Monetary Policy in a New Keynesian Model with Tobin's Q Investment Theory Features

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Abstract

The purpose of this study is to disentangle the internal mechanics of monetary policy in the context of a New-Keynesian model, accentuating the channel of firm investment. To do this, we develop a simple medium-scale New-Keynesian model with both capital accumulation and investment adjustment costs. For a deeper insight of the monetary transmission mechanism, we analyze two alternative versions of the model, based on the two most common monetary policy instruments: money supply and interest rate. First, we demonstrate that firm investment operates as an important propagating factor in the monetary transmission mechanism and considerably affects the efficasy of the monetary policy instrument. Also, we found that although both instruments lead to similar dynamics, interest rate seems to generate more vigorous transitional dynamics for firm investment.

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Keywords: New Keynesian Model; Monetary Policy; Tobin's Q; Taylor Rule

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1 Introduction

The ascertainment of the instability of the traditional Phillips curve in the late 60s led to a fundamental change in the macroeconomic literature on aggregate fluctuations. Dynamic Stochastic General Equilibrium (DSGE hereafter) models superseded the, until then, dominant doctrine of "neoclassical synthesis". Two classes of such models were developed: the new classical and the new Keynesian DSGE models. In the first class, all markets are assumed perfectly, and wages and prices are assumed perfectly flexible. In the second class, product and/or labor markets are assumed monopolistically competitive and also nominal ridigities in prices and wages are incorporated.

In the last two decades, "New Keynesian" models (NK hereafter) became very popular with both academic economists and policymakers, especially for monetary policy analysis. The main reason for that is that these models, when equipped with a rich set of frictions, explain the data relatively well as it was demonstrated by Smets and Wouters (2003, 2007). Therefore, in the last ten years many extensions were made in the basic framework of the three-equations NK model (consisting of an Euler equation, a Phillips curve and a Taylor-type rule) leading to much more complex formations, the so-called "medium-scale" DSGE models.

In this paper we use a medium-scale NK model with capital accumulation and investment adjustment costs in order to disentangle the role of monetary policy instruments in the monetary transmission mechanism, accentuating the role of firm investment. To this end, we analyze two alternative versions of the model, based on the two most common monetary policy tools: money supply and interest rate. In the first version, monetary policy is characterized by a simple exogenous rule for money growth. In the second version, we assume that the independent monetary authority determines the bonds' nominal interest rate through a Taylor-type feedback rule. Moreover, in order to examine the efficiency of the fiscal policy and its interactions with the monetary one, we adopt a simple rule for public consumption.

Since investment depends on real interest rates, it constitutes a key element to understand the internal mechanics of monetary policy. Therefore, we develop a medium-size DSGE model with endogenous capital, *a lá* Real Business Cycle (RBC hereafter) theory, and quadratic investment adjustment costs (Jorgenson, 1963, Christiano et al., 2005). The analysis of investment dynamics can take place either from the point of view of the households or from the point of view of firms, depending on the assumption about who is the owner of the capital stock. Although the first option, is simpler and hence extensively used in DSGE models, the second one, i.e. that the firms - and not the households - are those who decide the level of investment in each period, is much more realistic. Therefore, we follow the second approach. This approach has been widely used to study the investment process, leading to the so-called Tobin's Q theory (Tobin, 1969; Hayashi, 1982), which allows to study the investment process based on the dynamics of the Q-ratio that represents the ratio between the market value of the firm and the replacement cost of its installed capital. The incorporation of these "Tobin's Q Investment Theory" features in a NK model allows us to investigate the interplay between firm investment dynamics and the monetary transmission mechanism. To this end, we compare the results of our model with a simplified version of it without capital accumulation and investment. Also since investment is a channel through which many fiscal instruments act, the analysis of its dynamics is very useful to understand the implications of the fiscal policy and its interaction with the monetary policy.

We analyze the effects of firm investment dynamics on the monetary transmission mechanism in the context of a commonly used general equilibrium model with Calvo-type price stickiness (Woodford, 2003; Gali, 2015). More specifically we consider a canonical set-up model in which labor markets are competitive and the goods markets are monopolistically competitive. The key concept of our analysis is that we discern two kinds of firms: capital producing and final goods producing firms. Capital firms convert consumption goods into capital through investment, subject to quadratic investment adjustment costs, and rent this capital to goods producing firms for a rental rate. Final good firms use this capital along with labor for production.

A non-formal overview of the model, before we lay out the particular assumptions explicitly, follows. The model economy features three sectors, a consumption sector, a productive sector, and the government. Note that time is discrete and the planning horizon is infinite and that the number of the households is equal to the number of the firms.

The consumption sector is constituted by households that purchase consumption goods, save via bonds, and supply labor services to the productive sector. They derive utility from labor, money and consumption and are assumed to be representable by one stand-in agent who maximizes his recursive lifetime utility.

The economy's output is produced through labor and capital inputs. We discern two kinds of firms: capital producing and final good firms. Capital firms convert consumption goods into capital through investment, and rent this capital to goods producing firms for a rental rate. Moreover, capital accumulation is subject to real adjustment costs which generate a time varying real price of capital, Tobin's q. Final good firms use this capital parallel with labor for production. Monopolistic competition in the good's market gives rise to price setting power which is again constraint by Calvo-type stickiness. The owners of both capital producing firms and final goods firms are the households. Therefore, households are the recipients of firms' profits.

The public sector is constituted by the government and an independent monetary authority. The government conducts the fiscal policy and an independent monetary authority, the Central Bank, conducts the monetary one. To be more precise, the government exogenously purchases public consumption financed through taxes and government bonds. The government spending follows a simple autoregressive process. We discrete two alternative versions of monetary policy: (i) monetary policy is characterized by a simple exogenous money creation process, and (ii) the independent monetary authority determines the bonds' nominal interest rate through a Taylor-type feedback rule. Via the household's Euler equation for these bond's real interest, this rule impacts the real economy due to the presence of the above outlined distortions.

This paper contributes to the literature in several ways. First, we investigate the role of firm investment in the monetary transition mechanism in New-Keynesian models. Second, we evaluate the efficiency of nominal interest rate and money supply as monetary policy instruments and we disentangle their role in firm investment dynamics. Finally, we examine whether and how the interactions of fiscal and monetary policy depend on the monetary policy instruments.

We demonstrate that firm investment operates as a key propagating factor in the monetary transmission mechanism. Moreover, our findings imply that although both monetary policy instruments lead to very similar dynamics, nominal interest rate generates more vigorous transitional dynamics for firm investment. Finally, we found that the effects of fiscal policy on firm investment are amplified when monetary authorities use nominal interest rate as the monetary policy instrument.

The paper proceeds as follows. In the next section a medium-scale NK DSGE model with capital accumulation and investment adjustment costs is developed. In Section 3, the model is calibrated. In sections 4, the model is simulated and its dynamic properties are analyzed. Section 5 concludes.

2 The Model

2.1 Firms

We distinguish firms into goods producing and capital producing firms in order to simplify the derivation of the price setting equation on the one hand, and the investment/Q equation on the other hand. More specifically, capital producers convert consumption goods into capital through investment, and rent this capital to goods producers for a rental rate. Final good producers uses this capital along with labor for production.

2.1.1 Capital Producers

Capital firms convert consumption goods into capital through investment, and rent this capital to goods producing firms for a rental rate R_t^k. As we have already mention, the capital stock evolves according to the following law of motion,

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

and period profits for these firms are given by

$$\Pi_t^k = \frac{R_t^k}{P_t}K_t - I_t - \frac{\varphi_k}{2}\left[\frac{I_t}{K_t} - \delta\right]^2 K_t \tag{2}$$

where the last term captures convex adjustment costs to physical capital.

The firm wants to maximize its real value, i.e.

$$\max_{\{I_t,K_t\}_{s=t}^{\infty}} V_t = E_t \sum_{s=t}^{\infty} \left(\frac{1}{1+\rho}\right)^{s-t} \left\{ \frac{R_s^k}{P_s} K_s - I_s - \frac{\varphi_k}{2} \left[\frac{I_s}{K_s} - \delta\right]^2 K_s \right\}$$

subject to

$$I_s = K_{s+1} - (1-\delta)K_s$$

From the first order conditions for investment and capital respectively, we get,

$$q_t = 1 + \varphi_k\left(\frac{I_t}{K_t} - \delta\right) \tag{3}$$

$$q_t = \frac{1}{1+\rho} E_t \left\{ r_{t+1}^k - \frac{\varphi_k}{2}\left[\frac{I_{t+1}}{K_{t+1}} - \delta\right]^2 + \varphi_k \left[\left(\frac{I_{t+1}}{K_{t+1}}\right)^2 - \delta \frac{I_{t+1}}{K_{t+1}}\right] + (1-\delta) q_{t+1} \right\} \tag{4}$$

where $r_t^k = \frac{R_t^k}{P_t}$.

The Lagrange multiplier q_t plays a central role (this is Tobin's Q[1]) in our analysis. As any other Lagrange multiplier, it is a shadow price. In this case, q_t is the shadow price of capital in place at the end of period t. Under the optimal plan, firm invests such that the marginal cost of an additional unit of capital (which equals 1 plus the adjustment cost) must equal the shadow price of capital. We can also write this as the investment equation that Tobin (1969) posited:

$$I_t = \left[\frac{q_t - 1}{\varphi_k} + \delta\right] K_t \tag{5}$$

So investment is only positive when $q_t > 1$, i.e. when the shadow price of capital exceeds the price of new capital (before adjustments costs).

Equation (4) plays the role of an investment Euler condition. The shadow price of capital today must equal the discounted value of the return of capital in the next period, plus the next period savings in adjustment costs and plus the future shadow price (since capital can be sold in the next period).

By using the no-bubble condition $\lim_{T\to\infty} \frac{q_{t+T}}{(1+r)^T}$ and using iterative substitution we can rewrite equation (4) as follows,

$$q_t = \sum_{s=t+1}^{\infty} \left(\frac{1}{1+\rho}\right)^{s-t} \left\{ r_{s+1}^k + \frac{\varphi_k}{2}\left[\left(\frac{I_{s+1}}{K_{s+1}}\right)^2 - \delta^2\right]\right\} \tag{6}$$

[1] Recall that, formally, Tobin's Q is the ratio of the market value of a firm divided by the replacement cost of its capital, i.e. the average value of a unit of capital V_0/K. However, Hayashi (1982) laid out conditions under which the marginal value of an additional unit of capital, i.e. $q_t = \partial V_t / \partial K_{t+1}$, coincides with the average Tobin's Q. In particular, he showed that if: (i) the production function is homogeneous of degree one and (ii) the total adjustment cost function is homogeneous of degree one, then the average Tobin's Q and the marginal value of an additional unit of capital, q, coincide. Obviously, both conditions are satisfied in the context of this model.

so q_t reflects the net present value of all future marginal returns and reduced adjustment costs from purchasing one extra unit of capital.

2.1.2 Final Good Producers

Goods markets are monopolistically competitive. We assume that all firms have access to the same technology. Firms face three constraints in order to maximize their profits. Firstly, they have to work with a given production technology given by,

$$y_t(j) = A_t K_t(j)^a L_t(j)^{1-a} \tag{7}$$

which is a Cobb-Douglas production function with two inputs, labor and capital, and an aggregate technology A_t, common to all firms and subject to temporary shifts ε_t^a. The final good firms rent the capital stock from the capital producing firms.

Secondly, firms face the downward sloping demand curve given by,

$$y_t(j) = (\frac{p_{t(j)}}{P_t})^{-\varepsilon} Y_t \tag{8}$$

where Y_t denotes aggregate demand, and ε is the demand elasticity of substitution for individual goods ($\varepsilon > 1$).

Thirdly, we assume Calvo contracts (Calvo, 1983). According to them in any period a random proportion $(1-\gamma)$ of firms is able to change their price. Thus, in order to set prices today, firms ought to take into consideration the existing future economic conditions.

Hence, all firms which are able to change their prices in period t, solve the following profit maximization problem[2],

$$\max_{p_t(j)} E_t \sum_{s=0}^{\infty} [\beta\gamma]^s \left(\frac{C_{t+s}}{C_t}\right)^{-\sigma} \left\{ \frac{p_{t+s}(j)}{P_{t+s}} y_{t+s}(j) - \frac{W_{t+s}}{P_{t+s}} L_{t+s}(j) - \frac{R_{t+s}^k}{P_{t+s}} K_{t+s}(j) \right\} \tag{9}$$

under the constraints of the production function,

$$y_{t+s}(j) = A_{t+s} K_{t+s}(j)^a L_{t+s}(j)^{1-a}$$

$$y_{t+s}(j) = (\frac{p_{t+s(j)}}{P_{t+s}})^{-\varepsilon} Y_{t+s}$$

The solution of the above problem leads to the standard New Keynesian Phillips Curve (Woodford, 2003; Gali, 2015),

$$\pi_t = \beta E_t \pi_{t+1} + \kappa \hat{mc}_t^r \tag{10}$$

[2]Here the discount factor β is equal to $\frac{1}{1+\rho}$.

where

$$\kappa = \frac{(1-\gamma)(1-\beta\gamma)(1-a)(1-\varepsilon)}{\gamma\left[(1-a)(1-\varepsilon)+a\right]}$$

The variable $\hat{mc}_t^r$ denotes the log-linearized (around the steady state) form of the real marginal cost, which is given by[3],

$$MC_t^r = \left(\frac{r_t^k}{a}\right)^a \left(\frac{w_t^r}{1-a}\right)^{(1-a)} \tag{11}$$

where $w_t^r = \frac{W_t}{P_t}$ denotes the real wage, π_t denotes the inflation and is defined as $\pi_t = \frac{P_t}{P_{t-1}} - 1$.

Finally, from the firms' cost-minimization problem we get the following equation for the capital to labor ratio (Leith and von Thadden, 2008):

$$\frac{K_t}{L_t} = \frac{1-a}{a}\frac{w_t^r}{r_t^k} \tag{12}$$

2.2 Households

In each period t, a typical household i derives utility from consuming a basket C containing all the goods produced in economy while suffering disutility from labor effort, L. They also accumulate money and government bonds. Households maximize the expected discounted value of flow utility U over their life horizon. Flow utility is additive-separable. The intertemporal utility is given by:

$$E_t \sum_{t=0}^{\infty} (\frac{1}{1+\rho})^t [\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{L_t^{1+\lambda}}{1+\lambda} + \frac{1}{1-\psi}(\frac{M_t}{P_t})^{1-\psi}] \tag{13}$$

where C_t denotes the consumption, L_t the labor supply, M_t holdings of money in period t,$1/\sigma$ is the intertemporal elasticity of substitution in consumption, λ the Fritch elasticity of labor supply, and ψ is the inverse elasticity of substitution between money and consumption.

The consumption is consisted by many goods, indexed by j, j$\in [0,1]$. The aggregate consumption across the individual goods is defined in the following CES form,

$$C_t = \left[\int_0^1 c(j)^{\frac{\varepsilon-1}{\varepsilon}} dj\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{14}$$

where ε is the demand elasticity of substitution for the individual goods and $\varepsilon > 1$.

Households derive income by providing labor services (L_t) at the real wage rate ($w_t = W_t/P_t$). They can invest their wealth in a set of government bonds (B_{t-1}), with return the nominal interest rate i_t, and/or hold their money since they take utility from it.

The household enters period t with government bonds $B_{t-1}$and holdings of moneyM_{t-1}. It receives income on government bonds and labor income after paying a lump-sum tax (T_t) to the

[3]It is derived by the cost minimization problem of the firms.

government. It receives income from the profits of the firms (both capital and goods producers) since it is their owner. The household then purchases consumption (C_t), and updates its government bond investment along with its money holdings.

The period budget constraint (in real rems) may thus be written as:

$$C_t + \frac{B_t}{P_t} + \frac{M_t}{P_t} + T_t \leq \frac{W_t}{P_t} L_t + (1 + i_{t-1}) \frac{B_{t-1}}{P_t} + \frac{M_{t-1}}{P_t} + \Pi_t + \Pi_t^k \tag{15}$$

Households choose consumption, labor effort, money holdings and bond purchase in period t so as to maximize utility 13 over their whole life horizon subject to a budget constraint as 15.

The solution of the households' problem leads to the standard Euler equations for labor, bonds and real money balances (Walsh, 2010; Gali, 2015):

$$L_t^{\lambda} = \frac{W_t}{P_t} C_t^{-\sigma} \tag{16}$$

$$E_t\{(\frac{C_{t+1}}{C_t})^{\sigma}\} = \frac{1}{1+\rho}(1 + r_t) \tag{17}$$

$$\frac{i_t}{1+i_t} C_t^{-\sigma} = (\frac{M_t}{P_t})^{-\psi} \tag{18}$$

where $1 + r_t$ is the gross real interest rate on holdings of bonds between t $-$ 1 and t, defined by the standard Fisher equation:

$$(1 + r_t) = \frac{(1 + i_t)}{(1 + E_t \pi_{t+1})} \tag{19}$$

2.3 Government

2.3.1 Fiscal Policy

In some period, t, the government collects real taxes T_t, consumes a quantity G_t and issues bonds of nominal volume B_t which pay the predetermined nominal interest i_{t-1}. Thereby, it has to restrict its activity to policies that satisfy its budget constraint, conditional on not defaulting. Thus, the budget constraint of the government is given by,

$$B_t - B_{t-1} + P_t T_t = P_t G_t + i_{t-1} B_t \tag{20}$$

We assume that government spending is exogenous and evolves according to the following process:

$$\frac{G_t}{G_{SS}} = (\frac{G_{t-1}}{G_{SS}})^{\rho_g} e^{\varepsilon_t^g} \tag{21}$$

where G_{SS} stands for the government spending at steady state level, the parameter ρ_g is assumed to be between 0 and 1, and the stochastic shock ε_t^g is assumed to evolve according a white noise process with zero mean and finite variance σ_g^2.

Finally, the government is not allowed to apply a Ponzi scheme to intertemporally finance its expenditures. Thus, the debt growth rate, B_{t+1}/B_t, is capped.

2.3.2 Monetary Policy

In order to investigate the role that the instrument of the monetary policy plays, we analyze two alternative versions of model, based on the two most common monetary policy tools: money supply and interest rate. In the first version, we assume that monetary authorities control money supply through the following simple money creation process:

$$\frac{M_t}{M_{t-1}} = 1 + \mu_t \tag{22}$$

where:

$$\mu_t = \rho_m \mu_{t-1} + \varepsilon_t^m$$

The parameter ρ_m is assumed to be between 0 and 1, and the stochastic shock ε_t^m is assumed to evolve according a white noise process with zero mean and finite variance σ_m^2.

In the second version, we assume that monetary policy is conducted by an independent central bank. We assume that the central bank follows a Taylor-type (Taylor, 1993) rule of the form,

$$\left(\frac{i_t}{i_{ss}}\right) = \left(\frac{\pi_t}{\pi^*}\right)^{\varphi_\pi} \left(\frac{Y_t}{Y_{SS}}\right)^{\varphi_y} e^{v_t^i} \tag{23}$$

where:

$$\ln v_t^i = \rho_v \ln v_{t-1}^i + \varepsilon_t^i$$

φ_y and φ_π are positive coefficients, and ε_t^i is an exogenous stochastic disturbance in the nominal interest rate, which follows a white noise process with zero mean and finite variance σ_i^2. It is worth noting that since the constant in this rule is equal to ρ (which corresponds to the steady state value of the nominal interest rate), this rule is consistent with zero steady state inflation[4]. This rule implies a countercyclical monetary policy. When inflation is positive, the central bank increases nominal interest rates in order to reduce it. When employment is low, i.e. when output is lower than its "natural" level, the central bank reduces nominal interest rates in order to increase employment and nudge output towards its "natural" level. In addition, this feedback interest rate rule does not result in inflation and price level indeterminacy if the Taylor principle is satisfied, i.e. if the reaction of nominal interest rates to inflation is sufficiently strong.

[4] See Woodford (2003) for a more extensive and complete analysis

2.4 Aggregation and Equilibrium

In the equilibrium all markets clear. Aggregating the budget constraint (15) across households and combining it with the government's budget constraints yields the aggregate accounting identity (i.e. the resource constraint of the economy),

$$Y_t = C_t + G_t + I_t + \frac{\varphi_k}{2}\left[\frac{I_t}{K_t} - \delta\right]^2 K_t \tag{24}$$

The conditions which characterize dynamic equilibria at the aggregate level can be summarized as follows.

Economy

$$Y_t = C_t + G_t + I_t + \frac{\varphi_k}{2}\left[\frac{I_t}{K_t} - \delta\right]^2 K_t \tag{25}$$

$$(1 + r_t) = \frac{(1 + i_t)}{(1 + E_t\pi_{t+1})} \tag{26}$$

$$\pi_t = \beta E_t \pi_{t+1} + \kappa \hat{mc}_t^r \tag{27}$$

Households

$$L_t^{\lambda} = w_t^r C_t^{-\sigma} \tag{28}$$

$$E_t\{(\frac{C_{t+1}}{C_t})^{\sigma}\} = \frac{1}{1+\rho}(1 + r_t) \tag{29}$$

$$\frac{i_t}{1 + i_t} C_t^{-\sigma} = (M_t^r)^{-\psi} \tag{30}$$

Capital Producers

$$q_t = 1 + \varphi_k(\frac{I_t}{K_t} - \delta) \tag{31}$$

$$q_t = \frac{1}{1+\rho}\left\{ r_{t+1}^k - \frac{\varphi_k}{2}\left[\frac{I_{t+1}}{K_{t+1}} - \delta\right]^2 + \varphi_k\left[\left(\frac{I_{t+1}}{K_{t+1}}\right)^2 - \delta\frac{I_{t+1}}{K_{t+1}}\right] + (1-\delta)q_{t+1} \right\} \tag{32}$$

$$I_t = K_{t+1} - (1 - \delta)K_t \tag{33}$$

Goods Producers

$$Y_t = A_t K_t^a L_t^{1-a} \tag{34}$$

$$MC_t^r = \left(\frac{r_t^k}{a}\right)^a \left(\frac{w_t^r}{1-a}\right)^{(1-a)} \tag{35}$$

$$\frac{K_t}{L_t} = \frac{1-a}{a}\frac{w_t^r}{r_t^k} \tag{36}$$

$$\ln A_t = \rho_A \ln A_{t-1} + \varepsilon_t^A \tag{37}$$

Government

a) Fiscal Policy

$$\frac{G_t}{G_{SS}} = (\frac{G_{t-1}}{G_{SS}})^{\rho_g} e^{\varepsilon_t^g} \tag{38}$$

b) Monetary Policy

The model is closed by specifying a monetary policy rule. Therefore, the last equilibrium condition is either the equation 22 or the Taylor-type rule 23.

The 17 endogenous variables are $\{Y_t, C_t, M_t^r, L_t, \pi_t, w_t^r, i_t, r_t, r_t^k, MC_t^r, q_t, I_t, K_{t+1}, G_t, A_t, \mu_t \, or \, v_t\}$.

3 Calibration

Table 1 contains the calibrated parameters. The choice of parameters is one of the main features of the analysis as their choice must represent economic features and also to ensure the stability of the system. The parameters are separated into RBC and NK parameters. For the latter, we follow the standard literature. In particular, new Keynesian parameters are mostly chosen as in Galí (2008) and the more recent work by Poutineau, Sobczak and Vermandel (2015). For the RBC parameters we also follow the standard bibliography and more specifically we use the values from Cooley and Prescott (1995). Finally, the value for the investment adjustment cost parameter, φ_k, was received from Smets and Wouters (2003).

4 Quantitative Analysis

We next explore the internal mechanics of the model by plotting some impulse response functions. Each impulse response reports the effect of a one standard deviation shock on the variables of the model, expressed in percent deviation from their steady state level.

Productivity

Figure 1 shows the responses to a one percent positive productivity shock. The figure compares the equilibrium of our model (continuous lines) with that of the basic NK model without firm investment (dashed lines). Moreover, the figure compares the equilibrium obtained under the Taylor-type monetary policy rule 23 (blue lines) with the alternative monetary policy rule 22 (red lines).

The productivity enhancement leads to a significant output expansion. Firm investment, through the invigorated capital accumulation, amplifies substantially this output expansion. The shadow price of capital, i.e. Tobin's q, follows an analogous path to investment. Consumption increases and real money balances as well. A negative comevement between output and employment is observed. Inflation falls and so do the marginal cost and the nominal interest rate. These dynamics lie in accordance with the literature.

A comparison between the two alternative monetary policy rules reveals many similarities but also some notable differences, at least for the case of the simple NK model. In both cases output expands but this increase is much larger for the case of Taylor-type rule. This differential response is driven by real interest rate dynamics. The upward response of the real interest rate, implied by the unchanged money supply, under the exogenous money supply rule contrasts with its decline under the interest rate rule.

Importantly, the inclusion of firm investment in the NK model, on the one hand propagates the positive repercussion of the productivity shock in the economy (in terms of GDP), on the other hand it alleviates the differential responses across the two alternative monetary policy instruments.

Monetary Policy

The next set of impulse responses, plotted in Figure 2, shows the effects of a contractionary monetary shock. The shock is either an increase of the nominal interest rate for the case of the Taylor-type monetary policy rule 23 (blue lines) or a decrease in money growth for the case of the exogenous money supply monetary policy rule 22 (red lines).

Monetary contraction leads to an economic downturn. Output and aggregate demand fall. So do employment, capital, marginal cost, real money balances and wages. Once again, the shadow price of capital, i.e. Tobin's q, follows an analogous path to investment. The policy shock generates also an increase in the real rate and a decrease in inflation. These dynamics are quite similar for the two alternative monetary policy instruments for all endogenous variables [5] apart from capital (its reduction is substantially larger in the case of the Taylor-type rule) and real rate. The magnitude of the increase in the real interest rate is significantly larger in the case of the Taylor rule, implying that the real effects of the monetary shock are amplified when monetary authorities use nominal interest rate as the monetary policy instrument.

However, the most important implication of Figure 2 is that reveals the role of firm investment in the effectiveness of monetary policy. The inclusion of firm investment in the baseline NK model

[5]Note that only for the case of the baseline NK model under the Taylor-type monetary policy rule, the nominal rate goes up, though by less than its exogenous component—as a result of the downward adjustment induced by the decline in inflation and the output. In order to bring about the observed interest rate response, monetary authorities must engineer a reduction in the money supply. Therefore, a liquidity effect is generated (Galí, 2008). This effect does not emerge either under the exogenous money supply rule or in the augmanted model with firm investment.

magnifies the effects of the monetary shock on the economy, implying that investment constitutes a vital part of the monetary transmission mechanism in the context of the NK models.

Fiscal Policy

Finally, Figure 3 illustrates the dynamic effects of an expansionary fiscal policy shock. Since there is only one lump-sum tax in this model, the Recardian equivalence holds. The shock raises aggregate demand, which puts pressure on the general price levels. Thus, inflation rises. Fiscal expansion raises output due to a negative "wealth effect" and real interest rate as well. In particular, the central bank raises the basic rate of interest (or decreases the money supply), something which compresses the price of government bonds, thus increasing demand for these bonds. Also, households feel poorer (because they know that they have to pay more taxes, either now or in the future). Thus they consume less and work more, which in turn leads to a rise in output. Moreover, government spending crowds out firm investment and thus capital accumulation falls. Again, the path of capital's shadow price, i.e. Tobin's q, follows an analogous path to investment. Interestingly, the negative effects of fiscal expansion on firm investment seem to be amplified when monetary authorities use nominal interest rate as the monetary policy instrument.

5 Conclusions

The purpose of this study is threefold. First, we investigate the role of firm investment in the monetary transmission mechanism in the context of the NK DSGE models. Second, we examine the role of monetary policy instruments in this mechanism and their linkage with the firm investment dynamics. Finally, we examine whether and how the interactions of fiscal and monetary policy depend on the monetary policy instruments.

To this end, we develop a simple medium-scale New-Keynesian model with firm investment, capital accumulation and investment adjustment costs. We analyze two alternative versions of the model, based on the two most common monetary policy instruments: money supply and interest rate. In the first version, monetary policy is characterized by an exogenous rule for money supply. In the second version, we assume that the independent monetary authority determines the bonds' nominal interest rate through a Taylor-type feedback rule.

Our findings imply that firm investment operates as an important propagating factor in the monetary transmission mechanism and considerably affects the effectiveness of the monetary policy instrument. Also, although both instruments were found to lead to similar dynamics, interest rate generates more vigorous transitional dynamics for firm investment. Finally, we found that the impact of fiscal policy on firm investment is amplified when monetary authorities use nominal interest rate as the monetary policy instrument.

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Figures

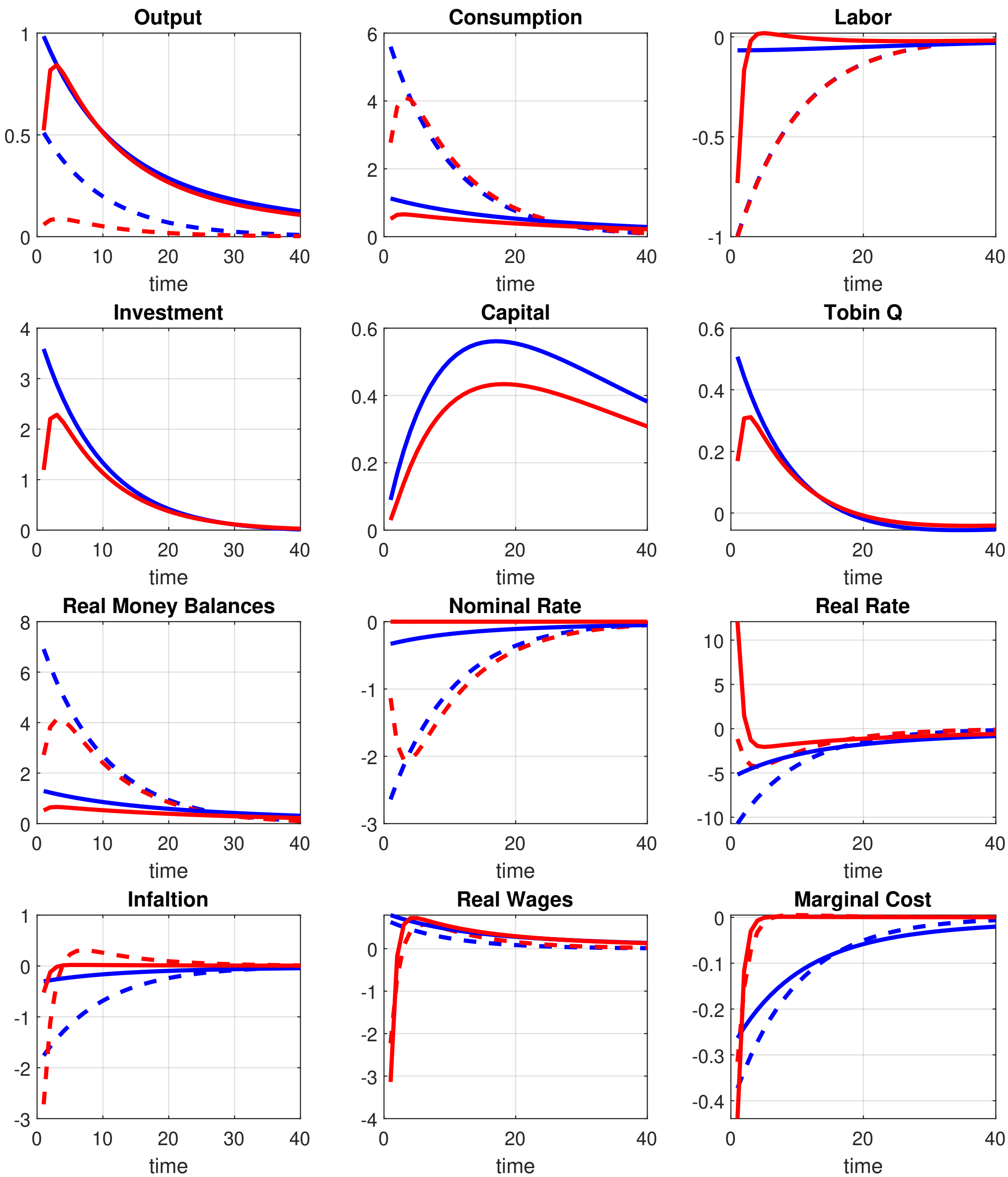

Figure 1: Productivity Shock

Notes: The figure compares the equilibrium of our model (solid lines) with that of the basic NK model without firm investment (dashed lines). Moreover, the figure compares the equilibrium obtained under the Taylor-type monetary policy rule (blue lines) with the alternative exogenous money supply monetary policy rule (red lines).

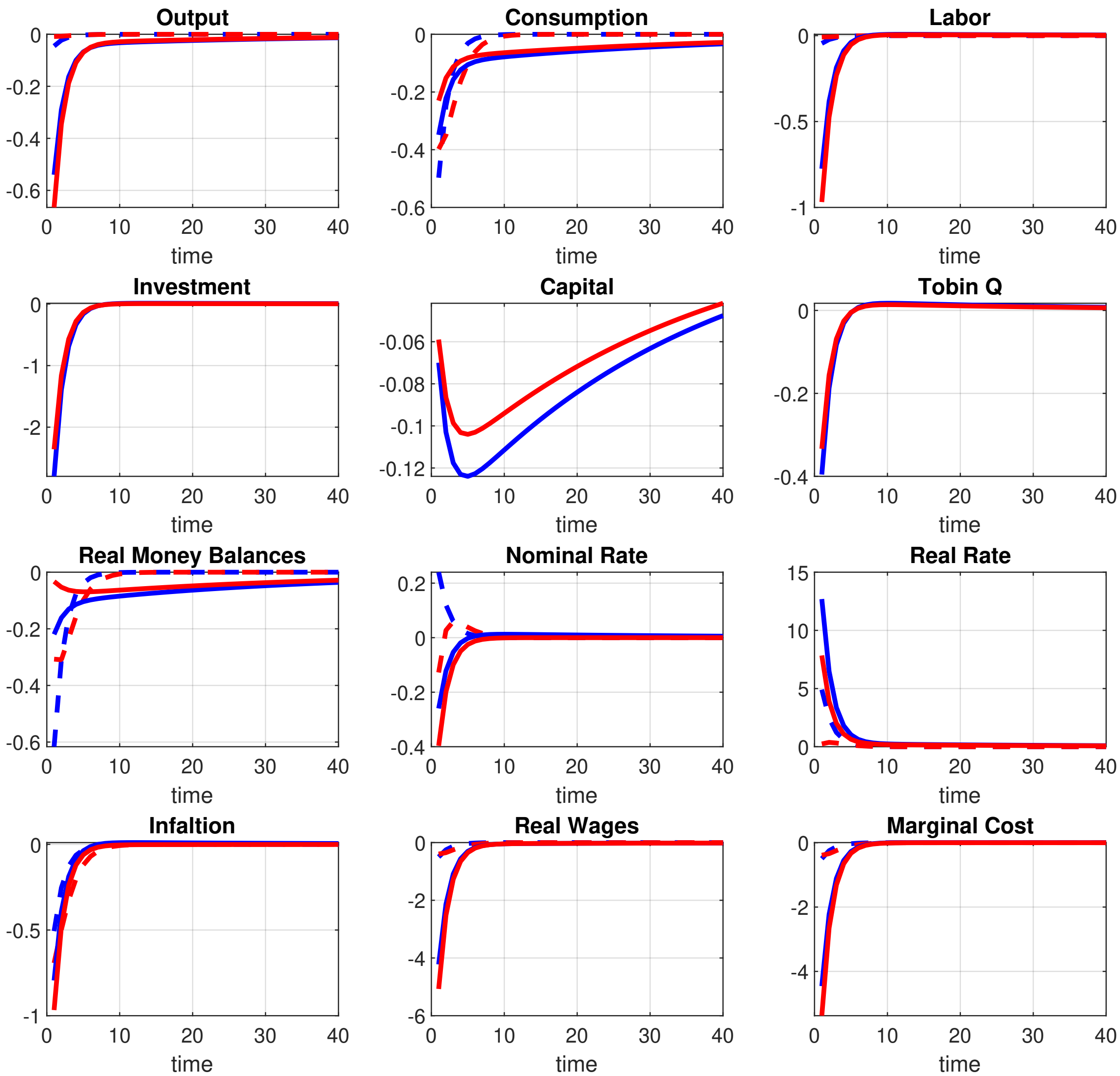

Figure 2: Monetary Shock

Notes: The figure compares the equilibrium of our model (solid lines) with that of the basic NK model without firm investment (dashed lines). Moreover, the figure compares the equilibrium obtained under the Taylor-type monetary policy rule (blue lines) with the alternative exogenous money supply monetary policy rule (red lines).

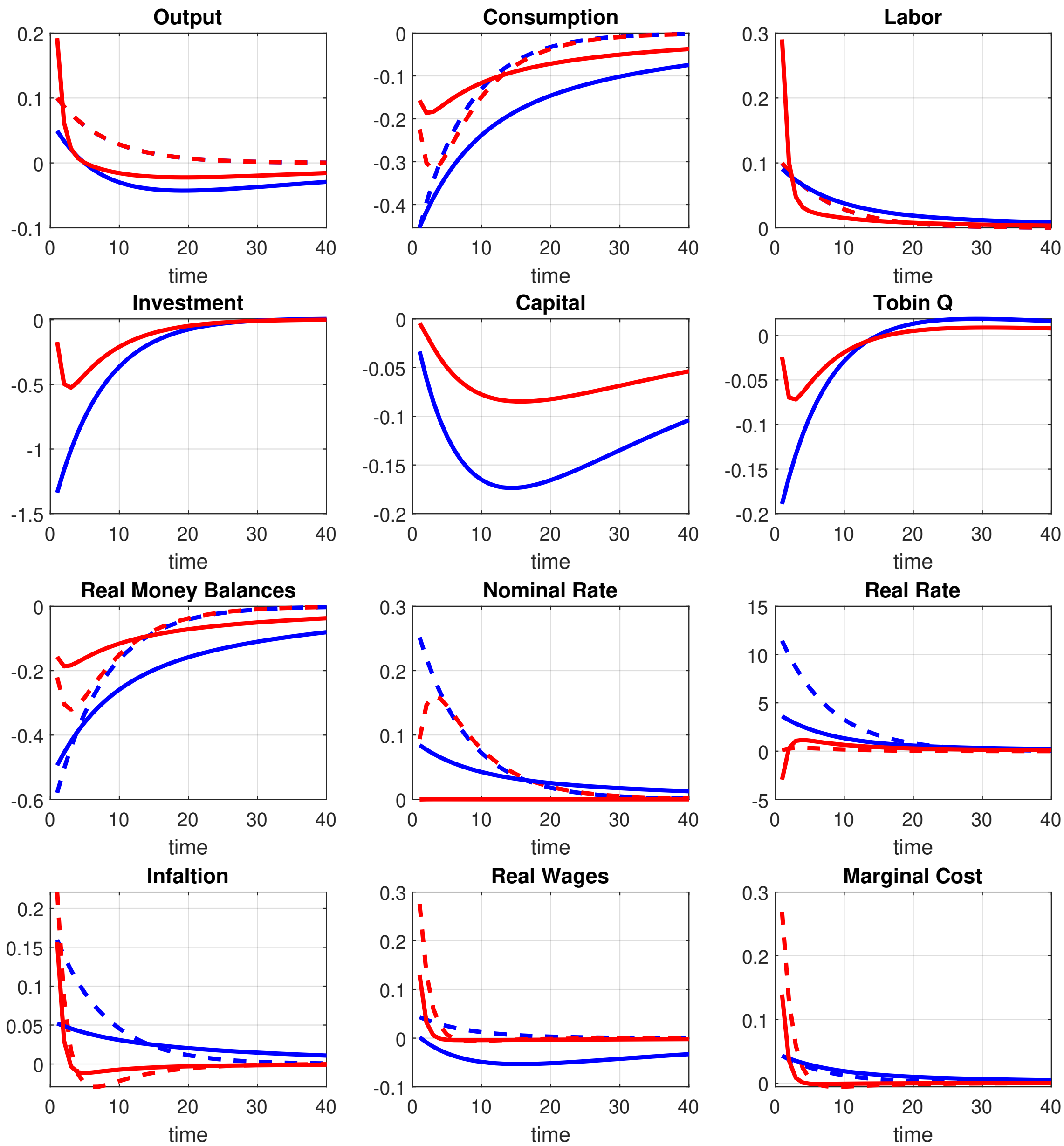

Figure 3: Government Spending Shock

Notes: The figure compares the equilibrium of our model (solid lines) with that of the basic NK model without firm investment (dashed lines). Moreover, the figure compares the equilibrium obtained under the Taylor-type monetary policy rule (blue lines) with the alternative exogenous money supply monetary policy rule (red lines).

Tables

Parameter	Description	Value
α	share of capital in output	0.36
ρ	discount factor	0.01
δ	depreciation of capital	0.025
σ	risk aversion for consumption	1
λ	labor disutility	5
ψ	risk aversion for cash	1
ε	elasticity of substitution for individual goods	9
γ	portion of firms that cannot change their prices in t	0.75
φ_k	investment adjustment cost parameter	5.8
φ_y	monetary policy GDP growth target	0.125
φ_π	monetary policy inflation growth target	1.5
ρ_v	monetary policy smoothing parameter	0.50
ρ_g	government sending's shock smoothing parameter	0.87
ρ_m	money supply's shock smoothing parameter	0.50
ρ_A	productivity's shock smoothing parameter	0.90

Table 1: Calibrated Parameters