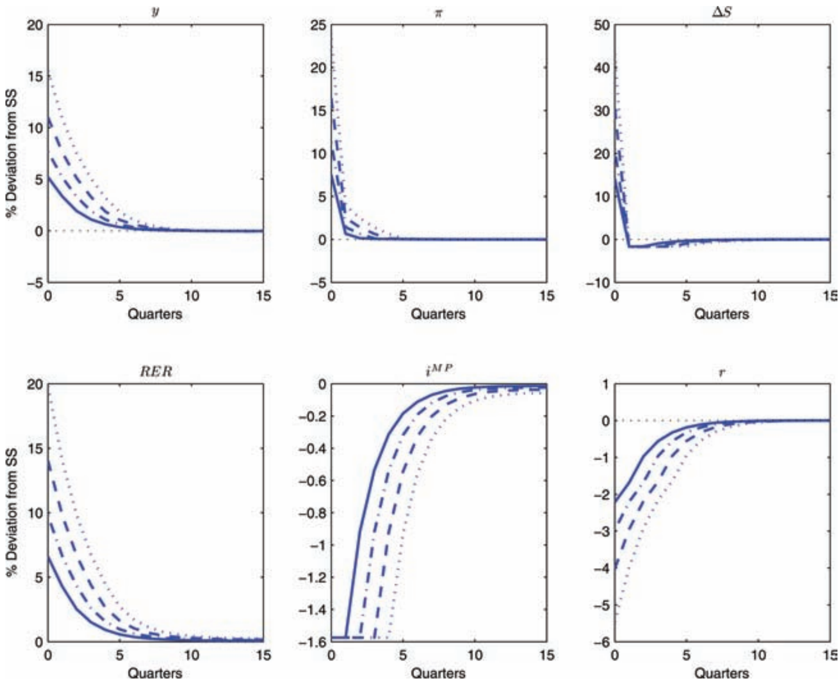
Note: The solid, dashed-dotted, dashed, and dotted lines correspond, respectively, to $k = 2, 3, 4, 5$, with $T = 6$. The shock is a permanent increase in B_t^{*CB} equivalent to 10 percent of nominal GDP in steady state, which is fully reversed in $T-k$ but is not anticipated, while i_t^{MP} remains in its steady-state value until T.

Figure 13. Purchase of Foreign Assets Financed with a Monetary Expansion, Unexpected Gradual Reversal, Different k's



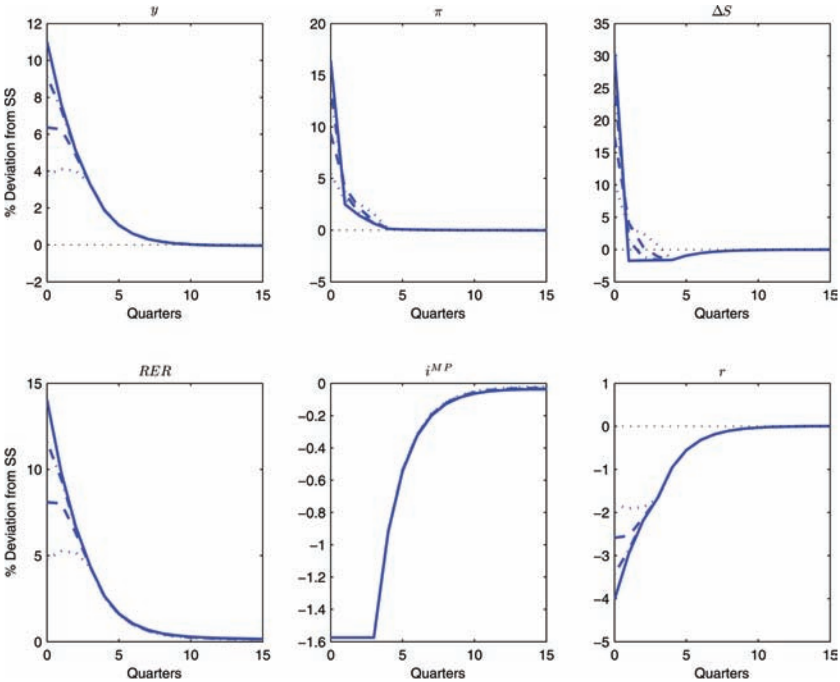
Note: The solid, dashed-dotted, dashed, and dotted lines correspond, respectively, to $k = 2, 3, 4, 5$, with $T = 6$. The shock is a permanent increase in B_t^{*CB} equivalent to 10 percent of nominal GDP in steady state, which is reversed slowly starting at $T - k$ but is not anticipated, while i_t^{MP} remains in its steady-state value until T.

Figure 14. Driving i_t^{mp} to Zero: Different T's, $p_t = 0$



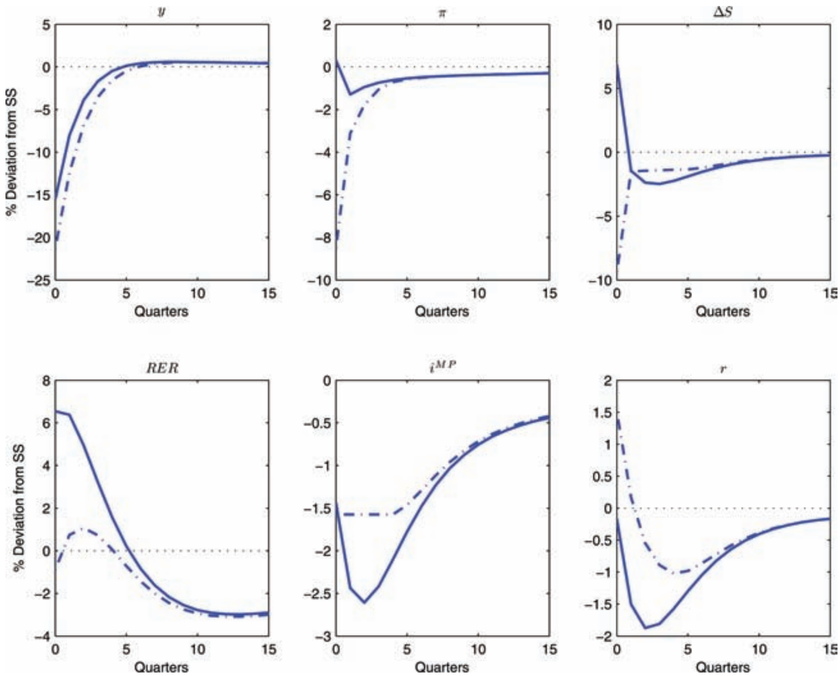
Note: The solid, dashed-dotted, dashed, and dotted lines correspond to the response of driving i_t^{MP} to zero and keeping it at this value until, respectively, $T = 1, 2, 3, 4$.

Figure 15. Driving i_t^{mp} to Zero: $T = 3$, $p_t = p^t$, Different p's



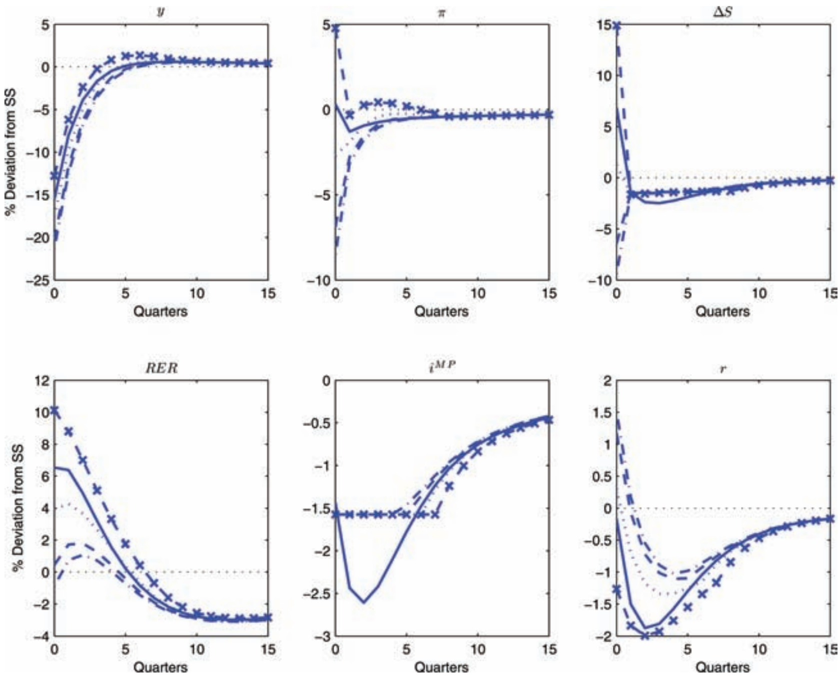
Note: The solid, dashed-dotted, dashed, and dotted lines correspond to the response of driving i_t^{MP} to zero and keeping it at this value until $T = 3$, with $p_t = p^t$ and, respectively, $p = 0, 0.3, 0.6, 0.9$.

Figure 16. The Effects of a Contractionary Shock Under Different Policy Rules



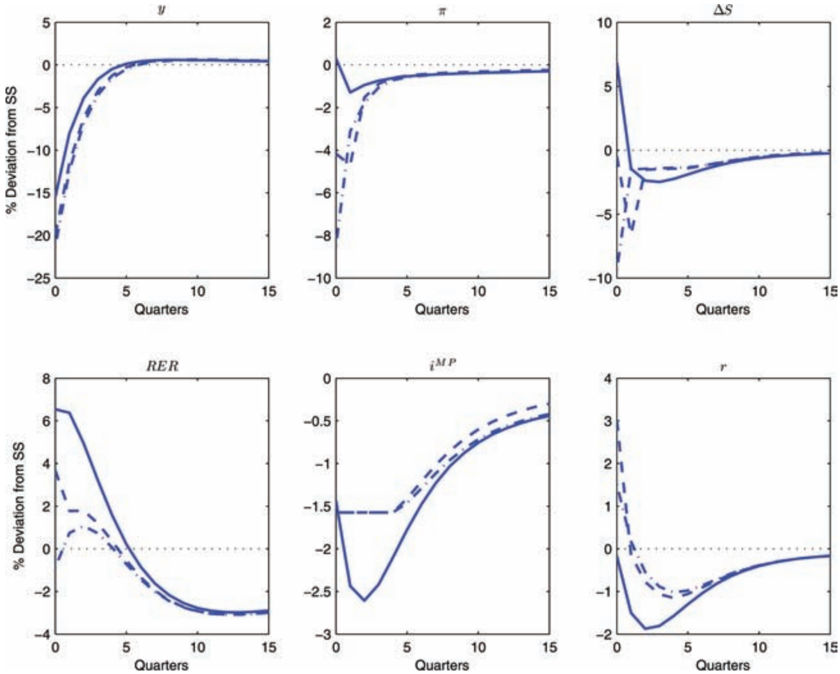
Note: The solid line shows the case when the policy rate is allowed to be negative, while the dashed-dotted line considers a truncated Taylor rule.

Figure 17. The Effects of a Contractionary Shock and Departures from the Taylor Rule



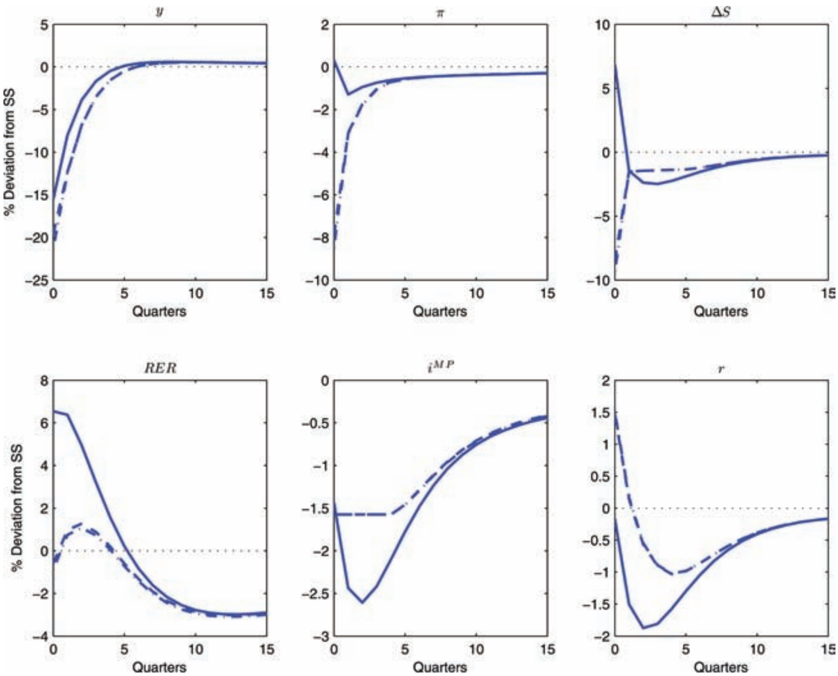
Note: The solid line shows the case when the policy rate is allowed to be negative; the dashed-dotted line considers a truncated Taylor rule; and the dashed, the dotted, and the crossed lines are the cases when i_t^{MP} is driven to zero and maintained at this value for, respectively, five, six, and seven quarters.

Figure 18. The Effects of a Contractionary Shock and Purchase of Foreign Assets Financed with a Monetary Expansion



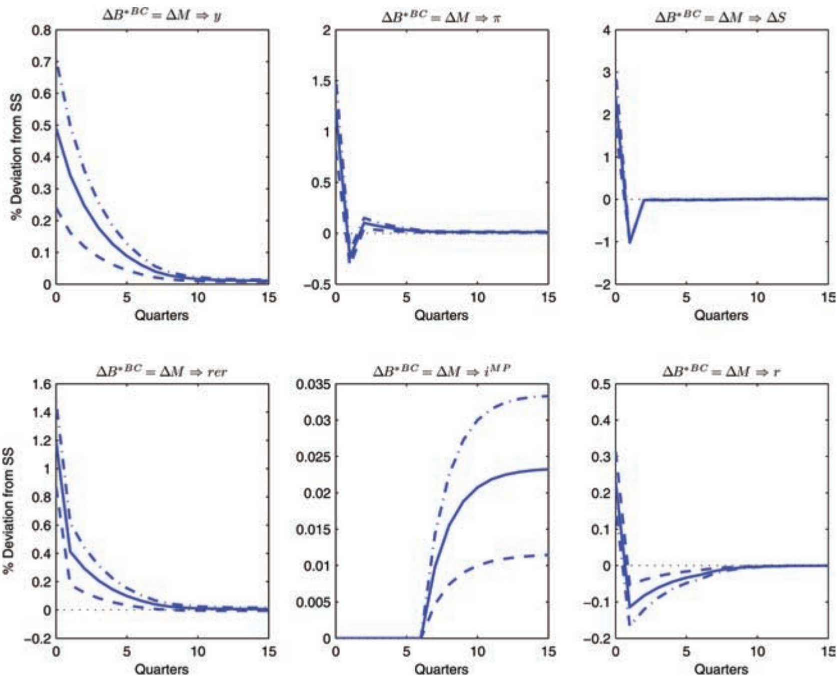
Note: The solid line shows the case when the policy rate is allowed to be negative, the dashed-dotted line considers a truncated Taylor rule, and the dashed line is the case of a truncated Taylor rule coupled with a purchase of foreign assets financed with a monetary expansion equivalent to 50 percent of the steady-state nominal GDP.

Figure 19. The Effects of a Contractionary Shock and Purchase of Long Debt Financed with New Short Debt



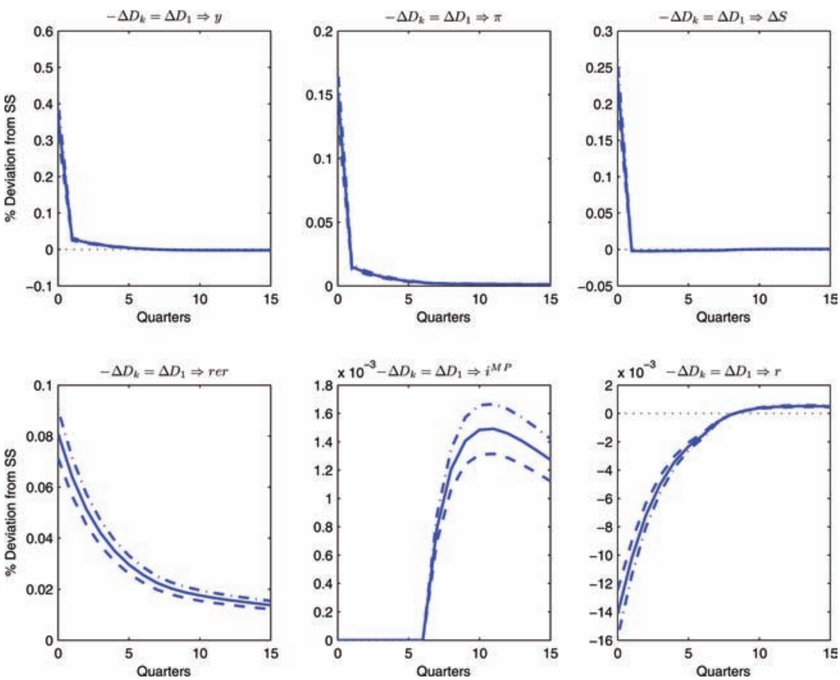
Note: The solid line shows the case when the policy rate is allowed to be negative, the dashed-dotted line considers a truncated Taylor rule, and the dashed line is the case of a truncated Taylor rule coupled with a purchase of long debt financed with new short debt equivalent to 50 percent of the steady-state nominal GDP.

Figure 20. Purchase of Foreign Assets Financed with a Monetary Expansion: $T = 6$, $p_t = 0$, Robustness with Respect to φ_m



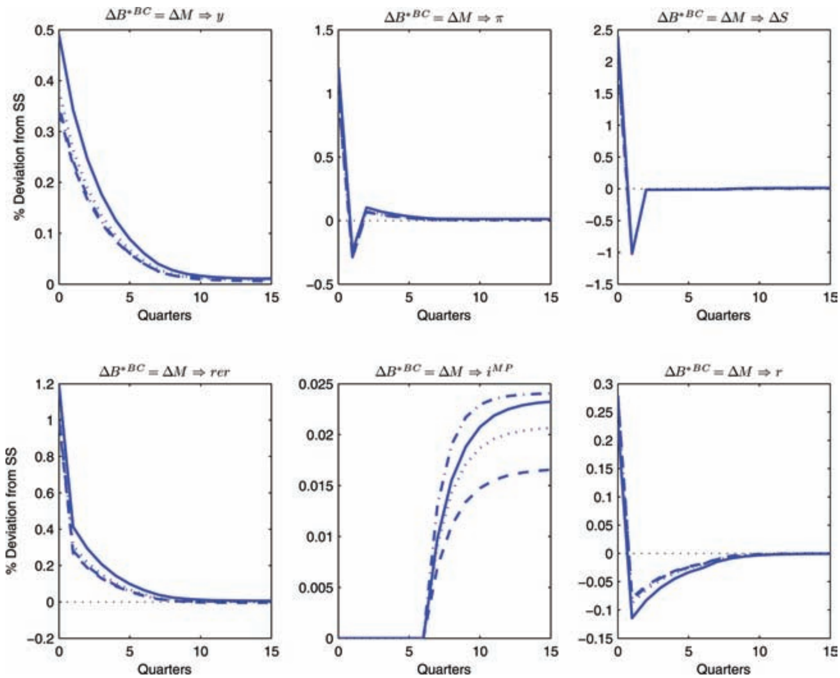
Note: The solid line corresponds to the benchmark case ($\varphi_m = -0.0014$), while the dashed-dotted and dashed lines are the cases with $\varphi_m = -0.0021$ and $\varphi_m = -0.0007$, respectively. The shock is a permanent increase in B_t^{*CB} equivalent to 10 percent of nominal GDP in steady state, while i_t^{MP} remains in its steady-state value until T.

Figure 21. Purchase of Long Debt Financed with New Short Debt: $T = 6$, $p_t = 0$, Robustness with Respect to φ_k



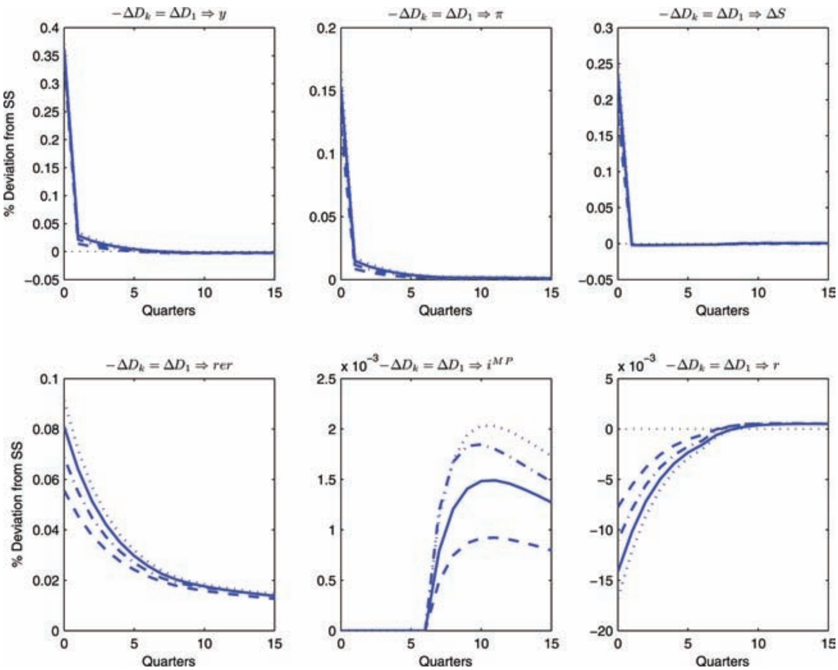
Note: The solid line corresponds to the benchmark case ($\varphi_k = 0.017$), while the dashed-dotted and dashed lines are the cases with $\varphi_m = 0.019$ and $\varphi_m = 0.015$, respectively. The shock is a permanent increase in B_t^{*CB} equivalent to 10 percent of nominal GDP in steady state, while i_t^{MP} remains in its steady-state value until T.

Figure 22. Purchase of Foreign Assets Financed with a Monetary Expansion: $T = 6$, $p_t = 0$, Robustness with Respect to the Taylor Rule



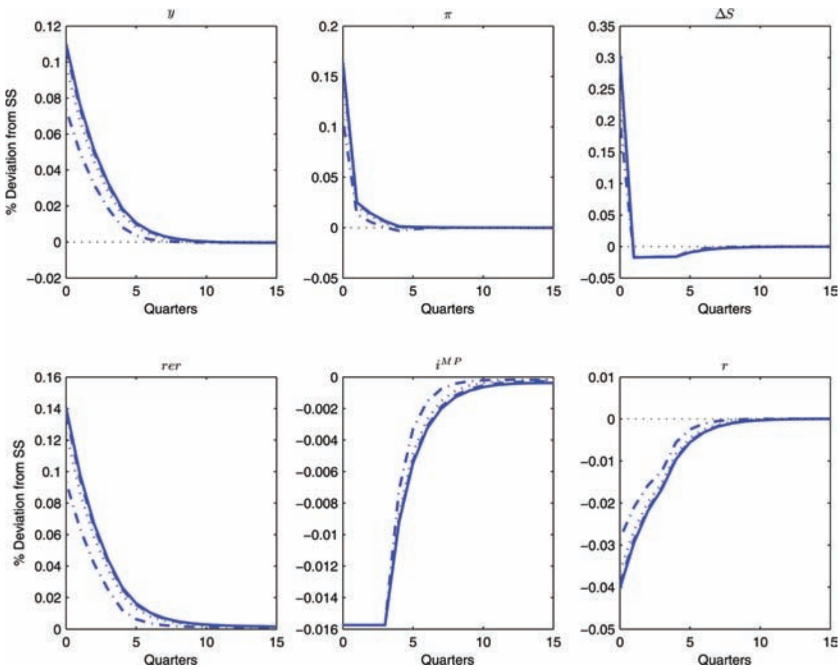
Note: The solid line corresponds to the benchmark case ($\rho_i = 0.74$, $\alpha_\pi = 1.67$, and $\alpha_\pi = 0.39$), while the dashed-dotted, dashed, and dotted lines are the cases with $\rho_i = 0.37$, $\alpha_\pi = 3.39$, and $\alpha_\pi = 0.78$, respectively. The shock is a permanent increase in B_t^{*CB} equivalent to 10 percent of nominal GDP in steady state, while i_t^{MP} remains in its steady-state value until T.

Figure 23. Purchase of Long Debt Financed with New Short Debt: $T = 6$, $p_t = 0$, Robustness with Respect to the Taylor Rule



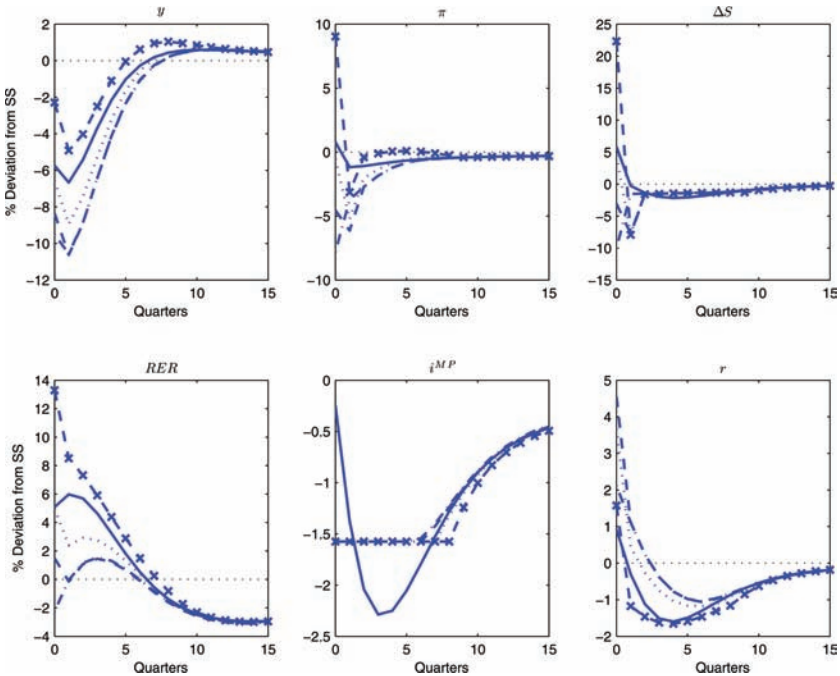
Note: The solid line corresponds to the benchmark case ($\rho_i = 0.74$, $\alpha_\pi = 1.67$, and $\alpha_\pi = 0.39$), while the dashed-dotted, dashed, and dotted lines are the cases with $\rho_i = 0.37$, $\alpha_\pi = 3.39$, and $\alpha_\pi = 0.78$, respectively. The shock is a permanent increase in B_t^{*CB} equivalent to 10 percent of nominal GDP in steady state, while i_t^{MP} remains in its steady-state value until T.

Figure 24. Driving i_t^{mp} to Zero: $T = 3$, $p_t = 0$. Robustness with Respect to the Taylor Rule



Note: The solid line corresponds to the benchmark case ($\rho_i = 0.74$, $\alpha_\pi = 1.67$, and $\alpha_\pi = 0.39$), while the dashed-dotted, dashed, and dotted lines are the cases with $\rho_i = 0.37$, $\alpha_\pi = 3.39$, and $\alpha_\pi = 0.78$, respectively. The experiment is to drive i_t^{MP} to zero and to keep it at this value until $T = 3$, with $p_t = 0$.

Figure 25. The Effects of a Contractionary Shock and Departures from the Taylor Rule in a Model with Habits



Note: The solid line shows the case when the policy rate is allowed to be negative; the dashed-dotted line considers a truncated Taylor rule; and the dashed, the dotted, and the crossed lines are the cases when i_t^{MP} is driven to zero and maintained at this value for, respectively, five, six, and seven quarters.

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