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Merola, Rossana

Universitè Catholique de Louvain la neuve

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Rossana Merola
Universitè Catholique de Louvain la neuve

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Abstract

Recent developments in Canada, the United Kingdom, the euro area, Japan, Sweden, Switzerland and the United States have triggered a debate on whether monetary policy is effective when the nominal interest rate is close to zero. In this context, the monetary authority is no longer in a position to pursue a policy of monetary easing by lowering nominal interest rates further. However, some economists have down-played the risk of hitting the zero lower bound, at least for the US economy.

In this paper, I assess the implications of the zero lower bound in a DSGE model with financial frictions. The financial accelerator mechanism is formalized as in Bernanke, Gertler and Gilchrist (1995).

The paper attempts to address three main issues.

First, I evaluate whether the zero lower bound – by limiting the use of the nominal interest rate as a policy instrument – might hamper the monetary authority from offsetting the negative effects of an adverse shock.

Second, I analyze whether price-level targeting, through the stabilization of private sector expectations, might be a better monetary rule than inflation targeting in order to avoid the "liquidity trap".

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Third, I investigate the effectiveness of fiscal stimulus (namely, an increase in government expenditure) when financial markets are imperfect and the nominal interest rate is close to its zero lower bound. In this context, two questions will be addressed: first, do financial frictions weaken the effect of a fiscal expansion? Second, how are results affected when the zero lower bound is binding?

To address these questions, I introduce a negative demand shock and an adverse financial shock. I find that by adopting a price-level targeting rule, the monetary authority might alleviate the recession generated by the interaction of financial frictions and lower-bounded nominal interest rates. Alternatively, an increase in government expenditure has a positive impact on output, but fiscal multipliers are below one, due to a strong crowding-out effect of private consumption. This effect is muted when the nominal interest rate is lower bounded. In analyzing discretionary fiscal policy, this paper does also focus on two crucial aspects: the duration of the fiscal stimulus and the presence of implementation lags.

JEL classification: E31, E44, E52, E58.

Keywords: Optimal monetary policy, financial accelerator, lower bound on nominal interest rates, price-level targeting, fiscal stimulus.

Contents

1 Introduction

For several decades, many central banks around the world have enacted disinflationary policies and have successfully brought inflation down. As a consequence, in recent years interest rates were low, which brought the potential threat of deflation and a binding zero bound on nominal interest rate into focus. In this context, the monetary authority is no longer in a position to pursue a policy of monetary easing by lowering nominal interest rates further.[1] By the second quarter of 2009, policy interest rates had fallen below one per cent in Canada, the United Kingdom, the euro area, Sweden, Switzerland and the United States. The Japanese example offers the most compelling case: since the late 1990s, Japan has experienced deflation and a short rate very close to zero leaving monetary policy almost helpless to boost economic activity. These developments have triggered a debate on whether monetary policy is impotent at the zero bound.

However, some economists have down-played the risk of a binding zero lower bound, at least for the US and the euro area (Viñals (2001); Coenen, Orphanides & Wieland (2003); Schmitt-Grohe and Uribe (2007)). This strand of literature does not take into account the role played by financial

[1] Under these circumstances, monetary policy may still be effective via other transmission channels than nominal interest rates. Therefore, a binding zero lower bound is a necessary but not a sufficient condition for the liquidity trap to prevail. I follow Buiter & Panigirtzoglou (2000) in their definition of a liquidity trap. An economy is said to be in a liquidity trap if all channels of monetary transmission are blocked. Only in one case, the liquidity trap and the zero bound on nominal interest rates are identical concepts. This applies if the nominal interest is the only monetary transmission channel.

frictions.

The purpose of this paper is to analyze the extent to which a lower bound on nominal interest rates might deepen the recession, in the presence of frictions in financial markets. The structure of the model is a closed economy DSGE model which contains standard features, such as investment adjustment costs and sticky prices. In addition, I add financial frictions that are formalized as in Bernanke Gertler and Gilchrist (1995) and Bernanke and Gertler (1989, 1998). The source of the financial accelerator is the asymmetric information that will make it costly for lenders to evaluate the quality of firms' investments. Therefore, lenders require a premium for external funds over the real opportunity costs equivalent to the riskless interest rate. In the short run, the presence of a financial risk premium distorts the dynamic allocation of capital and investment and leads to an inefficiently low level of capital, and hence output. The underlying mechanism works in the following way. An adverse shock lowers current cash flows, reducing the ability of firms to self-finance investment projects. This decline in net worth raises the external finance premium and the cost of new investments. Declining investment lowers economic activity and cash flow in subsequent periods, amplifying and propagating the effect of the initial shock. The presence of a binding zero lower bound constraint on nominal interest rates might further deepen the recessionary spiral triggered by the financial accelerator mechanism. In the face of an adverse shock that pushes the premia upward, it could be appropriate to lower the nominal interest rate in order to mitigate – at least partially – the recession. This may not be possible if the zero lower bound on nominal interest rates starts to bind.

The paper attempts to address three main issues. First, I evaluate whether the zero lower bound might strengthen the effects of a negative shock by hampering the monetary authority from offsetting the negative effects of an adverse shock. Second, I investigate how monetary policy should be set in order to make the zero lower bound less binding. I analyze whether the price level is a better target than inflation in order to avoid the "liquidity trap" that might be generated by a binding zero lower bound. The motivation is the following: when agents are forward-looking and the monetary authority credibly commits to a price-level targeting rule, private sector expectations work as automatic stabilizers. Therefore, the initial disinflation – and hence the variability of interest rates – is dampened. Third, I investigate whether fiscal policy can alleviate the effects of a binding zero lower bound constraint. For this purpose, I assess the effectiveness of fiscal policies when financial markets are imperfect and interest rates are very close to the lower bound. It is a relevant issue to explore because, with the prospect of a severe global recession that started in 2008-2009, many governments put forward fiscal stimulus plans in order to underpin a recovery.[2] However, many economies, such as the US are experiencing low interest rates that fuel the risk of falling into a liquidity trap. In this context, two questions arise: first, do financial frictions weaken or raise the effect of a fiscal expansion? Second, are results affected when the zero lower bound is binding?

[2] To list some examples: the American Recovery and Reinvestment Act in the United States; the "Konjunkturpakete I und II" in Germany; the "Plan de reliance"in France; the "Pacchetto fiscale"in Italy; the "El Plan E."in Spain; the pre-Budget Report in the United Kingdom.

To address these issues, I introduce two types of shocks: a negative demand shock and a financial shock. Intuitively, these types of shocks, putting downward pressure on both output and inflation, can cause the economy to hit the zero lower bound. Output will fall, resulting in lower inflation in the same period. Both effects lead to a lower nominal interest rate.

The paper is structured as follows. In section 2, I present an overview of the literature. I develop the model in section 3. In section 4, I investigate whether the lower bound enhances the negative effects of adverse shocks. In section 5 and section 6, I discuss the role played by monetary and fiscal policy when the zero lower bound is binding. More precisely, in section 5, in order to evaluate the role of monetary policy, I assess whether the price level is a better target than inflation in order to avoid a "liquidity trap" generated by a binding zero lower bound. In section 6, I introduce an exogenous government spending shock to assess the role of fiscal policy. I provide an assessment of the use of a fiscal stimulus to underpin a recovery from a severe recession when the effectiveness of monetary policy weakens after hitting the zero interest-rate bound. For this purpose, I investigate first how fiscal multipliers are affected by the presence of financial frictions. Then, I also assess whether fiscal multipliers are larger when the zero lower bound on nominal interest rate is binding. Section 7 provides concluding remarks and outlines further extensions that can be addressed in future work.

2 Review of the literature

Recently, several papers have analyzed the implication of the zero lower bound on nominal interest rates on the conduct of optimal monetary policy. In this section I first review part of the theoretical literature on the zero lower bound; then I provide an overview of empirical or historical evaluations of issues related to the zero lower bound.

From a theoretical point of view, four main strands of the literature focusing on the zero lower bound can be distinguished.[3]

The first one has been pioneered by Krugman (1998) who has emphasized the importance of lifting expected inflation in order to reduce the real interest rate. In this view, two solutions have been proposed.

The first way to lift inflation expectations is to set a history-dependent rule, such as a price-level target rule[4] or a super-inertial rule, that would be able to control expectations and hence would deliver a lower variability in the nominal interest rate and inflation. Similarly, Svensson (2000) and Smets (2000) argue that price-level targeting might be a better way to anchor expectations than an inflation target. Reifschneider and Williams (2000) show that simple policy rules formulated in terms of a price-level target can significantly reduce real distortions associated with the zero lower bound on

[3] For a more detailed review of policies that are able to reduce the risk of hitting the zero lower bound, see Yates (2002). For an assessment of the potential effectiveness of non-standard monetary policy at the zero lower bound, see Bernanke, Reinhart and Sack (2004).

[4] Duguay (1994) and Coulombe (1998) also document that a price level target path implies that expectations help resisting deflation and profund downturns if the economy falls into a zero lower bound situation.

interest rates. Eggertsson and Woodford (2003) consider a simple stochastic setup in which the economy never falls into a liquidity trap. They show that a credible commitment to the right sort of history-dependent policy can largely mitigate the distortions created by the zero bound. In their model, optimal policy involves a commitment to adjust interest rates so as to achieve a time-varying price-level target, when this is consistent with the zero bound. They characterize the optimal policy in such a setting and they show that it indeed involves a commitment to a history-dependent policy. In particular, a price-level target commits the central bank to undo any deflation by subsequent inflation; a larger disturbance, that creates a larger initial deflation, automatically creates greater inflation expectations in response. Thus, there is an "automatic stabilizer" built into the price-level target, that is lacking under a strict inflation targeting regime.

Nevertheless, the benefits of history-dependent rules depends on the assumption that expectations are forward-looking. For example, the less forward-looking are expectations, the weaker will be the effect on future expected nominal rates and expected inflation of committing to a price level target. In addition, Covas and Zhang (2010) show that, with imperfections in both debt and equity markets, the gain of the price-level targeting regime over the inflation targeting regime depends on the degree of financial market frictions.

A second way to lift inflation expectations is to choose a positive inflation target (around 2%).[5] Nevertheless, this approach has been criticized

[5]Stochastic simulations with macroeconometric models suggest that, at an average inflation rate of 2%, the fraction of time spent at the zero lower bound is likely to be around 2%. And even for an average inflation rate of 1%, the corresponding figure is only

by Svensson (2000) who argues that the mere announcement of a positive inflation target is not likely to be enough to raise inflation expectations. Coenen, Orphanides & Wieland (2003) also criticize this argument, asserting that it might also be difficult to raise inflation expectations because price stickiness can make the expected future price also sticky. Williams (2009) argues that, if monetary policy follows the standard Taylor rule, an inflation target of 2 % may be insufficient to keep the zero lower bound from imposing sizable costs in terms of macroeconomic stabilization in a much more adverse macroeconomic climate.

To conclude, according to this first strand of literature, the key to effective central-bank action to escape a "liquidity trap" and to combat a deflationary slump is the management of expectations.

The second strand of literature builds from Buiter & Panigirtzoglou (2000) and Goodfriend (2000) who suggested the introduction of so-called Gesell money. This would imply decreasing the zero nominal interest floor by taxing money holdings. Recall that the zero bound on short-term interest rates comes about because investors can always hold cash, which pays a guaranteed zero return. Any mechanism that seeks to lower the return on cash below zero would therefore lower the zero floor to interest rates.

A third theoretical approach has been proposed by Svensson (2001). He suggests a "foolproof " way to escape from the binding zero lower bound in an open economy framework. The idea is to jump-start the economy by a real depreciation of the currency via unlimited interventions and in so doing increase inflationary expectations. Initially, an exchange rate peg is

up to around 5%. For further details, see the studies surveyed in Yates (2003).

established, which is later replaced by a price-level or inflation target when the price-level target has been reached. In so doing the risk of overheating is avoided.

Finally, Christiano (2004) suggests a fourth approach. He extends the analysis of Eggertsson and Woodford (2003) and shows that, when capital and government spending are introduced into the analysis, the zero bound is not likely to bind, and if it does the consequences may not be severe. Moreover, the multiplier on government spending is predicted to be very large in the event of a binding zero bound, so that an increase in government spending should help to turn the economy around when monetary policy is not working. Similar conclusions are reached by Christiano, Eichenbaum and Rebelo (2009) and Erceg and Linde (2009). They argue that the spending multiplier can be much larger than in normal situations, and fiscal stimulus can be implemented rapidly. Moreover, the budgetary costs may be small as the large response of output boosts tax revenues, allowing for a "fiscal free lunch".

Concerning the empirical evaluation of issues related to the zero lower bound, the literature is abundant. Some authors have down-played the risk of hitting the zero lower bound, at least for the euro area and the US. According to Coenen, Orphanides & Wieland (2003), the risk of hitting the zero bound would be negligible for the US with an average nominal interest rate over the cycle of 3%. To obtain this result, they use stochastic simulations of a small structural rational expectations model. They assume stochastic shocks similar in magnitude to those over the 1980s and 1990s. Only with a lower level of the average nominal interest rate, they found a significant risk of a binding zero bound. Using a similar model, Viñals (2001) compared the US and the euro area probability of hitting the zero lower bound. His findings for the US are close to those of Coenen, Orphanides & Wieland (2003). For the euro area, his results suggest an even smaller probability than for the US, due to the structural characteristics of the euro area. However, the probability of a binding zero lower bound depends on the likelihood of a combination of extreme shocks. Since the frequency of such shocks is limited, they are hard to assess econometrically. Schmitt-Grohe and Uribe (2007) analyze the zero bound problem in a medium-scale DSGE model (calibrated on US data) with distortionary taxes and three shocks: aggregate productivity, investment-specific productivity and government spending shocks. They conclude that the probability of the nominal interest rate approaching the zero bound is negligible. On the opposite side, Williams (2009) found that an additional 4 percentage point rate cut would have limited the rise in the U.S. unemployment rate and would bring unemployment and inflation more quickly to steady-state values, but the zero lower bound precludes such a sharp rate cut. Christiano (2004) argues that additional research allowing for a broader range of shocks may improve our understanding of the factors that occasionally force central banks to face the zero bound on nominal interest rates. Based on this argument, Amano and Shukayev (2009) consider a broader range of economic shocks. Their results indicate that even under a zero inflation policy, historically-measured aggregate shocks - such as productivity, investment-specific productivity, government spending and money demand shocks - do not drive the nominal interest rate to the zero bound. The only shock in their analysis that forces the central bank to face the zero bound is a risk premium shock.

Moving to an open economy context, Bodenstein, Erceg and Guerrieri (2009) analyze the transmission of foreign demand shocks to the US economy using a two-country DSGE model. They find that when interest rates are bounded, the impact of an adverse foreign demand shock on the United States is greatly amplified. If the shock occurs against the backdrop of a liquidity trap in the US, the output contraction is mainly attributable to rising real interest rates, as short-term nominal rates cannot decline further while expected inflation falls. As a result, the contraction in net exports is reinforced by a sharp contraction in private domestic demand. On the contrary, in the "normal" situation in which policy rates can adjust, lower real interest rates would cause private domestic demand to expand, and hence cushion the impact on US output.

Indeed, as Yates (2002) points out, conclusions about the risks of hitting the zero bound, are going to depend on many factors, such as assumptions about the variance of shocks, about the rule the central bank follows in setting monetary policy and about the representation of the economy, which propagates the shocks into distributions for desired interest rates.

3 Model presentation

The model used is a closed economy DSGE model similar to Christensen and Dib (2006). The model contains standard features, such as adjustment cost on investment and sticky prices. In addition, I add financial frictions as in Bernanke Gertler and Gilchrist (1995) and Bernanke and Gertler (1989, 1998). The source of the financial accelerator is the asymmetric information that will make it costly for lenders to evaluate the quality of firm's investments.

There are five sectors in the economy: households, entrepreneurs, capital producers, retailers and final goods producers. In addition, there is the monetary authority that sets the nominal interest rate, according to a standard Taylor rule. Households finance entrepreneurs' purchase of capital by lending deposits. The presence of asymmetric information between entrepreneurs and lenders creates financial frictions which make entrepreneurial demand for capital depend on their financial position. Capital producers build unfinished capital and sell it to entrepreneurs. Competitive final good firms combine the final capital good produced by entrepreneurs and labour supplied by households. They combine these two factors to produce a homogeneous final good. Retailers are the source of nominal frictions. They differentiate the homogeneous final good and sell it in monopolistically competitive retail markets. They set nominal prices in a staggered fashion à la Calvo (1983).

3.1 Households

Preferences of a household $j \in [0,1]$ at time t are described by:

$$\max U_t^{(j)} = E_0 \sum_{t=0}^{\infty} \beta^t u(C_t^{(j)}, H_t^{(j)})$$

where β is the discount factor, C_t is a composite consumption index and H_t is labor supply.

Let the functional form of u be given by:

$$u(C_t^{(j)}, H_t^{(j)}) = \frac{1}{1-\sigma}(C_t^{(j)})^{1-\sigma} - \eta \frac{H_t^{(j)1+\psi}}{1+\psi}$$

A consumer's revenue flow comes from her supply of hours of work to firms for wages W_t, profits Π_t from firms and the return on assets B_t .

$$P_t C_t = W_t^{(j)} H_t^{(j)} + \Pi_t + (R_t + Z_t) B_t - B_{t-1}$$

The first order conditions (hereafter, f.o.c.) from the maximization problem are:

$$E_t \beta [(R_t + Z_t)(C_{t+1})^{-\sigma}] = (C_t)^{-\sigma}$$

$$W_t = \left(-\frac{U_{Lt}}{U_{Ct}}\right) = \eta H^{\psi} (C_t)^{\sigma}$$

The disturbance term Z_t drives a wedge between the interest rate controlled by the central bank and the return on assets held by households.

Z_t follows the first-order autoregressive process:

$$Z_t = \rho_Z Z_{t-1} + \varepsilon_{Z_t}$$

where $\rho_Z \in (0,1)$ is an autoregressive coefficient and ε_{Z_t} is normally distributed with mean zero and standard deviation σ_{Z} .

A positive risk premium shock increases the return on assets held by households and hence increases savings and reduces current consumption.

At the same time, this shock also increases the cost of capital and reduces investment. The risk premium shock helps to explain the comovement of consumption and investment.[6]

Finally, for the Fisher condition, the real interest rate is defined as follows:

$$R_t = R_t^n \frac{P_{t+1}}{P_t}$$

3.2 Production sectors

3.2.1 Capital producers

Production of unfinished capital goods is carried out by competitive firms. Newly produced capital goods replace depreciated capital and add to the capital stock. I assume that capital producers are subject to quadratic capital adjustment costs, so that the marginal return to investment in terms of capital goods is declining in the amount of investment undertaken, relative to the current capital stock.

Capital producers make their production plans one period in advance. They maximize

$$\max E_{t-1} \left\{ \left[Q_t I_t - I_t - \frac{\chi}{2} \left(\frac{I_t}{K_t} - \delta \right)^2 \right] K_t \right\}$$

The f.o.c. gives the standard Tobin's Q equation:

$$Q_t = 1 + \chi \left(\frac{I_t}{K_t} - \delta \right)$$

[6] This effect makes this shock different from a discount factor shock as in Christiano, Eichenbaum and Rebelo (2009).

Furthermore, the capital stock evolves according to:

$$K_t = I_t + (1 - \delta)K_{t-1}$$

In addition, total output is also determined by exogenous government spending G_t. I assume that exogenous spending follows a first-order autoregressive process:

$$G_t = \rho_G G_{t-1} + \varepsilon_{G_t}$$

where $\rho_G \in (0, 1)$ is an autoregressive coefficient and ε_{G_t} is normally distributed with mean zero and standard deviation σ_G .

Final output is the sum of consumption, investment goods and government spending

$$Y_t = C_t + I_t + G_t$$

3.2.2 Entrepreneurs

The entrepreneurs' behaviour is modelled along the line of Bernanke, Gertler and Gilchrist (hereafter, BGG), where the source of financial frictions is the existence of an agency problem that makes external finance more expensive than internal funds. The entrepreneurs observe their output which is subject to a random outcome costlessly. Lenders incur an auditing cost to observe an entrepreneur's output. After observing her project outcome, an entrepreneur decides whether to repay her debt or to default. If she defaults, the financial intermediary audits the loan and recovers the project outcome less monitoring costs. Accordingly, the marginal external financing cost is equal to a gross premium for external funds plus the gross real opportunity costs equivalent to the riskless interest rate.

BGG show that the optimal contract implies that the external finance premium, $s(\bullet)$, depends on the entrepreneurs' balance sheet position. In particular the external finance premium increases with the leverage ratio and can thus be characterized by the following functional form:

$$s_t = s\left(\frac{K_t Q_t}{N_t} X_t\right)$$

where $s'(\bullet) > 0$ and $s(1) = 1$.

The entrepreneurs' demand for capital depends on the marginal productivity of capital and on the capital gain:

$$E_t(F_{t+1} + Z_t) = E_t\left\{\frac{r_{t+1}^K + (1-\delta)Q_{t+1}}{Q_t}\right\}$$

where F_{t+1} is the external funds rate and and r_{t+1}^K is the marginal productivity of capital, at $t+1$. The risk premium disturbance affects the cost of capital.

Thus, the demand for capital should satisfy the following optimality condition that states that the expected real return on capital is equal to the external financing cost:

$$F_{t+1} = R_t s_t$$

To determine the external finance premium, I adopt the following functional form:

$$s_t = \left(\frac{K_t Q_t}{N_t} X_t\right)^{\omega}$$

where $\omega > 0$. Therefore, at time t, the gross external financial premium $\left(\frac{K_t Q_t}{N_t} X_t\right)^{\omega}$ depends on borrowers' leverage ratio $\left(\frac{K_t Q_t}{N_t}\right)$, the elasticity of the external finance premium with respect to the leverage ratio (ω) and the disturbance term X_t.[7] The shock X_t follows the first-order autoregressive process:

$$X_t = \rho_X X_{t-1} + \varepsilon_{X_t}$$

where $\rho_X \in (0,1)$ is an autoregressive coefficient and ε_{X_t} is normally distributed with mean zero and standard deviation σ_X .

To ensure that entrepreneurs' net worth (the firm's equity) will never be enough to fully finance the new capital acquisition, following BGG, I assume that entrepreneurs have finite lives. The probability that an entrepreneur will survive until the next period is ν, so the expected lifetime horizon is $\frac{1}{1-\nu}$. The entrepreneur's aggregate net worth is the equity held by entrepreneurs surviving from the previous period, and it is defined as follows:

$$N_{t+1} = \nu \left[F_t Q_t K_t - R_t \left(\frac{K_t Q_t}{N_t} X_t\right)^{\omega} (K_t Q_t - N_t) \right] + (1-\nu) g_t$$

Here, $(1-\nu)$ is the share of new entrepreneurs entering the economy and g_t is the transfer or "seed money" that newly entering entrepreneurs

[7] In a model without financial frictions, the leverage ratio is equal to 1 and the elasticity $\omega = 0$.

receive from entrepreneurs that depart. Since the costs of pure debt finance are infinite, I include the transfer g_t to ensure that new entrepreneurs can operate. I take g_t as given; in this quantitative exercise it is of negligible size.

A fall in the price of capital affects the leverage ratio.[8] As the leverage ratio rises, the risk premium also rises. On the one hand, the higher risk premium will increase the cost of borrowing. On the other hand, the lower price of capital will decrease the return on capital. Therefore, the entrepreneurial net worth will decrease at the end of the period and *ceteris paribus*, the leverage ratio will be higher, amplifying the recession.

3.2.3 Final goods producers

Production is carried out by firms that follow a constant-returns-to-scale technology. To produce output Y_t, firms combine final capital goods and labour. The technology is defined as follows:

$$Y_t = AK_t^{\alpha} H_t^{1-\alpha}$$

where A is the productivity parameter.

Firms minimize production costs, so the first order conditions are:

$$W_t = MC_t(1-\alpha)\frac{Y_t}{H_t}$$

$$r_t^K = MC_t \alpha \frac{Y_t}{K_t}$$

where MC_t denotes the marginal production cost for a firms.

[8]Fluctuations in the price of capital Q_t create a link between asset price movements and the credit cycle (e.g. Kyotaki and Moore (1997) and Christiano, Gust and Roldos (2002)).

3.2.4 Retailers

Retailers purchase the wholesale goods at a price equal to nominal marginal costs and differentiate them at no cost. They then sell these differentiated retail goods on a monopolistically competitive market.

I introduce a monopolistic competition framework à la Dixit and Stiglitz:

$$P_{t+l} = (\int_0^1 p_{jt+l}^{1-\vartheta} dj)^{1/1-\vartheta}$$

$$Y_{t+l} = (\int_0^1 Y_{jt+l}^{\vartheta-1/\vartheta} dj)^{\vartheta/\vartheta-1}$$

where ϑ is the elasticity of substitution between varieties of goods.

The aggregate price is

$$P_t^{1-\vartheta} = (1-\varphi)(P_t^*)^{1-\vartheta} + \varphi P_{t-1}^{1-\vartheta}$$

Following Calvo, I am assuming that firms cannot change their selling prices unless they receive a random signal. The constant probability to receive such a signal is $(1-\varphi)$. Each firm j sets the price $p_t^*(j)$ that maximizes the expected profit for l periods, where $l = \dfrac{1}{1-\varphi}$ is the average length of time that a price remains unchanged.

The maximization problem is

$$Max E_0 \sum_{t=0}^{\infty} \left[(\beta\varphi)^l \lambda_{t+l} (p_t^*(j) - mc_{t+l}) \frac{Y_{t+l}(j)}{P_{t+l}} \right]$$

$$s.t.\ Y_{t+l}(j) = (\frac{p_t^*(j)}{P_{t+l}})^{-\vartheta} Y_{t+l}$$

The first order condition is:

$$p_t^*(j) = \frac{\vartheta}{\vartheta - 1} \frac{E_0 \sum_{t=0}^{\infty} [(\beta\varphi)^l \lambda_{t+l} mc_{t+l}) \frac{Y_{t+l}(j)}{P_{t+l}}]}{E_0 \sum_{t=0}^{\infty} [(\beta\varphi)^l \lambda_{t+l} \frac{Y_{t+l}(j)}{P_{t+l}}]}$$

These equations lead to the following New Keynesian Phillips curve:

$$\pi_t = \frac{(1-\beta\varphi)(1-\varphi)}{\varphi} m\hat{c}_t + \beta E_t \pi_{t+1}$$

where $\pi_t = \dfrac{P_t}{P_{t-1}}$ is the inflation rate and $m\hat{c}_t$ is the log deviation of real marginal cost from its steady state level.

3.3 Monetary policy

I introduce the zero lower bound (hereafter, ZLB) on the nominal interest rate, defining the Taylor rule in the following way:

$$R_t^n = dummy^{MP} \bar{R}^n + (1 - dummy^{MP}) \left[\left(\frac{\pi_t}{\bar{\pi}} \right)^{\gamma_\pi} (R^n)^{1-\rho_{RN}} \left(R_{t-1}^n \right)^{\rho_{RN}} \right]$$

When the nominal interest rate falls below the zero lower bound ($\bar{R}^n$), the variable $dummy^{MP}$ becomes active and assumes value 1. Otherwise, it is set equal to 0.

The parameter γ_π governs the degree to which the inflation rate is targeted around the desired target $\bar{\pi}$. Moreover, I am assuming that the monetary authority does not react immediately and adjust interest rate with a degree of inertia measured by ρ_{RN}.

One *caveat* is that imposing the ZLB through the introduction of a dummy variable implies that agents are not able to rationally anticipate the possibility of hitting the ZLB. Therefore they will not immediately reduce their output and inflation expectations correspondingly. Therefore, the policy response is less aggressive than in a model in which agents were able to anticipate the possibility of hitting the ZLB.[9]

3.4 Calibration

Following the literature, I set the steady-state rate of depreciation of capital (δ) equal to 0.025 which corresponds to an annual rate of depreciation equal to 10 %; the discount factor β is equal to 0.99, which corresponds to an annual real rate in steady-state of 4 %.

Also other parameters are quite standard. The relative risk aversion coefficient (σ) is set equal to 1.2. The steady-state share of capital in the final goods production function (α) is equal to 0.5. The probability ν that entrepreneurs will survive for the next period is set equal to 0.9728, therefore on average entrepreneurs stay in business for 36 years. The elasticity of labor supply (ψ), and the coefficient of labor in utility (η) are both set equal to 1. The steady-state value of the elasticity of substitution between varieties

[9] For a further discussion of the role of expectations in models with a zero lower bound on interest rates, see Adam ad Billi (2006).

of goods is equal to 6, which implies a mark-up of 20%. The Calvo price parameter is set equal to 0.75.

The parameters of the monetary policy rule are based on the estimates of Clarida, Gali, and Gertler (2000) for the post-82 period. The coefficient on inflation γ_π is set equal to 1.5, while the interest rate smoothing parameter ρ_{RN} is equal to 0.8.

There is no consensus on the parameter χ describing investment adjustment costs. I set this parameter equal to 1.42.

Finally, the elasticity of risk premia to the leverage ratio (ω) is assumed to be equal to 0.05 and the steady-state value of the leverage ratio equal to 2. The value I choose for the leverage ratio is consistent with a strand of literature that sets this parameter at a value of 2 for the US.[10]

4 The effects of the ZLB constraint

In this section, I assess the implications of the ZLB constraint on the nominal interest rate in a model that entails financial frictions. For this purpose, I introduce two kinds of shocks: a negative demand shock (e.g. a risk premium shock) and an adverse financial shock (e.g. an increase in the financial risk premium). Both shocks are modelled as an $AR(1)$ process with a fairly high degree of persistence (the autoregressive coefficient is set equal to 0.9). These two types of shocks are suitable for analyzing the dynamics when the ZLB is binding, as they put downward pressure on both output and inflation,

[10] To be precise, BGG define the leverage ratio at time t as $\frac{N_t}{Q_{t-1}K_t}$ and so they choose a steady-state value equal to 0.5.

which can cause a binding ZLB. Therefore, this potentially creates a more severe downturn. I contrast the effects under normal situations (i.e. when the central bank has the ability to lower interest rates in response to the demand shock) with a situation when the nominal short-term interest rate is subject to the lower bound. Then, I analyze whether the economy is likely to be pushed into a more severe recession when the ZLB binds.

4.1 Risk premium shock

In Figure 1, I compare the responses to a risk premium shock under two alternative specifications of the model: the baseline model (namely, the model without the ZLB constraint, as described in section 4) and a model which features a binding lower bound on the nominal interest rate. In this latter specification, the real interest rate is limited in its possibility to stimulate the economy, after the initial drop in consumption and output. A risk premium shock reduces both private consumption and investment. On the one hand, this shock stimulates private savings by increasing the required return on assets held by households. On the other hand, the price of capital drops as it depends positively on its expected value and the expected rental capital rate and negatively on the ex-ante real risk-free interest rate and the risk premium disturbance. The collapse of the capital price translates into lower investment and capital. The drop of both consumption and investment results in lower output and lower inflation. The presence of the ZLB makes the drop in investment more severe, as the risk premium shock produces a deterioration of the leverage ratio, an increase of the financial risk premium and a reduction of entrepreneurial net worth. This mechanism is amplified when the ZLB constraint is binding and hence the increase in the financial risk premium is stronger. As a consequence, the cost of new investment raises and the recession is amplified.

4.2 Financial shock

Figure 2 displays the response of the main macro variables to a financial shock that pushes up the financial risk premium, worsening entrepreneurs' balance sheets. As enterprises are limited in their ability to self-finance, the level of investment falls and the economy is pushed onto a recessionary-deflationary path. The recession is amplified if the lower bound on the nominal interest rate is binding, as the monetary authority is no longer able to offset the negative effects of an adverse shock by using the nominal interest rate as an instrument.

5 Is price-level targeting a solution to avoid the ZLB?

In this section, I explore the issue of whether the price level (hereafter, PLT) is a better target for monetary policy in order to limit the probability to hit the ZLB. The motivation is that – when expectations are forward-looking – a PLT rule introduces a desirable inertia that affects the private sector's expectations; hence it results in less volatile interest rates.

The mechanism operates as follows. Assume that a deflationary disturbance leads to a fall in the price level relative to the target (e.g. a negative demand shock). Economic agents observing the shock understand that the central bank will correct the deviation from the target aiming at an above-average inflation rate. As a result, inflation expectations increase, which helps to mitigate the initial impact of the deflationary shock. Under a credible price level target, inflation expectations operate as automatic stabilizers.[11]

The main difference between inflation-targeting (hereafter, IT) and PLT is that, under IT, unexpected disturbances to the price-level are ignored, while under PLT they are reversed. This implies that, under PLT, the price level has a predetermined targeted path and uncertainty about the future price level is bounded.

If the monetary authority is concerned about price level stability, the Taylor rule introduced in paragraph 3.3. is modified as follows:

$$R_t^n = dummy^{MP}\bar{R}^n + (1 - dummy^{MP})\left[\left(\frac{P_t/\bar{P}_t}{(P_{t-1}/\bar{P}_{t-1})^{\eta_P}}\right)^{\rho_P}(R^n)^{1-\rho_{RN}}\left(R_{t-1}^n\right)^{\rho_{RN}}\right]$$

where $\bar{P}_t$ is the target or steady-state value for the price level at period t. Note that for $\eta_P = 1$, the rule is the Taylor rule defined for inflation targeting, while $\eta_P = 0$ signifies pure price-level targeting. For $0 < \eta_P < 1$ the rule is a hybrid one in which the central bank is concerned about reaching the inflation target rate but also about the evolution of prices on the way to the inflation target. As for the IT regime, when the nominal interest rate falls below the zero lower bound ($\bar{R}^n$), the variable $dummy^{MP}$ becomes active and assumes value 1. Otherwise, it is set equal to 0.

[11] The beneficial impact of a PLT rule on inflation expectations was lacking in the first strand of theoretical analysis based on backward-looking models, as in Lebow, Roberts, and Stockton (1992), Haldane and Salmon (1995) and Fillion and Tetlow (1994).

Figure 3 and 4 show the response of the nominal interest rate and other key variables, to the risk premium shock and to the financial shock. The probability of hitting the ZLB is lower if the monetary authority decides to target the price level instead of the inflation rate. When agents are forward-looking and the monetary authority credibly commits to a PLT rule, such a rule yields a lower variability of inflation and of nominal interest rates. Agents expect that the monetary authority will correct the deviation from the target aiming at an above-average inflation rate. Private sector expectations of future inflation after a deflationary shock dampen the initial disinflation and – hence – stabilize interest rates.[12] Therefore, a PLT rule will lower the probability to hit the ZLB for the nominal interest rate.

6 The effectiveness of fiscal stimulus in times of crisis

The recent worldwide economic crisis has renewed attention on the role of fiscal policy during both the economic downturn and the "exit" strategy phase. With the prospect of a severe global recession in 2008-2009, many governments have put forward fiscal stimulus plans in order to underpin a recovery. Then, at a second stage many countries are expected to implement significant fiscal consolidation packages, once the economy has started to recover and the current fiscal stimulus policies have been phased out. As a response to the renewed interest in the role of fiscal policy, the literature

[12] Similar conclusions are reached by Giannoni (2000); Black, Macklem and Rose (1997); Vestin (2006).

has investigated the role of fiscal policy in the presence of financial frictions (Röger and in't Veld (2009), Erceg and Lindè (2009), Villaverde (2010)).

Moreover, it is sometimes feared that, when nominal interest rates reach the lower bound, monetary policy will become impotent in stimulating demand. In these circumstances, fiscal policy may offer a necessary tool when the nominal interest rate hits its ZLB. A recent strand of the literature (Christiano, Eichenbaum and Rebelo (2009); Erceg and Lindé (2009); Woodford (2010)) has found that especially large fiscal multipliers are plausible when monetary policy is constrained by the ZLB on nominal interest rate. The underlying mechanism is that when the ZLB binds, the fiscal intervention has much more stimulative effects on the economy. This stimulative effect stems from the fact that when the economy is hit by a deflationary shock, the higher real interest rate increases desired savings and decreases desired investments. If the nominal interest rate is lower bounded, the fall in output must be larger to equate savings and investments. This larger fall in output is undone by an increase in government purchases and hence government spending multipliers are larger when the zero lower bound binds.

One practical objection to using fiscal policy when the ZLB binds is that there are long lags in implementing an increase in government spending. Christiano, Eichenbaum and Rebelo (2009) study the size of government spending multipliers in the presence of implementation lags. They find that the key determinant of the size of the multiplier is the state of the world in which new government spending comes on line. If it comes on line in future periods when the nominal interest rate is zero, there is a large effect on output. If it comes on line in future periods where the nominal interest rate is positive, the current effect of government spending is smaller. On the other hand, Erceg and Lindé (2009) show that if fiscal expansion is plagued by implementation lags and eventually needs to be financed by distortionary taxes, then fiscal expansion can have contractionary effects on economic activity that are magnified if the ZLB on nominal rates is binding. Indeed, "timing" seems to become a crucial aspect to take into account in implementing fiscal policy when the nominal interest rate is close to the ZLB. Corsetti, Meier and Müller (2009) and Corsetti, Kuester, Meier and Müller (2010) argue that the prospect of future spending cuts enhance the short-run stimulus effect, because it reduces inflation expectations and hence reduces the long-term interest rate. This argument holds also when the nominal short-term interest rate is bounded. Nevertheless, if monetary policy is constrained by the ZLB, the timing of the spending reversals is crucial. Reverting expenditure too early – while the ZLB is still binding and the economy is facing the risk of deflation – might further delay the exit from the ZLB. Postponing the reversal, instead, would reduce the stimulative short-term effects of fiscal policy.

In the previous section, I have investigated whether a PLT monetary policy rule might help to avoid the ZLB. Instead, in this section, I explore whether fiscal policy is a good tool when the ZLB is hit. For this purpose, I examine the effect of fiscal stimulus if the economy is characterized by frictions in financial markets and falls into a liquidity trap. Indeed, by the second half of 2008, many economies experienced a severe financial crisis and nominal interest rates in the U.S. and other major world economies reached historically low levels and in some cases have gone down close to zero.

Following Corsetti, Kuester, Meier and Müller (2010), I do not distinguish between Ricardian and non-Ricardian agents and I assume an exogenous path for government expenditure. Fiscal stimulus is modelled as a 1% government spending shock that follows an $AR(1)$ process with a high degree of persistence ($\rho_G = 0.9$).

Figure 5 displays the response of total output and its components (namely, consumption and investment) to a risk premium shock in order to assess the effect of the fiscal stimulus. I also consider a specification of the model that does not involve the financial accelerator (hereafter, FA). The series marked by spheres describes the reaction in a model affected only by the risk premium shock, while the series marked by triangles describes a model which allows also for the fiscal stimulus. Here, the fiscal stimulus is introduced as a temporary measure, implemented only at the first period. I distinguish three alternative specifications of the model: the baseline model with FA (Figure 5a), the model without FA (Figure 5b) and the model with FA and the ZLB (Figure 5c). If the monetary policy is not constrained by the ZLB, the government spending shock is leading to a crowding-out of private investment.

Table 1 (rows 2-4) displays the value of the government spending multiplier in the three alternative specifications. Again, the fiscal stimulus is implemented at the initial time. If the ZLB is not binding, the net impact on output is positive but the value of the fiscal multiplier[13] is below one. The simulations show that the financial accelerator mechanism weakens the effects of the fiscal stimulus, as displayed in the second row. The reason is that, in the presence of frictions in financial markets, the initial decline of

[13] The short-term effect of fiscal stimulus is calculated over a one-year horizon.

the price of capital and the capital stock is translated into a higher leverage ratio, higher costs of new investment and hence lower economic activity. In this way, the financial accelerator mechanism dampens the expansionary effect of government spending, leading to a lower multiplier.

The ZLB increases the multiplier substantially. As displayed in the fourth row, the government spending multiplier is slightly larger than one. The reason for this result is that, with nominal interest rates held constant, the higher inflation generated by an expansionary fiscal policy will lead to a decrease in real interest rates and this indirect monetary channel amplifies the GDP impact of the fiscal stimulus. This result is in line with the literature reported above.

An opposite conclusion is reached in Cogan et al. (2009). Using an empirical New Keynesian model calibrated for the US economy, they predict small multiplier effects of increased government purchases during a situation in which the ZLB is binding. The crucial difference is that they assume an increase in government spending that lasts as long as the ZLB is binding.

Indeed, the duration of the fiscal stimulus turns out to be a crucial aspect to take into account in implementing fiscal policy, especially when the nominal interest rate is close to the ZLB. There exists a general agreement across models on the weak effects of a prolonged fiscal stimulus. Coenen et al. (2010) summarizes and compares the keys results of a broad class of models.[14] They find that, if fiscal expansion is not perceived to be temporary, it

[14]Specifically, the seven models considered are: the QUEST model (European Commission), the GIMF model (IMF), FRB-US and SIGMA (the Board of Governors of the Federal Reserve System, BoC-GEM (Bank of Canada), the NAWM model (European

results in long-run crowding out of private spending.

Table 1 (row 5) displays the fiscal multiplier in case of a prolonged fiscal stimulus. In this case, the fiscal stimulus is still modelled as a 1% highly persistent shock to the government expenditure, but now it is implemented for 4 periods (namely, as long as the nominal interest rate is at the ZLB). In this case, the multiplier effect is still positive and higher than those arising in a situation in which the ZLB is not binding. Nevertheless, the prolonged fiscal stimulus is less effective than a temporary one.

Fiscal stimulus becomes even counter-productive, if it is expected to continue beyond the point at which the ZLB ceases to bind. Table 1 (row 6) suggests that if the fiscal stimulus is lasting 5 periods, it has contractionary effects on output, as shown by the negative value of the multiplier.

It has often been argued that one of the disadvantages of discretionary fiscal policy is that it is not timely, due to implementation lags. In the last row, Table 1 assesses the size of the government spending multiplier in the presence of implementation lags. If government spending still comes on line in future periods when the nominal interest rate is zero, but is delayed, the effects on output remain quite large, even though weaker than those generated by a "timely" fiscal intervention.

7 Conclusions and further extensions

In this paper, I have analyzed the implications of the zero lower bound on nominal interest rates in a DSGE model with financial frictions. Three main

Central Bank), and the OECD Fiscal model.

findings are worth to be highlighted. First, the recession is magnified in the presence of both financial frictions and a binding constraint on nominal interest rates. Second, when the central bank adopts a price-level targeting rule (instead of an inflation targeting rule), the probability to hit the lower bound is reduced. When agents are forward-looking and the monetary authority credibly commits to a price-level targeting rule, such a rule yields lower variability of inflation and of nominal interest rates. Agents expect that the monetary authority will correct the deviation from the target, aiming at an above-average inflation rate. The private sector's expectations of future inflation after a deflationary shock dampen the initial disinflation and hence stabilize interest rates. Third, an increase in government spending cushions the output fall but leads to a crowding-out of private consumption. Therefore, the net impact of a fiscal stimulus on output is still positive, but the value of the fiscal multiplier is below one. However, when the ZLB constraint is binding, the expansionary effects of the government spending shock are magnified and fiscal multipliers are larger than one. This result is in line with the most recent literature on fiscal stimulus.

Concerning the effectiveness of the fiscal stimulus when the nominal interest rate is close to the ZLB, two further results are worth to be highlighted. First, the duration of fiscal stimulus turns out to be a crucial aspect to take into account in implementing fiscal policy. If the fiscal stimulus continues beyond the period at which the zero lower bound ceases to bind, then it has contractionary effects on output. Second, the presence of lags in implementing discretionary fiscal policy might weaken the expansionary effects on output. Nevertheless, if government spending is delayed but still comes on line in future periods when the nominal interest rate is zero, the stimulative effect on output remains quite large.

This analysis opens the door to further extensions and future work. First, the robustness of the results should be checked with respect to some model parameters. Specifically, the implications of higher nominal rigidity and of a more elastic labour supply could be explored. Moreover, the implications of setting alternative monetary rules are worth examining.[15] Finally, a further step might be to distinguish the effects of several types of fiscal instruments, such as government spending, transfers, labour tax cuts, consumption tax cuts, etc...

[15] For instance, Williams (2009) explores the implications of setting a Taylor rule that responds very aggressively to movements in the output gap. He finds that outcomes for output gap and inflation rate variability close to those of the unconstrained classic Taylor rule, at the cost of somewhat greater interest rate variability. Interestingly, too strong a response to the output gap can be counterproductive, due to the asymmetry of the policy response resulting from the ZLB. When the output gap is positive, policy tightens sharply. But when the output gap is negative, the policy response may be truncated by the ZLB. This asymmetric response causes output gap variability to rise at very low inflation rate targets during the recession.

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A The steady-state equilibrium

At the steady-state:

$$A = 1$$

$$Q = 1$$

$$\pi = 1$$

$$R^n = \frac{1}{\beta}$$

$$R = R^n$$

$$N = \frac{1}{lev} QK$$

$$MC = \frac{\vartheta^P - 1}{\vartheta^P} P$$

$$F = \left(\frac{QK}{N} \right)^{\omega} R$$

$$premium = \frac{F}{R}$$

$$r^K = [F - (1 - \delta)] Q$$

$$I = \delta K$$

$$Y = C + I$$

B The linearized model

The log-linearized model is described as it follows:

Consumers:

$\hat{C}_t = \hat{C}_{t+1} - \frac{1}{\sigma}[\hat{R}^n_t - \hat{\pi}_{t+1} + \hat{Z}_t)]$

$\hat{\lambda}_t = -\sigma\hat{C}_t$

$\hat{W}_t = \psi\hat{H}_t - \hat{\lambda}_t$

$\hat{\pi}_{t+1} = \hat{R}^n_t - \hat{R}_t$

then, $\hat{\lambda}_{t+1} = \hat{\lambda}_t - \hat{R}_t - \hat{Z}_t$

Firms:

$\hat{Y}_t = \hat{A}_t + \alpha\hat{K}_t + (1-\alpha)\hat{H}_t$

$\hat{r}^k_t = \hat{Y}_t + \hat{M}C_t - \hat{K}_t$

$K_t = \delta\hat{I}_t + (1-\delta)\hat{K}_{t-1}$

$\hat{Q}_t = \chi(\hat{I}_t - \hat{K}_t)$

Entrepreneurs:

$\hat{F}_t + \hat{Q}_{t-1} = \frac{r^k}{F}\hat{r}^k_t + \frac{(1-\delta)}{F}\hat{Q}_t$

$\hat{F}_{t+1} = -\omega\hat{N}_t + \omega\hat{K}_t + (\hat{R}_t + \hat{Z}_t) + \omega\hat{Q}_t + \omega\hat{X}_t$

$\frac{\hat{N}_{t+1}}{\nu F} = \frac{K}{N}\hat{F}_t - (\frac{K}{N}-1)(\hat{R}_t+\hat{Z}_t) - \omega(\frac{K}{N}-1)(\hat{K}_t+\hat{Q}_t+\hat{X}_t) + [\omega(\frac{K}{N}-1)+1]\hat{N}_t$

$\hat{p}remium_t = E_t\hat{F}_{t+1} - \hat{R}_t - \hat{Z}_t$

Price setting:

$\hat{\pi}_t = \beta\hat{\pi}_{t+1} + \frac{(1-\beta\varphi)(1-\varphi)}{\varphi}(\hat{M}C_t - P_t)$

Equilibrium

$\hat{Y}_t = \frac{C}{Y}\hat{C}_t + \frac{I}{Y}\hat{I}_t + \frac{G}{Y}\hat{G}_t$

Monetary Policy rule:

$\hat{R}_t^n = \gamma_\pi(\hat{\pi}_t - \bar{\pi}) + \rho_R \hat{R}_{t-1}^n$

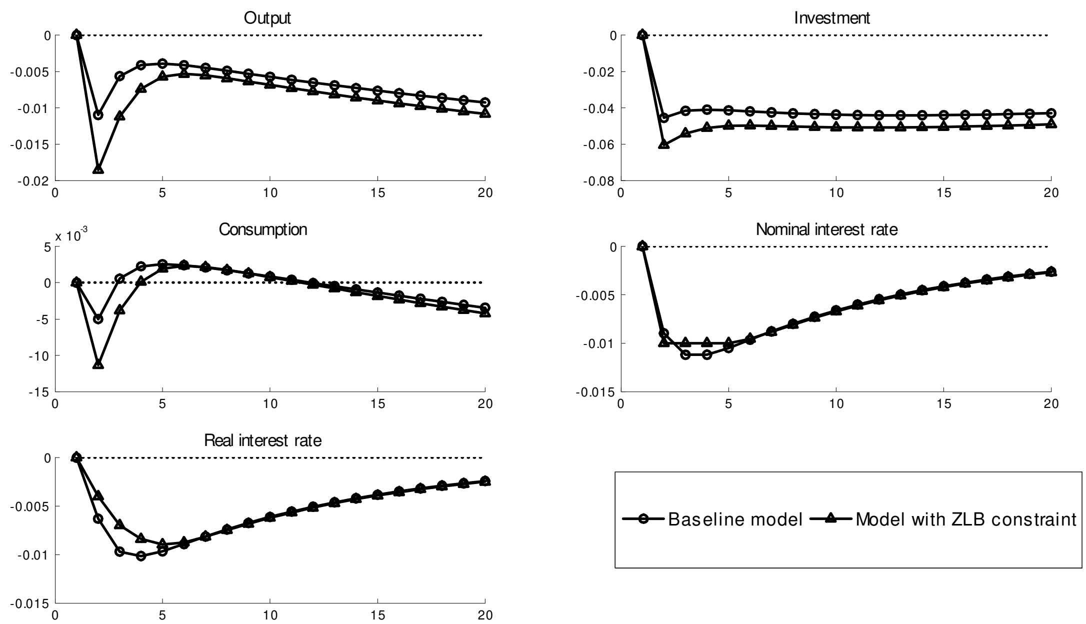

Figure 1: Risk premium shock

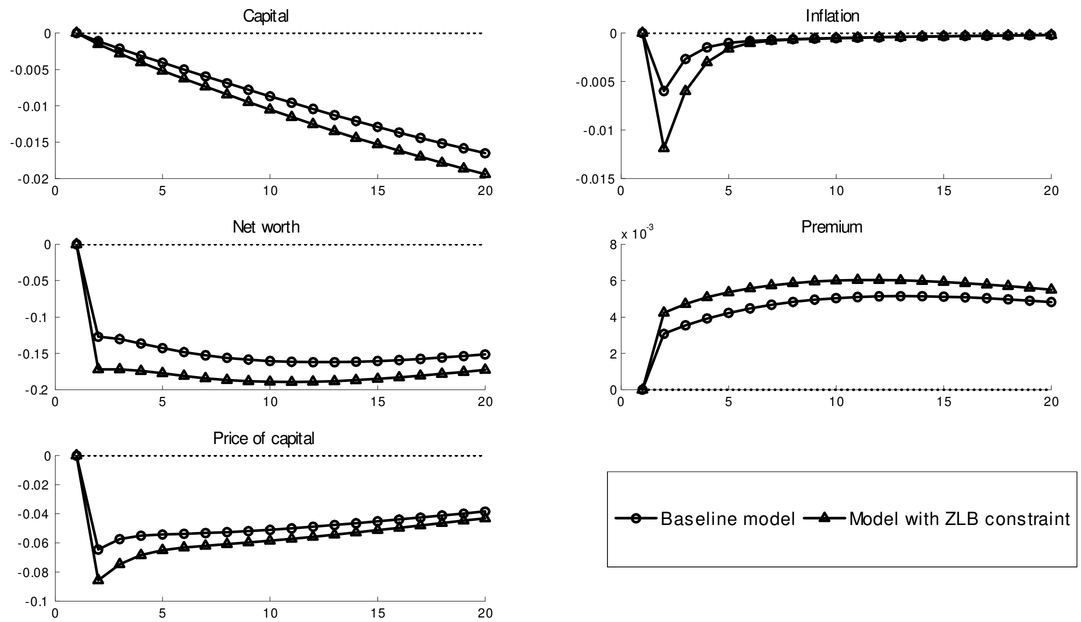

Figure 1 *bis*: Risk premium shock

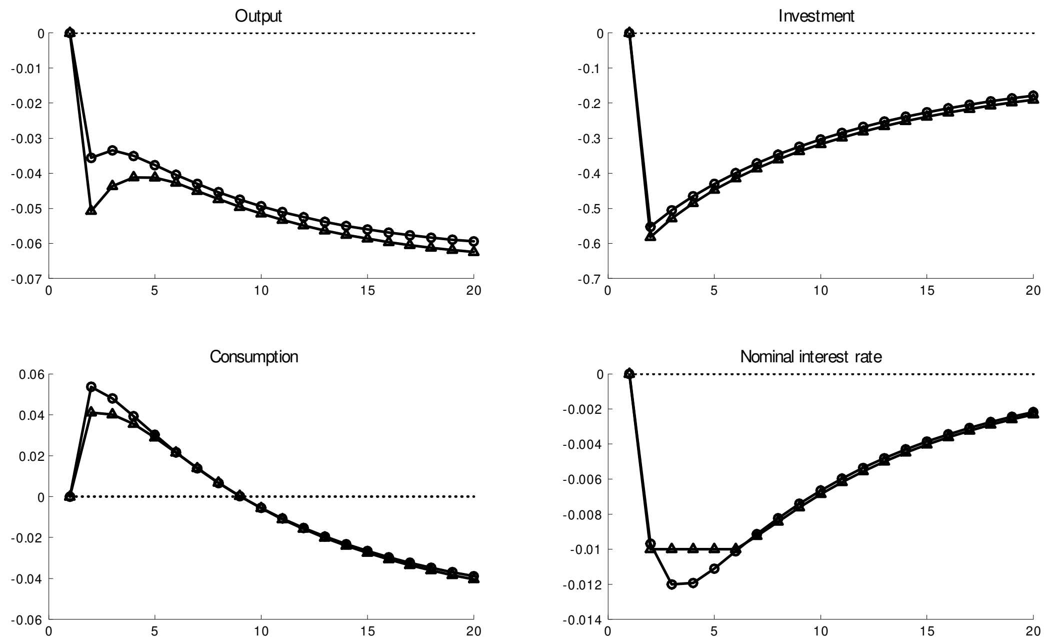

Figure 2: Financial shock

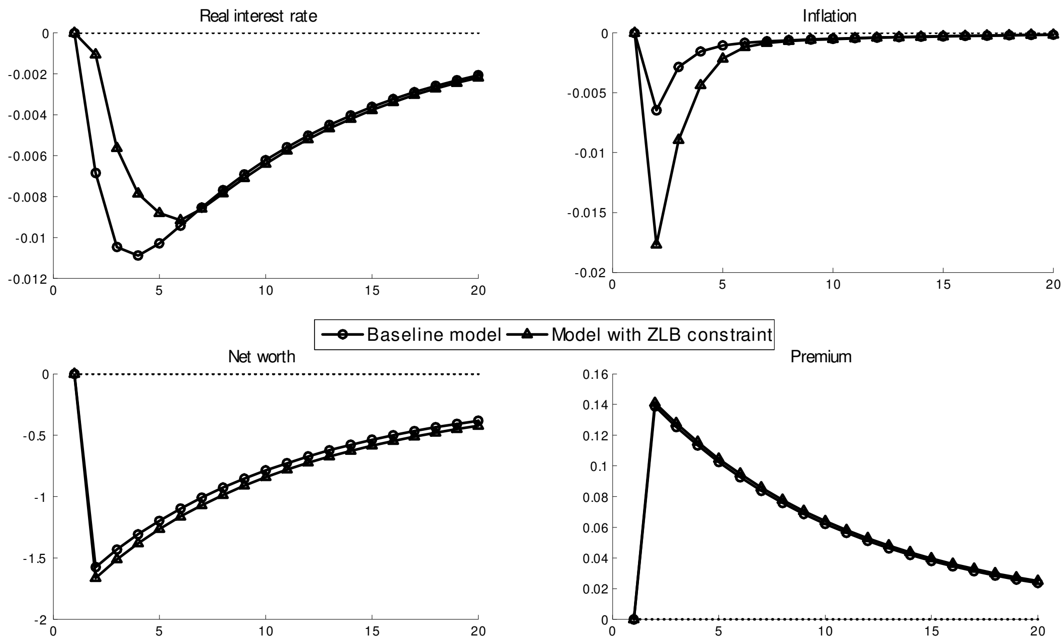

Figure 2 *bis:* Financial shock

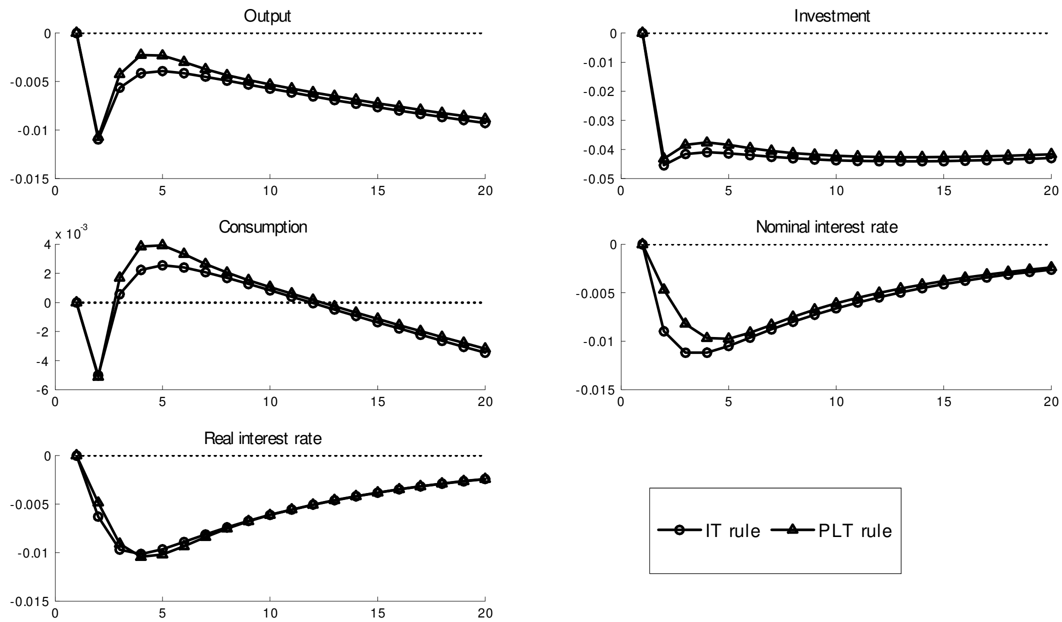

Figure 3: Risk premium shock

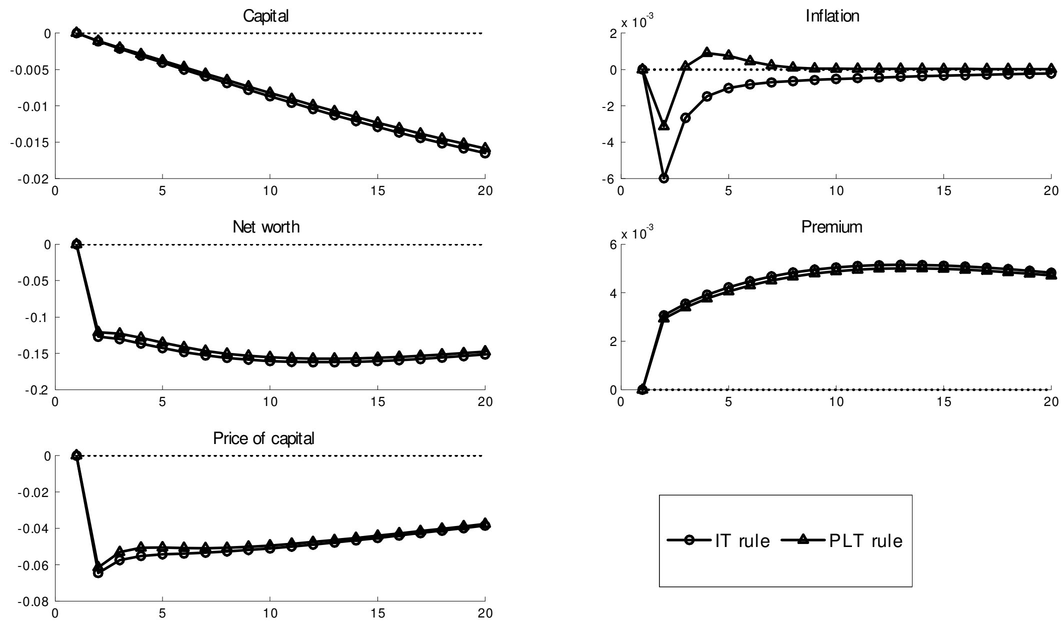

Figure 3 *bis*: Risk premium shock

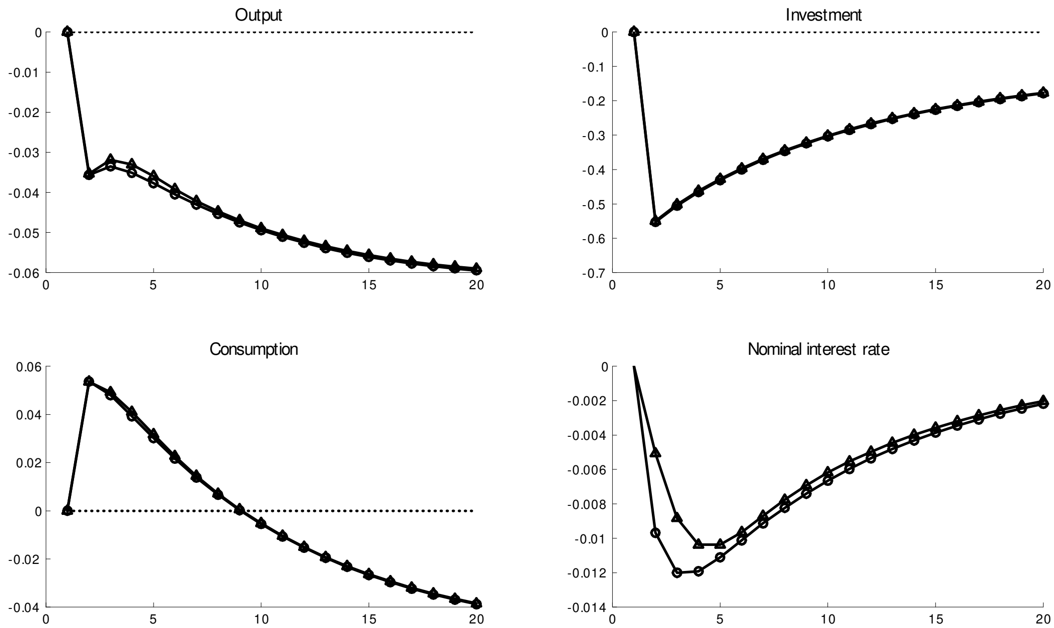

Figure 4: Financial shock

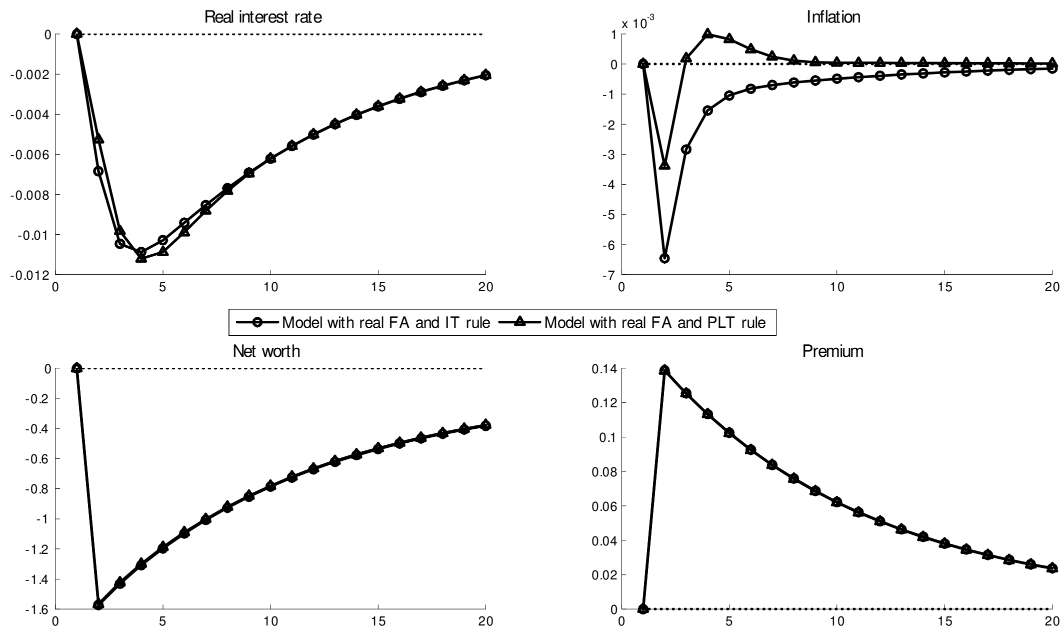

Figure 4 *bis*: Financial shock

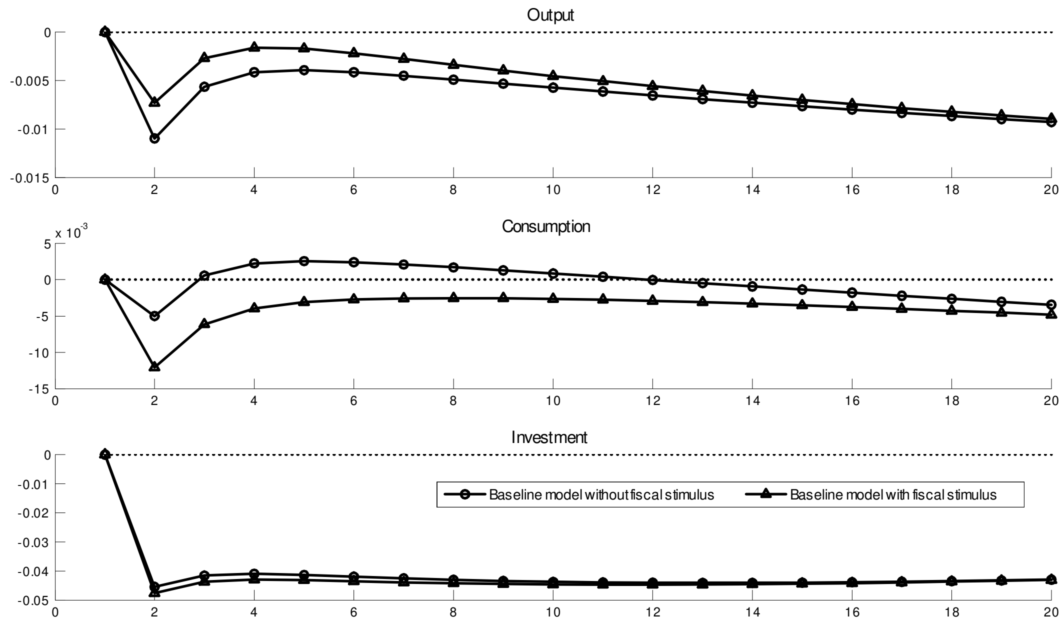

Figure 5a: Fiscal stimulus in the baseline model with FA

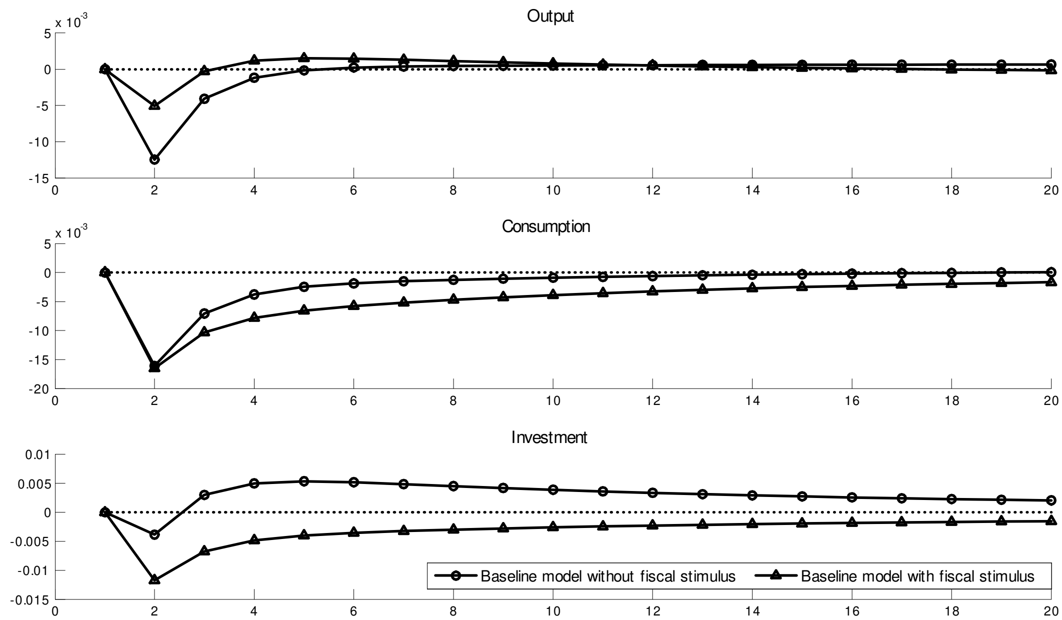

Figure 5b: Fiscal stimulus in the model without FA

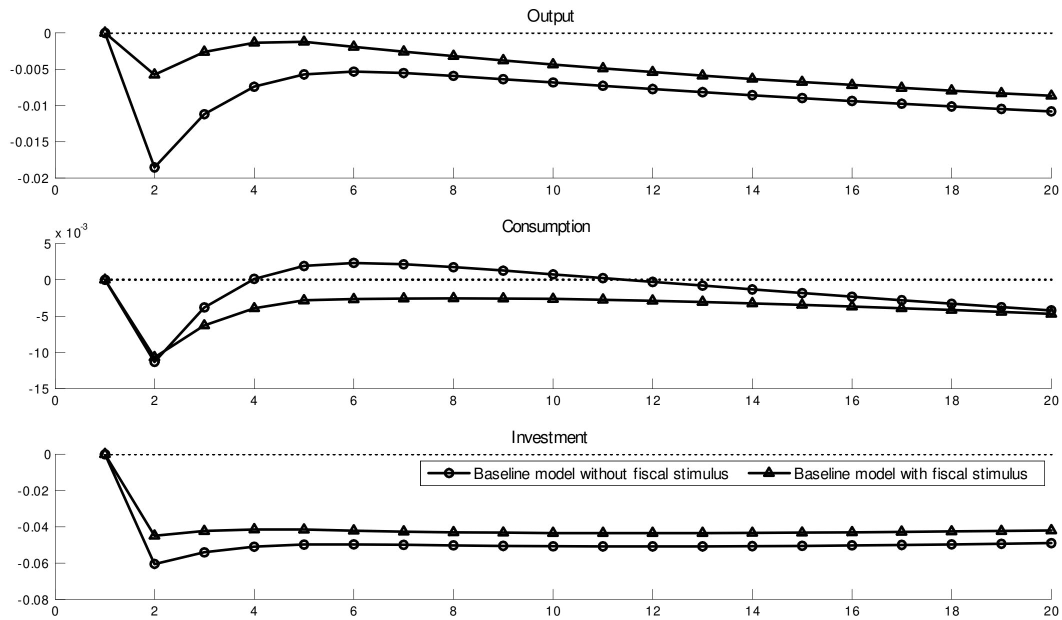

Figure 5c: Fiscal stimulus in the model with FA and the ZLB

Model specification	**Fiscal stimulus**	$\frac{\Delta Y}{\Delta G}$
Model with FA	temporary	0.502
Model without FA	temporary	0.336
Model with FA+ZLB	temporary	1.015
Model with FA+ZLB	prolonged as long as the ZLB binds	0.945
Model with FA+ZLB	prolonged beyond the ZLB binds	-0.474
Model with FA+ZLB	delayed	0.922

Table 1: Government spending multipliers