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Financial Instability and Optimal Monetary Policy Rule

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Abstract

This paper investigates the effect of financial instability on the design of monetary policy rule for a small open economy. We find evidence that optimal monetary policy rule reacts directly to financial imbalances and, as a result, to the real exchange rate movements. However, optimal rule would not react to the real exchange rate changes directly if central bank does not care about the financial instability. For a quantitative analysis, impulse responses of some macroeconomic variables and financial instability to the domestic productivity and foreign country output shocks, resulting from simulation, are also analysed in this paper.

JEL Codes: E 52, G 01
Keywords: Financial instability; Optimal monetary policy rule; Real exchange rate; Open economy

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ABSTRACT

This paper investigates the effect of financial instability on the design of monetary policy rule for a small open economy. We find evidence that optimal monetary policy rule reacts directly to financial imbalances and, as a result, to the real exchange rate movements. However, optimal rule would not react to the real exchange rate changes directly if central bank does not care about the financial instability. For a quantitative analysis, impulse responses of some macroeconomic variables and financial instability to the domestic productivity and foreign country output shocks, resulting from simulation, are also analysed in this paper.

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1. Introduction

Dynamic Stochastic General Equilibrium (DSGE) models based on the New-Keynesian framework use micro-foundations of households and firms' optimization problems to describe monetary policy transmission mechanism and fluctuation of main macroeconomic variables. This study uses a small open economy DSGE model similar to Gali and Monacelli (2005) and Divino (2009), to investigate the optimal central bank policy rule with respect to the financial imbalances. Studies about small open economies, using DSGE models are well documented. However, according to my knowledge, determining the optimal monetary policy rule regarding financial imbalances matter has not been studied yet. The core objective of the present model, therefore, is to investigate the optimal policy rule for the central bank in order to stabilize the economy and prevent financial imbalances from arising in the economy. Besides the central bank, there are two other sides: households and firms. The representative household seeks to maximize his utility function. The staggered price setting, following Calvo (1983), is used by firms to maximize their profit function.

One of the measures used for studying financial instability in an economy is asset prices. The main point is that boom and busts in asset prices may affect the stability of the economy with making some costs. Borio and Lowe (2002) argue that the asset price bubbles are not the main concern per se. However, swings, and booms and busts in asset prices are associated with high investment and build up debt. During the upswing and existence of bubbles in asset prices the optimists' view about the future return leads to more demand for assets and prompt investors to borrow more to finance further capital accumulation. The appreciation of asset value leads to a rise in the value of collaterals, which may facilitate the accumulation of debt. As Bean (2004) discusses, bursting the bubble quickly affects the net value of the borrower's wealth. That is, perhaps it might not lead to a very healthy balance sheet of households. This may be followed by a kind of credit crunch which is the reaction of financial intermediaries to the fall in a borrower's net wealth that is, financial imbalances. This type of monetary tightening may lead to bankruptcies in real sectors of the economy because credit crunches limit access to money for firms and results in some negative shocks to the factor productivity. Thus, I consider credit crunches as one of the proxies of imbalances in the financial system to study the impact of financial imbalances on monetary policy in an open economy model. In addition, I also consider a special class of asset prices namely, the exchange rate channel, in the model. The fluctuation of the exchange rate might be important for the stability of national economy and output. Therefore, the policy maker is concerned about exchange rate depreciation because he wants to prevent causing any possible imbalances in the domestic market of foreign exchange, and then in the financial state of households and firms in an open economy context. Moreover, the higher the exchange rate, that is the exchange rate depreciation, the higher the devaluation, meaning more expensive imports. The present model, thus, allows the financial imbalances effect and its impact on the marginal cost of firms to examine the effect of financial imbalances on monetary policy. That is, on the one hand, real exchange rate depreciation that has a positive effect on Consumer Price Index leads to an increase in wages because of workers' behaviour of wage setting. On the other hand, there is no more money for firms to overcome the real devaluation effects because of credit crunch. As a result, labour productivity may fall. In fact, it can be read as a negative shock to the technology that reduces labour productivity, increasing firms' real marginal cost. This is the main point that this paper seeks to indicate in an optimal monetary policy literature for an open economy where the real exchange rate plays an important role in the economy. The model is akin to Gali and Monacelli (2005) and also, to some extent, to Divino (2009). However, in canonical representation, the present model is different from that proposed by Gali and Monacelli (2005), and Clarida, Gali and Gertler (2001) in terms of the New-Keynesian Phillips curve. In addition, the current model derives the optimal monetary policy rule with respect to one of the financial stability subjects. Devereux(2004), Svensson(2000),Taylor(2001) and Benigno(2004) are some recent studies about the role of exchange rate and its channel in the transmission of the monetary policy. However, they do not investigate the financial instability issue in the context of open economies. Precisely, the question of whether or not monetary policy should response to financial instability and exchange rate movements still remains in recent studies. This study tries to answer this question and uses calibration data from Gali and Monacelli (2005) with the derived optimal monetary policy, and then compares the impulse responses resulting from simulation with those in Gali and Monacelli (2005).

The remainder of the paper is organized as outlined below:

- Section Two describes the concept of financial stability and the main variables which are often used to explain the financial [in] stability concept.
- Section Three is specified to the structure of the economy model which consists of the household section of the model, production section and profit maximization behaviour of firms.

- Section Four displays dynamics of inflation, output, the IS curve, financial imbalances and economy stability.
- Section Five describes financial imbalances and optimal monetary policy, and deriving the optimal policy rule with respect to financial stability concept.
- Section Six indicates the impulse response analysis and the comparison between the model impulse responses and those in Gali and Monacelli (2005).
- Section Seven covers the summary and conclusions reached after analysing all the information.

2. Financial stability

There is no consensus on the definition of financial instability. However, for any financial stability study, oscillation of some variables is often considered. House and stock prices, exchange rate and the price of some other financial assets, on the one hand, and household debt growth and debt accumulation, on the other hand, are some of the main variables which are used to investigate the financial imbalances issue. As Farooqe *et al.* (2007) discuss, the exchange rate fluctuation is an important issue because the firms' competitiveness can be reinforced by the exchange rate depreciation through increasing the foreign demand for the firms' products. This policy makes sense, especially in a situation when there is a probability of firm bankruptcy and downturn. However, devaluation may cause an increase of imported inflation and may have a positive impact on the consumer price index (CPI). Whereas, a huge exchange rate appreciation means cheap foreign goods and may cause an increase in cheap imports from the foreign country. This can threaten domestic firms through decreasing domestic demand for the firms' products. As a result, this can lead to a kind of loss in the firms' competitiveness, which affects the financial state of firms. That is, less sale and money for firms, and hence decreasing the productivity. Thus, it is a crucial issue for the monetary authority to consider fluctuation of the exchange rate to stabilize the economy. However, the central bank thinks more about the exchange rate depreciation effects on the economy perhaps because devaluation effects are more important than effects of the exchange rate appreciation on the monetary authority for the national economy.

Households' debt growth and its impact on the economy is another indicator that can be considered as a proxy of financial imbalances and even financial instability. This paper assumes price appreciation in asset markets such as financial markets leads to more borrowing from the financial intermediaries and then debt accumulation. This may form some sort of bubble in the market where, bursting the bubble will depreciate the net value of households' wealth and then probably no money remains to repay the debt to the lender, which is a type of financial imbalance.

It is assumed that the policy maker and monetary authority is the central bank and it takes into account debt accumulation and exchange rate as the indicators of financial instability in setting an appropriate interest rate. This is to prevent any imbalances in the domestic market of foreign currency and huge households' debt growth because each or both of financial imbalances indicators may affect the financial state of households and firms and lead to a financial instability and, finally instability in the economy.

An increase in the real exchange rate (devaluation) has two effects on the marginal cost of firms. When a real devaluation occurs, domestic currency loses in value against the foreign currency, that is more expensive imported final goods and as a result a positive impact on the consumer price index. Therefore, wages should be increased, according to the worker's wage setting behaviour. This will increase the real marginal cost of production. Moreover, in this situation, central bank intervention in the market of foreign exchange, in a floating exchange rate regime, to prevent imported inflation, may cause a contraction in the monetary policy. That is, less working capital for firms, this could decrease labour productivity and increase real marginal cost of the firm. Thus, in the present model the central bank reacts to the financial instability proxy (outstanding debt accumulation and the exchange rate) under optimal policy rule.

3- The economy model

3-1-Households

The present model is a small open economy which assumes there are two classes of consumptions. Household consumption, therefore, is a composite of consumption of home produced and foreign produced goods which is defined by

$$(1)\quad C_t = [(1-\alpha)^{\frac{1}{\varphi}} C_{h,t}^{\frac{\varphi-1}{\varphi}} + \alpha^{\frac{1}{\varphi}} C_{f,t}^{\frac{\varphi-1}{\varphi}}]^{\frac{\varphi}{\varphi-1}}$$

where, φ is positive and defined as the elasticity of substitution between home and foreign country goods and α denotes degree of openness of the economy . According to Dixi and Stiglitz (1977), CES aggregator is used to indicate consumption sub indices. Therefore,

$C_{h,t}$= $[\int_0^1 C_{h,t}^{\frac{\varepsilon-1}{\varepsilon}}(j)dj]^{\frac{\varepsilon}{\varepsilon-1}}$ denotes domestic consumption of home-produced good and

$C_{f,t}$=$[\int_0^1 C_{f,t}^{\frac{\varepsilon-1}{\varepsilon}}(j)dj]^{\frac{\varepsilon}{\varepsilon-1}}$ denotes domestic consumption of the foreign country produced good, where $\varepsilon > 1$ is the elasticity of substitution across goods in a country.

The representative household seeks to maximize the utility function:

$$(2) \quad \text{Max Et } \sum_{k=0}^{\infty} \beta^k \ [U\left(C_{t+k}, \frac{M_{t+k}}{P_{t+k}}\right) - \frac{N_{t+k}^{1+\delta}}{1+\delta}]$$

Where, U (Ct+k, Mt+k/Pt+k) $= \frac{C_{t+k}^{1-\sigma}}{1-\sigma} + \ \chi(M_{t+k}/P_{t+k})^{\gamma}/1-\gamma$

Where wages are flexible and it is assumed that wages are identical for all workers. In addition, workers work the same number of hours. Moreover, σ, χ, δ and γ are greater than zero and $\beta \in [0,1]$.

The household's budget constraint can be written as:

$$(3) \quad P_t C_t + \ V_{t,1} F_t + M_t + \vartheta_t V_{t,1}^* \, F_t^* \leq W_t N_t + \Pi_t + F_{t-1} + M_{t-1} + \vartheta_t F_{t-1}^* + T_t$$

Where, C_t is the composite consumption index. F_t denotes home country financial assets such as bond, shares or a portfolio of both of them. F_t^* is corresponding foreign country financial assets and ϑ_t is the nominal exchange rate. $V_{t,1}$ can be read as the period price of financial assets such as the price of one-period domestic bond. It is formally assumed that $V_{t,1} = \frac{1}{R_t}$ where $R_t = 1 + i_t$. In addition, T_t is total lump-sum transfer from the government, Π_t are total profits from the ownership shares of the firm and P_t is consumer price index (CPI).

From optimal allocation of income within each category of goods the demand functions can be written as $C_{h,t}(j) = (\frac{P_{h,t}(j)}{P_{h,t}})^{-\varepsilon} \, C_{h,t}$ and $C_{f,t}(j) = (\frac{P_{f,t}(j)}{P_{f,t}})^{-\varepsilon} \, C_{f,t}$

Where, $P_{h,t} = [\int_0^1 P_{h,t}^{1-\varepsilon}(j)dj]^{\frac{1}{1-\varepsilon}}$ is the domestic price of home produced good i.e producer price index (PPI) and $P_{f,t} = [\int_0^1 P_{f,t}^{1-\varepsilon}(j)dj]^{\frac{1}{1-\varepsilon}}$ is the home price of foreign produced good. Thus, consumer price index (CPI) can be defined by total home consumption as

$$P_t = [(1-\alpha)P_{h,t}^{1-\varphi} + \alpha P_{f,t}^{1-\varphi}]^{\frac{1}{1-\varphi}}.$$

Using the standard Bellman equation for maximization of household's utility function subject to the budget constraint with expectation conditional on information of period t gives the following first order conditions:

(4) $V_{t,1} = \beta(\frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}}\frac{P_t}{P_{t+1}})$ which is the consumption Euler equation.

(5) $V_{t,1}^{*}\,\vartheta_t\,C_t^{-\sigma} = \beta\,(C_{t+1}^{-\sigma}\,\vartheta_{t+1}\,\frac{P_t}{P_{t+1}})$

This condition shows the relation between consumption and saving in one period foreign assets e.g. bond for a representative household decision making about consumption and saving.

(6) $\chi(\frac{M_t}{P_t})^{-\gamma} + \beta\left(C_{t+1}^{-\sigma}\,\frac{P_t}{P_{t+1}}\right) = C_t^{-\sigma}$ which is money demand equation.

(7) $C_t^{-\sigma}\left(\frac{W_t}{P_t}\right) = N_t^{\delta}$

Equation (7) indicates optimal labour supply of households. It is also assumed that the foreign country has the same equation as the home country Euler equation:

(8) $V_{t,1}^{*} = \beta(\frac{C_{t+1}^{*}}{C_t^{*}})^{-\sigma}(\frac{P_t^{*}}{P_{t+1}^{*}})$

From the first order conditions and consumption Euler equations the relation between prices can be read as $V_{t,1}^{*}\frac{\vartheta_t}{\vartheta_{t+1}} = V_{t,1}$ in which after some simple manipulation the nominal exchange rate can be written in a log-linear form as:

(9) $e_t - E_t e_{t+1} = i_t^{*} - i_t + \varsigma_t$

Where, $e_t = log(\vartheta_t)$, $i_t \backsimeq \log(1+i_t)$ and ς_t is the risk premia. It, actually, indicates any deviation from the Uncovered Interest Parity condition. The common assumption is that there is no arbitrage in international financial markets. Thus, e_t is the nominal uncovered interest rate parity (UIP). Equation (9), in fact, indicates the relation between exchange rate and interest rate differential in the small open economy and is read as an equilibrium condition in the model.

Different compositions of home and foreign country consumption over time lead to the swing of the real exchange rate. Moreover, Chari, Kehoe and Mcgrrattan (1997, 2002) also have tried to model the behaviour of real exchange rate in the real business cycle. Therefore, it is assumed that real exchange rate can be defined in a log linear version as:

$$(10) \qquad q_t = e_t + P_t^* - P_t$$

From the Euler equations of both countries, equation (5) and corresponding equation for the foreign country, under no arbitrage condition and after ignoring constant term which depends on the initial conditions, the relation between consumptions and real exchange rate, in log-linear version, can be written as following equations[1]:

$$(11) \qquad c_t = c_t^* + \frac{1}{\sigma} q_t$$

It shows that, for a given exchange rate, the difference between home country consumption and its foreign counterpart changes according to elasticity of inter-temporal substitution in consumption $\frac{1}{\sigma}$, meaning given the real exchange rate if elasticity of inter-temporal substitution in consumption is high, the consumption differential would be high.

To derive the relation between inflations and asset prices (exchange rate) the concept of *terms of trade* is defined as[2] $S_t = \frac{P_{f,t}}{P_{h,t}}$. From the CPI formula and its log-linear version one can write the dynamic of CPI as following equation

$$(12) \qquad \begin{aligned} p_t &= (1-\alpha)p_{h,t} + \alpha p_{f,t} \\ &= p_{h,t} + \alpha s_t \end{aligned}$$

Where $s_t = p_{f,t} - p_{h,t}$ denotes the log effective terms of trade. α refers to the degree of openness of the economy. In fact, it is read as the share of home consumption of foreign produced goods in home total consumption.

[1] See Chari, Kehoe and Mcgrrattan (2002) and Gali and Monacelli (2005).
[2] See, for example, Gali and Monacelli (2005) for more details.

As Gali and Monacelli (2005) indicate, under one price assumption in the model and no difference between CPI and domestic price level, $s_t = e_t + P_t^* - P_{h,t}$ and $e_t + P_t^* = s_t + P_{h,t}$.

Using this and from equation (10), to determine the relation between real exchange rate and terms of trade, the following expression can be written:

$$(13) \quad q_t = s_t + p_{h,t} - p_t$$
$$= (1 - \alpha)\, s_t$$

3-2- Firms

The firm uses the production function to produce differentiated good j as:

$$(14) \quad Y_t(j) = A_t N_t(j)$$

Let the aggregate output be $Y_t = [\int_0^1 Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj]^{\frac{\varepsilon}{\varepsilon-1}}$ analogous to the definition of consumption index. For future deriving of equations the log linear version of production function is needed. For this, let $N_t = \int_0^1 N_t(j)dj$ one can then show that, as Gali and Monacelli (2005) discuss, the aggregate relation can be written as $y_t = n_t + a_t$, i.e in log linear form.

For goods market clearing, the aggregate output must be equal to aggregate demand of good j. Therefore, the following equality can be written

$$(15) \quad Y_t(j) = C_{h,t}(j) + C_{h,t}^*(j)$$

Following Monacelli (2005) and Divino (2009), It is assumed that the open economy does not affect on foreign country, $C_t^* = C_{f,t}^*$ and $P_t^* = P_{f,t}^*$. Therefore, using the equation $C_t = KC_t^* Q_t^{\frac{1}{\sigma}}$ which is before- log version of equation (11) with constant, the definitions of $C_{h,t}(j)\ and\ C_{h,t}^*(j)$ and corresponding definitions for the foreign country the log linear result, after omitting the constant, yields :

$$(16) \quad y_t = y_t^* + \frac{1}{\sigma}(\psi s_t)$$

Where, $\psi = 1 + \alpha(2-\alpha)(\sigma\varphi - 1)$ which is positive when it is assumed that $\sigma\varphi \geq 1$. equation (16) indicates that output differential depends on terms of trade. Elasticity of inter-temporal substitution in consumption and degree of openness determine the sensitivity of the differential to terms of trade.

From the equilibrium condition for foreign country, $y_t^* = c_t^*$, and equations (11), (13) and (16), the following relationship can be derived:

$$(17) \quad c_t = \omega y_t + (1-\omega) y_t^*$$

Where, $\omega = \frac{1-\alpha}{\psi}$. The important point is that $\sigma\varphi$ is assumed to be equal or greater than 1. For this matter, $0 < \omega \leq 1$ must hold.

3-3- Marginal cost

The real marginal cost of the technology which is used by firms is given by:

$$(18) \quad m_t = w_t - a_t - p_t$$

Equation (7), the optimal condition of labour supply of household, in log linear version implies

$$(19) \quad w_t - p_t = \delta n_t + \sigma c_t$$

Where δ is the wage elasticity of labour supply.

Using equations (17), (18), (19) and the relation between CPI and domestic prices, the real marginal cost of the firm can be rewritten as:

$$(20) \quad m_t = (\delta + \sigma\omega) y_t + \sigma(1-\omega) y_t^* - (1+\delta) a_t^f$$

In order to show the financial imbalances effect in the model, following Bean (2004), domestic productivity depends on the state of technology and whether there are financial imbalances. Therefore, in this paper, financial imbalances are defined as a function of debt ratio and real exchange rate. Thus, domestic productivity and financial imbalances are defined, respectively as

(21) $$a_t^f = b_t - [\lambda_1(d_t - y_t) + \lambda_2 q_t]$$

(22) $$f_t = \lambda_1(d_t - y_t) + \lambda_2 q_t$$

Where f_t denotes financial imbalances which is a function of outstanding debt relative to the domestic output and real exchange rate. λ_1 and λ_2 are the relative weights on the debt ratio and the real exchange rate. Therefore, as equation (22) shows the marginal cost of firms is affected by the real exchange rate, which can be considered as a class of asset prices. From the equation (22), marginal cost equation can be rearranged as

(23) $$m_t = (\delta + \sigma\omega)y_t + \sigma(1-\omega)y_t^* + (1+\delta)\lambda_2 q_t - (1+\delta)a_t^d$$

(24) $$a_t^d = b_t - \lambda_1(d_t - y_t)$$

Where, a_t^f denotes labour productivity (the proxy of domestic productivity) which is affected by the existence of financial imbalances, that is the result of either debt outstanding accumulation or/and the effect of the real exchange rate. It is assumed that the policy maker is willing to control the exchange rate near a target, just to make sure that an increase in exchange rate does not lead to an increase in CPI and change of households' financial state. Moreover, up-swing of the exchange rate in a fully floating exchange rate regime may cause a sort of bubble in the domestic market of foreign exchange which may lead to the some imbalances in the future. b_t is a shock to technology, d_t is debt outstanding in period t and a_t^d,domestic productivity under the situation where there is outstanding debt accumulation, would be equal only to the state of technology when there is low debt relative to output i.e. $\lambda_1 = 0$. Thus, in this condition marginal cost would response positively only to the real exchange rate not to the debt ratio. When outstanding debt accumulation happens it is quite possible that credit crunch occurs because nobody is willing to lend in such conditions. It, therefore, can be assumed the existence of debt outstanding as a proxy of credit crunch. Thus, from the equation (23), the firm's real marginal cost is directly affected by real exchange rate. In addition, with a positive shock to aggregate demand, either foreign or domestic output, consumption of the domestic produced goods increase, affecting on labour demand real marginal cost.

The monetary authority should be concerned about the oscillation of exchange rate and, in addition, outstanding debt accumulation because both of them may cause financial imbalances and as a result economy instability.

Hence, the marginal cost of the firm depends on factor productivity which in turn it depends on whether or not there is a credit crunch and then financial imbalances. It is obvious from equation (20) that when productivity increases, the marginal cost of the firm falls. In fact, existence of financial imbalances acts as a negative shock to labour productivity which in turn increases real marginal cost.

4- Dynamics of output and inflation, IS curve, financial imbalances and economy instability

Equation (17) indicates that consumption depends on the weighted combination of domestic and foreign outputs. Using this equation and combining with Euler equation (4) in log linearized form, $c_t = E_t c_{t+1} - \frac{1}{\sigma}[i_t - E_t \pi_{t+1} - \rho]$, using the formal assumption that $V_{t,1} = \frac{1}{R_t}$ and $R_t = 1 + i_t$ where R_t is the gross nominal interest rate, the dynamic of output can be written as

$$(25) \qquad y_t = E y_{t+1} - \frac{1}{\sigma_c}\left[i_t - E\pi_{h,t+1} - \rho\right] + (\psi - 1)E\Delta y^*_{t+1}$$

Where $\sigma_c = \frac{\sigma}{\psi}$ and $\rho = -log\beta$. it is clear from the output equation that domestic output is sensitive to the degree of openness of the economy and fluctuation of the exchange rate because oscillation of the exchange rate can affect on imports, prices level and then interest rate. If the future change of the foreign output is positive, an increase to it leads to an increase to the domestic output.

Firms are assumed to set prices according to Calvo(1983), staggered price setting. Therefore, following Calvo(1983), let (1-θ) of firms set their prices each period. In fact, (1-θ) is the probability that a firm resets its price in a given period. Hence, the price level follows the below relationship overtime:

$$(26) \quad p_t = \theta p_{t-1} + (1\text{-}\theta) p^0_t$$

Where, p_t^0 is a price setting rule (in log) which is used by the firm. In fact, it is the optimal rule that a typical firm follows to reset its prices to maximize the firms' value.

$$(27) \quad p_t^0 = \mu + (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k E_t(m_{t+k}^n + p_{h,t})$$

It shows that mark up and weighted average of current and expected future nominal costs are determinants of prices setting rule. As Galli and Monacelli (2005) point out, in a flexible price setting where $\theta \to 0$ the price setting rule i.e. mark up rule can be read as $p_t^0 = \mu + m_t^n + p_{h,t}$.

For more interpretation, let $\mu_{t,t+k} = p_t^0 - m_{t+k}^n$[3]. After rearranging of equation (27) to derive the mark-up and then from equation (26) and (27) one can write the dynamics of inflation as:

$$(28) \qquad \pi_{h,t} = \beta E_t \pi_{h,t+1} + \Omega \overline{m_t}$$

Where, $\Omega = \theta^{-1}(1-\theta)(1-\beta\theta)$ and $\overline{m_t}$ is the deviation of real marginal cost from the marginal cost uder fully flexible price condition that is defined as $\overline{m_t} = m_t - m$.

Let $x_t = y_t - \overline{y_t}$ defined as output gap where, $\overline{y_t}$ is the output under fully flexible prices and $\lambda_2 = \frac{\alpha}{(1+\delta)(1-\alpha)}$ then degree of openness of the economy determines the intensity of response of the real marginal cost to the real exchange rate.

Using this and output gap definition and equation (23), $\overline{m_t}$ is given by:

$$(29) \qquad \overline{m_t} = \Phi x_t + \frac{\alpha}{1-\alpha} q_t$$

where $\phi = \delta + \sigma\omega$. Hence, substituting (29) into (28) yields the new Keynesian Phillips curve i.e. the supply curve which is affected by the real exchange rate directly:

$$(30) \qquad \pi_{h,t} = \beta E_t \pi_{h,t+1} + M x_t + \Lambda q_t$$

where, $M = \Omega\Phi$, $\Phi = (\delta + \sigma\omega)$ and $\Lambda = \Omega\frac{\alpha}{1-\alpha}$. Equation (30) is aggregate supply equation which is positively depends on the output gap and the real exchange rate which can be considered as a class of asset prices. The financial imbalances which affect through the

[3] This equality is also used by Gali (2002).

domestic productivity on output gap have an impact on aggregate supply curve too. Sensitivity of domestic inflation to the movements of output gap and real exchange rate depends on the degree of openness of the economy. The higher the degree of openness, domestic inflation is more sensitive to the real exchange rate changes.

In order to derive the expression of CPI inflation, from the definition of s_t and equations (12) and (13) one can write the following equation for the CPI level

$$p_t = p_{h,t} + (\tfrac{\alpha}{1-\alpha})q_t \tag{31}$$

Hence, under assumption of small open economy model and equation (31), the CPI inflation can be derived as follows which indicates the relation between CPI inflation and PPI inflation. This relation indicates that firm's real marginal cost responses to the real exchange rate directly and this response is increasing. Moreover, the sensitivity of the firm's real marginal cost to the moves of the real exchange rate depends on the degree of openness.

$$\pi_t = \pi_{h,t} + \tfrac{\alpha}{1-\alpha}\Delta q_t \tag{32}$$

The IS curve (aggregate demand equation) can be derived from the equation (25) and definition of terms of trade in relation to the domestic and foreign output

$$x_t = E_t x_{t+1} - \tfrac{1}{\sigma_c}\left[i_t - E_t\pi_{h,t+1} - \rho\right] + \varsigma\Delta E_t y^*_{t+1} - \left(\tfrac{1+\delta}{\Phi}\right)(1-\rho_a)a^f_t \tag{33}$$

$$x_t = E_t x_{t+1} - \tfrac{1}{\sigma_c}\left[i_t - E_t\pi_{h,t+1} - \overline{r_t}\right];$$

Where, $\varsigma = \left(\frac{\Phi(\psi-1)-\sigma(1-\omega)}{\Phi}\right)$, $\sigma_c = \frac{\sigma}{\psi}$ and $\overline{r_t} = \rho + \sigma_c\varsigma\Delta E_t y^*_{t+1} - (\frac{(1+\delta)\sigma_c}{\Phi})(1-\rho_a)a^f_t$ if it is assumed that a^f_t follows a autoregressive process with $\rho_a \in (0,1)$ and $v^a_t \sim iid(0, \sigma^2_a)$.

Natural interest rate depends on the degree of openness, changes in the foreign country output and domestic productivity. It is obvious that, in present model, output gap is not affected by the real exchange rate directly. The output gap equation is similar to its counterpart in the closed economy. However, degree of openness affects the sensitivity of output gap to the interest rate moves.

Now, assume that the central bank thinks about taking a policy to prevent instability in the economy. Let, therefore,ρ_f, normalized between zero and one, indicates the severity of financial imbalances effects on labour productivity and then firm's real marginal cost. Then one may write (21) as

$$a_t^f = b_t - \rho_f \left[\lambda_1 (d_t - y_t) + \lambda_2 q_t \right] \quad (34)$$
$$= b_t - \rho_f f_t$$

where $f_t = [\lambda_1 (d_t - y_t) + \lambda_2 q_t]$.

Output gap depends inversely on deviation of real interest rate from the natural rate, $\overline{r_t}$. When the financial imbalances occur in the economy the natural interest rate increases through the decrease in domestic productivity. In such a condition which is mainly because of outstanding debt accumulation, the deviation between real interest rate and its natural level decreases, given nominal interest rate, and as a result it leads to an increase in output gap

.

4-1- Economy instability

$\overline{y}$ denotes the output level under fully flexible prices which is affected by the probability of happening financial imbalances. Now, let $\widehat{y_t}$ is feasible output target that the central bank looks for when domestic productivity is not affected by the financial imbalances

$$\widehat{y_t} = \mathrm{v} \left[b_t - \Gamma_1 y_t^* \right] \quad (35)$$

Where, $\mathrm{v} = \frac{(1+\delta)}{\Phi}$, $\Gamma_1 = \frac{\sigma(1-\omega)}{(1+\delta)}$. In a normal condition, i.e no financial imbalances (or credit crunch), $\widehat{y_t}$ and $\overline{y_t}$ are identical. But when there are some imbalances they would be different from each other. Therefore, in this condition, the policy maker would like to stabilize the economy by minimizing the output gap relevant to gap between $\overline{y_t}$ and $\widehat{y_t}$. Let x_t^* be the relevant output gap which is defined as $x_t^* = y_t - \widehat{y_t}$ then this can be written as[4]:

$$x_t^* = (y_t - \overline{y_t}) + (\overline{y_t} - \widehat{y_t}) \quad (36)$$
$$= x_t + \mathrm{v} \left[a_t^f - \Gamma_1 y_t^* \right] - \mathrm{v} \left[b_t - \Gamma_1 y_t^* \right]$$
$$= x_t - \mathrm{v} \rho_f \left[\lambda_1 (d_t - y_t) + \lambda_2 q_t \right]$$

[4] The analogues discussion is in Bean (2004).

$$x_t^* = x_t - \mathrm{v}\rho_f f_t$$

Which x_t is output gap defined by equation (33).

Optimal interest rate rule, with respect to the financial imbalances issue, is derived in the next section. It shows that the optimal rule is different to the closed economy model and even to the recent studies of small open economies.

5- Financial instability and optimal monetary policy

The monetary authority seeks to set a nominal interest rate to bring output and inflation to targets value. Keeping output close to its target as much as possible contributes to stabilize economy in a flexible inflation targeting regime. In such a regime, the central bank's preference is not only inflation targeting, but also economy stability, interest rate smoothing and probably some other targets which shall be read as financial stability. The central bank, under commitment, minimizes the loss objective to solve the optimization problem in order to commit itself to the optimal rule, meaning that it will not deviate from the optimal rule.

In order to achieve to the stability in the economy, the policy maker looks for a welfare-based objective that can be derived from the representative household's utility function indicated in terms of steady state consumption. Thus, the central bank loss function, which also includes deviation of the nominal interest rate from its target, can be written as

$$(37)\quad \text{Min } \mathrm{E}_0 \sum_{k=0}^{\infty} \beta^k L_{t+k} = \text{Min } \mathrm{E}_0 \sum_{k=0}^{\infty} \beta^k \left[(\pi_{h,t+k})^2 + \gamma_x(\mathrm{x}_{t+k})^2 + \gamma_i(i_{t+k} - \bar{\imath})^2\right]$$

Where, $\gamma_x = \frac{((1+\delta)-(1-\sigma)\omega)(1-\theta)(1-\theta\beta)}{\theta\varepsilon}$ comes from the welfare function which is derived following Woodford (2003) and Rotemberg and Woodford (1998,1999) and setting the target of inflation as zero[5]. Thus the monetary authority seeks to minimize equation (37) subject to following constraints

$$(38)\qquad L_t = (\pi_{h,t})^2 + \gamma_x(\mathrm{x}_t)^2 + \gamma_i\,(i_t - \bar{\imath})^2$$

$$(39)\qquad q_t = E_t e_{t+1} + i_t^* - i_t + p_t^* - p_t$$

[5] See Divino (2009) for further details.

and equations (30),(36). Equation (38) is the period social welfare loss and equation (39) is the result of combination of Uncovered Interest Rate condition and equation (10).

After some manipulation with the constraints, supply curve can be written as following relations:

(40) $$(1+\Omega\alpha)\,\pi_{h,t}= \beta E_t\pi_{h,t+1} + Mx_t + \Lambda q_{t-1} + \Omega\alpha(i_{t-1} - i^*_{t-1} + \pi^*_t)$$

For a monetary policy rule under commitment, the Lagrangian as of time zero can be read as

(41) $$\text{Min}\quad E_0\sum_{t=0}^{\infty}\beta^t\{(\pi_{h,t})^2 + \gamma_x(x_t)^2 + \gamma_i(i_t-\bar{\iota})^2 + \psi_{1,t}[(1+\Omega\alpha)\,\pi_{h,t} - \beta E_t\pi_{h,t+1} - Mx_t - \Lambda q_{t-1} - \Omega\alpha(i_{t-1} - i^*_{t-1} + \pi^*_t) + \psi_{2,t}[x_t - E_t x_{t+1} + \frac{1}{\sigma_c}\left[i_t - E_t\pi_{h,t+1} - \overline{r_t}\right]\}$$

The Lagrangian technique which is implied in Woodford (2003) is used to reach the solution. When the problem is solved under commitment the policy rule is time consistent. The loss function does not apply expected losses from time zero onward and, therefore, it is not conditional on the new state of economy. Thus, as a result, it yields a timeless solution.[6]

The first order conditions for two periods are

(42) $$\pi_{h,t} + \psi_{1,t}(1+\Omega\alpha) - \psi_{1,t-1} - \frac{\psi_{2,t-1}}{\sigma_c\beta} = 0$$

(43) $$\gamma_x(x^*_t + V\rho_c F^c_t) - \psi_{1,t}M + \psi_{2,t} - \frac{\psi_{2,t-1}}{\beta} = 0$$

(44) $$\gamma_i(i_t - \bar{\iota}) + \frac{1}{\sigma_c}\psi_{2,t} = 0 \Rightarrow \psi_{2,t} = -\sigma_c\gamma_i(i_t - \bar{\iota})$$

Where $\psi_{1,t}$ and $\psi_{2,t}$ are Lagrangian multipliers and. To eliminated the lagrangian multipliers substitute (44) into (43) and (42) and solve for $\psi_{1,t}$ in (43). After substitution of the results into (42) , the optimal monetary policy rule can be written as

(45) $$i_t = \varphi_{0,i}\bar{\iota} + \varphi_{1,i}i_{t-1} - \varphi_{2,i}i_{t-2} + \varphi_\pi\pi_{h,t} + \varphi_{o,x}\left(x^*_t + V\rho_f f_t\right) - \varphi_{1,x}x_{t-1}$$

Where $\varphi_{0,i} = 1 - \left(\frac{1}{\beta} + \frac{1}{(1+\Omega\alpha)} + \frac{1}{\sigma_c(1+\Omega\alpha)} - \frac{1}{\beta(1+\Omega\alpha)}\right)$

[6] See Woodford (2003) for more discussion.

$$\varphi_{1,i} = \frac{1}{\beta} + \frac{1}{(1+\Omega\alpha)} + \frac{1}{\sigma_c(1+\Omega\alpha)}$$

$$\varphi_{2,i} = \frac{1}{\beta(1+\Omega\alpha)}$$

$$\varphi_{\pi} = \frac{M}{\sigma_c\gamma_i(1+\Omega\alpha)}$$

$$\varphi_{o,x} = \frac{\gamma_x}{\sigma_c\gamma_i}$$

$$\varphi_{1,x} = \frac{\gamma_x}{\sigma_c\gamma_i(1+\Omega\alpha)}$$

From the optimal policy rule equation (45), it is obvious that the monetary policy responds to the movement of exchange rate indirectly, through domestic output and inflation. However, the policy rule reacts directly to financial imbalances under optimal policy. With existence of financial imbalances, the monetary policy maker reacts to the real exchange rate directly because, for instance, changing of the nominal interest rate in response to devaluation in a situation where financial imbalances may occur can prevent probable future imbalances and instabilities. If the central bank does not see any financial imbalances, x_t^* will be equal to x_t and exchange rate would not have an effect on the optimal policy rule directly, and the response of the rule to the exchange rate is indirectly through the changes of domestic inflation and output gap. The severity of reaction to the financial imbalances depends on the preferences of the monetary authority to stabilize output and smoothing of interest rate. It is obvious that if the central bank is not willing to stabilize the economy (output stabilization) the optimal policy rule does not react to financial imbalances matter. A very important result here is that concerns about economy stability increases concerns about financial imbalances under the optimal monetary policy rule. In other words, in an inflation-targeting regime, which the central bank is, as well as being committed to economy stability, it should also think about financial imbalances in the economy to prevent any such possible instability from occurring.

The financial imbalances may cause the policy maker to set a higher nominal interest rate to prevent instability in the economy. Note that in a special case where $\sigma = \varphi = \omega = 1$, that is, no relation to the foreign country, the central bank responds to the financial imbalances situation according to the proportion of weights on output stability and interest rate smoothing. In this circumstance, if the central bank prefers to stabilize the economy higher it increases the response to financial imbalances under optimal monetary policy rule. Whereas, the intensity of the response to financial imbalances changes in an open economy also depends on the inverse of inter-temporal elasticity of substitution and the degree of openness of the economy.

6- Impulse Responses: A comparative analysis

In this section, the dynamic effects of two shocks on some variables are investigated. For a more precise investigation, impulse responses of the present model are compared with those in Gali and Monaceli (2005). On the whole, impulse responses indicate that shocks move output gap in one direction but real exchange rate in the opposite direction which is a result of nominal interest rate response. *Figure 1* indicates impulse responses to a domestic productivity shock. With an innovation to the domestic productivity, nominal interest rate remains more stable under the model's optimal rule compared to optimal policy in Gali and Monaceli (2005), (GM). The fall in nominal interest rate in both models supports the increase of output and consumption. Domestic inflation and output gap remain unchanged in GM, whereas domestic inflation increases and starts to decrease after two quarters and then reverts closely to the steady state value.

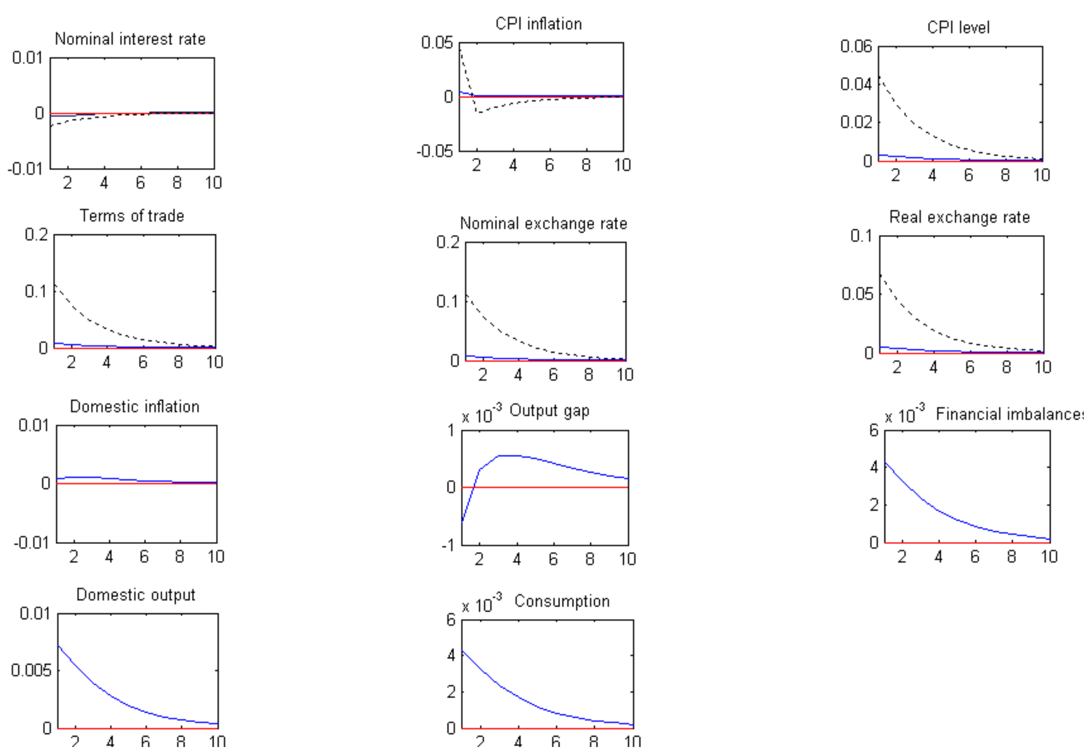

Figure 1. Impulse responses to a domestic productivity shock under optimal policy in GM (2005) [dashed line] and derived optimal policy rule in the present model [solid line]

On the other hand, output gap falls in the first two periods through the increase in domestic output and then increases because of an increase in the real exchange rate. Terms of trade, nominal, and real exchange rate also go up under the optimal policy in GM, but they remain almost stable under the present model. In other words, they are more muted than those in GM. In the present model, the financial imbalances behaviour is also analysed. With a shock to the domestic productivity, domestic output and consumption increases, and as a result exchange rate increases marginally through the fall in domestic nominal interest rate, resulting from uncovered interest parity, which leads to a rise in financial imbalances. This is because of an increase in imported inflation which has a positive effect on the consumer price index (CPI), and then on the imbalances of households' financial state. Moreover, exchange rate depreciation means more expensive imported items, leading perhaps to more households' debt accumulation relative to the domestic output. This creates a high severity of financial imbalances, meaning that the financial state of households might not be that good. In GM, domestic inflation remains unchanged, whereas here it increases under optimal policy rule because domestic inflation responses directly and positively to the real exchange rate. That is, behaviour of domestic inflation depends on the real exchange rate. Likewise, output gap does not change in response to the domestic productivity shock in GM, whereas in the present paper output gap falls in the first two periods and is expected to rise and then to remain close to the steady state value in future periods.

Figure 2 displays impulse responses to a foreign output shock under optimal policy in two models which have not been displayed in GM. The shock leads to a fall in real and nominal exchange rates. In fact, with a shock to the foreign output, consumption increases, whereas domestic output falls. As a result, exchange rate decreases through the rise in domestic nominal interest rate, resulting from uncovered interest parity. The real and nominal exchange rates decrease more under the optimal policy rule in the present paper in comparison with GM, which means relatively more financial stability. In the present model, CPI level and CPI inflation fall and stay below those in GM. Nominal interest rate does not respond in GM but increases very closely to the steady state value under the present optimal policy. Output gap seems to remain stable in response to the foreign output shock in both models.

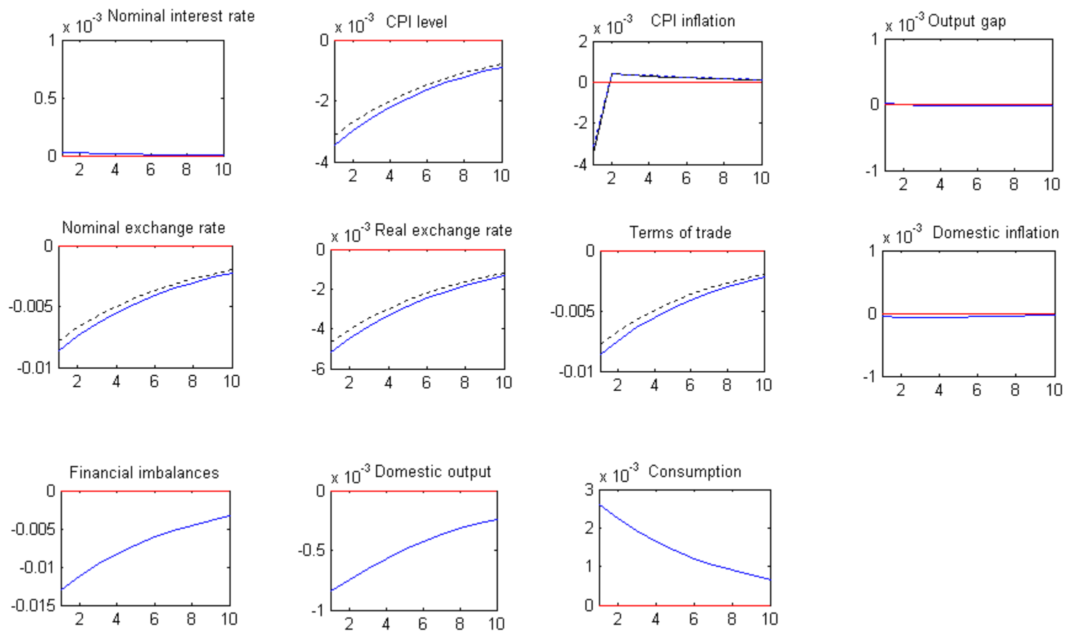

Figure 2. Impulse responses to a foreign output shock under optimal policy in GM (2005) [dashed line] and derived optimal policy rule in the present model [solid line]

7- Summary and conclusion

A small open economy model is constructed to examine the impact of financial imbalances on monetary policy. Dynamic Stochastic General Equilibrium (DSGE) models based on New-Keynesian framework use micro foundations of households and firms' optimization problems to describe monetary policy transmission mechanism and fluctuation of main macroeconomic variables. This study uses a small open economy DSGE model akin to Gali and Monacelli (2005) and Divino (2009) to investigate the central bank's optimal policy rule under commitment with respect to financial imbalances in the economy. The real exchange rate plays an important role in the small open economy. It affects directly the dynamics of domestic inflation (aggregate supply) and firm's marginal cost but has indirect effect on the aggregate demand.

There is no consensus on a definition of financial instability. However, for financial stability study, oscillation of some variables is often considered. House and stock prices, exchange rate and the price of some other financial assets, on the one hand, and household debt growth and debt accumulation, on the other hand, are some of the main variables which are used to investigate the financial imbalances issue.

The present optimal monetary policy rule indicates that the monetary policy responds to the movement of exchange rate indirectly, through the domestic output and inflation. However, the policy rule reacts directly to financial imbalances under optimal policy. Financial imbalances cause the monetary policy maker reacts to the real exchange rate directly because, for instance, changing of the nominal interest rate in response to devaluation in a situation where financial imbalances may occur can prevent probable future imbalances and instabilities. On the other hand, the monetary authority may use the monetary policy to improve the terms of trade and purchasing power of domestic consumers through the real appreciation in exchange rate. It is, therefore, essential to the central bank to consider the real exchange rate when it wants to set a suitable policy rule to increase the welfare.

This study also does a quantitative analysis with doing a simulation to investigate the behaviour of some macro variables in response to domestic and foreign shocks. With a shock to the domestic productivity, domestic output and consumption increases and as a result exchange rate increases slightly through the fall in domestic nominal interest rate, resulting from uncovered interest parity which leads to a rise in financial imbalances. This is because of an increase in imported inflation which has a positive effect on the CPI and then on the imbalances of households' financial state. Moreover, exchange rate depreciation means more expensive imported items, leading perhaps to more households' debt accumulation relative to the domestic output. This creates high financial imbalances, meaning that the financial state of households might not be that good.

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