Monetary and fiscal activism in general equilibrium *

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Abstract

This paper studies the possible merits of macroeconomic policy activism. By policy activism, we refer both to how much to adjust policy instruments in light of recent changes in real activity (the output gap) and to the array of policy instruments employed for this task. We study a wide array of fiscal and monetary policy actions (standard and non-standard) within a unified DSGE setting, which includes all the main building blocks of an economy (households, firms, private banks, a Central Bank and the Treasury). Activism is contrasted to the case of passive policy with no reaction to the business cycle. Our main policy result is that a combination of monetary and fiscal policy activism can help the real economy. This happens when fiscal (tax-sending) policy instruments react to the output gap at a moderate degree and, at the same time, the central bank keeps the nominal policy interest rate constant at a low level, while the use of open market operations and remittances to the Treasury remains mild. In addition, the efficacy of the central bank quantitative easing policies depends on certain premises; the characteristics of the public debt holders and the existence of financial frictions on the demand rather than the supply side of the credit markets.

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1 Introduction

The approach to macroeconomic policy has changed radically and several times since the 1960s. After the belief in Keynesian type intervention in the 1960s and 1970s, most economists believed that the emphasis should shift to the role of policy in supporting price stability (regarding monetary policy) and economy's growth potential (regarding fiscal policy). This changed radically during the 2007-8 world crisis. Since 2008, reacting to the severe economic downturn, most governments and central banks around the world have adopted an unprecedented peacetime countercyclical policy expansion.[1]

The efficacy of this policy is still a debated issue. To put the same thing differently, does monetary and fiscal activism help? By activism, we typically mean expansionary policies during periods of recession. Specifically, by activism, as stated in an early contribution by Okun (1972), we refer both to how much to adjust policy instruments in light of recent changes in economic activity and to the array of policy instruments employed for this task. The former has to do with the magnitude of the reaction to macroeconomic indicators like the output gap. The latter has to do with the number of policy instruments used, and, in particular, with the inclusion of new, or unconventional, instruments like quantitative easing (QE).[2]

This paper studies a wide array of fiscal and monetary policy actions, as well as, their interactions, in a DSGE model which includes all the main building blocks of an economy (households, firms, private banks, a Central Bank and the Treasury). That is, we study activism across a wide range of policy regimes. Activism, as defined above, will then be contrasted to the case of passive policy with no reaction of policy instruments to the output gap. Our work differs from most of the related literature because, while there is a rich literature on the role of monetary policy[3] and on the role of fiscal policy[4], there has not been a systematic analysis of the stabilization efficacy of the main monetary and fiscal policy instruments within a unified micro-founded general equilibrium framework. That is, the focus here is on the *instrument problem*: which instrument to employ and how to use it in recessionary periods.[5]

[1] See Feldstein (2009) for a brief review of changes in the role of policy since the World War II.

[2] See Cúrdia and Woodford (2010) for conventional and unconventional monetary policies in a DSGE framework, as well as the debate on this. This issue has become even more complex in the Eurozone, where there is a single central bank for different countries. For instance, in the debate on the European debt crisis, there are those who argue that a necessary feature of governance in the Eurozone is that the ECB can act as lender of last resort in the government bond markets (see e.g. De Grauwe, 2013). On the other hand, there are those who argue that the ECB's bond-buying program is harmful for the Eurozone (see e.g. Sinn, 2014).

[3] For monetary policy, see e.g. Smets and Wouters (2007), Gertler and Karadi (2011) and Carlstrom et al. (2017).

[4] For fiscal policy, see e.g. Blanchard and Roberto (2002), Auerbach (2009) and Leeper et al. (2009, 2017).

[5] We follow a "*normative*" approach to policy, i.e. our purpose is to recommend the fiscal-monetary policy mix that can help more an economy in recession. See, also, Taylor (2000), who discusses the "*normative*

Following most of the related literature (see e.g. Schmitt-Grohé and Uribe, 2007, and Philippopoulos et al., 2017), we will follow a Taylor rule-like approach to policy. In particular, we will allow the policy instruments to react endogenously to a small number of easily observable macroeconomic indicators and, mainly, since we focus on a recessionary episode, to the output gap. We adopt such a feedback approach to policy because this is closer in spirit to activism; as the word "activism" itself declares, action means shifts in policy triggered by changes in the state of the economy.[6] Besides, there is empirical support that the endogenous reaction of policy instruments to deviations of indicators from their targets, namely the magnitude of feedback policy coefficients, changes over the business cycle.[7]

Our medium-scale DSGE model consists of a private sector and a policy sector. In the private sector, there are three different groups of households, while firms are distinguished into firms producing final goods, intermediate goods and capital goods. Private banks intermediate between savers and borrowers and, since giving loans is relatively costly, introduces a financial friction as in e.g. Cúrdia and Woodford (2010). In the policy sector, there are a Central Bank, which has a wide range of conventional and unconventional policy instruments in its hands, and the Treasury, which sets the standard tax-spending policy instruments.

We will work in three steps. In the first step, we feed the above described DSGE model with a variety of shocks widely used by the business cycle literature.[8] We find that a single adverse temporary shock to total factor productivity, propagated by the internal dynamics of our model, can, on its own, account relatively well for the behavior of the main macroeconomic variables in the recent recession period. However, we need to clarify that our aim is not to reproduce the sub-prime crisis or the disruptions of any specific financial market; our aim is just to get a depression and then study what fiscal-monetary policy can (or cannot) do about this.

In the second step, assuming that transition dynamics are driven by the above TFP shock, we, first, allow for monetary policy activism, as mentioned above. This means that standard (policy interest rate) and non-standard monetary policy instruments (open market operations (OMOs) and dividends from the Central Bank to the Treasury), as well as, extra unconventional ones (extra loans to private banks and direct loans to private firms), are allowed to react to

macroeconomics", the new approach to macroeconomic policy evaluation.

[6] A feedback rule-like approach differs methodologically from the recent literature on policy multipliers, that usually studies the macroeconomic effects of exogenous policy shocks, and, in particular, temporary shocks to policy rules (see e.g. Coenen et al., 2012, and Coenen et al., 2013, for rich reviews of fiscal policy multipliers in the euro area and the US). A rule-like approach also differs from the early Keynesian approach to policy, which also supported discretionary actions (see e.g. Hofmann and Bogdanova, 2012 and Taylor, 2014).

[7] See e.g. the discussion in Coenen et al. (2012).

[8] See e.g. Chari et al. (2007).

the output gap. We experiment with one instrument at a time, as well as, with combinations.

Regarding the central bank balance sheet policies, namely the various QE programs, while there is evidence in favor of the effects of these policies on financial conditions, their links to macroeconomic variables are still not straightforward.[9] From a theoretical perspective, many macroeconomic models show that these type of policies are neutral, based on a variation of the Modigliani-Miller proposition, as first noted by Wallace (1981).[10] In our baseline set up, we will model the financial sector relatively simple so as to keep a balance between fiscal and monetary policy and not favour policies that alleviate specific market imperfections. We will, then, experiment with alternative financial frictions and modelling assumptions and study their implications for real macroeconomic variables. In particular, we will consider separately the financial frictions on the supply and the demand side of the credit market, in order to identify the mechanisms through which QE policies are transmitted to the real economy.

We find that the real effects of monetary activism are quantitatively small. Furthermore, the unconventional QE-type monetary programs appear to be effective complements to conventional policies only when demand-side credit frictions and rebalancing portfolio effects are present (this is similar to the results in Araújo et al., 2015, where the effects of monetary policies depend critically on the type and degree of collateral constraints). All this is relative to passive policy. Also, all this is without fiscal activism.

In the third step, we allow for fiscal activism, as a second line of defense against an economic downturn. This means that, in the above described monetary framework, fiscal policy instruments (public spending and tax rates on consumption, labor and profits) are also allowed to react to the output gap. We now find that there can be real benefits from a fiscal-monetary policy mix. In particular, policy activism helps the real economy when fiscal (tax-sending) policy instruments and OMOs react to the output gap at a moderate degree and, at the same time, the nominal interest rate remain constant at a low level. This mix can perhaps rationalize the policies having been followed by most central banks and treasuries in several countries since 2008.

The rest of the paper is organized as follows. Section 2 relates the literature on monetary policy to our model. Section 3 sets up the model. Parameterization and steady state solution are in section 4. This solution will serve as the departure for our policy experiments. Section 5 deals with the first step as discussed above. Section 6 studies monetary activism. Section 7 presents the effects of fiscal-monetary policy mixes. Section 8 closes the paper.

[9] See e.g. Chen et al. (2012), Reifschneider (2016) and Kiley (2018).

[10] See e.g. Cúrdia and Woodford (2010) and Iovino and Sergeyev (2018).

2 A brief review on monetary policy

Before we present the model, we provide a short review of the literature on the modelling of monetary policy and explain how our model relates to this literature.

2.1 Monetary policy instruments

We will briefly discuss the policy instruments used by two key central banks, the FED and the ECB.

Starting with the FED,[11] in normal times, its instruments have been open market operations, discount lending and reserve requirement ratios. Specifically, open market operations (OMOs), in the case of FED, mainly take the form of purchases of government securities. Discount lending means very short-term lending to private banks with short-term liquidity problems at the primary discount rate, where the latter is the interest rate in the interbank market plus 1%. (Note that the interest rate in the interbank lending/borrowing market is called the funds rate in the USA, LIBOR in the UK or Euribor in the euro zone). Its reserve requirement ratios range between 3 and 10% depending on the type of deposits. By using these instruments, the FED tries to affect the interest rate in the interbank market. For instance, by purchasing government bonds, by lowering the discount rate or by decreasing the reserve requirements ratio, the FED reduces the funds rate.[12] In addition, to counter the 2007-8 financial crisis, the FED began using a number of unconventional policy measures that include the ability to pay interest on reserves and the implementation of large-scale asset purchases (labelled QE).

Continuing with the ECB,[13] its policy instruments in normal times are open market operations, standing facilities and a minimum reserve system. Specifically, open market operations, in the case of ECB and prior to the introduction of its QE program in 2015, mainly took the form of "main refinancing operations", which means that the ECB sets the interest rate, the total amount to be allocated to banks and the collateral system, where the latter is the assets pledged as collaterals for the granting of loans. Standing facilities, in the case of the ECB, are used to control the short-term market interest rates. In particular, the ECB offers a lending facility (it provides loans to banks at 1% more than the interest rate used in the main refinancing operations which means that this rate works as a ceiling policy interest rate) and a

[11] For the FED policy, see e.g. Mishkin and Eakins (1998).

[12] A purchase of government bonds by the central bank raises the stock of (non-borrowed) reserves since the central bank pays for this purchase by crediting the seller's bank account with the amount of the purchase (see Walsh, 2010, p. 535).

[13] For the ECB policy, see e.g. ECB Economic Bulletin (2015, issue 4).

deposit facility (it accepts bank reserves paying 1% less than the interest rate used in the main refinancing operations which means that this rate works as a floor policy interest rate), where both facilities have an overnight maturity. Minimum reserves ratios, in the case of ECB, vary between 0 and 2% depending on the type of deposits. By using these instruments, in normal times, the ECB tries to affect "the price at which banks can trade reserves in the interbank market" or, to put it differently, it "supplies inelastically the quantity of reserves required by the banking system in order to control the short-term interest rate"[14] and in particular the interest rate in the interbank lending/borrowing market. In addition, since the eruption of the 2007-8 crisis, the ECB, along with the FED and other central banks, has taken further QE type actions that include (see e.g. ECB Economic Bulletin, 2015, issue 4): (*a*) The provision of increasing liquidity to the banking system, through the implementation of longer-term refinancing operations and the increase of collateral availability, so as to accommodate banks' increased demand for liquidity; the idea is that when the interbank market breaks down, the central bank may need to provide reserves in excess of the "regular" liquidity needs so as to stabilize and reassure the banking system as well as to prevent a rise in interest rates beyond levels desired by monetary policy. (*b*) Direct lending to the non-bank private sector and purchases of private sector assets. (*c*) Purchase of government securities on a large scale. In particular, in 2015, the ECB started its asset purchase program at an amount of 60 billion euros per month and this continued until the end of 2017. This program is expected to continue this year, until at least the end of September 2018, at an amount of 30 billion per month and the plan is to terminate it by the beginning of 2019. Also, since March 2016, the ECB has kept its main refinancing rate at 0%, its marginal lending rate at 1.25% and the deposit rate at -0.4%; as a result, the Euribor has remained very low and close to the deposit rate. These main policy interest rates are not expected to rise before mid-2019 and full allotment has given banks planning security. For a brief review of the recent policy of the ECB, see chapter 1 in the EEAG Report on the European Economy (2018), while for two opposing critiques of the ECB policy during the crisis, see Sinn (2014) on one hand and De Grauwe (2016, chapter 9.5) on the other hand.

2.2 Transmission mechanisms

Monetary policy (re)actions, like the ones discussed above, can be transmitted to the real economy through, at least, two core channels; the *interest-rate channel* and the *credit channel.*

According to the traditional interest-rate channel, the Central Bank, by setting the nominal

[14] See ECB Economic Bulletin (2015, issue 4, p. 2).

interest rate or the nominal money supply, affects the real interest rates, which, in turn, determine agents' consumption and investment decisions. The transmission mechanism relies on frictions, like portfolio and informational frictions or wage and price rigidities (see e.g. Walsh, 2010, chapters 5, 6 and 8).[15] In the model used in this paper, we will adapt the latter and, specifically, we will assume Rotemberg-type nominal rigidities.

However, as already said above and as is widely recognized (see e.g. Walsh, 2010, chapter 11 and in particular p. 511), to the extent that one wishes to study the effects of the "actual implementation" of monetary policy, one cannot treat the nominal money supply or the interest rate on government bonds (as is typically the practice followed by relatively simple macroeconomic models, especially before the 2007-8 crisis) as variables controlled by the monetary authorities. Instead, one has to use variables like those listed above (e.g. the policy interest rates, standing facilities, minimum reserves and QE-type policies) as actual policy instruments. In terms of modelling, this requires the introduction of asset heterogeneity (e.g. not a single financial asset called "bond") and agent heterogeneity, which allows for interest rate differentials and well-defined demand and supply functions in financial markets.[16]

What is critical in all this is the presence of frictions in financial markets. When financial markets are imperfect, monetary policy can have additional effects on credit, aside on prices. The credit channel describes the linkages between the policy variables, set directly by the monetary authorities, and credit, which affects the paths of consumption and investment. Specifically, credit frictions in form of agency problems between borrowers and lenders,[17] transaction costs[18] or asset heterogeneity (e.g. different funding sources are imperfect substitutes),[19] generate a wedge between the cost of external and internal finance, which varies with the monetary policy actions and shapes the amount and price of credit. Furthermore, a more recent literature has shown that the credit channel also operates when the monetary policy alters, mostly through the procyclicality of leverage, the risk undertaken by financial intermediaries and investors.[20]

[15] Walsh (2010, chapter 8) also mentions that the quantity of money affects the consumption spending through a wealth effect ("*Pigou effect*"). However, since these wealth effects are found to be small at business cycle frequencies, this channel is not frequently included in models used for policy analysis.

[16] Borrowing and lending cannot occur in a representative-agent world so that agents must differ in some way that gives rise to borrowers and lenders. Also, not all borrowers and not all lenders are alike. Popular ways of producing agent heterogeneity include differences in time discount rates (see e.g. Kiyotaki and Moore, 1997, Iacoviello, 2005, Garín, 2015, Guntner, 2015 and Philippopoulos et al., 2017b) or in preferences and the degree of risk aversion (see e.g. Bernanke and Gertler, 1989, Carlstrom and Fuerst, 1997, Bernanke et al., 1999, and Cúrdia and Woodford, 2011).

[17] See e.g. Bernanke and Gertler (1989), Carlstrom and Fuerst (1997), Gertler and Kiyotaki (2011), Garín (2015), Güntner (2015) and Ajello (2016).

[18] See e.g. Uribe and Yue (2006).

[19] See e.g. Walsh (2010) chapter 10.6.1

[20] See e.g. Nicolò et al. (2010), Dell' Ariccia et al. (2010) and Borio and Zhu (2012).

In the model used in this paper, we will model financial heterogeneity and frictions in a relatively simple way by assuming that various households differ in their time discount factors and that private banks face transaction costs that are increasing in loans and decreasing in reserves and deposits (see also e.g. Cúrdia and Woodford, 2010, 2011, 2016); however, we also study the case in which financial frictions take the form of agency problem between borrowers and lenders (see e.g. Gertler and Kiyotaki, 2011, and Gertler and Karadi, 2011).

3 Model

In this section, we develop and solve a medium-scale closed economy DSGE model with a private and a policy sector. The policy sector includes both monetary and fiscal policy authorities.

3.1 Informal description of the model

The private sector consists of three different groups of households. The first group of households is assumed to consume, work, hold currency and save in form of bank deposits and government bonds; for convenience, we will refer to them as "savers". The second group of households is assumed to consume, work, hold currency and, being the owners of private firms, receive the profits made by them; for convenience, we will refer to these households as "firm-owners". The third group is assumed to consume, work, hold currency and, being the owners of private banks, receive the profits made by them; for convenience, we will refer to these households as "bankers".[21] On the production side, private firms are distinguished into firms producing final goods, intermediate goods and capital goods. As in most of the related literature, we model final goods and capital goods firms in a stylized way, while intermediate goods firms act monopolistically and are also assumed to hold currency and borrow from private banks so as to finance their investment and labour costs. Since private firms are owned by firm-owners, firms' time preference rate equals firm-owners' inter-temporal marginal rate of substitution in consumption. Similarly, since private banks are owned by bankers, banks' time preference rate equals bankers' inter-temporal marginal rate of substitution in consumption. To get reasonable differences across different interest rates, as well as, positive steady state values of financial variables, we assume that bankers are more patient than savers who are in turn more patient

[21] For similar assumptions of agents heterogeneity, see e.g. Kiyotaki and Moore (1997), Cúrdia and Woodford (2010, 2011 and 2016), Dib (2010), Brunnermeier and Sannikov (2014), Güntner (2015) and Philippopoulos et al. (2017), while e.g. Gertler and Kiyotaki (2011) work with a consolidated family or household consisting of different types of family members.

than firm-owners.[22] Private banks intermediate between lenders and borrowers, where this financial intermediation introduces a friction a la Cúrdia and Woodford (2010, 2011 and 2016) according to which giving loans implies an extra cost. We shall start by assuming that private banks make loans to private firms and hold reserves at the central bank as assets, while they receive deposits from households on the liability side. Loans made to firms, deposits received by households and reserves held at the central bank pay different interest rates. At a later stage, with respect to private banks, we shall enrich their liability side by allowing them to receive excess liquidity or loans provided by the central bank. For simplicity, we assume away interbank lending.

The policy or government sector consists of a Central Bank and the Treasury. We shall start by assuming that the Central Bank holds government bonds on the asset side, while, on the liability side, there is the currency held by the non-bank public (households and private firms) and reserves held by private banks at the central bank.[23] Within this baseline set up, and following e.g. Hall and Reis (2015), Del Negro and Sims (2015) and Benigno and Nisticò (2017), the policy instruments of the central bank include the nominal interest rate paid on reserves (the so-called policy rate), the amount of government bonds purchased by the central bank (the so-called open-market operations) and the remittances or dividends from the central bank to the government. At a later stage, to mimic the unconventional extra measures taken by most central banks since the financial crisis started in 2007-8, we shall enrich the asset side of the central bank by incorporating excess liquidity or loans to the banking sector, as well as, direct loans to the non-bank private sector.[24] In other words, we include both standard and non-standard monetary policy instruments. Finally, the Treasury, or the government, issues government bonds and levies distorting taxes to finance public spending. As said, government bonds can be held by private agents and by the central bank. We assume away the possibility of default on public debt.

Note that, following the literature on DSGE models with financial intermediation and financial frictions, we explicitly study the role of the central bank's balance sheet. Thus, monetary policy, in the form of interest rate and reserve supply policy, is transmitted indirectly

[22]The main reason for having different types of agents with different degrees of impatience to consume is to allow for financial intermediation, so that borrowers cannot borrow directly from savers at a single interest rate. This facilitates an equilibrium spread between the lending and deposit rate. See Woodford (2010) for a criticism on pre-crisis models with a single interest rate.

[23]The critical role of interest bearing reserves during the recent financial crisis is highlighted in the Bank of England CCBS Handbook (2015) and the paper of Reis (2016). Caglar et al. (2011) report that reserves at the Bank of England have tripled since the introduction of QE policies in 2010.

[24]See e.g. Caglar et al. (2011) and McMahon et al. (2015) for QE policies in different countries.

via private banks but it is also transmitted directly to the macro-economy through the purchase of government bonds, the provision of extra liquidity and direct lending to the private sector. Besides, money will not be neutral in the transition because of Rotemberg-type nominal fixities faced by intermediate goods firms, as in New Keynesian DSGE literature.

3.2 Households

In this subsection, we model the three types of households.

3.2.1 Households as savers

There are N^h identical households-savers indexed by superscript $h = 1, 2, 3, ..., N^h$. Each one of them maximizes lifetime utility given by:

$$\sum_{t=0}^{\infty} \left(\beta^h\right)^t u\left(c_t^h, u_t^h, g_t\right) \tag{1}$$

where c_t^h is h's consumption, u_t^h is h's hours of work, g_t is real public spending and $0 < \beta^h < 1$ is a time preference rate. In our numerical solutions below, for simplicity, we will use the additively separable function $u(c_t^h, u_t^h, g_t) = \ln c_t^h + \nu^h \ln(1 - u_t^h) + \chi_g \ln(g_t)$, where ν^h and χ_g are preference parameters.

Each h's maximization is subject to the budget constraint (written in real terms):

$$\begin{aligned}(1+\tau_t^c)\, c_t^h + d_{t+1}^h + b_{t+1}^h + m_{t+1}^h = (1-\tau_t^y)\, w_t u_t^h + \\ +(1+i_t^d)\frac{p_{t-1}}{p_t} d_t^h + (1+i_t^b)\frac{p_{t-1}}{p_t} b_t^h + \frac{p_{t-1}}{p_t} m_t^h\end{aligned} \tag{2}$$

where d_{t+1}^h and b_{t+1}^h are h's end-of-period real bank deposits and real government bond holdings respectively, i_t^d denotes the nominal interest rate on bank deposits and i_t^b the nominal interest rate on government bonds between $t-1$ and t, p_t is the current price level, m_{t+1}^h is h's end-of-period real money holdings, u_t^h is h's hours of work, w_t is the real wage rate, and $0 < \tau_t^y, \tau_t^c < 1$ are tax rates on labor and consumption respectively.

To give money a role, we use simple cash-in advance constraints.[25] In this case, the cash-in-advance constraint is defined as:

$$m_{t+1}^h \geq a^h \left(1+\tau_t^c\right) c_t^h \tag{3}$$

[25] For a similar modeling of money demand, see e.g. Niemann et al (2013) and Schmitt-Grohé and Uribe (2007).

where $a^h \geq 0$ is a parameter.

Details on the saver's problem and its first-order conditions are in Appendix 1.

3.2.2 Households as firm-owners

There are N^e identical households firm-owners indexed by superscript $e = 1, 2, 3, ..., N^e$. These households own the private firms and hence receive their profits. Each one of them maximizes lifetime utility given by:

$$\sum_{t=0}^{\infty} (\beta^e)^t \, u\left(c_t^e, u_t^e, g_t\right) \tag{4}$$

where notation is as above except that now we use the superscript e instead of the superscript h. We assume $0 < \beta^e < \beta^h < 1$, namely, households as firm-owners are less patient than households as savers; this is, as mentioned above, in order to allow for differences between lending and deposit interest rates in equilibrium. We will again use $u(c^e, u_t^e, g_t) = \ln c_t^e + \nu^e \ln(1 - u_t^e) + \chi_g \ln(g_t)$ for the period utility function.

The maximization is subject to the budget constraint and the cash-in-advance constraint, which are:

$$(1 + \tau_t^c)\, c_t^e + m_{t+1}^e = \pi_t^f + (1 - \tau_t^y)\, w_t u_t^e + \frac{p_{t-1}}{p_t} m_t^e \tag{5}$$

$$m_{t+1}^e \geq a^e \left(1 + \tau_t^c\right) c_t^e \tag{6}$$

where m_{t+1}^e is e's end-of-period real money holdings, u_t^e is e's hours of work and π_t^f is net profits or dividends distributed by private firms to their owners.

Details on the firm-owner's problem and its first-order conditions are in Appendix 1.

3.2.3 Households as bankers

There are N^b identical households-bankers indexed by superscript $b = 1, 2, 3, ..., N^b$. These households own the private banks and hence receive their profits. Each one of them maximizes lifetime utility given by:

$$\sum_{t=0}^{\infty} \left(\beta^b\right)^t u\left(c_t^b, u_t^b, g_t\right) \tag{7}$$

where notation is as above except that now we use the superscript b instead of the superscript h or e. We assume $0 < \beta^e < \beta^h < \beta^b < 1$; in other words, households as bankers are more patient than the other two types of households; this is in order to get positive amounts of loans and deposits at the steady state. We will again use $u(c^b, u_t^b, g_t) = \ln c_t^b + \nu^b \ln(1-u_t^e) + \chi_g \ln(g_t)$ for the period utility function.

The maximization is subject to the budget constraint and the cash-in-advance constraint, which are:

$$(1+\tau_t^c)\, c_t^b + m_{t+1}^b = \pi_t^b + (1-\tau_t^y)\, w_t u_t^b + \frac{p_{t-1}}{p_t} m_t^b \tag{8}$$

$$m_{t+1}^b \geq a^b\,(1+\tau_t^c)\, c_t^b \tag{9}$$

where m_{t+1}^b is b's end-of-period real money holdings, u_t^b is b's hours of work and π_t^b is net profits or dividends distributed by private banks to their owners.

Details on the banker's problem and its first-order conditions are in Appendix 1.

3.3 Production sector

There are three stages of production and correspondingly three types of firms. Final goods firms produce a single final good by combining differentiated intermediate goods through a Dixit-Stiglitz technology. Intermediate goods firms produce differentiated intermediate goods acting as monopolists in their own product market and by using capital goods and labour services; these firms also face Rotemberg-type nominal fixities in New Keynesian tradition. Capital goods firms use existing capital to produce new capital which is sold to intermediate goods firms. For simplicity, we use simple devices to model these production stages and, as said above, we assume that all these devices/firms are owned by firm-owners who receive all profits in a lump-sum fashion.[26]

3.3.1 Production of final goods

There are N^s identical final goods firms indexed by superscript $s = 1, 2, 3, ..., N^s$. Each one of them produces an amount of final output, y_t^s, using intermediate goods, y_t^f, according to the

[26] For a similar modeling of the production sector, see e.g. Carillo and Poilly (2013), Brzoza-Brzezina et al (2013), Garín (2015) and Güntner (2015). Alternatively, as mentioned before, we could simply assume, as in Gertler and Kiyotaki (2011), that there is a single household/family and there are different types of household/family members called workers, bankers, etc. All these alternatives are not expected to change the main results (see also the discussion in Gertler and Kiyotaki, 2011).

Dixit-Stiglitz CES production function:

$$y_t^s \equiv \left[\sum_{f=1}^{N^f} \lambda \left[y_t^f\right]^{\phi}\right]^{\frac{1}{\phi}} \tag{10}$$

where $0 < \phi \leq 1$, N^f is the number of intermediate goods firms and $\lambda = 1/N^f$ to avoid scale effects in equilibrium. Thus, in a symmetric equilibrium below, we will simply have $y_t^s = y_t^f \equiv y_t$.

Under perfect competition, in each period, the firm chooses y_t^f to maximize profits:

$$p_t y_t^s - \sum_{f=1}^{N^f} \lambda p_t^f y_t^f \tag{11}$$

where p_t is the price of the final good and p_t^f is the price of each intermediate good f.

Taking prices as given, the first-order condition for y_t^f is:

$$p_t^f = \left(\frac{y_t^f}{y_t^s}\right)^{\phi-1} p_t \tag{12}$$

or equivalently $y_t^f = \left(\frac{p_t^f}{p_t}\right)^{\frac{1}{\phi-1}} y_t^s$.

Then, if profits are zero in the competitive final-goods sector, we have the price index:

$$p_t = \left[\sum_{f=1}^{N^f} \lambda \left[p_t^f\right]^{\frac{\phi}{\phi-1}}\right]^{\frac{\phi-1}{\phi}}$$

Thus, in a symmetric equilibrium below, we will simply have $p_t = p_t^f$.

3.3.2 Production of capital goods

There are N^c identical capital producing firms indexed by superscript $c = 1, 2, 3, ..., N^c$. Capital goods producers generate new capital, which they sell to intermediate goods firms at a price, q_t. Following e.g. Güntner (2015) and Gertler and Kiyotaki (2011), we simply assume that their objective is to maximize profits defined as:[27]

$$\sum_{t=0}^{\infty} \beta_t^c \left[q_t k_{t+1}^c - i_t^c - q_t \left(1-\delta\right) k_t^c\right] \tag{13}$$

[27] For simplicity, we do not include capital adjustment costs.

where i_t^c is investment, $0 \leq \delta \leq 1$ is the capital depreciation rate and β_t^c is the time discount rate. In equilibrium, since firms are owned by firm-owners, we will set $\beta_t^c \equiv (\beta^e)^t \frac{\lambda_t^e}{\lambda_0^e}$ (see also e.g. Altug and Labadie, 1994, chapter 4).

The law of motion of the firm's capital is given by:

$$k_{t+1}^c = (1-\delta)k_t^c + \xi_t i_t^c \tag{14}$$

where ξ_t is an investment shock similar to that in e.g. Chari et al. (2007) and Fisher (2006).

The first-order condition for i_t^c implies:

$$q_t = 1 \tag{15}$$

and in turn the capital goods firm's profits are zero in equilibrium.

3.3.3 Production of intermediate goods

There are N^f differentiated intermediate-goods firms indexed by superscript $f = 1, 2, 3, ..., N^f$. Each one of them maximizes the present discounted value of its stream of profits subject to the demand function for its own product, cash-in-advance constraint and Rotemberg-type nominal fixities.[28] In particular, each firm maximizes:

$$\sum_{t=0}^{\infty} \beta_t^f \pi_t^f \tag{16}$$

where in equilibrium we will set $\beta_t^f \equiv (\beta^e)^t \frac{\lambda_t^e}{\lambda_0^e}$, since firms are owned by firm-owners.

In each period, the real profit is defined as:

$$\pi_t^f = (1-\tau_t^\pi)\left\{\frac{p_t^f}{p_t}y_t^f - w_t u_t^f\right\} - q_t i_t^f + l_{t+1}^f - (1+i_t^l)\frac{p_{t-1}}{p_t}l_t^f - \tag{17}$$
$$-m_{t+1}^f + \frac{p_{t-1}}{p_t}m_t^f - \frac{\chi}{2}\left(\frac{p_t^f}{p_{t-1}^f} - 1\right)^2$$

where the first term in brackets on the RHS is the gross profit made by each firm and $0 < \tau_t^\pi < 1$ is the associated tax rate on gross profits (see also e.g. Turnovsky, 1995), i_t^f is investment made by each intermediated goods firm and q_t is the associated price of capital, l_{t+1}^f is the end-of-period loans taken by the firm from private banks and i_t^l is the associated nominal interest rate

[28] For similar modeling of the firm and its relation to households as firm-owners, see e.g. Uribe and Yue (2006) and Garín (2015).

on these loans between $t-1$ and t, m_{t+1}^f is the end-of-period real money balances held by each firm and $\frac{\chi}{2}\left(\frac{p_t^f}{p_{t-1}^f}-1\right)^2$ is a standard Rotemberg-type cost function from price changes. At a later stage, we will follow e.g. Gertler and Karadi (2011, 2013), Gertler and Kiyotaki (2011) and Güntner (2015) by assuming that intermediate-goods firms are financially constrained in the sense that they have to finance their capital acquisition in advance of production. In other words, we will assume that the real amount of new loans equals the quantity of new capital at the end of each period, $l_{t+1}^f = k_{t+1}^f$. This friction introduces feedback effects between the financial and real sectors and, through them, a direct channel of monetary policy transmission. Also, as already said, later on we will add, as a QE type policy, direct loans to these firms from the central bank.

The motion of capital for each firm is:

$$k_{t+1}^f = (1-\delta)k_t^f + \xi_t i_t^f \tag{18}$$

The maximization is also subject to the demand function (12), as well as a production function and a cash-in-advance constraint, which are respectively:[29]

$$y_t^f = f\left(k_t^f, u_t^f\right) = A_t\left(k_t^f\right)^\alpha\left(u_t^f\right)^{1-\alpha} \tag{19}$$

$$m_{t+1}^f \geq a^f w_t u_t^f \tag{20}$$

Details on the intermediate-goods firm's problem and its first-order conditions are in Appendix 2.

3.4 Private banks

There are N^b identical private banks indexed by superscript $b = 1, 2, 3, ..., N^b$. In our baseline setup presented so far, private banks hold loans to firms and reserves at the central bank as assets, while their liabilities consist of the funds deposited by savers. For simplicity, as said above, we assume away an interbank market.[30]

As in the literature on banking, banks intermediate between lenders and borrowers and this introduces a financial friction that adds to the overall cost of credit faced by borrowers.

[29] The firm's cash-in-advance constraint is as in e.g. Uribe and Yue (2006).

[30] We could add an interbank market where private banks lend to (or borrow from) each other. In equilibrium, meaning ex post, since private firms are alike, interbank loans will be zero $\left(l_t^{ib}=0\right)$ at any time t. Also, depending on the specification of the bank's cost function the funds rate and the policy rate could be either imperfect or perfect substitutes.

Here, following e.g. Cúrdia and Woodford (2010, 2011 and 2016), we model this friction in a simple way by assuming that private banks need to pay a cost to manage their assets and liabilities.[31] In particular, this cost increases with the amount of loans made to private firms, whereas it decreases with the amount of reserves held at the central bank and the amount of deposits received by savers.[32] It is worth adding here that we have also experimented with alternative financial frictions like those in Gertler and Kiyotaki (2011) and Gertler and Karadi (2011, 2013), who assume an agency problem between lenders and borrowers, which results in an endogenous constraints on banks leverage ratios, and our main results do not change (see below for further details).

The bank' cost function is assumed to be of the form:

$$\Psi\left(l_t^b, d_t^b, m_t^r\right) = \frac{\eta^l}{2}\left(l_t^b\right)^2 + \frac{\eta^d}{2}\left(d_t^b\right)^{-2} + \frac{\eta^m}{2}\left(m_t^r\right)^{-2} \tag{21}$$

where l_t^b, d_t^b, m_t^r are respectively loans made to private firms, deposits received by households and reserves held at the central bank and where $\eta^l, \eta^d, \eta^m \geqslant 0$ are the associated cost parameters. That is, we assume $\Psi_{l^b}(.) > 0, \Psi_{d^b}(.) < 0$ and $\Psi_{m^r}(.) < 0$.

Each private bank maximizes:

$$\sum_{t=0}^{\infty} \widetilde{\beta}_t^b \pi_t^b \tag{22}$$

where, in equilibrium we will set $\widetilde{\beta}_t^b \equiv \left(\beta^b\right)^t \frac{\lambda_t^b}{\lambda_0^b}$, since banks are owned by households as bankers.

In each period, the real profits net of costs is defined as:[33]

[31] Thus, in our model, bank intermediation incurs at a simple cost as in Freixas and Rochet (1997, chapter 3), Aghion and Howitt (2009, chapter 6), Cúrdia and Woodford (2010, 2011, 2016), Corsetti at el. (2103) and many others. As mentioned above, financial frictions can also be introduced via collateral constraints where agents' ability to borrow is constrained to be less than a fraction of the value of its collaterized assets (see e.g. Kiyotaki and Moore, 1997, Iacoviello, 2005, Brunnermeier and Sannikov, 2014, Araújo et.al., 2015, Ajello, 2016) and via reserves requirements and leverage ratios a la BASEL III (see e.g. De Nicolò et al., 2014), via margin requirements (see e.g. Carrillo and Poilly, 2013), etc. Reviews of the literature on financial frictions can be found in e.g. Brzoza-Brzezina et al. (2013).

[32] We can add an extra financial friction like "bad loans" as in e.g. Corsetti et al. (2013), who assume that bad loans are a fraction of total loans, where this fraction increases with the government bond spread. We report that, under such loans, our results remain qualitatively the same.

[33] Alternatively, as in the case of firms above, we could assume that banks maximize the present value of their net cash flows where their financial decisions include the issuance of equities and corporate bonds (bought by firm-owners). See e.g. Gertler and Kiyotaki (2011), Gertler and Karadi (2011, 2013).

$$\pi_t^b \equiv \frac{p_{t-1}}{p_t}\left\{(1+i_t^l)l_t^b - (1+i_t^d)d_t^b + (1+i_t^r)m_t^b\right\} + \\ +d_{t+1}^b - l_{t+1}^b - m_{t+1}^r - \Psi(l_{t+1}^b, d_{t+1}^b, m_{t+1}^r) \quad (23)$$

Later on, we will also allow to receive excess liquidity or loans provided by the central bank (on their liability side). Details on the bank's problem and its first-order conditions are in Appendix 3.

In addition, Appendix 4 presents the budget constraint of the consolidated private sector.

3.5 Economic policy

There are two policy authorities, the Treasury and the Central Bank.[34]

3.5.1 The Treasury (i.e. fiscal authorities)

The within-period budget constraint of the fiscal branch of the government (the so-called Treasury) is in aggregate and real terms:

$$g_t + \frac{p_{t-1}}{p_t}(1+i_t^b)b_t^T = \tau_t^c\left(c_t^h + c_t^e + c_t^b\right) + \left(\tau_t^y - \tau_t^\pi\right)w_t u_t^f + \tau_t^\pi \frac{p_t^f}{p_t} f\left(k_t^f, u_t^f\right) + b_{t+1}^T + rcb_t \quad (24)$$

where b_{t+1}^T is the end-of-period total real public debt, rcb_t is real transfers from the central bank to the government, $0 \leq \tau_t^c, \tau_t^y, \tau_t^\pi < 1$ are tax rates on consumption, labor income and profits respectively, g_t is total real public spending and i_t^b is the nominal interest rate on government bonds. Note that, in equilibrium, $b_{t+1}^T = b_{t+1}^{cb} + b_{t+1}^h$, which means that government bonds will be purchased by private agents, b_{t+1}^h, and the Central Bank, b_{t+1}^{cb}.

Following usual practice, we will view the tax rates, $\tau_t^c, \tau_t^y, \tau_t^\pi$, and government spending as share of output, defined as s_t^g, as the independently set of fiscal policy instruments. Then, b_{t+1}^T will follow residually to satisfy the flow budget constraint in (24). Strictly speaking, since $b_{t+1}^T = b_{t+1}^{cb} + b_{t+1}^h$ in equilibrium, where b_{t+1}^{cb} is treated as a monetary policy instrument (see below), it will be b_{t+1}^h that follows residually. The processes of the independently set fiscal policy instruments are specified in subsection 3.6 below.

[34] The analysis of the policy sector follows Walsh (2010, chapter 4) and is also consistent with the analysis in Reis (2017).

3.5.2 The Central Bank (i.e. monetary authorities)

The Central Bank's liabilities consist of the currency held by households and firms and reserves held by banks, on which it pays the nominal interest rate i_t^r. These liabilities fund in turn the Central Bank's holdings of government debt, b_{t+1}^{cb}, and the remittances or dividends given to the fiscal authority, rcb_t. However, as already said, to complete the menu of monetary policy instruments used after 2007-8, we will also allow, in subsection 6.5, for loans to private banks and to private firms on the asset side of the Central Bank.

The within-period budget constraint of the Central Bank that links changes in assets and liabilities is in aggregate and real terms:

$$
\begin{aligned}
&b_{t+1}^{cb} + rcb_t + \frac{p_{t-1}}{p_t}(m_t^h + m_t^e + m_t^f + m_t^b + (1+i_t^r)m_t^r) \equiv \\
&\equiv (1+i_t^b)\frac{p_{t-1}}{p_t}b_t^{cb} + m_{t+1}^h + m_{t+1}^e + m_{t+1}^f + m_{t+1}^b + m_{t+1}^r
\end{aligned} \tag{25a}
$$

which can be rewritten in a more explanatory way as:

$$
\begin{aligned}
&\left(b_{t+1}^{cb} - \frac{p_{t-1}}{p_t}b_t^{cb}\right) + rcb_t \equiv i_t^b\frac{p_{t-1}}{p_t}b_t^{cb} + \\
&+[m_{t+1}^h + m_{t+1}^e + m_{t+1}^f + m_{t+1}^b + m_{t+1}^r] - \frac{p_{t-1}}{p_t}[m_t^h + m_t^e + m_t^f + m_t^b + (1+i_t^r)m_t^r]
\end{aligned} \tag{25b}
$$

Thus, as in Walsh (2010, equation 4.2), the last two terms on the RHS denote the change in the central bank's own net liabilities, where these liabilities are called high-powered money or the monetary base, because they are the stock of currency held by the non-bank private sector plus the reserves holdings of the banking sector.

Following Hall and Reis (2015), Del Negro and Sims (2015) and Benigno and Nisticò (2017), we will treat the nominal interest rate on reserves, i_t^r, the real value of the central bank's government bond purchases or equivalently its open market operations (OMOs), b_{t+1}^{cb}, and the real value of remittances from the central bank to the government, rcb_t, as the independently set monetary policy instruments (as said, later on, we will also add loans made to private banks and firms as monetary policy instruments). Then, to the extent that currency held by the non-bank public as well as reserves held by private banks are demand determined, the central bank's budget constraint in (25a) or (25b) can provide an extra equation to determine the inflation rate or the price level. The processes of the independently set monetary policy instruments are specified in subsection 3.6 below.

It is important to clarify two issues here. First, there is a rich menu of choices regarding the classification between exogenously set monetary policy instruments and the residually determined one.[35] Here, we choose this specific classification (namely, the nominal interest rate on reserves, the real value of OMOs and remittances to the fiscal authorities to be the independently set monetary policy instruments) because we find it to be more intuitive as well as more consistent with the conduct of monetary policy followed in practice (see e.g. Mishkin and Eakins, 1998). We report however that we have experimented with several other classifications and the main results, especially for the real variables, do not change; these results are available upon request. Second, as is well recognized (see e.g. Walsh, 2010 chapter 4), there are several ways of determining the inflation rate or the price level including the use of money market equilibrium conditions or the intertemporal budget constraint of the consolidated public sector (the latter is the fiscal theory of the price level). Here, other things equal, the inflation rate will be determined by the central bank's period budget constraint. Again, we report that we have experimented with several other specifications and the main results do not change; these results are available upon request.

In addition, Appendix 5 presents the budget constraint of the consolidated public sector.

3.6 Modelling of policy instruments

Following most of the related literature, we adopt a rule-like approach to policy (see e.g. Philippopoulos et al., 2017, for a review). In particular, we assume that the policy instruments can follow feedback, or state-contingent, simple policy rules according to which, in addition to a conventional exogenous AR(1) component, they can also react to a number of endogenously determined macroeconomic indicators. These rules are:

$$s_t^g = (1-\rho^g)\, s^g + \rho^g s_{t-1}^g - \gamma^{g,b}\left(\frac{b_t^T}{y_{t-1}} - \frac{b^T}{y}\right) - \gamma^{g,y}\,(y_t - y) + \varepsilon_t^g \tag{26a}$$

$$\tau_t^c = (1-\rho^c)\, \tau^c + \rho^c \tau_{t-1}^c + \gamma^{c,b}\left(\frac{b_t^T}{y_{t-1}} - \frac{b^T}{y}\right) + \gamma^{c,y}\,(y_t - y) + \varepsilon_t^c \tag{26b}$$

$$\tau_t^y = (1-\rho^y)\, \tau^y + \rho^y \tau_{t-1}^y + \gamma^{y,b}\left(\frac{b_t^T}{y_{t-1}} - \frac{b^T}{y}\right) + \gamma^{y,y}\,(y_t - y) + \varepsilon_t^y \tag{26c}$$

$$\tau_t^\pi = (1-\rho^\pi)\, \tau^\pi + \rho^\pi \tau_{t-1}^\pi + \gamma^{\pi,b}\left(\frac{b_t^T}{y_{t-1}} - \frac{b^T}{y}\right) + \gamma^{\pi,y}\,(y_t - y) + \varepsilon_t^\pi \tag{26d}$$

[35] For example, Reis (2017, p. 7) assumes that the monetary policy consists of choices of the interest rate paid on reserves and the balance sheet policies of central bank's government bond holdings and reserves.

$$b^{cb}_{t+1} = \left(1-\rho^{b}\right) b^{cb} + \rho^{b} b^{cb}_{t} - \gamma^{cb,y}\left(y_t - y\right) + \varepsilon^{b}_{t} \tag{26e}$$[36]

$$rcb_{t+1} = \left(1-\rho^{rcb}\right) rcb + \rho^{rcb} rcb_{t} - \gamma^{rcb,y}\left(y_t - y\right) + \varepsilon^{rcb}_{t} \tag{26f}$$[37]

$$\log\left(1+i^{r}_{t+1}\right) = \left(1-\rho^{i}\right)\log\left(1+i^{r}\right) + \rho^{i}\log\left(1+i^{r}_{t}\right) + \gamma^{i,\pi}\log\left(\Pi_t/\Pi\right) + \gamma^{i,y}\log\left(y_t/y\right) + \varepsilon^{i}_{t} \tag{26g}$$

where γ's are feedback policy coefficients, variables without time subscripts denote steady state values, the $0 \leq \rho$'s≤ 1 are persistence parameters, and policy shocks, $\varepsilon^{p}_{t} \equiv (\varepsilon^{g}_{t}, \varepsilon^{c}_{t}, \varepsilon^{y}_{t}, \varepsilon^{\pi}_{t}, \varepsilon^{b}_{t}, \varepsilon^{rcb}_{t}, \varepsilon^{i}_{t})$, are assumed to be iid, $\varepsilon^{p}_{t} \sim NIID\left(0, \sigma^{2}_{p}\right)$.

Two things are important in the above rules. The first is the macroeconomic indicators selected. The second is the magnitude of the feedback policy coefficients. We discuss them in turn.

Regarding macroeconomic indicators, our selection, although ad hoc, is as in most of the related literature. In other words, we allow the monetary policy instruments, to react to the output gap defined as the deviation of current output from its deterministic steady state value. Notice that monetary policy instruments react to this gap in a counter-cyclical manner; this is what we label as *policy activism*. In addition, we assume that the policy interest rate in (26g) can also react to inflation, as is the case in the standard Taylor rule.[38] With respect to fiscal policy instruments, we allow them to react to public debt imbalances defined as the deviation of the inherited public debt-to GDP ratio from its steady state value or from a target value below the data average. In general, this is required for dynamic stability.[39]

Regarding the magnitude of the feedback policy coefficients (the γ's), it is widely recognized that their values can be an important factor in the variation of dynamic determinacy and/or multipliers across different models.[40] Since their values matter along the transition path only,

[36] Following Gertler and Karadi (2011, 2013), we could also allow central banks' purchases of government debt to react positively to the deviation of government bond spread from its steady state value. In our set up, we report that this is not important.

[37] Benigno and Nistico (2017) discuss alternative specifications of the dividend rules.

[38] Following several papers in the literature on monetary policy (see e.g. Christiano et al., 2005, Smets and Wouters, 2007, Corsetti et al., 2013 and Carrillo and Poilly, 2013), in equation (26g), we treat the gross interest rate as an instrument. Using the net rate is not important to our results.

[39] See Leeper (1991).

[40] A large body of research has pointed out the importance of policy instruments' response to macroeconomic indicators for determinacy/multiplicity and macroeconomic outcomes. See Coenen et al. (2012) and Coenen et al. (2013) for policy and its multipliers. See e.g. Schmitt-Grohé and Uribe (2005, 2007) and Philippopoulos et al. (2015, 2016, 2017) for optimized monetary and fiscal feedback policy rules in DSGE models. Schmitt-Grohe

we will discuss this issue after we solve for the steady state. At this stage, we just report that here, following most of the literature (see e.g. Walsh, 2010, p. 341), when we add feedback policy rules like the above to the model, we just ensure that the values of the associated feedback policy coefficients do not render the system unstable or introduce multiple equilibria.

3.7 Modelling of exogenous stochastic variables

Except from the policy shocks defined above, all other shocks (namely, TFP and investment shocks) are assumed to follow $AR\left(1\right)$ stochastic processes of the form:

$$\log A_{t+1} = (1-\rho^{\alpha})\log A + \rho^{\alpha}\log A_t + \varepsilon_t^{\alpha} \tag{27a}$$

$$\log \xi_{t+1} = \left(1-\rho^{\xi}\right)\log \xi + \rho^{\xi}\log \xi_t + \varepsilon_t^{\xi} \tag{27b}$$

where variables without time subscripts denote steady state values, $0 \leq \rho^{a}, \rho^{\xi} \leq 1$ are persistence parameters, while $\varepsilon_t^{a} \sim NIID\left(0, \sigma_a^2\right)$ and $\varepsilon_t^{\xi} \sim NIID\left(0, \sigma_{\xi}^2\right)$ are random variables.

3.8 Macroeconomic equilibrium

We can now combine all the above to solve for a decentralized equilibrium for any feasible policy. In this equilibrium, (i) all households maximize utility; (ii) all firms maximize profits; (iii) all constraints are satisfied; (iv) all markets clear via price flexibility. We solve for a symmetric equilibrium in which all firms and all households belonging to a specific type are alike ex post.

This equilibrium system is presented in detail in Appendix 6. It consists of 31 equations in 31 endogenous variables, $\{c_t^h, c_t^e, c_t^b, u_t^h, u_t^e, u_t^b, d_{t+1}, l_{t+1}, k_{t+1}, i_t, b_{t+1}^h, m_{t+1}^h, m_{t+1}^e, m_{t+1}^f, m_{t+1}^b, m_{t+1}^r,$ $\lambda_t^h, \lambda_t^e, \lambda_t^b, \psi_t^h, \psi_t^e, \psi_t^f, , \psi_t^b, y_t, w_t, i_{t+1}^b, i_{t+1}^d, i_{t+1}^l, \pi_t^f, \pi_t^b, \Pi_t \equiv p_t/p_{t-1}\}_{t=0}^{\infty}$. This is for given the independently set policy instruments as defined in subsection 3.6, the exogenous stochastic variables as defined in subsection 3.7 and initial values for the state variables.

3.9 What is next and solution methodology

The above model will be solved numerically. Section 4 presents parameter values and the steady state solution. This steady state solution will serve as the baseline for all experiments. In particular, in section 5, we will assume that the economy is initially at this steady state

and Uribe (2005) compare optimized feedback policy rules to fully optimal (Ramsey) policy.

and experiences unanticipated shocks with known properties. We will experiment with various shocks but, as we report below in more detail, a single adverse temporary TFP shock can account relatively well for a recession scenario. In this section policy is passive. Then, in the next sections 6 and 7, transition dynamics will be driven by this TFP shock only and we will study monetary activism using standard and non-standard instruments. Throughout the paper, we compute linear transition dynamics using the Dynare toolbox.

4 Parameterization and steady state solution

This section presents parameter values and the resulting steady state solution.[41]

4.1 Parameter values and policy instruments

Regarding preference and technology parameters, we will use typical values borrowed from the literature. For instance, from the Euler equations for deposits and loans, the value of time preference rates for savers, β^h, and firm-owners, β^e, follow so as to be consistent with typical steady state values of deposit and lending rates which are 1% and 5% respectively (see also Garín, 2015). The time preference rates for bankers, β^b, is set to a value higher than β^e, in order ensure a positive quantity of loans and deposits at the steady state. Also, the coefficients in the cash-in-advance constraints for firms and households, α^h,α^e,α^f,α^b are set equal to 1 as in Niemann et al. (2013) and Auerbach and Obstfeld (2005). Finally, in the private banks' cost function, the coefficients of loans and reserves are chosen so as to get a loan to reserve ratio approximately equal to 3.

Regarding the exogenous stochastic variables of TFP and the investment shock, we set $\rho^j = 0.95$ and $\sigma^j = 0.1$, $j = \alpha,\xi$, for the persistence parameters and standard deviation respectively. For symmetry, we choose the same standard deviation for all policy instruments, whereas their persistence parameters are set at 0.

Concerning the steady state values of monetary variables, we set $b^{cb}/y = 0.1$, which is approximately the QE1 in the USA, while we set the reserve interest rate at $i^r = 0.001$, which is close to the zero lower bound (ZLB). For the steady state value of fiscal variables, as well as for preference and technology parameters not discussed so far, we will use common values in the literature.

All preference-technology parameters, parameters and policy values related to fiscal policy and parameters and policy values related to monetary policy are listed respectively in Tables

[41] The steady state system is presented in Appendix 7.

1a, 1b and 1c.

Table 1a. Preference-technology parameters

Parameter	Value	Description
β^h	0.99	savers' discount factor
β^e	0.9524	firm-owners' discount factor
β^b	0.995	bankers' discount factor
ν^h	2	disutility of labor for savers
ν^e	1	disutility of labor for firm-owners
ν^b	1	disutility of labor for bankers
χ_g	0.1	preference parameter for public good
δ	0.05	depreciation rate of capital
α	0.33	share of capital
α^h	1	coefficient in savers' cash-in-advance
α^e	1	coefficient in firm-owners' cash-in-advance
α^b	1	coefficient in bankers' cash-in-advance
α^f	1	coefficient in firms' cash-in-advance
χ	1.2	coefficient in Rotemberg-type costs
ϕ	0.9	product mark up
η^l	0.064	loans' coefficient in cost function
η^d	0.005	deposits' coefficient in cost function
η^m	0.00005	reserves' coefficient in cost function
A	1	steady state TFP
ξ	1	steady state capital quality shock
ρ^α	0.95	persistence of TFP
ρ^ξ	0.95	persistence of capital quality shock
σ^α	0.05	st.dev. of TFP

Table 1b. Fiscal policy instruments

Parameter	Value	Description
s^g	0.43	government spending as share of GDP
τ^c	0.19	consumption tax rate
τ^y	0.38	labor tax rate
τ^π	0.30	capital tax rate
ρ^g	0	persistence of government spending
ρ^c	0	persistence of consumption tax rate
ρ^y	0	persistence of labor tax rate
ρ^π	0	persistence of profit tax rate
$\gamma^{g,b}$	0.05	response of government spending to public debt
$\gamma^{c,b}$	0	response of consumption tax rate to public debt
$\gamma^{y,b}$	0	response of labor tax rate to public debt
$\gamma^{\pi,b}$	0	response of profit tax rate to public debt
σ^g	0.05	st.dev. of government spending
σ^c	0.05	st.dev. of consumption tax rate
σ^y	0.05	st.dev. of labor tax rate
σ^π	0.05	st.dev. of profit tax rate

Table 1c. Monetary policy instruments

Parameter	Value	Description
i^r	0.001	interest rate on reserves
b^{cb}/y	0.1	C.B. government debt as % of GDP
ρ^i	0	persistence of policy interest rate
ρ^b	0	persistence of C.B. government debt
ρ^{rcb}	0	persistence of remittances
$\gamma^{i,\pi}$	1.5	response of policy interest rate to inflation
$\gamma^{i,y}$	0	response of policy interest rate to output gap
$\gamma^{cb,y}$	0	response of C.B. government debt to output gap
$\gamma^{rcb,y}$	0	remittances response to output gap
σ^i	0.05	st.dev. of policy interest rate
σ^b	0.05	st.dev. of C.B. government debt
σ^{rcb}	0.05	st.dev. of C.B. remittances

4.2 Steady state solution

Using the above parameterization, we now solve numerically for the steady state of the equilibrium system as defined above. In this steady state, we exogenously set the gross inflation rate at one, $\Pi = 1$, and we allow remittances, rcb, to be endogenously determined.

Also, since the policy instruments respond to deviations of macroeconomic indicators from their long-run values, the feedback policy coefficients in the policy rules play no role in the steady state.

The solution is reported in Table 2. The main macroeconomic variables and the great ratios take reasonable values which are not far away from the data averages of advanced economies. This solution can therefore serve as a departure point in what follows.

Table 2. Steady state solution

Variables	Description	Value
u^h	savers' hours worked	0.3079
u^e	firm-owners' hours worked	0.3307
u^b	bankers' hours worked	0.4923
y	output	1.4659
c/y	consumption-to-GDP	0.4575
m/y	money-to-GDP	1.27
k/y	capital-to-GDP	2
i/y	investment-to-GDP	0.1
b^T/y	total debt-to-GDP	0.7
l	loans	0.7
d	deposits	1.178
m^r	reserves	0.2333
rcb	Central Bank's real transfers	0.0012
π	inflation	1
i^b	nominal government debt rate	0.01
i^l	nominal lending rate	0.05
i^d	nominal deposit rate	0.01
i^r	nominal reserves rate	0.001

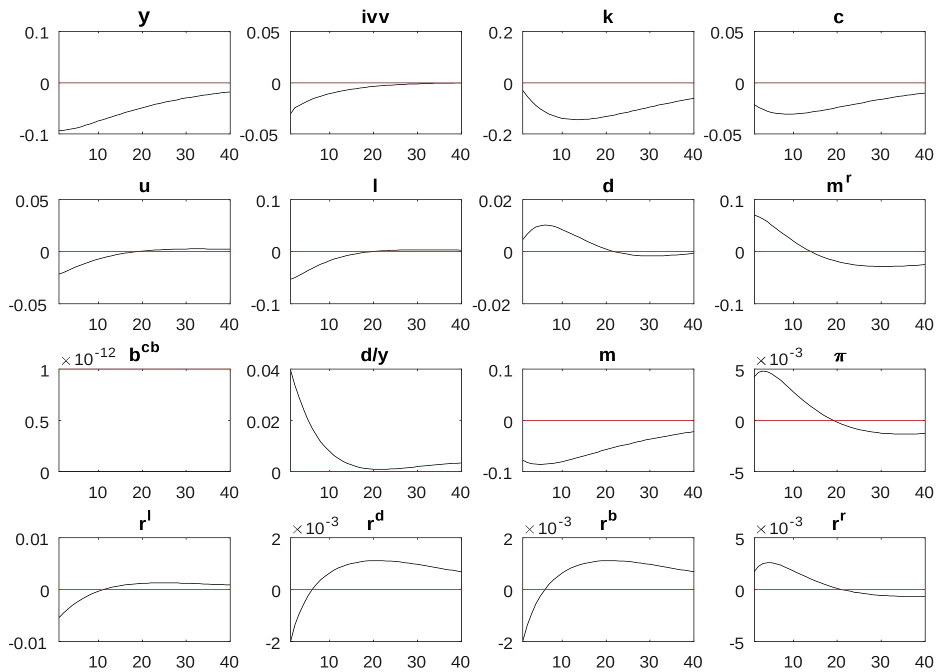
5 Shocks and transition dynamics under passive policy

In this section, we start by studying the dynamic behavior of the model under passive policy. This means that none of the monetary and fiscal policy instruments is allowed to react to the output gap or to any other indicator of real economic activity. We will only allow the policy interest rate to respond to price inflation (as in the standard Taylor rule) and the government spending to-GDP-ratio to respond to the public debt-to-GDP ratio; these responses are required for dynamic stability. To put the same thing differently, if monetary policy reacts to inflation and fiscal policy does not react to the public debt gap, the equilibrium is dynamically indeterminate.

Transition dynamics will be driven by a temporary 5% negative TFP shock only. We report however that, in addition to TFP shocks, we have experimented with shocks to investment (similar to Gertler and Kiyotaki, 2011, which is considered as a proxy of a financial shock), tax rates and government spending, which are also the four types of shocks employed by Chari et al. (2007) in their business cycle study of the US economy over the postwar period. We have experimented with one shock at a time as well as with mixes of shocks at the same time. Since the addition of other shocks does not appear to add anything substantial, we will report results with TFP shocks only (transition dynamics driven by shocks to investment, tax rates and government spending shocks are presented in Appendix 8).

Simulated impulse response functions (IRFs) for the main macroeconomic variables are shown in Figure 1. Specifically, y denotes real output, ivv is for investment, k is for the capital stock, c is total private consumption, u is total hours of work, l is for loans, d is for deposits, m^r is banks' reserves, b^{cb} is CB's government debt holdings, d/y is total public debt-to-GDP ratio, m is the currency held by the non-bank public (households and private firms), π is for price inflation, r^l is the real lending rate, r^d is the real deposit rate, r^b is the real government bond rate and r^r is the real reserve's rate. To save on space, we choose to report only the paths of the real interest rates. The nominal interest rates, due to the Taylor rule along with the no-arbitrage conditions, behave similarly to inflation.

Figure 1. Effects of a negative 5% TFP shock under passive policy



The results in Figure 1 show that an adverse temporary TFP shock, propagated by the internal dynamics of our theoretical model, can on its own produce time paths that mimic relatively well the key features of a ("great") recession episode. For instance, output falls by 10%, investment, consumption and work hours also fall, while the public debt to GDP ratio rises. Deposits increase, but banks increase their reserves at the Central Bank instead of increasing loans to firms. Regarding prices, the inflation rate increases, although this increase is small in magnitude and lasts for a few periods only after the shock.[42]

[42] We report that the behavior of the inflation rate depends on the specification of the dividends rule. For example, if we assume that the Central Bank has in its charter to pay out a dividend equal to its net income (see e.g. Hall and Reis, 2015, and Benigno and Nisticò, 2017), the inflation rate exhibits a decrease of almost the same magnitude.

6 Monetary activism

In this section, we consider monetary policy and study whether it can mitigate the recessionary effects of a negative TFP shock upon the core macroeconomic variables. In particular, we allow monetary policy instruments to react to the output gap.

We start our policy experiments with the most standard monetary policy measure to a slowing economy; the central bank allows the policy rate on reserves to react to the output gap, along with inflation, according to a Taylor-type rule. That is in subsection 6.1. Then, we continue with non-standard monetary policies. Specifically, in subsection 6.2, monetary policy is conducted via the policy interest rate on reserves and the real value of the central bank's government bond holdings, which are the two policy instruments typically employed by central banks. OMOs are allowed to respond relatively mildly to the output gap, while the policy interest rate follows a standard Taylor rule, as in subsection 6.1. In subsection 6.3, we keep the policy interest rate constant at a low value and allow OMOs only to react to the state of the economy. Subsection 6.4 is like subsection 6.2, but we also allow for a countercyclical response of the third monetary policy instrument available, namely, the remittances from the Central Bank to the Treasury. Finally, in the last subsection 6.5, we enrich the menu of monetary policy instruments by incorporating unconventional, quantitative easing (QE) type programs. Specifically, we study a policy of direct lending to private firms and a discount window policy. Such QE type-policies resemble those followed by most central banks in the aftermath of the 2008 world crisis.

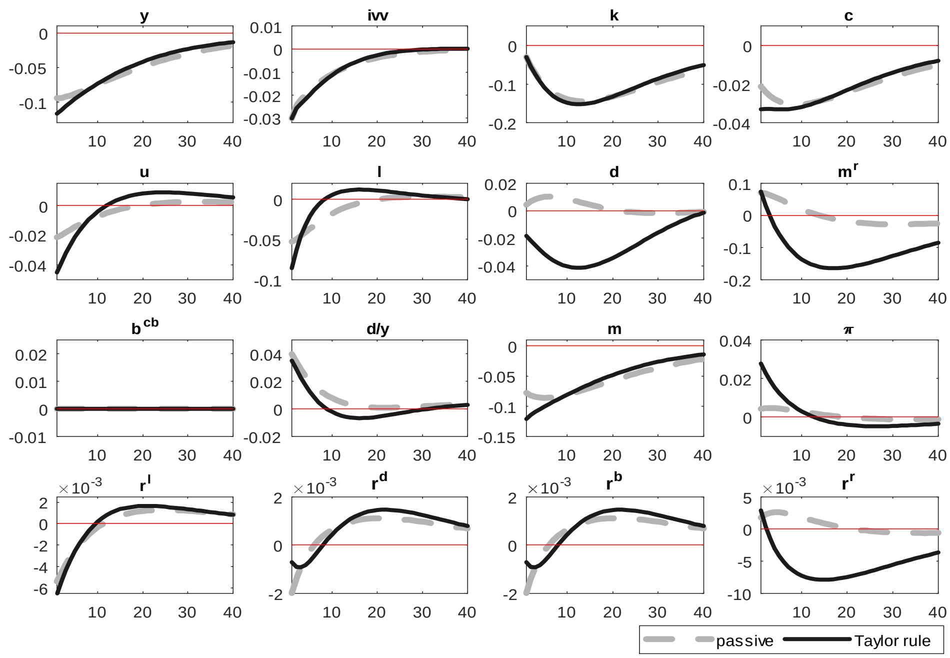
To be able to understand the logic of our results, and possibly identify the policy that helps more the real economy, we will consider one policy change at a time. Also, in each new policy experiment, the new results will be compared to the passive policy studied in section 5.

6.1 Standard monetary policy

As a first experiment of countercyclical monetary policy, we assume that the central bank aims to stabilize the economy and allows the policy rate to react to the deviations of output from its steady state value. Specifically, we switch on the feedback reaction of the policy rate to the output gap and set the respective feedback policy coefficients, $\gamma^{i,y}$, at a relatively mild degree, say 0.2, which is a value within commonly used parameter ranges.[43] IRFs for this scenario (black solid lines) are reported in Figure 2. Also, we include the IRFs under the passive policy (grey dotted lines) studied in section 5 above.

[43] For instance, see Leeper (1991), Schmitt-Grohé and Uribe (2007), Coenen et al. (2013), Kliem and Kriwoluzky (2014), Philippopoulos et al. (2016, 2017) and Coenen et al. (2012).

Figure 2. Reaction to the output gap using the policy rate



Inspection of the IRFs in Figure 2 implies that the real effects of standard monetary activism are quantitatively small.[44] Specifically, this policy hurts the real economy on impact, while it helps it marginally in the transition (see e.g. the time paths of output, capital, work hours and consumption), mainly through the lower inflation. On the positive side of effects, the public debt-to-GDP ratio falls below, whereas loans rise above, their respective steady states values in the medium-run.

Summing up, the above results raise doubts about the efficacy of standard monetary activism implemented via an operational Taylor rule.

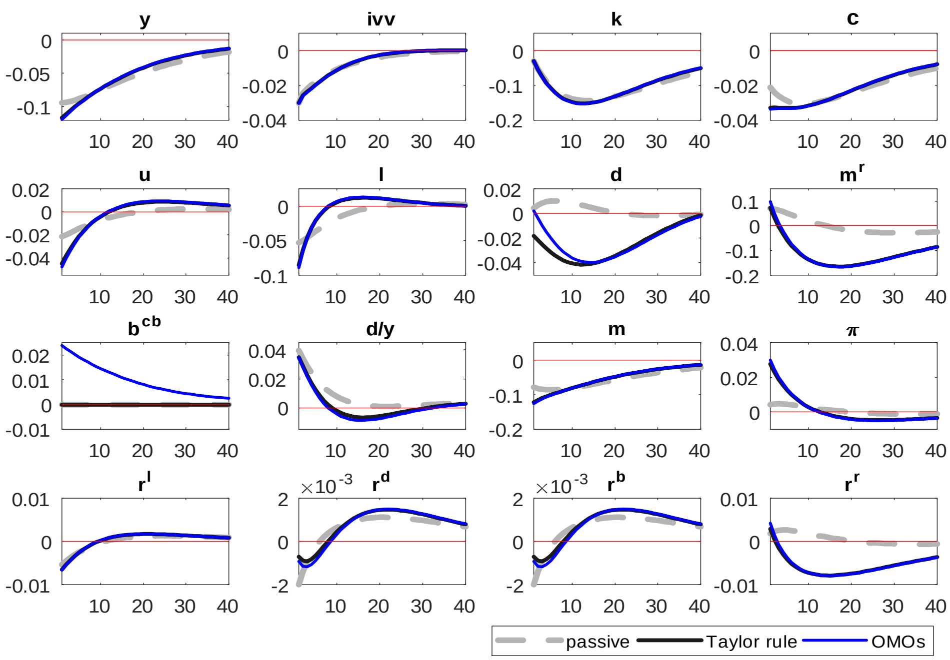
6.2 Open market operations

In this subsection, we experiment with the policy interest rate and OMOs. In other words, the central bank purchases government bonds by extending liquidity to the banking sector, while it also allows its policy rate to respond to the output gap. Specifically, the policy rate and bond purchases react to the output gap with the associated feedback policy coefficients, $\gamma^{i,y}$ and $\gamma^{cb,y}$, set at the same degree of 0.2. Notice that, since our goal is to study the potential

[44] See also subsection 6.4 for larger scale government bond purchases by the Central Bank.

merits of monetary policy activism rather than to compute the best policy mix, we apply uniformly the same value of feedback policy reaction to the output gap across all monetary policy instruments. IRFs for this scenario (blue line) are reported in Figure 3. For comparison, we include the IRFs under the passive policy (dotted grey line), studied in section 5, and under the simple Taylor rule (black line), studied in the previous subsection 6.1.

Figure 3. Reaction to the output gap by using Taylor rule and OMOs



The new IRFs seem to verify the neutrality of OMOs.[45] The portfolio effects of OMOs induce only a slightly higher decrease of private debt holdings, and a subsequently lower decrease of deposits, relatively to the standard form of monetary activism of previous subsection.

Summing up, our results so far indicate the need for additional countercyclical monetary policies on the top of a mild reaction of the policy interest rate and OMOs to the output gap.

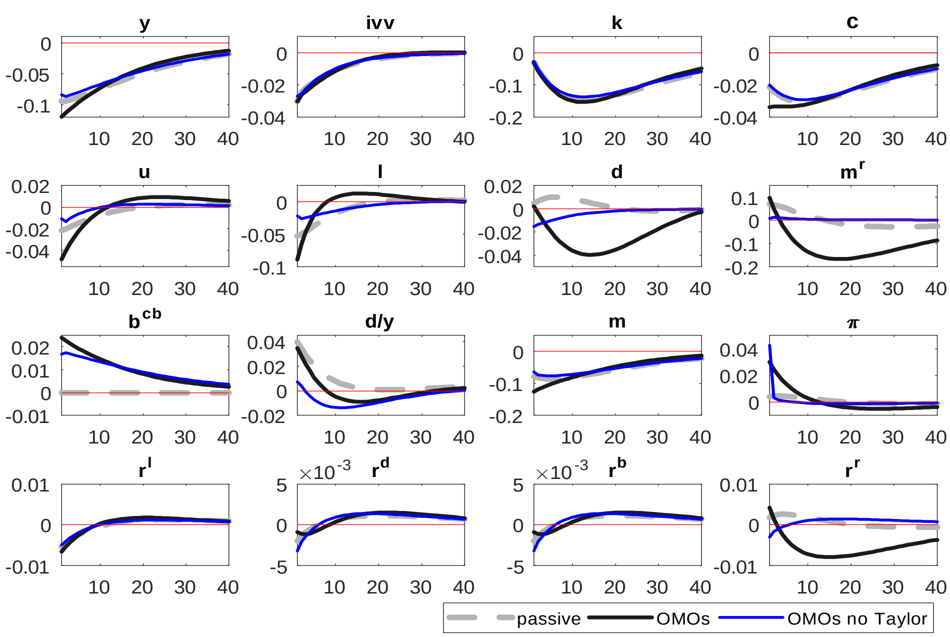
6.3 Fixing the policy interest rate at a low level

To mimic the constantly low interest rate policy employed during the recent financial crisis, and contribute, possibly, to the debate on the efficacy of QE policies at the ZLB, we now

[45] See, also, Benigno and Nisticò (2017) for a characterization of the theoretical conditions supporting that property.

assume that the central bank abandons the state-contingent Taylor rule in (26g) and, instead, keeps the nominal interest rate on reserves constant at a low, almost zero, level over time. The government spending to-GDP-ratio still responds to the public debt-to-GDP ratio (this response is required for dynamic stability). Specifically, the policy rate, i^r, is now kept constant at its steady state value (which is $i^r = 0.001$) all the time, i.e. we switch off the feedback response of the policy rate to inflation and the output gap. All other things are equal. IRFs of this scenario are in blue and reported in Figure 4. For comparison, we include again the passive policy of section 5 (grey line) and the policy mix of the previous subsection 6.2 (black line).

Figure 4. Reaction to the output gap while keeping the policy interest rate constant



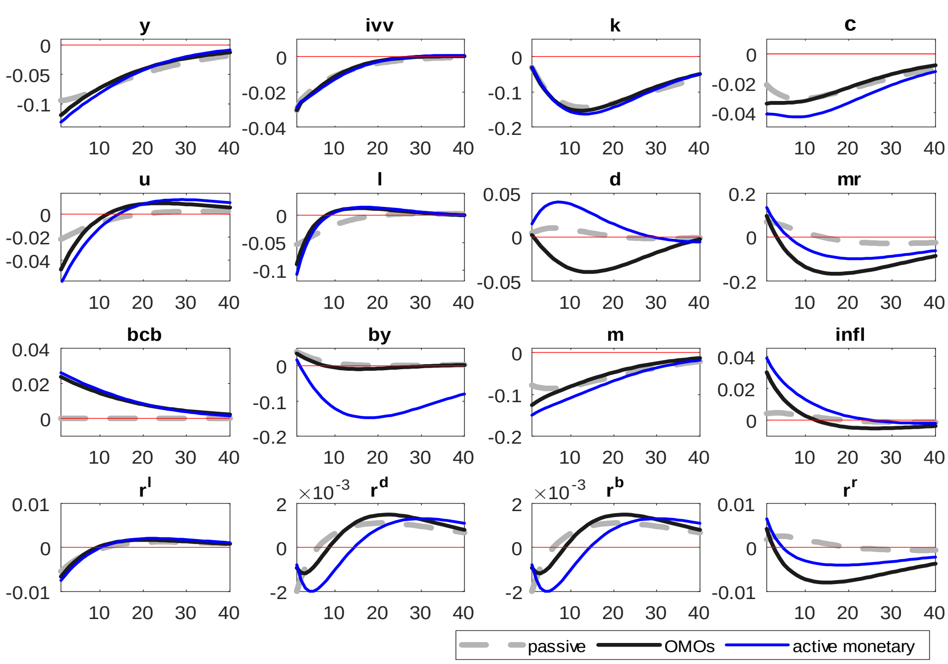
The new IRFs show that the constant interest rate policy mitigates the short-run costs of OMOs. This result is consistent with the literature. For instance, in a similar experiment, Gertler and Karadi (2013) have shown that the rise in the short-term interest rate, generated by an endogenous Taylor rule, offsets more than 80 percent of the exoect of OMOs on output. Araújo et al. (2015) have found that central bank's operations, in the absence of any change in the nominal interest rate, can affect prices and real allocations.

Compared to passive policy, the real economy marginally benefits and this happens mainly via an increase in work hours and a higher decrease of the public debt-to-GDP ratio. On the other hand, when the central bank does not allow its interest rate instrument to co-move with inflation, it loses its ability to hit a possible inflation target and inflation falls below its steady state value after period 1. This result seems to be close to reality, where, at least in the eurozone, after ten years of extensive OMO programs there is no upsurge in inflation and still a rather sluggish recovery. Summing up, when the policy interest rate is kept constant, OMOs have small effects on the time paths of the main macroeconomic variables.[46]

6.4 Adding remittances to the Treasury as a weapon of counter-cyclical policy

Here, we switch on the feedback response of remittances to the output gap. In other words, we now allow all three conventional monetary instruments to react counter-cyclically to the recession. In doing so, we set $\gamma^{i,y} = \gamma^{cb,y} = \gamma^{rcb,y} = 0.2$, so that this reaction is relatively mild. We define this policy as *active monetary policy*. Results are reported in Figure 5. As before, we include in the same graph, for comparison, the passive case (as studied in section 5) and the case of countercyclical OMOs (as studied in the subsection 6.2).

Figure 5. Active monetary policy reaction to the output gap



[46] See Bernanke (2017) and Kiley (2018).

The IRFs in Figure 5 imply that the countercyclical response of remittances cannot add significant benefits to the case of OMOs alone (see e.g. the time paths of output, capital and work hours). Specifically, this policy mix strengthens the portfolio effects of OMOs, which in turn result in a sharp reduction of both private debt and total public debt-to-GDP ratio. It is worth adding here that the magnitude of the portfolio effects is sensitive to the specification of the remittances rule. For example, if we assume that the Central Bank has in its charter to pay out a dividend equal to its net income (see e.g. Hall and Reis, 2015, and Benigno and Nistico, 2017), we observe much higher portfolio effects. However, the latter fail to stimulate the real economy, mainly, due to the high increase of the inflation rate.[47] Also, absent asset heterogeneity, deposits and government bonds are perfect substitutes and the indifferent private agents, namely savers, respond to the higher supply of governments bonds by rebalancing their portfolios towards deposits.

On the other hand, consumption would be better under OMOs alone at all times, because of the adverse inter-temporal substitution effect coming from lower real interest rates that discourage savings in the short term and hence consumption over time. Furthermore, lower interest rates do not seem to trigger any movement into cash; all private money holdings suffer a higher decrease. Regarding prices, we observe a more persistent increase of the inflation rate as well as of nominal interest rates. Summing up, when the central bank adds remittances to the Treasury as a weapon of counter-cyclical policy, it can significantly affect the total public debt.

For the standard (policy interest rate) and non-standard monetary policy instruments (OMOs and dividends from the Central Bank to the Treasury) studied so far, we, also, perform a sensitivity analysis, in order to account for the large scale government bond purchases by the central banks after the recent crisis, and, also, to possibly identify the instrument that helps more the real economy. Specifically, we experiment with one instrument at a time and increase the feedback coefficient on the output gap to 0.8, instead of 0.2, used in experiments so far, other things equal.[48] IRFs are presented in Appendix 9.

The main policy result is that when we allow for an aggressive reaction to the output gap, the most effective mix, at least in the medium-run, appears to be the one in which the central bank cuts strongly its nominal policy interest rate, which falls below the ZLB. Regarding the case of OMOs on a large scale, the IRFs imply that there are no demonstrable real benefits of

[47] The higher decrease of public debt could possibly enhance the efficacy of this policy mix in a model of sovereign default.

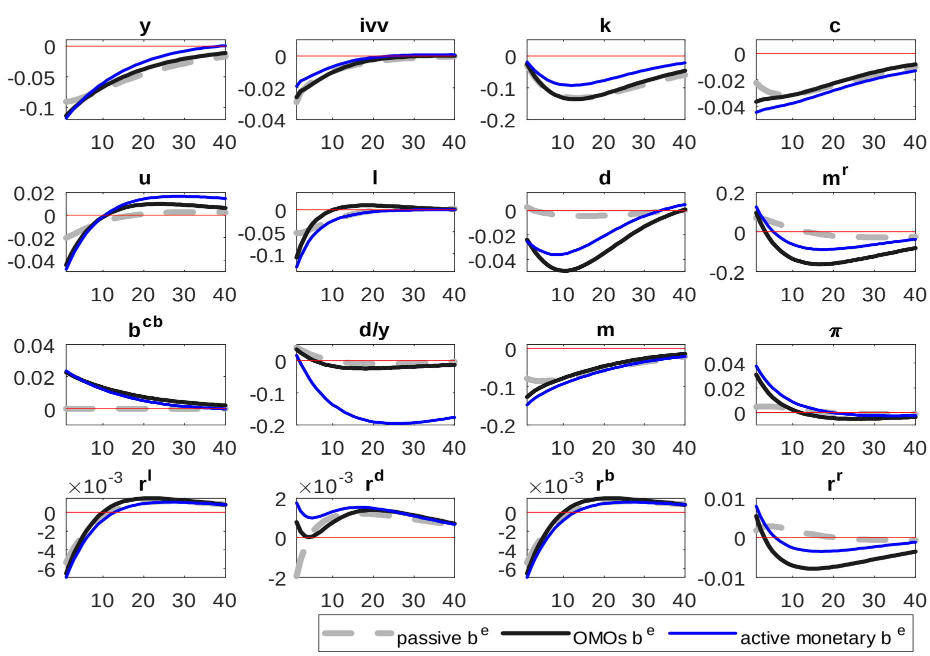
[48] This experiment could be considered as a preliminary step of the more complex and computationally intense (due to the number of policy instruments) exercise of computing optimized policy rules.

extra government bond purchases by the central bank.[49] In particular, that policy hurts the real economic activity on impact, due to the increase in inflation, which is the main criticism against the extension of QE programs, while, it slightly helps it in the medium-run, mainly through the big public debt-to-GDP ratio reduction. Finally, we report that our main results remain unchanged when we introduce an agency problem between banks and their respective depositors (modeling and numerical details are available upon request).

6.4.1 Does it matter who holds government debt?

In this subsection, we discuss how the above results of monetary activism depend on which private agent holds government debt. In our baseline model, it is households as savers (see subsection 3.2). We now modify the model by assuming that government bonds are purchased by households as firm-owners, instead of households as savers, so that, perhaps, the portfolio effects can help the real economy. The new IRFs under monetary activism are presented in Figure 6, whereas the new equilibrium system is presented in Appendix 10.

Figure 6. Active monetary policy reaction to the output gap when firm owners hold government debt



[49] See also Reis (2016) and Blinder et al. (2017).

A comparison of Figures 5 and 6 verifies the importance of the portfolio effects of OMOs; see the time paths of capital, investment and output which are now clearly above their counterparts in the passive case at least after the first negative impact effect.[50] The policy mix of countercyclical OMOs and remittances delivers stronger portfolio effects, which now help investment, and finally output, as firm-owners switch to capital.

6.5 Unconventional QE-type policies

We continue with the extra unconventional monetary policies employed by several central banks since the beginning of the financial crisis in 2007. In particular, we study direct lending to private firms and a discount window policy.

6.5.1 Direct lending to private firms

To mimic an unconventional QE type policy employed by several central banks during the recent crisis, namely, direct lending to non-financial institutions,[51] we add central bank's loans to private firms, denoted as l^{cb}, as an extra monetary policy instrument.[52] Following Cúrdia and Woodford (2010a, 2010b), we assume that these loans pay the same lending rate as bank loans and follow a rule similar to (26e).[53] Specifically,

$$l_{t+1}^{cb} = \left(1 - \rho^{lcb}\right) l^{cb} + \rho^{lcb} l_t^{cb} - \gamma^{lcb,y} \left(y_t - y\right) + \varepsilon_t^l \tag{28}$$

In order to be able to compare the joint policy of OMOs and direct loans to firms against the policy of OMOs alone, we set $\gamma^{lcb,y} = 0.2$ (an equal response of direct loans to the output gap) and $\rho^{lcb} = 0$. Results are reported in Figure 7, where the blue lines describe the case with direct lending to firms, other things equal relative to Figure 5.

As can be seen, central bank's asset purchases of direct loans and government bonds, do not affect real allocations, relative to the case of government bond purchases only (the only exception is the slight increase in total loans). The reason is that these two assets, namely government bonds and loans, share close characteristics. Government bonds are chosen by savers while loans by firms, where both agents are financially unconstrained and bear no

[50] Portfolio rebalancing effects were the main explanation of ECB's policy. For a theoretical background on these effects, see, for example Zampolli (2012) for an overview of the theory on the portfolio rebalancing effects or Greenwood and Vayanos (2008) and Vayanos and Vila (2009).

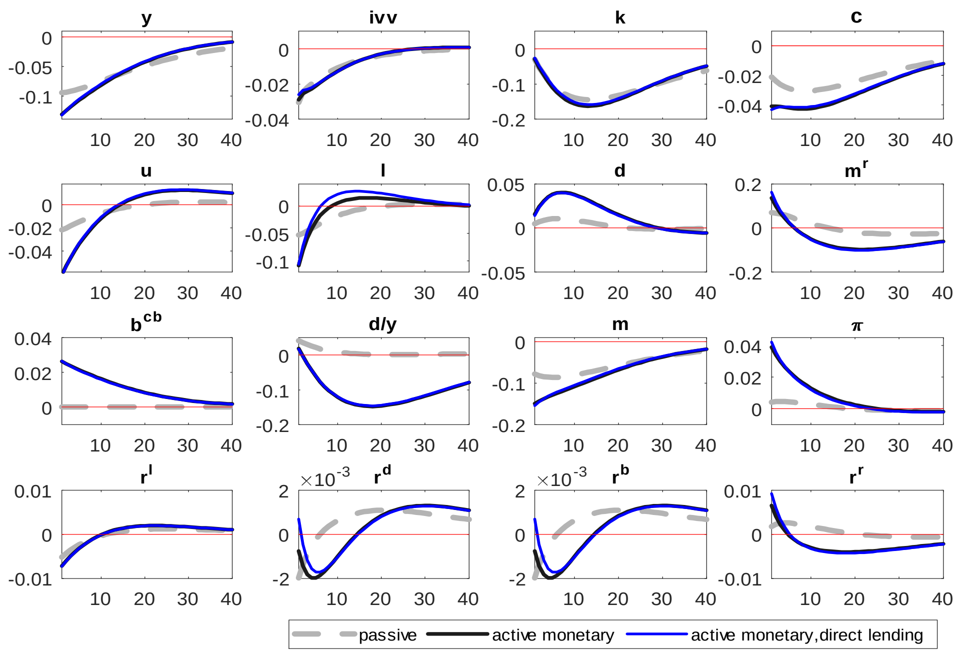
[51] E.g. the Corporate Sector Purchase Program by ECB and Long Scale Asset Purchase program by FED.

[52] The market-clearing in the loans market, eq. (37e), changes to $l_{t+1}^{f} = l_{t+1}^{b} + l_{t+1}^{cb}$. The equilibrium system does not change.

[53] In Gertler and Karadi (2011, 2013), Central Bank's private loans are a fraction, which is an increasing function of lending spread, of total loans.

transaction costs.[54] Thus, asset purchases cannot trigger strong portfolio effects.

Figure 7. Reaction to the output gap using monetary activism plus direct lending to firms



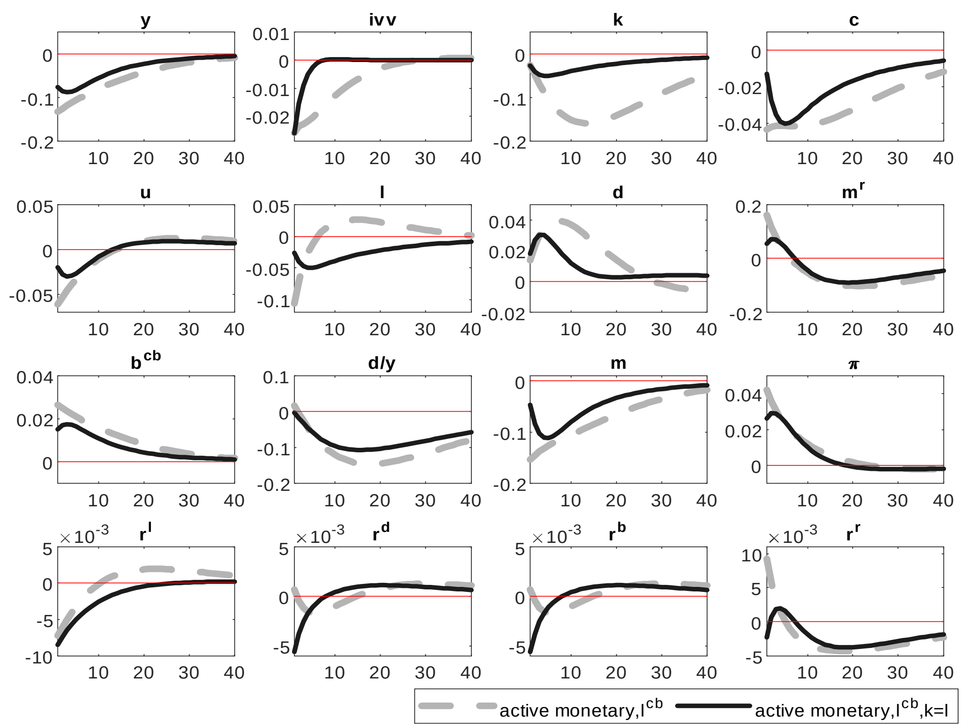
What happens if firms are financially constrained

As already mentioned in previous sections, our main results remain unchanged when we introduce an additional financial friction in the form of an agency problem between banks and their respective depositors as in Gertler and Kiyotaki (2011), which ties the supply of loans to banks' wealth. However, the implications of a policy of direct lending would change though if we follow e.g. Gertler and Karadi (2011, 2013), Gertler and Kiyotaki (2011), Güntner (2015), by assuming that intermediate-goods firms should finance their physical capital acquisition in advance of production. In other words, we will impose additional frictions on credit demand and, in particular, we will assume that the real quantity of new loans equals the quantity of new capital at the end of each period ($l^f_{t+1} = k^f_{t+1}$).

[54] We have not assumed any type of cost, i.e. monitoring costs, associated with CB's direct lending to private sector, in order not to favor any particular QE policy. On the contrary, Gertler and Karadi (2013) assume smaller intermediation cost in government debt compared to private loans market

New results are presented in Figure 8, where the grey line is for the case of monetary activism and direct lending when firms are financially unconstrained (as in Figure 7) and the black line is for the same policy mix when firms are financially constrained.

Figure 8. Reaction to the output gap using monetary activism plus direct lending to firms when $l_{t+1}^{f} = k_{t+1}^{f}$



The new IRFs verify the results of the aforementioned authors. In particular, the extra liquidity provided to private firms is now beneficial since it is directly translated into higher capital and investment, and in turn, output. In sum, the real effects of direct lending to private firms by the central bank depend crucially upon the presence of borrowing constraints on the demand side (firms) rather than the supply side (banks) of the credit market.

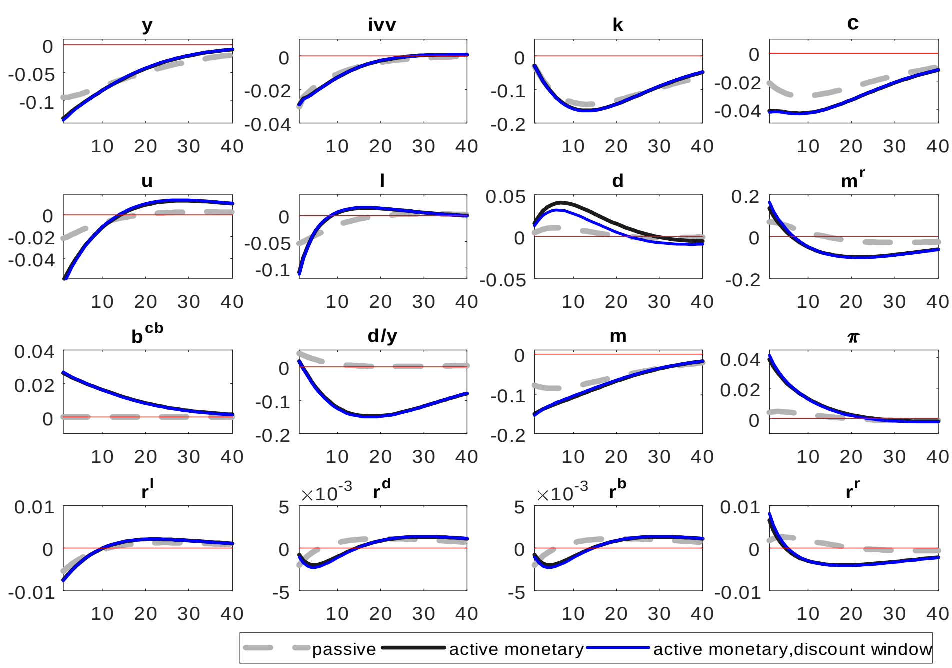
6.5.2 Extra loans to private banks

Upon the eruption of the financial crisis of 2007-2008, most central banks extended the discount window in order to provide extra liquidity to financial institutions and thereby restore bank lending to the real economy.[55] To mimic this type of QE policy, we add a new monetary policy instrument, central bank's loans to private banks, denoted as d^{cb}.[56] These loans are assumed to pay the same interest rate as deposits. The new monetary policy instrument follows a rule similar to c), which is:

$$d_{t+1}^{cb} = \left(1 - \rho^{dcb}\right) d^{cb} + \rho^{dcb} d_t^{cb} - \gamma^{dcb,y} \left(y_t - y\right) + \varepsilon_t^d \tag{29}$$

As in the previous experiment, for reasons of comparability, we set $\gamma^{dcb,y} = 0.2$ (an equal response of bank loans to the output gap) and $\rho^{dcb} = 0$. New results are reported in Figure 9, where the blue lines describe the case with discount window lending to banks, other things equal.

Figure 9. Reaction to the output gap using monetary activism plus lending to banks



The same results and rationale, as in the case of central bank's loans to private firms, apply also here. Central bank's purchases of assets other than government bonds, which are

[55] The theoretical and empirical literature on banking (see e.g. Rajan, 2005, Borio and Zhu, 2012) has highlighted the importance of the "bank lending" channel for the transmission of monetary policy.

[56] The market-clearing in the deposits market, eq. (37f), changes to $d_{t+1}^b = d_{t+1}^{cb} + d_{t+1}^h$. The equilibrium system does not change.

held by the same agent (savers), deliver no real differences. Savers just exchange deposits for government debt. Summing up, a policy of direct lending to private banks does not appear to benefit the real economy.

Summarizing the results of monetary policy activism across the different regimes studied in this section, and having already reported the results for each main category of monetary policy at the end of each subsection above, we close with some more general statements. First, the policy rate seems to remain the most powerful weapon at the hands of central bank. Relative to passive policy, the policy mix that benefits, slightly though, the real economy, at least in the short and medium-run, is when the policy rate remains constant at a low level, while the central bank buys government bonds at a moderate degree. Second, the efficacy of the various asset purchasing programs (namely OMOs, direct loans to firms and banks) depends on certain premises; their interactions with the other monetary policy instruments, the characteristics of the public debt holders and the existence of specific credit frictions that need to be addressed. For example, without countercyclical remittances from central bank to treasury, the portfolio effects of OMOs are negligible. In addition, the extra unconventional QE type programs are potentially effective complements to conventional policies only when firms are financially stressed. Thus, for monetary activism to be effective there should be a careful consideration of market imperfections along with the intrinsic characteristics of market participants.

7 Adding fiscal activism

Can fiscal activism mitigate any negative and/or reinforce any positive effect of monetary activism? Today, while there has been a revival of interest in countercyclical fiscal policy as a stabilization tool,[57] the feasibility or the desirability of fiscal policy activism remains a debated issue, since its practice and effects depend crucially on the state of the economy and the stance of monetary policy.[58]

In this section we also allow for active fiscal policy across different monetary policy regimes, so as to examine the potential benefits of fiscal-monetary policy interaction. In particular, given the activist monetary policies studied in the previous section, we now also allow the tax rates and the government spending-to-GDP ratio to react to the output gap.

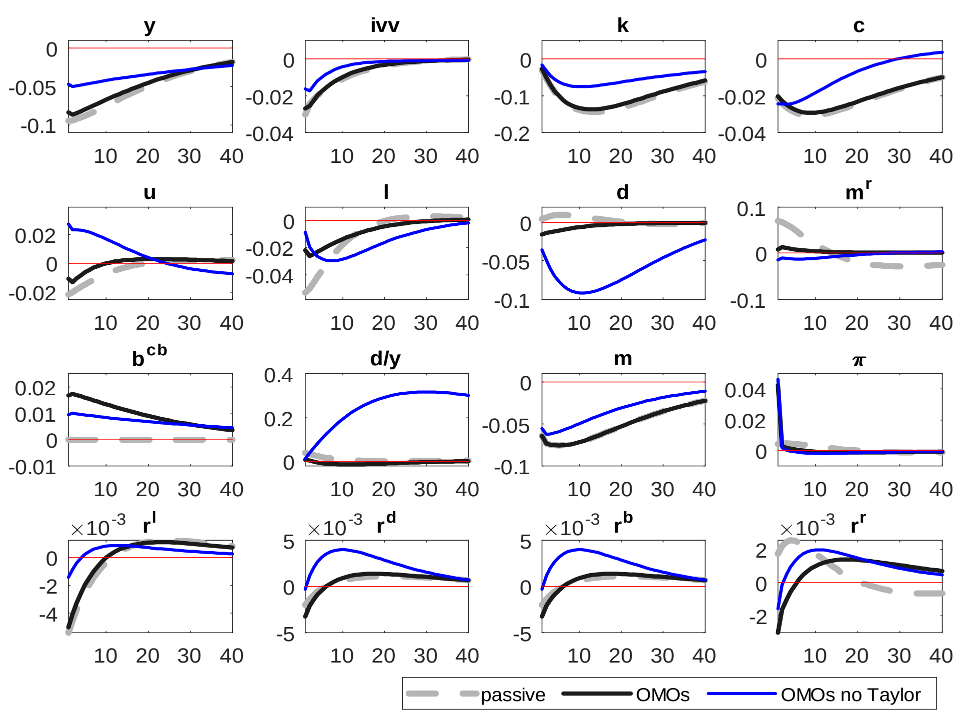
[57] See e.g. Auerbach and Gale (2009) for a review of practice and effects of countercyclical fiscal policy interventions in the U.S. after the 1980. Also, Auerbach and Gorodnichenko (2017) showed that fiscal policy contributed to the US recovery after the severe slowdown of 2008-2009.

[58] See, for example, Taylor (2000), Taylor (2009), Feldstein (2009) and Blinder (2006) for a criticism on active fiscal policy.

In what follows, to save on space, we will report only the results of fiscal activism when it is combined with OMOs under a constant nominal policy rate, the monetary policy mix that has been found to help more an economy in recession (results for all the alternative monetary policy regimes studied in section 6 are available upon request). Specifically, we switch on the feedback reaction to the output gap in fiscal policy rules ((26a)-(26d)) and set the associated feedback coefficients at 0.2, ($\gamma^{g,y} = \gamma^{c,y} = \gamma^{y,y} = \gamma^{\pi,y} = 0.2$). At the same time, the policy rate is kept constant at its steady state value (which is $i^r = 0.001$), while the central bank buys government bonds ($\gamma^{cb,y} = 0.2$), the monetary policy mix.

Results are shown in Figure 10. The new results are compared again to passive policy, as studied in section 5 (grey line) and to the monetary policy alone, as studied in subsection 6.3. For the joint fiscal-monetary policy, we add a new IRFs shown in blue color.

Figure 10. Reaction to the output gap using both policies while keeping the policy interest rate constant



The IRFs in Figure 10 shows that there are real benefits from fiscal-monetary coordination. In particular, relative to the passive policy, a joint policy reaction to the output gap helps consumption (this is driven by the rise in real interest rates that stimulate savings in the short term and consumption in the medium term according to the standard inter-temporal substitution effect) and work hours (this is driven by the cut in the labor tax rate according to the feedback policy rule (26c)). As a result, output decrease is almost half compared to the case of passive policy. These results are consistent with the literature. For example, in their review paper on fiscal stimulus, Coenen et al. (2012) have also provided evidence that fiscal multipliers increase in a variety of DSGE models when the nominal interest rate remains unchanged.

Summing up, there appear to be non-negligible benefits to the real economy from fiscal-monetary activism. Fiscal activism increases the demand for consumption and investment, stimulates aggregate demand, and thus, gets the economy on path to recovery. However, the higher public debt tempers the positive medium run effects of that policy mix.

8 Conclusions

In this paper, using a medium scale DSGE model that included all maim building blocks of a market economy, we studied the potential merits of macroeconomic (monetary and fiscal) policy activism. Since the results have been already listed in the Introduction, here we close with two potential extensions. First, it would be interesting to see what changes in an open economy context and, in particular, in a model of a currency union where the single currency plays extra roles. Second, a full treatment of policy would be achieved through the optimized policy rules, in other words, the optimal values of the feedback policy coefficients.

References

[1] Acharya, V.V., Naqvi, H., 2012. The seeds of a crisis: a theory of bank liquidity and risk taking over the business cycle. Journal of Financial Economics, 106 (2), 349-366.

[2] Aghion, P., Howitt, P., 2009. The Economics of Growth. MIT Press.

[3] Ajello, A., 2016. Financial intermediation, investment dynamics, and business cycle fluctuations. American Economic Review, 106(8), 2256-2303.

[4] Altug, S., Labadie, P., 1994. Dynamic Choice and Asset Markets. Academic Press

[5] Araújo, A., Schommer, S., Woodford M., 2013. Conventional and Unconventional Policy with Endogenous Collateral Constraints. American Economic Journal: Macroeconomics, 7(1), 1-43.

[6] Auerbach, A., Obstfeld, M., 2005. The Case for Open-Market Purchases in a Liquidity Trap. American Economic Review, 95(1), 110-137.

[7] Auerbach, A., Gale, W.G., 2009. Activist fiscal policy to stabilize economic activity. Proceedings-Economic Policy Symposium-Jackson Hole, Federal Reserve Bank of Kansas City, 327-374.

[8] Auerbach, A., Gorodnichenko, Y., 2017. Fiscal Stimulus and Fiscal Sustainability. NBER working paper 23789.

[9] Benigno, P., Nisticò, S., 2017. Non-neutrality of open market operations. CEPR, discussion paper 10594.

[10] Bernanke, B. Gertler, M., 1989. Agency costs, net worth, and business fluctuations. American Economic Review, 79, 14-31.

[11] Bernanke, B., Gertler, M., Gilchrist, S., 1999. The financial accelerator in a quantitative business cycle framework. Handbook of Macroeconomics, 1, 1341-1393.

[12] Bi, H., 2012. Sovereign default risk premia, fiscal limits and fiscal policy. European Economic Review, 56, 389-410.

[13] Bi, H., Leeper, M., Leith, C., 2013. Uncertain Fiscal consolidations. Economic Journal, 0, 31-63.

[14] Blinder, A., Ehrmann, M., Haan, J., Jansen. D.J., 2017. Necessity as the mother of invention: monetary policy after the crisis. Economic Policy, 32(92), 707-755.

[15] Boivin, J., Kiley, M., Mishkin, F., 2010. How has the monetary transmission mechanism evolved over time? Handbook of Monetary Economics, 3, 369-422.

[16] Borio, C., Zhu, H., 2012. Capital regulation, risk-taking and monetary policy: A missing in the transition mechanism? Journal of Financial Stability, 8(4), 236-251.

[17] Brock, W.A., Turnovsky, S.J., 1981. The Analysis of Macroeconomic Policies in Perfect Foresight Equilibrium. International Economic Review, 22(1), 179-209.

[18] Brunnermeier, M.K, Sannikov, Y., 2014. A Macroeconomic Model with a Financial Sector. American Economic Review, 104(2), 379-421.

[19] Brzoza-Brzezina, M., Kolasa, M., Makarski, K., 2013. The anatomy of standard DSGE models with financial frictions. Journal of Economic Dynamics and Control, 37(1), 32-51.

[20] Caglar, E., Chadha, J.S., Meaning, J., Warren, J., Waters, A., 2011. Non-Conventional Monetary Policies: QE and DSGE literature. Studies in Economics 1110, School of Economics, University of Kent.

[21] Canzoneri, M.B., Cumby, R.E., Diba, B.T., 2001. Is the Price Level Determined by the Needs of Fiscal Solvency? American Economic Review, 91(5), 1221-1238.

[22] Carillo, J.A., Poilly, C., 2013. How do financial frictions affect the spending multiplier during a liquidity trap? Review of Economic Dynamics, 16(2), 296-311.

[23] Carlstrom, C.T., Fuerst, S., 1997. Agency costs, net worth, and business fluctuations: a computable general equilibrium analysis. American Economic Review, 87, 893-910.

[24] Carlstrom, C.T., Fuerst, S., Paustian, M., 2017. Targeting Long Rates in a Model with Segmented Markets. American Economic Journal: Macroeconomics, 9(1): 205-42.

[25] CCBS Handbook 2015. Bank of England.

[26] Chari, V.V., Kehoe, P.J., McGrattan, E., 2007. Business Cycle Accounting. Econometrica, 75(3), 781-836,05.

[27] Chen, H., Cúrdia, V., Ferrero, A., 2012. The Macroeconomic Effects of Large-scale Asset Purchase Programmes. Economic Journal, 122(564), 289-315.

[28] Christiano, L., Eichenbaum, M., Evans, C.L., 2005. Nominal rigidities and the dynamic effects of a shock to monetary policy. Journal of Political Economy, 113(1), 1-45.

[29] Christiano, L.J., Trabandt, M., Walentin, K., 2010. DSGE Models for Monetary Policy Analysis. In: Friedman, B.M., Woodford, M., (Ed.), Handbook of Monetary Economics, ed. 1, vol 3., 285-367, Elsevier.

[30] Clerk, L., Derviz, A., Mendicino, C., Moyen, S., Nikolov, K., Stracca, L., Suarez, J., Vardoulakis, A.P., 2015. Capital Regulation in a Macroeconomic Model with Three Layers of Default. International Journal of Central Banking, 11(3), 9-63.

[31] Coenen, G., Mohr, M., Straub, R., 2008. Fiscal consolidation in the euro area: long-run benefits and short-run costs. Economic Modelling, 25, 912–932.

[32] Coenen, G., Erceg, C., Freedman, C., Furceri, D., Kumhof, M., Lalonde, R., Laxton, D., Lindé, J., Mourougane, A., Muir, D., Mursula, S., Carlos d, 2012. Effects of fiscal stimulus in structural models. American Economic Journal: Macroeconomics, 4 (1), 22–68.

[33] Coenen, G., Straub, R., Trabandt M., 2013. Gauging the effects of fiscal stimulus packages in the euro area. Journal of Economic Dynamics and Control, 37(2), 367-386.

[34] Corsetti, G., Kuester, K., Meier, A., Müller, G.J., 2013. Sovereign Risk, Fiscal Policy and Macroeconomic Stability. Economic Journal, 0, 99-132.

[35] Cúrdia, V., Woodford, M., 2010. Conventional and unconventional monetary policy. Review, Federal Reserve Bank of St. Louis, issue May, 229–264.

[36] Cúrdia, V., Woodford, M., 2011. The central bank balance-sheet as an instrument of monetary policy. Journal of Monetary Economics, 58(1), 54–79.

[37] Cúrdia, V., Woodford, M., 2016. Credit frictions and optimal monetary policy. Journal of Monetary Economics, 84(C), 30–65.

[38] Davig, T., Leeper, E., 2011. Monetary-fiscal policy interactions and fiscal stimulus. European Economic Review, 55(2), 211-227.

[39] De Grauwe, P., 2013. The European Central Bank as lender of last resort in the government bond markets. CESifo Economic Studies, 59, 520-535.

[40] De Nicolò, G., Gamba, A., Lucchetta, M., 2014. Microprudential Regulation in a Dynamic Model of Banking. Review of Financial Studies, 27(7), 2097-2138.

[41] Del Negro, M., Sims, C. A., 2015. When does a central bank's balance sheet require fiscal support? Journal of Monetary Economics, 73(C), 1-19.

[42] Dell'Ariccia G., Marquez R. and Laeven L., 2010.Monetary policy, leverage, and bank risk-taking. IMF Working Papers 10/276.

[43] Dib, A., 2010. Banks, credit market frictions and business cycles. Working paper 10-24, Bank of Canada.

[44] Dixit, A., Stiglitz, J., 1977. Monopolistic competition and optimum product diversity. American Economic Review, 67(3), 297-308.

[45] Fahr, S., Motto, R., Rostagno, M., Smets, F., Tristani, O., 2013. A monetary policy strategy in good and bad times: lessons from the recent past. Economic Policy, 28(74), 243-288.

[46] Feldstein, M.S., 2009. Rethinking the role of fiscal policy. American Economic Review, 99(2), 556-559.

[47] Fisher, J.D.M., 2006. The Dynamic Effects of Neutral and Investment-Specific Technology Shocks. Journal of Political Economy, 114(3), 413-451.

[48] Forni, M., Giannone, D., Lippi, M., Reichlin, L., 2009. Opening the Black Box: Structural Factor Models with Large Cross Sections. Econometric Theory, 25(05), 1319-1347.

[49] Frexias, X., Rochet, J.C., 1997. Microeconomics of Banking. MIT Press.

[50] Friedman, M., 1982. Monetary Policy: Theory and Practice. Journal of Money, Credit and Banking, 14(1), 98-118.

[51] Friedman, M., 1970. A Theoretical Framework for Monetary Analysis. Journal of Political Economy, 78(2), 193-238.

[52] Gambacorta, L., Hoffman, B., Peersman, G., 2011. The Effectiveness of Unconventional Monetary Policy at the Zero Lowe Bound: A Cross-Country Analysis. Journal of Money, Credit and Banking, 46(4), 615-642.

[53] Garín, J., 2015. Borrowing constraints, collateral fluctuations, and the labor market. Journal of Economic Dynamics and Control 57 (C), 112–130.

[54] Gertler, M., Karadi, P., 2011. A Model of Unconventional Monetary Policy. J. Monet. Econ., 58 (1), 17–34.

[55] Gertler, M., Karadi, P., 2013. QE 1 vs 2 vs 3. . . : A Framework for Analyzing Large-Scale Asset Purchases as a Monetary Policy Tool. International Journal of Central Banking, 9(1), 5-53.

[56] Gertler, M., Kiyotaki, N., 2011. Financial intermediation and credit policy in business cycle analysis. In: Friedman, B.M., Woodford, M. (Ed.), Handbook of Monetary Economics, ed. 1, vol. 3., 547-599, Elsevier.

[57] Gilchrist S., Oriz, A., Zakrajsek, E., 2009. Credit risk and the macroeconomy: evidence from an estimated DSGE model. Paper presented at the Financial Markets and Monetary Policy Conference, sponsored by the Federal Reserve Board and the Journal of Money, Credit, and Banking, June 4-6.

[58] Greenwood, R., Vayanos, D., 2008. Bond Supply and Excess Bond Returns. Review of Financial Studies, 27(3), 663-713.

[59] Güntner, J.H.F., 2015. The federal funds market, excess reserves, and unconventional monetary policy. Journal of Economic Dynamics and Control, 53(C), 225–250.

[60] Hall, R. E., Reis, R., 2016. Achieving Price Stability by Manipulating the Central Bank's payment on Reserves. NBER working paper 22761.

[61] Hofmann, B., Bogdanova, B., 2012. Taylor rules and monetary policy: a Global Great Deviation? BIS Quarterly Review, 37-49.

[62] Iacoviello, M., 2005. House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle. American Economic Review, 95(3), 739-764.

[63] Iovino, L., Sergeyev, D., 2018. Central bank balance sheet policies without rational expectations. Unpublished manuscript, Bocconi University.

[64] Jermann, U., Quadrini, V., 2012. Macroeconomic effects of financial shocks. American Economic Review, 102 (1), 238-71.

[65] Kiley, M.T., 2018. Quantitative Easing and the "New Normal" in Monetary Policy. Finance and Economics Discussion Series 2018-004, Washington: Board of Governors of the Federal Reserve System.

[66] Kiyotaki, N., Moore, J., 1997. Credit cycles. Journal of Political Economy, 105, 211–248.

[67] Kliem, M., Kriwoluzky, A., 2014. Toward a Taylor Rule for Fiscal Policy. Review of Economic Dynamics, 17(2), 294-302.

[68] Leeper, E., 1991. Equilibria under active and passive monetary and fiscal policies. Journal of Monetary Economics, 27, 129–147.

[69] Leeper, E., Walker, B., Yan, S-C.S., 2009. Government Investment and Fiscal Stimulus in the Short and Long Runs. NBER working paper 15153.

[70] Leeper, E., Traum, N., Walker, T.B, 2017. Clearing up the fiscal multiplier morass. American economic Review, 107(8), 2409-2454.

[71] Lenza, M., Pill, H., Reichlin, L., 2010. Monetary policy in exceptional times. Economic Policy, 25, 295-339,04.

[72] Ljungqvist, L., Sargent, T.J., 2012. Recursive Macroeconomic Theory, MIT Press.

[73] Lucas, R., 1990. Supply side economics: an analytical review. Oxford Economic Papers, 42, 293-316.

[74] McMahon, M., Peiris, U., Polemarchakis, H., 2018. Perils of unconventional monetary policy. Journal of Economic Dynamics and Control, 93, 92–114.

[75] Miao, J., 2014. Economic Dynamics in Discrete Time. MIT Press.

[76] Mishkin, F., Eakins, S.,1998. Financial Markets and Institutions. NJ: Prentice Hall.

[77] Niemann, S., Pichler, P., Sorger, G., 2013. Central Bank Independence and the Monetary Instrument Problem. International Economic Review, 54, 1031-1055,08.

[78] Okun, M., 1972. Fiscal-Monetary Activism: Some Analytical Issues. BPEA, 132-33.

[79] Philippopoulos, A., Varthalitis, P., Vassilatos, V., 2015. Optimal fiscal and monetary policy action in a closed economy. Economic Modelling, 48, 175–188.

[80] Philippopoulos A., Varthalitis P. and Vassilatos V., 2016. Fiscal consolidation in an open economy with sovereign premia, mimeo, forthcoming in International Journal of Central Banking.

[81] Philippopoulos, A., Varthalitis, P., Vassilatos, V., 2017. Fiscal consolidation and its cross-country effects. Journal of Economic Dynamics and Control, 83, 55–106.

[82] Priftis, R., Vogel, L., 2016. The portfolio balance mechanism and QE in the euro area. Manchester School 84, 84–195.

[83] Rajan, R.G., 2005. Has financial development made the world riskier? Proceedings-Economic Policy Symposium-Jackson Hole, Federal Reserve Bank of Kansas City, 313-368.

[84] Ravenna, F., Walsh, C.E., 2006. Optimal monetary policy with the cost channel. Journal of Monetary Economics, 53, 199–216.

[85] Reifschneider, D., 2016. Gauging the Ability of the FOMC to Respond to Future Recessions. Finance and Economics Discussion Series 2016-068, Washington: Board of Governors of the Federal Reserve System.

[86] Reinhart, C., Rogoff, K., 2010. Growth in a time of debt. American Economic Review, 100, 573–578.

[87] Reis, R., 2016. Funding Quantitative Easing to Target Inflation. CEPR Discussion Papers 11505, C.E.P.R. Discussion Papers.

[88] Reis, R., 2017. Can the Central Bank Alleviate Fiscal Burdens? CEPR Discussion Papers 11736, C.E.P.R. Discussion Papers.

[89] Rotemberg, J. J., 1982. Monopolistic price adjustment and aggregate output. Review of Economic Studies, 49, 517-531.

[90] Sargent, T.J., Macroeconomic Theory. Academic Press, second edition.

[91] Schmitt-Grohé, S., Uribe, M., 2005. Optimal fiscal and monetary policy in a medium-scale macroeconomic model. In: Gertler, M., Rogoff, K. (Eds.), NBER Macroeconomics Annual, MIT Press, Cambridge MA, 385–425.

[92] Schmitt-Grohé, S., Uribe, M., 2007. Optimal simple and implementable monetary and fiscal rules. Journal of Monetary Economics, 54, 1702-1725.

[93] Schmitt-Grohé, S., Uribe, M., 2016. Multiple equilibria in open economy models with collateral constraints: overborrowing revisited. NBER working paper, 22264.

[94] Schmitt-Grohé, S., Uribe, M., 2017. Open Economy Macroeconomics. Princeton University Press.

[95] Sinn, H.-W., 2010. Rescuing Europe, CESifo Forum, 11, 1-22.

[96] Sinn, H.-W., Wollmershäuser T., 2012. Target loans, current account balances and capital flows: the ECB's rescue facility. International Tax and Public Finance, 19(4), 468-508.

[97] Smets, F., Wouters, R., 2007. Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach. American Economic Review, 97(3), 586-606.

[98] Taylor, J.B., 2000. Reassessing Discretionary Fiscal Policy. Journal of Economic Perspectives, 14(3), 21-36.

[99] Taylor, J.B., 2009. The lack of an empirical rationale for a revival of discretionary fiscal policy. American Economic Review, 99, 550-555.

[100] Taylor, J.B., 2014. Monetary policy and the state of the economy. Economics working papers 14107, Hoover Institution, Stanford University.

[101] Tobin, J., 1982. Money and Finance in the Macroeconomic Process. Journal of Money, Credit and Banking, 14(2), 171-204.

[102] Turnovsky, S.J., 1995. Methods of Macroeconomic Dynamics. MIT Press.

[103] Uribe, M., Yue, V.Z., 2006. Country Spreads and Emerging Countries: Who drives whom? Journal of International Economics, 69(1), 6-36.

[104] Uzawa, H., 1968. Time preference, the consumption function, and optimum asset holdings. Value, Capital, and Growth: Papers in Honour of Sir John Hicks, 485-505 .

[105] Vayanos, D., Vila, J.-L., 2009. A Preferred-Habitat Model of the Term Structure of Interest Rates. NBER working paper 15487.

[106] Wallace, N., 1981. A Modigliani-Miller Theorem for Open-Market Operations. American Economic Review, 71(3), 267-274.

[107] Walsh, C.E., 2009. Using monetary policy to stabilize economic activity. Financial Stability and Macroeconomic Policy. Federal Reserve Bank of Kansas City, 245-296.

[108] Walsh, C.E., 2003. Monetary Theory and Policy. MIT Press, second edition.

[109] William, B., Tobin, J., 1992. On the Internalization of Portfolios. Oxford. Econ. Papers, Oxford University Press, 44(4), 533-565.

[110] Woodford, M., 2016. Quantitative easing and financial stability. NBER Working Paper 22285.

[111] Zampolli, F., 2012. Sovereign debt management as an instrument of monetary policy: an overview. BIS Papers chapters, in: Bank of International Settlements (ed.), Threat of fiscal dominance?, vol. 65, 97-118.

9 Appendix 1: Households

This Appendix presents the solution of the three types of households' problem.

9.1 Household saver's optimality conditions

There are N^h identical households-savers indexed by superscript $h = 1, 2, 3, ..., N^h$. Each saver chooses $\{c_t^h, u_t^h, d_{t+1}^h, b_{t+1}^h, m_{t+1}^h\}_0^\infty$ to maximize (1) subject to (2)-(3) in the main text. The first-order conditions include:

$$\frac{1}{c_t^h} = \lambda_t^h (1 + \tau_t^c) + a^h \psi_t^h (1 + \tau_t^c) \tag{30a}$$

$$\lambda_t^h = \beta^h \lambda_{t+1}^h (1 + i_{t+1}^d) \frac{p_t}{p_{t+1}} \tag{30b}$$

$$\lambda_t^h = \beta^h \lambda_{t+1}^h (1 + i_{t+1}^b) \frac{p_t}{p_{t+1}} \tag{30c}$$

$$\lambda_t^h - \psi_t^h = \beta^h \lambda_{t+1}^h \frac{p_t}{p_{t+1}} \tag{30d}$$

$$\frac{\nu^h}{1 - u_t^h} = \lambda_t^h (1 - \tau_t^y) w_t \tag{30e}$$

$$\psi_t^h \left[m_{t+1}^h - a^h (1 + \tau_t^c) c_t^h \right] = 0 \tag{30f}$$

where λ_t^h is the multiplier associated with the budget constraint (2) and ψ_t^h is the multiplier associated with the cash-in-advance constraint (3). Thus, including the budget constraint in (2) we have 7 equations in $\{c_t^h, u_t^h, d_{t+1}^h, b_{t+1}^h, m_{t+1}^h, \lambda_t^h, \psi_t^h\}_0^\infty$. We will assume that the cash-in-advance constraint is binding all the time, so that $m_{t+1}^h = a^h (1 + \tau_t^c) c_t^h$ and $\psi_t^h \neq 0$ at all t.

9.2 Household firm-owner's optimality conditions

There are N^e identical households firm-owners indexed by superscript $e = 1, 2, 3, ..., N^e$. Each firm-owner chooses $\{c_t^e, u_t^e, m_{t+1}^e\}_0^\infty$ to maximize (4) subject to (5)-(6) in the main text. The first-order conditions include:

$$\frac{1}{c_t^e} = \lambda_t^e (1 + \tau_t^c) + a^e \psi_t^e (1 + \tau_t^c) \tag{31a}$$

$$\lambda_t^e - \psi_t^e = \beta^e \lambda_{t+1}^e \frac{p_t}{p_{t+1}} \tag{31b}$$

$$\frac{\nu^e}{1-u_t^e} = \lambda_t^e \left(1-\tau_t^y\right) w_t \tag{31c}$$

$$\psi_t^e \left[m_{t+1}^e - a^e \left(1+\tau_t^c\right) c_t^e\right] = 0 \tag{31d}$$

where λ_t^e is the multiplier associated with the budget constraint (5) and ψ_t^h is the multiplier associated with the cash-in-advance constraint (6).

Thus, including the budget constraint in (5), we have 5 equations in $\left\{c_t^e, u_t^e, m_{t+1}^e, \lambda_t^e, \psi_t^e\right\}_0^\infty$. We will assume that the cash-in-advance constraint is binding all the time, so that $m_{t+1}^e = a^e \left(1+\tau_t^c\right) c_t^e$ and $\psi_t^e \neq 0$ at all t.

9.3 Household banker's optimality conditions

There are N^b identical households bankers indexed by superscript $b = 1, 2, 3, ..., N^b$. Each banker chooses $\left\{c_t^b, u_t^b, m_{t+1}^b\right\}_0^\infty$ to maximize (7) subject to (8)-(9) in the main text. The first-order conditions include:

$$\frac{1}{c_t^b} = \lambda_t^b \left(1+\tau_t^c\right) + a^b \psi_t^b \left(1+\tau_t^c\right) \tag{32a}$$

$$\lambda_t^b - \psi_t^b = \beta^b \lambda_{t+1}^b \frac{p_t}{p_{t+1}} \tag{32b}$$

$$\frac{\nu^b}{1-u_t^b} = \lambda_t^b \left(1-\tau_t^y\right) w_t \tag{32c}$$

$$\psi_t^b \left[m_{t+1}^b - a^b \left(1+\tau_t^c\right) c_t^b\right] = 0 \tag{32d}$$

where λ_t^b is the multiplier associated with the budget constraint (8) and ψ_t^b is the multiplier associated with the cash-in-advance constraint (9).

Thus, including the budget constraint in (8), we have 5 equations in $\left\{c_t^b, u_t^b, m_{t+1}^b, \lambda_t^b, \psi_t^b\right\}_0^\infty$. We will assume that the cash-in-advance constraint is binding all the time, so that $m_{t+1}^b = a^b \left(1+\tau_t^c\right) c_t^b$ and $\psi_t^b \neq 0$ at all t.

10 Appendix 2: Firms

This Appendix presents the solution of the intermediate-goods firm's problem. There are N^f differentiated intermediate-goods firms indexed by superscript $f = 1, 2, 3, ..., N^f$. Each firm chooses $\left\{u_t^f, i_t^f, k_{t+1}^f, l_{t+1}^f, m_{t+1}^f\right\}_{t=0}^\infty$ to maximize (16) subject to (12), (18)-(20) in the main text. The first-order conditions include:

$$\left(\frac{1}{\xi_t}\right)\lambda_t^e = \beta^e\lambda_{t+1}^e\left(\frac{1}{\xi_{t+1}}\right)q_{t+1}\left(1-\delta\right)+\beta^e\lambda_{t+1}^e\left(1-\tau_{t+1}^{\pi}\right)\phi\frac{\partial y_{t+1}^f}{\partial k_{t+1}^f}- \tag{33a}$$

$$-\beta^e\lambda_{t+1}^e\chi\left(\frac{p_{t+1}}{p_t}-1\right)\frac{p_{t+1}}{p_t}\frac{(\phi-1)}{y_{t+1}^f}\frac{\partial y_{t+1}^f}{\partial k_{t+1}^f}-(\beta^e)^2\lambda_{t+2}^e\chi\left(\frac{p_{t+2}}{p_{t+1}}-1\right)\frac{p_{t+2}}{p_{t+1}}\frac{(1-\phi)}{y_{t+1}^f}\frac{\partial y_{t+1}^f}{\partial k_{t+1}^f}$$

$$\lambda_t^e\left(1-\tau_t^{\pi}\right)w_t+\psi_t^f a^f\lambda_t^e w_t = \lambda_t^e\left(1-\tau_t^{\pi}\right)\phi\frac{\partial y_t^f}{\partial u_t^f}+ \tag{33b}$$

$$+\lambda_t^e\chi\left(\frac{p_t}{p_{t-1}}-1\right)\frac{p_t}{p_{t-1}}\frac{(1-\phi)}{y_t^f}\frac{\partial y_t^f}{\partial u_t^f}-\beta^e\lambda_{t+1}^e\chi\left(\frac{p_{t+1}}{p_t}-1\right)\frac{p_{t+1}}{p_t}\frac{(1-\phi)}{y_t^f}\frac{\partial y_t^f}{\partial u_t^f}$$

$$\lambda_t^e = \beta^e\lambda_{t+1}^e(1+i_{t+1}^l)\frac{p_t}{p_{t+1}} \tag{33c}$$

$$\lambda_t^e\left(1-\psi_t^f\right) = \beta^e\lambda_{t+1}^e\frac{p_t}{p_{t+1}} \tag{33d}$$

$$\psi_t^f\left[m_{t+1}^f - a^f w_t u_t^f\right] = 0 \tag{33e}$$

Thus, including the definition for profits in (16), the law-of-motion of capital (18) and the production function in (19), we have 8 equations in $\left\{u_t^f, i_t^f, k_{t+1}^f, l_{t+1}^f, m_{t+1}^f, \psi_t^f, y_t^f, \pi_t^f\right\}_0^{\infty}$. We will assume that the cash-in-advance constraint is binding all the time, so that $m_{t+1}^f = a^f w_t u_t^f$ and $\psi_t^f \neq 0$ at all t.

11 Appendix 3: Private banks

This Appendix presents the solution of the bank's problem. There are N^b identical private banks indexed by superscript $b = 1,2,3,...,N^b$. Each private bank chooses $\left\{l_{t+1}^b, d_{t+1}^b, m_{t+1}^r\right\}$ to maximize (22).

The first-order conditions imply:

$$l_{t+1}^b = \frac{\widetilde{\beta}^b(1+i_{t+1}^l)\frac{p_t}{p_{t+1}}-1}{\eta^l} \tag{34a}$$

$$\left(d_{t+1}^b\right)^{-3} = \frac{\widetilde{\beta}^b(1+i_{t+1}^d)\frac{p_t}{p_{t+1}}-1}{\eta^d} \tag{34b}$$

$$\left(m_{t+1}^{r}\right)^{-3}=\frac{1-\widetilde{\beta}^{b}(1+i_{t+1}^{r})\frac{p_t}{p_{t+1}}}{\eta^{m}} \tag{34c}$$

According to these first-order conditions, the supply of loans given to firms and reserves held at the central bank are increasing functions of the lending and the reserve rate respectively, while the demand for deposits is a decreasing function of the deposit rate. If reserves are negative ($m_{t+1}^{r}<0$), i.e. private banks borrow from the central bank, they become a decreasing function of the policy rate. As mentioned above, we assume that $\beta^{e}<\beta^{h}<\beta^{b}$, in order to get positive amounts of loans and deposits in the steady state solution.

12 Appendix 4: The budget constraint of the consolidated private sector

This Appendix presents the budget constraint of the consolidated private sector. If we combine all the accounting constraints of the private agents, equations (2), (5),(8), (17) and (23), and assume that $N^{h}=N^{e}=N^{s}=N^{c}=N^{f}=N^{b}\equiv 1$, in order to avoid scale effects (so that population fractions do not matter in equilibrium), the within-period budget constraint of the consolidated private sector is:

$$\begin{aligned}(1+\tau_t^{c})\left(c_t^{h}+c_t^{e}+c_t^{b}\right)+q_t i_t^{f}+b_{t+1}^{h}+\frac{\chi}{2}\left(\frac{p_t^{f}}{p_{t-1}^{f}}-1\right)^{2}+\frac{p_{t-1}}{p_t}\Psi(l_t^{b},d_t^{b},m_t^{r}) &= \\ =(1-\tau_t^{\pi})\frac{p_t^{f}}{p_t}f\left(k_t^{f},u_t^{f}\right)-(\tau_t^{y}-\tau_t^{\pi})\,w_t u_t^{f}+\frac{p_{t-1}}{p_t}\left(1+i_t^{b}\right)b_t^{h}- \\ -\left[m_{t+1}^{h}+m_{t+1}^{e}+m_{t+1}^{f}+m_{t+1}^{b}+m_{t+1}^{r}-\frac{p_{t-1}}{p_t}\left(m_t^{h}+m_t^{e}+m_t^{f}+m_t^{b}+(1+i_t^{r})\,m_t^{r}\right)\right]\end{aligned} \tag{35}$$

13 Appendix 5: The budget constraint of the consolidated public sector

This Appendix presents the budget constraint of the consolidated public sector. If we combine the accounting constraints of the Treasury and the Central Bank, (24) and (25a), the budget constraint of the consolidated public sector is:

$$(1+i_t^b)\frac{p_{t-1}}{p_t}b_t^{cb}+(1+i_t^r)\frac{p_{t-1}}{p_t}m_t^r \equiv \tau_t^c\left(c_t^h+c_t^e+c_t^b\right)+\left(\tau_t^y-\tau_t^\pi\right)w_t u_t^f+\tau_t^\pi\frac{p_t^f}{p_t}f\left(k_t^f,u_t^f\right)-g_t+ \tag{36}$$

$$+\left[m_{t+1}^h+m_{t+1}^e+m_{t+1}^f+m_{t+1}^b-\frac{p_{t-1}}{p_t}\left(m_t^h+m_t^e+m_t^f+m_t^b\right)\right]+$$

$$+b_{t+1}^{cb}+m_{t+1}^r$$

where $b_t^h+m_t^r$ is total liabilities of the two branches of the government (fiscal and monetary), the first term/line on the RHS is tax revenues minus government spending, the second term/line on the RHS is the so-called seigniorage revenue (see Reis (2017), section 4) and the last term/line on the RHS is the end-of-period total liabilities. The above accounting relation makes clear that central bank liabilities, m_t^r, should be counted as part of public debt. In other words, as Reis (2017) points out, bank reserves, being a liability of the central bank, they are also a government liability.

14 Appendix 6: Macroeconomic equilibrium

This Appendix presents in details the equilibrium system.

14.1 Market-clearing conditions

The market-clearing conditions in the markets for the final good, labor, investment, capital, loans, deposits and government debt are respectively (for notational simplicity and in order to avoid scale effects, we set as said before $N^h=N^e=N^s=N^c=N^f=N^b\equiv 1$ so that population fractions do not matter in equilibrium):

$$c_t^h+c_t^e+c_t^b+i_t+g_t+\frac{\chi}{2}\left[\frac{p_t}{p_{t-1}}-1\right]^2+\frac{p_t}{p_{t-1}}\left(\Psi(l_t,d_t,m_t^r)\right)=y_t \tag{37a}$$

$$u_t^f=u_t^h+u_t^e+u_t^b\equiv u_t \tag{37b}$$

$$i_t^f=i_t^c\equiv i_t \tag{37c}$$

$$k_{t+1}^f=k_{t+1}^c\equiv k_{t+1} \tag{37d}$$

$$l_{t+1}^{f} = l_{t+1}^{b} \equiv l_{t+1} \tag{37e}$$

$$d_{t+1}^{h} = d_{t+1}^{b} \equiv d_{t+1} \tag{37f}$$

$$b_{t+1}^{T} = b_{t+1}^{cb} + b_{t+1}^{h} \tag{37g}$$

14.2 Equilibrium equations

The decentralized equilibrium can be summarized by the following equilibrium conditions:

$$\begin{aligned}(1+\tau_t^c)\,c_t^h + d_{t+1} + b_{t+1}^h + m_{t+1}^h = (1-\tau_t^y)\,w_t u_t^h + \\ +(1+i_t^d)\frac{p_{t-1}}{p_t}d_t + (1+i_t^b)\frac{p_{t-1}}{p_t}b_t^h + \frac{p_{t-1}}{p_t}m_t^h\end{aligned} \tag{38}$$

$$\frac{1}{c_t^h} = \lambda_t^h\,(1+\tau_t^c) + a^h\psi_t^h\,(1+\tau_t^c) \tag{39}$$

$$\lambda_t^h = \beta^h\lambda_{t+1}^h(1+i_{t+1}^d)\frac{p_t}{p_{t+1}} \tag{40}$$

$$\lambda_t^h = \beta^h\lambda_{t+1}^h(1+i_{t+1}^b)\frac{p_t}{p_{t+1}} \tag{41}$$

$$\lambda_t^h - \psi_t^h = \beta^h\lambda_{t+1}^h\frac{p_t}{p_{t+1}} \tag{42}$$

$$\frac{\nu^h}{1-u_t^h} = \lambda_t^h\,(1-\tau_t^y)\,w_t \tag{43}$$

$$m_{t+1}^h = a^h\,(1+\tau_t^c)\,c_t^h \tag{44}$$

$$(1+\tau_t^c)\,c_t^e + m_{t+1}^e = \pi_t^f + (1-\tau_t^y)\,w_t u_t^e + \frac{p_{t-1}}{p_t}m_t^e \tag{45}$$

$$\frac{1}{c_t^e} = \lambda_t^e\,(1+\tau_t^c) + a^e\psi_t^e\,(1+\tau_t^c) \tag{46}$$

$$\lambda_t^e - \psi_t^e = \beta^e\lambda_{t+1}^e\frac{p_t}{p_{t+1}} \tag{47}$$

$$\frac{\nu^e}{1-u_t^e} = \lambda_t^e \left(1-\tau_t^y\right) w_t \tag{48}$$

$$m_{t+1}^e = a^e \left(1+\tau_t^c\right) c_t^e \tag{49}$$

$$\left(1+\tau_t^c\right) c_t^b + m_{t+1}^b = \pi_t^b + \left(1-\tau_t^y\right) w_t u_t^b + \frac{p_{t-1}}{p_t} m_t^b \tag{50}$$

$$\frac{1}{c_t^b} = \lambda_t^b \left(1+\tau_t^c\right) + a^b \psi_t^b \left(1+\tau_t^c\right) \tag{51}$$

$$\lambda_t^b - \psi_t^b = \beta^b \lambda_{t+1}^b \frac{p_t}{p_{t+1}} \tag{52}$$

$$\frac{\nu^b}{1-u_t^b} = \lambda_t^b \left(1-\tau_t^y\right) w_t \tag{53}$$

$$m_{t+1}^b = a^b \left(1+\tau_t^c\right) c_t^b \tag{54}$$

$$\pi_t^f = \left(1-\tau_t^\pi\right) \left\{ y_t - w_t \left(u_t^h + u_t^e \right) \right\} - i_t + l_{t+1} - \left(1+i_t^l\right) \frac{p_{t-1}}{p_t} l_t - \\ - m_{t+1}^f + \frac{p_{t-1}}{p_t} m_t^f - \frac{\chi}{2} \left(\frac{p_t}{p_{t-1}} - 1 \right)^2 \tag{55}$$

$$y_t = f\left(k_t, u_t^h, u_t^e\right) = A_t \left(k_t\right)^\alpha \left(u_t^h + u_t^e\right)^{1-\alpha} \tag{56}$$

$$m_{t+1}^f = a^f w_t \left(u_t^h + u_t^e\right) \tag{57}$$

$$\left(\frac{1}{\xi_t}\right) \lambda_t^e = \beta^e \lambda_{t+1}^e \left(\frac{1}{\xi_{t+1}}\right) (1-\delta) + \beta^e \lambda_{t+1}^e \left(1-\tau_{t+1}^\pi\right) \phi \frac{\partial y_{t+1}}{\partial k_{t+1}} - \\ - \beta^e \lambda_{t+1}^e \chi \left(\frac{p_{t+1}}{p_t} - 1\right) \frac{p_{t+1}}{p_t} \frac{(\phi-1)}{y_{t+1}} \frac{\partial y_{t+1}}{\partial k_{t+1}} - \left(\beta^e\right)^2 \lambda_{t+2}^e \chi \left(\frac{p_{t+2}}{p_{t+1}} - 1\right) \frac{p_{t+2}}{p_{t+1}} \frac{(1-\phi)}{y_{t+1}} \frac{\partial y_{t+1}}{\partial k_{t+1}^f} \tag{58}$$

$$\lambda_t^e \left(1-\tau_t^\pi\right) w_t + \psi_t^f a^f \lambda_t^e w_t = \lambda_t^e \left(1-\tau_t^\pi\right) \phi \frac{\partial y_t}{\partial \left(u_t^h + u_t^e\right)} + \\ + \lambda_t^e \chi \left(\frac{p_t}{p_{t-1}} - 1\right) \frac{p_t}{p_{t-1}} \frac{(1-\phi)}{y_t} \frac{\partial y_t}{\partial \left(u_t^h + u_t^e\right)} - \beta^e \lambda_{t+1}^e \chi \left(\frac{p_{t+1}}{p_t} - 1\right) \frac{p_{t+1}}{p_t} \frac{(1-\phi)}{y_t} \frac{\partial y_t}{\partial \left(u_t^h + u_t^e\right)} \tag{59}$$

$$\lambda_t^e = \beta^e \lambda_{t+1}^e (1 + i_{t+1}^l) \frac{p_t}{p_{t+1}} \tag{60}$$

$$\lambda_t^e \left(1 - \psi_t^f\right) = \beta^e \lambda_{t+1}^e \frac{p_t}{p_{t+1}} \tag{61}$$

$$k_{t+1} = (1-\delta)k_t + \xi_t i_t \tag{62}$$

$$\pi_t^b = \frac{p_{t-1}}{p_t} \left\{(1+i_t^l)l_t - (1+i_t^d)d_t + (1+i_t^r)m_t^b\right\} + d_{t+1} - l_{t+1} - m_{t+1}^r - \Psi(l_{t+1}, d_{t+1}, m_{t+1}^r) \tag{63}$$

$$l_{t+1} = \frac{\widetilde{\beta}^b (1 + i_{t+1}^l) \frac{p_t}{p_{t+1}} - 1}{\eta^l} \tag{64}$$

$$(d_{t+1})^{-3} = \frac{\widetilde{\beta}^b (1 + i_{t+1}^d) \frac{p_t}{p_{t+1}} - 1}{\eta^d} \tag{65}$$

$$\left(m_{t+1}^r\right)^{-3} = \frac{1 - \widetilde{\beta}^b (1 + i_{t+1}^r) \frac{p_t}{p_{t+1}}}{\eta^m} \tag{66}$$

$$\begin{aligned} &b_{t+1}^{cb} + rcb_t + \frac{p_{t-1}}{p_t}(m_t^h + m_t^e + m_t^f + m_t^b + (1+i_t^r)\, m_t^r) = \\ &= (1+i_t^b)\frac{p_{t-1}}{p_t} b_t^{cb} + m_{t+1}^h + m_{t+1}^e + m_{t+1}^f + m_{t+1}^b + m_{t+1}^r \end{aligned} \tag{67}$$

$$g_t + \frac{p_{t-1}}{p_t}(1+i_t^b)\left(b_t^h + b_t^{cb}\right) = \tau_t^c \left(c_t^h + c_t^e + c_t^b\right) + (\tau_t^y - \tau_t^\pi)\, w_t u_t^f + \tau_t^\pi y_t + b_{t+1}^h + b_{t+1}^{cb} + rcb_t \tag{68}$$

The equilibrium system can be summarized by 31 equations in 31 endogenous variables, $\{c_t^h, c_t^e, c_t^b, u_t^h, u_t^e, u_t^b, d_{t+1}, l_{t+1}, k_{t+1}, i_t, b_{t+1}^h, m_{t+1}^h, m_{t+1}^e, m_{t+1}^f, m_{t+1}^b, m_{t+1}^r, \lambda_t^h, \lambda_t^e, \lambda_t^b, \psi_t^h, \psi_t^e, \psi_t^f,$ $,\psi_t^b, y_t, w_{t,} i_{t+1}^b, i_{t+1}^d, i_{t+1}^l, \pi_t^f, \pi_t^b, \Pi_t \equiv p_t/p_{t-1}\}_{t=0}^{\infty}$.This is for any feasible policy, as defined in subsection 2.6 above.

15 Appendix 7: Decentralized equilibrium in the steady state

In this appendix we solve for the steady state starting by writing the above system without time subscript.

We solve for the steady state starting by writing the above system without time subscript. In the steady state, we set inflation at one, $\pi = 1$, and we allow rcb to be endogenously determined.

$$(1+\tau^c)\,c^h = (1-\tau^y)\,wu^h + i^b b^h + i^d d \tag{69}$$

$$\frac{1}{c^h} = \lambda^h\,(1+\tau^c) + a^h\psi^h\,(1+\tau^c) \tag{70}$$

$$1 = \beta^h(1+i^d) \tag{71}$$

$$1 = \beta^h(1+i^b) \tag{72}$$

$$1 - \frac{\psi^h}{\lambda^h} = \beta^h \tag{73}$$

$$\frac{\nu^h}{1-u^h} = \lambda^h\,(1-\tau^y)\,w \tag{74}$$

$$m^h = a^h\,(1+\tau^c)\,c^h \tag{75}$$

$$(1+\tau^c)\,c^e = \pi^f + (1-\tau^y)\,wu^e \tag{76}$$

$$\frac{1}{c^e} = \lambda^e\,(1+\tau^c) + a^e\psi^e\,(1+\tau^c) \tag{77}$$

$$1 - \frac{\psi^e}{\lambda^e} = \beta^e \tag{78}$$

$$\frac{\nu^e}{1-u^e} = \lambda^e\,(1-\tau^y)\,w \tag{79}$$

$$m^e = a^e\,(1+\tau^c)\,c^e \tag{80}$$

$$(1+\tau^c)\,c^b = \pi^b + (1-\tau^y)\,wu^b \tag{81}$$

$$\frac{1}{c^b} = \lambda^b \left(1 + \tau^c\right) + a^b \psi^b \left(1 + \tau^c\right) \tag{82}$$

$$1 - \frac{\psi^b}{\lambda^b} = \beta^b \tag{83}$$

$$\frac{\nu^b}{1 - u^b} = \lambda^b \left(1 - \tau^y\right) w \tag{84}$$

$$m^b = a^b \left(1 + \tau^c\right) c^b \tag{85}$$

$$\pi^f = \left(1 - \tau_t^\pi\right) \left\{y - w\left(u^h + u^e\right)\right\} - i + i^l l \tag{86}$$

$$y = f\left(k, u^h, u^e\right) = A k^\alpha \left(u^h + u^e\right)^{1-\alpha} \tag{87}$$

$$m^f = a^f w \left(u^h + u^e\right) \tag{88}$$

$$1 = \beta^e \left(\left(1 - \delta\right) + \left(1 - \tau^\pi\right) \phi \frac{\partial y}{\partial k} - \right) \tag{89}$$

$$\left(1 - \tau^\pi + \psi^f a^f\right) w = \left(1 - \tau^\pi\right) \phi \frac{\partial y}{\partial \left(u^h + u^e\right)} \tag{90}$$

$$1 = \beta^e (1 + i^l) \tag{91}$$

$$1 - \beta^e = \psi^f \tag{92}$$

$$i = \delta k \tag{93}$$

$$\pi^b = i^l l - i^d d + i^r m^r - \Psi(l, d, m^r) \tag{94}$$

$$l = \frac{\widetilde{\beta}^b (1 + i^l) - 1}{\eta^l} \tag{95}$$

$$(d)^{-3} = \frac{\widetilde{\beta}^b (1 + i^d) - 1}{\eta^d} \tag{96}$$

$$(m^r)^{-3} = \frac{1 - \widetilde{\beta}^b (1 + i^r)}{\eta^m} \tag{97}$$

$$rcb = i^b b^{cb} - i^r m^r \tag{98}$$

$$rcb = g + i^b \left(b^{cb} + b^e\right) - \tau^c \left(c^h + c^e + c^b\right) - (\tau^y - \tau^\pi)\, w u^f - \tau^\pi y \tag{99}$$

16 Appendix 8: Transition dynamics under passive policy

Figure 11: Effects of a negative 5% investment shock

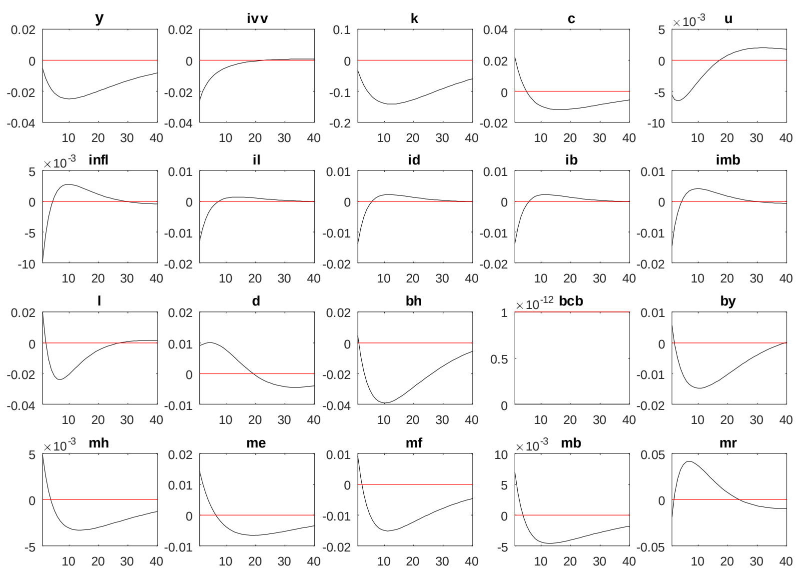


Figure 12: Effects of a positive 5% government spending shock

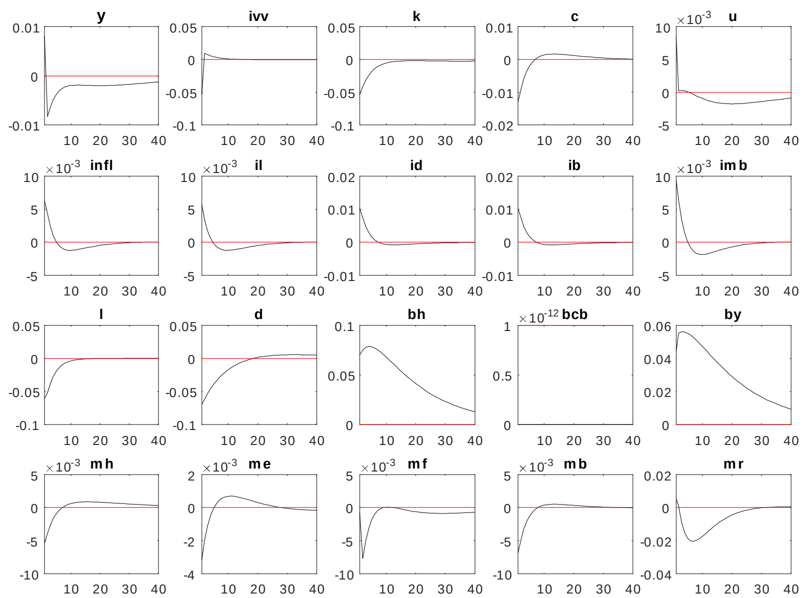
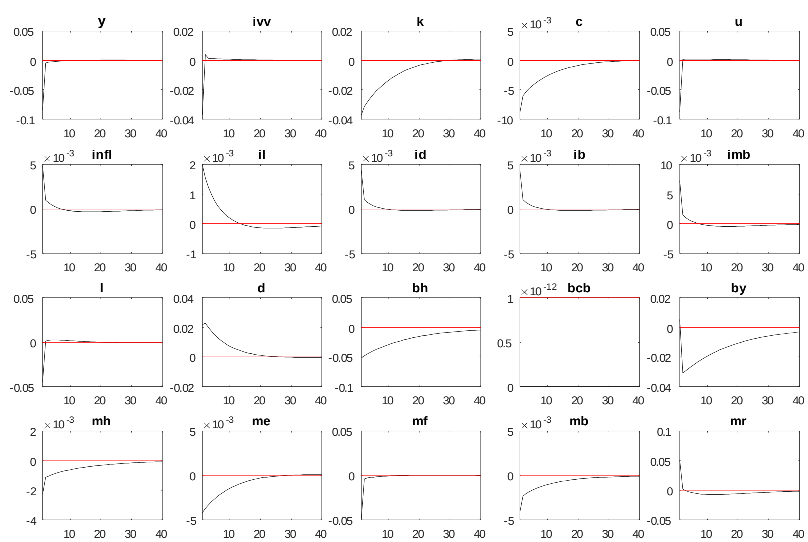


Figure 13: Effects of a positive 5% labor tax shock

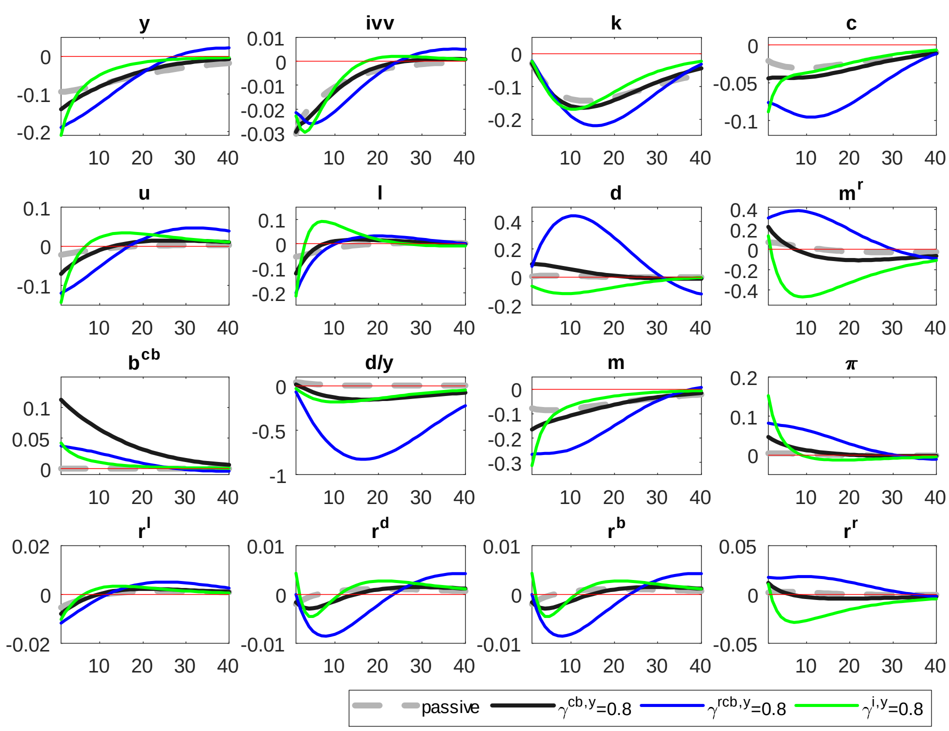


17 Appendix 9: Stronger monetary activism

In this subsection, we allow for a stronger degree of monetary activism by increasing the feedback response of all three monetary policy instruments employed, on the output gap. Specifically, we experiment with one instrument at a time and set the feedback coefficient at 0.8 instead of 0.2, used in experiments so far, other things equal.

Results are reported in Figures 14; the black line represents the case of a higher response of OMOs to the output gap $\left(\gamma^{rcb.y} = \gamma^{i.y} = 0.2, \gamma^{cb.y} = 0.8\right)$, the blue line the case of a higher response of remittances to the output gap $\left(\gamma^{cb.y} = \gamma^{i.y} = 0.2, \gamma^{rcb.y} = 0.8\right)$, and the green the case of a higher response of policy rate to the output gap $\left(\gamma^{cb.y} = \gamma^{rcb.y} = 0.2, \gamma^{i.y} = 0.8\right)$. For comparison, we include again the passive case studied in subsection 5 (dotted grey line).

Figure 14. Aggressive monetary policy reaction to the output gap



18 Appendix 10: Firm-owners hold government debt

In this Appendix we adopt the economic framework as described in Section 3, with the only difference that government bonds are held by firm-owners, b^e, instead of savers.

The decentralized equilibrium can be summarized by the following equilibrium conditions:

$$\begin{aligned}(1+\tau_t^c)\,c_t^h + d_{t+1} + m_{t+1}^h = (1-\tau_t^y)\,w_t u_t^h + \\ +(1+i_t^d)\frac{p_{t-1}}{p_t}d_t + \frac{p_{t-1}}{p_t}m_t^h\end{aligned} \tag{100}$$

$$\frac{1}{c_t^h} = \lambda_t^h\,(1+\tau_t^c) + a^h\psi_t^h\,(1+\tau_t^c) \tag{101}$$

$$\lambda_t^h = \beta^h\lambda_{t+1}^h(1+i_{t+1}^d)\frac{p_t}{p_{t+1}} \tag{102}$$

$$\lambda_t^h - \psi_t^h = \beta^h\lambda_{t+1}^h\frac{p_t}{p_{t+1}} \tag{103}$$

$$\frac{\nu^h}{1-u_t^h} = \lambda_t^h\,(1-\tau_t^y)\,w_t \tag{104}$$

$$m_{t+1}^h = a^h\,(1+\tau_t^c)\,c_t^h \tag{105}$$

$$(1+\tau_t^c)\,c_t^e + b_{t+1}^e + m_{t+1}^e = \pi_t^f + \pi_t^b + (1-\tau_t^y)\,w_t u_t^e + (1+i_t^b)\frac{p_{t-1}}{p_t}b_t^e + \frac{p_{t-1}}{p_t}m_t^e \tag{106}$$

$$\frac{1}{c_t^e} = \lambda_t^e\,(1+\tau_t^c) + a^e\psi_t^e\,(1+\tau_t^c) \tag{107}$$

$$\lambda_t^e - \psi_t^e = \beta^e\lambda_{t+1}^e\frac{p_t}{p_{t+1}} \tag{108}$$

$$\frac{\nu^e}{1-u_t^e} = \lambda_t^e\,(1-\tau_t^y)\,w_t \tag{109}$$

$$\lambda_t^e = \beta^e\lambda_{t+1}^e(1+i_{t+1}^b)\frac{p_t}{p_{t+1}} \tag{110}$$

$$m_{t+1}^e = a^e\,(1+\tau_t^c)\,c_t^e \tag{111}$$

$$(1+\tau_t^c)\,c_t^b + m_{t+1}^b = \pi_t^b + (1-\tau_t^y)\,w_t u_t^b + \frac{p_{t-1}}{p_t} m_t^b \tag{112}$$

$$\frac{1}{c_t^b} = \lambda_t^b\,(1+\tau_t^c) + a^b \psi_t^b\,(1+\tau_t^c) \tag{113}$$

$$\lambda_t^b - \psi_t^b = \beta^b \lambda_{t+1}^b \frac{p_t}{p_{t+1}} \tag{114}$$

$$\frac{\nu^b}{1-u_t^b} = \lambda_t^b\,(1-\tau_t^y)\,w_t \tag{115}$$

$$m_{t+1}^b = a^b\,(1+\tau_t^c)\,c_t^b \tag{116}$$

$$\pi_t^f = (1-\tau_t^\pi)\left\{y_t - w_t\left(u_t^h + u_t^e\right)\right\} - i_t + l_{t+1} - (1+i_t^l)\frac{p_{t-1}}{p_t} l_t - \tag{117}$$

$$-m_{t+1}^f + \frac{p_{t-1}}{p_t} m_t^f - \frac{\chi}{2}\left(\frac{p_t}{p_{t-1}} - 1\right)^2$$

$$y_t = f\left(k_t, u_t^h, u_t^e\right) = A_t\,(k_t)^\alpha \left(u_t^h + u_t^e\right)^{1-\alpha} \tag{118}$$

$$m_{t+1}^f = a^f w_t \left(u_t^h + u_t^e\right) \tag{119}$$

$$\left(\frac{1}{\xi_t}\right)\lambda_t^e = \beta^e \lambda_{t+1}^e \left(\frac{1}{\xi_{t+1}}\right)(1-\delta) + \beta^e \lambda_{t+1}^e \left(1-\tau_{t+1}^\pi\right)\phi \frac{\partial y_{t+1}}{\partial k_{t+1}} - \tag{120}$$

$$-\beta^e \lambda_{t+1}^e \chi \left(\frac{p_{t+1}}{p_t} - 1\right)\frac{p_{t+1}}{p_t}\frac{(\phi-1)}{y_{t+1}}\frac{\partial y_{t+1}}{\partial k_{t+1}} - (\beta^e)^2 \lambda_{t+2}^e \chi \left(\frac{p_{t+2}}{p_{t+1}} - 1\right)\frac{p_{t+2}}{p_{t+1}}\frac{(1-\phi)}{y_{t+1}}\frac{\partial y_{t+1}}{\partial k_{t+1}^f}$$

$$\lambda_t^e\,(1-\tau_t^\pi)\,w_t + \psi_t^f a^f \lambda_t^e w_t = \lambda_t^e\,(1-\tau_t^\pi)\,\phi \frac{\partial y_t}{\partial\left(u_t^h + u_t^e\right)} + \tag{121}$$

$$+\lambda_t^e \chi \left(\frac{p_t}{p_{t-1}} - 1\right)\frac{p_t}{p_{t-1}}\frac{(1-\phi)}{y_t}\frac{\partial y_t}{\partial\left(u_t^h + u_t^e\right)} - \beta^e \lambda_{t+1}^e \chi \left(\frac{p_{t+1}}{p_t} - 1\right)\frac{p_{t+1}}{p_t}\frac{(1-\phi)}{y_t}\frac{\partial y_t}{\partial\left(u_t^h + u_t^e\right)}$$

$$\lambda_t^e = \beta^e \lambda_{t+1}^e (1+i_{t+1}^l)\frac{p_t}{p_{t+1}} \tag{122}$$

$$\lambda_t^e\left(1-\psi_t^f\right)=\beta^e\lambda_{t+1}^e\frac{p_t}{p_{t+1}} \tag{123}$$

$$k_{t+1}=(1-\delta)k_t+\,\xi_t i_t \tag{124}$$

$$\pi_t^b=\frac{p_{t-1}}{p_t}\left\{(1+i_t^l)l_t-(1+i_t^d)d_t+(1+i_t^r)m_t^b\right\}+d_{t+1}-l_{t+1}-m_{t+1}^r-\Psi(l_{t+1},d_{t+1,}m_{t+1}^r) \tag{125}$$

$$l_{t+1}=\frac{\widetilde{\beta}^b(1+i_{t+1}^l)\frac{p_t}{p_{t+1}}-1}{\eta^l} \tag{126}$$

$$(d_{t+1})^{-3}=\frac{\widetilde{\beta}^b(1+i_{t+1}^d)\frac{p_t}{p_{t+1}}-1}{\eta^d} \tag{127}$$

$$\left(m_{t+1}^r\right)^{-3}=\frac{1-\widetilde{\beta}^b(1+i_{t+1}^r)\frac{p_t}{p_{t+1}}}{\eta^m} \tag{128}$$

$$\begin{aligned}&b_{t+1}^{cb}+rcb_t+\frac{p_{t-1}}{p_t}(m_t^h+m_t^e+m_t^f+m_t^b+(1+i_t^r)m_t^r)=\\&=(1+i_t^b)\frac{p_{t-1}}{p_t}b_t^{cb}+m_{t+1}^h+m_{t+1}^e+m_{t+1}^f+m_{t+1}^b+m_t^r\end{aligned} \tag{129}$$

$$g_t+\frac{p_{t-1}}{p_t}(1+i_t^b)\left(b_t^e+b_t^{cb}\right)=\tau_t^c\left(c_t^h+c_t^e+c_t^b\right)+(\tau_t^y-\tau_t^\pi)\,w_tu_t^f+\tau_t^\pi y_t+b_{t+1}^e+b_{t+1}^{cb}+rcb_t \tag{130}$$

The equilibrium system can be summarized by 31 equations in 31 endogenous variables, $\{c_t^h, c_t^e, c_t^b, u_t^h, u_t^e, u_t^b, d_{t+1}, l_{t+1}, k_{t+1}, i_t, b_{t+1}^e, m_{t+1}^h, m_{t+1}^e, m_{t+1}^f, m_{t+1}^b, m_{t+1}^r, \lambda_t^h, \lambda_t^e, \lambda_t^b, \psi_t^h, \psi_t^e, \psi_t^f,$ $, \psi_t^b, y_t, w_{t,} i_{t+1}^b, i_{t+1}^d, i_{t+1}^l, \pi_t^f, \pi_t^b, \Pi_t \equiv p_t/p_{t-1}\}_{t=0}^{\infty}$.This is for any feasible policy, as defined in subsection 2.6 above.