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Fabián de ACHÁVAL and Xavier FAIRISE

08 – 13

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Fabián de Achával* and Xavier Fairise†

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Abstract

Standard small open economy models are often unsuitable to deal with the specific economic characteristics of emerging markets. In this paper we lay out a dynamic general-equilibrium model of an emerging small open economy in order to analyze the performance of alternative monetary policies. Our analysis incorporates to the model a non-walrasian labor market and an exchange rate pass-through to domestic prices. One of the central arguments of this paper is that the nature of the trade off between fixed and floating exchange rate regimes in emerging markets' economies may be quite different to that of the industrial countries. In line with empirical evidence, our model predicts that countries exhibiting a high exchange rate pass-through will tend to smooth the exchange rate volatility.

Keywords: Monetary Policy, Labor Market Search, Inflation, Exchange Rate Arrangements, Emerging Markets.

JEL Classification:

1 Introduction

The debate about the merits of fixed versus flexible exchange rates has renewed its interest due to the financial crises of the last decade. At the same time, fiscal discipline problems are not as evident as they tended to be in Latin America and thus observers have started to feel that the main problems are 'soft peg'

*University of Evry, EPEE and TEPP (FR N3126, CNRS) ; Address : EPEE-Département d'Economie, Université d'Evry-Val-d'Essonne, Bd François Mitterrand, 91025 EVRY Cedex; Email : fabian.deachaval@univ-evry.fr

†University of Evry, EPEE and TEPP (FR N3126, CNRS); Email : xavier.fairise@univ-evry.fr

exchange rate regimes. Since then, the choice has been turning around different forms of "hard pegs", such as dollarization and a given form of floating exchange rate.

The benefits of floating exchange regimes are well-known. Most importantly, if an open economy is faced with exogenous real shocks -such as terms of trade shocks or real interest rate shocks- and if there are price or wage rigidities, then flexible exchange rates are superior to fixed rates. These facts are also shown in modern dynamic general equilibrium models with nominal rigidities such as in Céspedes, Chang and Velasco (2000), Galí and Monacelli (2002), Parrado and Velasco (2002), and Schmidt-Grohe and Uribe (2001). As a consequence, there is a vast literature on optimal monetary policy in open economies under price stickiness.

However, until recently, the discussion on exchange rate regimes concentrated on developed countries, while specific institutional features of developing countries were brushed aside. Among those, the most prevalent characteristics of emerging markets' economies are currency mismatches between assets and liabilities, monetary policy credibility problems, and high exchange rate pass-through to domestic prices. The standard reference of modern open economy macroeconomics (Obstfeld and Rogoff 1995), leaves all those issues unattended.

These characteristics may help to explain why developing countries are much more concerned with stabilizing the nominal exchange rate than developed countries, as evidence suggests. In a seminal contribution, Calvo et al. (2002) coined the expression "fear of floating" to refer to the cases in which a country claims to be pursuing a policy goal that is independent from the exchange rate, but keeps intervening in the foreign exchange. Eichengreen (2002) and Eichengreen and Hausmann (2003) suggest that another reason for this behaviour is that exchange rate flexibility may increase uncertainty and reduce the access of emerging economies to the international financial markets.

No matter the reason, the questions remain open: should an emerging market economy choose a predetermined exchange rate regime or a floating one? Do institutional features specific to some regions affect the ranking of optimal monetary policies?

In terms of modelling, it is evident that we have to depart from an ideal and a highly stylized world in which money is a veil, and where exchange rate regimes are neutral in terms of performance. In other words, the real sector's response to different shocks will not be the same and will depend on the exchange rate regime.

A relatively new literature on the fear of floating tries to explain the implications of those economic characteristics in an open economy general equilibrium model.

Lahiri and Vegh (2002) introduce depreciation costs in order to explain this reluctance. They model these costs by introducing wage rigidities. Movements in the nominal exchange rate will have consequences in the actual real wage, thus generating "voluntary" or "involuntary" unemployment by moving away from the first best. However, the central banker also faces an intervention cost and thus in the occurrence of depreciation he will be confronted with a trade-off

and the final response will depend on the size of the shocks.

Faia and Monacelli (2002) introduce exogenous financial dollarization and provide a general framework to study the interaction between the exchange rate and the financial variables in an economy with credit market frictions. The resulting "financial exposure" provoked by the detrimental balance sheet effects will explain why a regime of flexible rates amplifies the response of both real and financial variables to domestic shocks. Similarly, Choi et al. (2004) and Cook (2004) show that in an environment where financial institutions deal with currency mismatch, fixed exchange rates offer greater stability than an interest rule that targets inflation. Finally, Chamon and Hausmann (2005) argue that if domestic firms have large foreign nominated liabilities, unexpected changes in the real exchange rate can drive the firms into costly bankruptcy.

Devereux (2002) and Devereux et al. (2006) compare alternative monetary policies for an emerging market economy that experiences external shocks both in the foreign interest rates and in the terms of trade. This happens with financial frictions and in the presence of high and delayed pass-through. In either case, the exchange rate pass-through proved to be critical for the assessment of monetary policy, whereas financial constraints did not affect the ranking of alternative policy rules.

Finally, Chang and Velasco (2006) analyse the implications of endogenizing both the portfolio choice and the exchange rate policy in a single-period small open economy. They do so by assuming that the Central Bank chooses the exchange rate regime after debts and wage contracts have been signed. Thus, borrowers will choose the amount of domestic and foreign currency bonds as a function of the risk-return characteristics of these securities.

In this paper we develop a dynamic general-equilibrium (DGE) model of a small open economy to investigate the performance of alternative exchange rate arrangements. In line with the existing literature on the "fear of floating", one of the main arguments of the paper is that the nature of the trade-off between fixed and floating exchange rate regimes in emerging markets may be different than that of the industrial countries. We suppose that a distinctive feature of emerging markets is the degree to which their price levels are sensitive to fluctuations in exchange rates. Accordingly, exchange rate shocks in emerging markets' economies tend to impact the aggregate inflation at a much faster rate than they do in industrial economies. Empirical evidence by Choudhri and Hakura (2003), Devereux (2003) and Devereux and Yetman (2005) support this view.

As one can easily observe, the literature mentioned above relies on both 1) the literature about sticky prices and 2) the literature on the "classic" determinants of the "fear of floating", but leaves unattended an important dimension of the economy: the persistent levels of unemployment in equilibrium.

As shown in a recent strand of the literature, the fact of leaving behind the assumption of a frictionless, perfectly competitive labor market constitutes an important step forward, not only for the improvement of the empirical performance of the standard sticky-prices model, but also for a better understanding of the relationship between monetary policy and inflation dynamics.

In this line, Walsh (2005) shows that the incorporation of a non-walrasian labor market amplifies the response of output and reduces the impact of inflation relative to a similar model with a walrasian labor market. Moyen and Sahuc (2005) show that real frictions help match the stylized facts of the labor market in the Euro area. Trigari (2006) shows in a hybrid model that the addition of search frictions helps the New Keynesian (NK) model explain the inertia of inflation and the persistence of the output that are observed in the data. Faia (2006) finds in a similar model that the optimal inflation volatility is an increasing function of worker's bargaining power. Tang (2006) studies the introduction of labor market search into a NK framework and concludes that the optimal monetary policy may differ across countries with different labor-market institutions, thus giving a non-trivial role to labor-market fundamentals. Faia(2008) finds that a rule that responds to unemployment and inflation performs best. Finally, Thomas (2008) studies the joint dynamics of unemployment and inflation and finds that under staggered nominal wage bargaining, the monetary authority should use inflation as a means of avoiding excessive unemployment volatility and excessive dispersion of hiring rates.

Our motivation to include labor-market search into the framework is twofold. First, as noted by Tang (2006) the introduction of real rigidities when the Hosios condition is not satisfied changes the optimal monetary policy response to the shocks. Once the Hosios condition is not satisfied the steady state is not efficient and complete inflation stabilization is not optimal. The second reason is related to the second building block of the model, namely, the exchange rate pass-through. Since, as noted by Walsh (2005), the inclusion of search into the model reduces the impact of inflation, one may argue that the nature of the trade-off between fixed and floating exchange rate arrangements for a given degree of pass-through (and therefore for different types of countries), may be drastically affected. The reason for this is straightforward: in view of the fact that the pass-through affects the trade-off between inflation and output stabilization and that this, in turn, inclines the balance towards the adoption of either flexible or fixed arrangements, a fewer incidence of inflation might reduce the trade-off, and hence change the predictions.

In terms of the model used, the paper is related to Devereux et al. (2006). The model is a three-sector, small open economy where nominal rigidities are present in the form of sticky non-traded goods' prices. The economy will face labor market search and will be subject to a series of external shocks, to which it must adjust whatever exchange rate policy is followed. We also study the optimal monetary policy that follows the Ramsey approach, according to which the monetary authority sets the optimal path of all variables in the economy by maximizing the agents' welfare.

We depart from previous research in two ways. First, we focus on optimal monetary policy in addition to interest rate policy rules. Second, we add labor market rigidities by incorporating search and matching into the model. Finally, we compare the performance of the alternative exchange rate regimes in both a Taylor and a Ramsey-oriented approach. Furthermore, up until now and to our knowledge, no work has been done in order to study the implications that

the frictional labor market has in the optimal monetary policy of an emerging market-oriented DGE model.

The goal of this paper is threefold. First, and most importantly, we try to analyse to which extent the trade-off faced by developing economies is similar to that of the developed countries. Second, we intend to assess the interaction between nominal and real rigidities in the design of the optimal monetary policy in a small open economy. In practice, both frictions are present in Latin American countries, and it is not clear how a monetary policy should deal simultaneously with these distortions. Finally, as opposed to most of the literature on open economy macroeconomics, we solve the Ramsey problem to characterize the optimal monetary policy in the presence of such distortions and see how monetary policy should be implemented to correct multiple distortions in a given economy.

The remainder of the paper is organized as follows: section 2 is devoted to the presentation of the model, while the calibration and simulation results are presented in sections 3 and 4. Section 5 will analyse the welfare cost for each monetary policy. Section 6 draws a conclusion.

2 The model

The structure of the economy is as follows: there are three sets of domestic actors in the model: consumers, three types of firms (non traded, intermediate and export) and the monetary authority. There is also a retail-firm that imports and sells goods. In addition, there is the rest of the world, where foreign currency prices of export and import goods are set. In this setup, three goods are produced in the domestic economy: non-traded goods, intermediate goods and export goods.

The intermediate goods' sector produces H_t hiring only labor. In turn, the non-traded goods' sector produces Y_N using H_t as input. The export firm will produce goods using both an intermediate good H_t and an imported intermediate input I_M .

We introduce imperfect competition both into the non-traded sector and in the local importing retailer. Therefore firms will only adjust their prices to movements in the exchange rate gradually, giving rise to the exchange rate pass-through. Finally, we also introduce real rigidities in the form of labor market search and matching. These building blocks will generate not only a role for monetary policy but will also allow a non-trivial comparison between exchange rate regimes.

As far as the monetary policy goes and in order to compare the performance of alternative exchange rate arrangements, the monetary policy follows a Taylor-type monetary policy rule and resolves a Ramsey monetary policy problem. The real exchange rate will be determined by domestic macroeconomic equilibrium.

2.1 A small open economy

Households of the domestic economy can borrow in terms of foreign currency. Let D_{t+1} denote the debt contracted in t and i_{t+1}^* the foreign interest rate for period t . We suppose that the foreign interest rate follows an exogenous stationary stochastic process defined by :

$$(1 + i_{t+1}^*) = (1 + i_t^*)^{\rho_{i^*}} (1 + i^*)^{1-\rho_{i^*}} \exp(v_t) \quad (1)$$

v_t being independently, identically and normally distributed, that is $v_t \sim N(0, \sigma_v^2)$. ρ_{i^*} is a persistence parameter and satisfies $|\rho_{i^*}| < 1$, and i^* is the stationary foreign nominal interest rate.

The domestic economy also trades goods with the rest of the world. The domestic country exports one good, with price $P_{X,t}^*$ in terms of foreign currency, and imports two goods, a consumption good and an intermediate good, with prices $P_{M,t}^*$ and $P_{1M,t}^*$ respectively, both in terms of foreign currency. All prices are taken as given by the agents of the domestic economy.

Foreign prices are subject to both common shocks and specific shocks, such as terms of trade shocks. We assume that the foreign prices follow these processes :

$$P_{X,t}^* = P_{X,t-1}^* (1 + \pi_t^*) \quad (2)$$

$$(1 + \pi_t^*) = (1 + \pi^*) \exp(v_{P^*,t}) \quad (3)$$

$$v_{P^*,t} = \rho_{v_{P^*}} v_{P^*,t-1} + \varepsilon_t^{v_{P^*}} \quad (4)$$

$$P_{M,t}^* = P_{M,t-1}^*{}^{\rho_M} P_{X,t-1}^*{}^{1-\rho_M} \left(\frac{P_X^*}{P_M^*} \right)^{-(1-\rho_M)} (1 + \pi^*) \exp(v_{M,t} + v_{P^*,t}) \quad (5)$$

$$P_{1M,t}^* = P_{1M,t-1}^*{}^{\rho_{1M}} P_{X,t-1}^*{}^{1-\rho_{1M}} \left(\frac{P_X^*}{P_{1M}^*} \right)^{-(1-\rho_{1M})} (1 + \pi^*) \exp(v_{1M,t} + v_{P^*,t}) \quad (6)$$

where π_t^* is the foreign inflation and π^* its stationary level. The persistence parameters $\rho_{v_{P^*}}$, ρ_M and ρ_{1M} are in absolute value less than one. $\varepsilon_t^{v_{P^*}}$, $v_{M,t}$ and $v_{1M,t}$ are independently, identically and normally distributed, meaning that $\varepsilon_t^{v_{P^*}} \sim N(0, \sigma_{\varepsilon^{v_{P^*}}}^2)$, $v_{M,t} \sim N(0, \sigma_{\varepsilon^{v_M}}^2)$ and $v_{1M,t} \sim N(0, \sigma_{\varepsilon^{v_{1M}}}^2)$.

The terms of the trade process is given by :

$$\frac{P_{X,t}^*}{P_{M,t}^*} = \left(\frac{P_{X,t}^*}{P_{M,t}^*} \right)^{\rho_M} \left(\frac{P_X^*}{P_M^*} \right)^{1-\rho_M} \exp(-v_{M,t}) \quad (7)$$

$$\frac{P_{X,t}^*}{P_{1M,t}^*} = \left(\frac{P_{X,t}^*}{P_{1M,t}^*} \right)^{\rho_{1M}} \left(\frac{P_X^*}{P_{1M}^*} \right)^{1-\rho_{1M}} \exp(-v_{1M,t}) \quad (8)$$

Let S_t be the nominal exchange rate. The law of one price holds for export goods and for the imported intermediate goods. We thus have :

$$\begin{aligned} P_{X,t} &= S_t P_{X,t}^* \\ P_{1M,t} &= S_t P_{1M,t}^* \end{aligned}$$

Conversely, the law of one price does not hold for the imported consumption goods. The local pricing of imported consumption goods will be described later.

2.2 The labor market

In this section we present the structure of the labor market. Following Pissarides (1990), we assume that labor market trade is costly and uncoordinated. We are thus departing from a walrasian labor market. Let V_t and U_t be respectively the number of vacancies and the number of unemployed workers. The labor force is normalized to one. Thus, if N_t denotes the number of employed workers, we have $U_t = 1 - N_t$. There exists a technology that determines the number of hiring M_t in function of V_t and U_t . We assume that the matching technology is a constant-return-to scale one, and is represented by the following function :

$$M_t = \chi V_t^\theta (1 - N_t)^{1-\theta} \text{ with } \theta \in]0, 1[, \chi > 0 \quad (9)$$

Separations in the labor market occur at a rate s . It follows that at each date, sN_t employees move to unemployment. At the aggregate level, employment evolves according to :

$$N_{t+1} = (1 - s)N_t + M_t \quad (10)$$

Let $\phi_t \equiv \frac{M_t}{V_t}$ and $\psi_t \equiv \frac{M_t}{U_t}$ be respectively the proportion of vacant jobs filled and the proportion of unemployed workers hired. They also respectively correspond to the probability for a firm to fill a vacancy and the probability for an unemployed worker to find a job. Firms and workers take these probabilities as given. It is useful to write these probabilities as follow :

$$\phi_t = \chi \left(\frac{1 - N_t}{V_t} \right)^{1-\theta} \quad (11)$$

$$\psi_t = \chi \left(\frac{V_t}{1 - N_t} \right)^\theta \quad (12)$$

2.3 The representative household

The economy is populated by a large number of infinitely lived households. At a time t , a household may be employed or unemployed. The instantaneous utility of a household is contingent to its state in the labor market. The state of a household in the labor market is denoted by s with $s = 0$ if unemployed and $s = 1$ if employed.

The household time endowment is normalized to 1. At each date, employed and unemployed workers are randomly drawn among the population. The population is normalized to one. N_t denotes the working population and represents also the probability to be employed. The working time of an employed household is h_t (the determination will be discussed later) whereas the working time of an

unemployed household is 0. W_t is the nominal wage, an employed household working a time h earns $W_t h$.

The household enters period t with a stock of government bonds B_t and debt D_t in terms of foreign currency. Government bonds' nominal interest rate is i_t and the foreign interest rate is i_t^* . At each period, households also receive a nominal lump sum transfer¹ T_t . The profit made by the different firms is, at each date, distributed to the households. Each household receives the nominal amount Π_t .

The instantaneous utility function is:

$$u(C_t(s), h_t(s)) = \begin{cases} \frac{[C_t(1)]^{1-\sigma}}{1-\sigma} + \frac{\xi_1}{1-\eta}(1-h_t)^{1-\eta} \\ \frac{[C_t(0)]^{1-\sigma}}{1-\sigma} + \frac{\xi_2}{1-\eta}(1)^{1-\eta} \end{cases}$$

where, $\sigma \in]0, 1[\cup]1, +\infty[$ and $\eta \in]0, 1[\cup]0, +\infty[$ are respectively the consumption and the leisure intertemporal elasticities of substitution. The leisure utility parameter will differ according to the employment status of the agent so that $\xi_1 > \xi_2$: a given leisure time provides more utility to an employed household. Finally, $C_t(s)$ denotes the household consumption at state s .

We suppose that there exists a complete insurance market. Since households are risk averse, they choose an insurance contract that provides them with the same consumption levels (C_t) whether they are employed or unemployed [$C_t = C_t(0) = C_t(1)$]. The unemployment insurance ensures that employed and unemployed households have the same demand of bonds, that is B_{t+1}^d and D_{t+1}^d . The unemployment insurance also implies that households earn the same amount $W_t h N_t$.

We can now define a representative household, with the following utility function and instantaneous budget constraint:

$$u(C_t, h_t, N_t) = \frac{C_t^{1-\sigma}}{1-\sigma} + N_t \frac{\xi_1}{1-\eta} (1-h_t)^{1-\eta} + (1-N_t) \frac{\xi_2}{1-\eta} (1)^{1-\eta} \quad (13)$$

and

$$\begin{aligned} S_t D_{t+1}^d - B_{t+1}^d + (1+i_t)B_t - (1+i_t^*)S_{t-1}D_t - P_t C_t \\ + W_t h_t N_t + T_t + \Pi_t - P_t \frac{\psi_d}{2} \left(\frac{D_{t+1}^d S_t}{P_t} - \bar{d} \right)^2 = 0 \end{aligned}$$

¹The government gives lump sum monetary transfers T_t to the households. These transfers are financed by issuing non-contingent bonds. The government budget constraint is given by :

$$\frac{B_{t+1}}{1+i_t} - B_t - T_t = 0$$

B_t is the government bonds stock at the beginning of period t and i_t is the government bonds interest determined by the monetary authorities.

Finally, T_t will adjust in order to satisfy the government budget constraint.

The last term in the above budget constraint is a portfolio adjustment cost². C_t is the aggregate consumption and is given by :

$$C_t = \left(\frac{C_{N,t}}{a} \right)^a \left(\frac{C_{M,t}}{1-a} \right)^{1-a} \quad \text{with } a \in]0, 1[\quad (14)$$

where $C_{N,t}$ is the consumption of non-traded goods and $C_{M,t}$ is the consumption of imported goods.

The household demand and the aggregate price are :

$$C_{N,t} = a \frac{P_{N,t}}{P_t} C_t \quad (15)$$

$$C_{M,t} = (1-a) \frac{P_{M,t}}{P_t} C_t \quad (16)$$

$$1 = \left(\frac{P_{N,t}}{P_t} \right)^a \left(\frac{P_{M,t}}{P_t} \right)^{1-a} \quad (17)$$

The household takes for granted the probability ψ_t of finding a job. The employment evolution equation relevant at the household level is :

$$N_{t+1} = (1-s)N_t + \psi_t(1-N_t)$$

The representative household maximizes its expected intertemporal discounted utility subject to the budget constraint and the employment evolution equation. The program writes :

$$\begin{aligned} \max_{\mathbf{C}_t} E_0 \sum_{t=1}^{\infty} \beta^t & \left[\frac{C_t^{1-\sigma}}{1-\sigma} + N_t \frac{\xi_1}{1-\eta} (1-h_t)^{1-\eta} + (1-N_t) \frac{\xi_2}{1-\eta} (1)^{1-\eta} \right] \\ \text{s.t.} & \begin{cases} S_t D_{t+1}^d - B_{t+1}^d + (1+i_t)B_t - (1+i_t^*)S_{t-1}D_t - P_t C_t \\ + W_t h_t N_t + T_t + \Pi_t - P_t \frac{\psi_d}{2} \left(\frac{D_{t+1}^d S_t}{P_t} - \bar{d} \right)^2 = 0 \\ (1-s)N_t + \psi_t(1-N_t) - N_{t+1} = 0 \end{cases} \end{aligned}$$

where $\mathbf{C}_t = (C_t, B_{t+1}^d, D_{t+1}^d)$ and $\beta \in]0, 1[$ is the discount factor.

The household program may be written as a recursive maximization problem and gives:

²Following [?], the portfolio adjustment cost allows to avoid the unit root problem in a small open economy.

$$V^H(\Theta_t) = \max_{C_t} \left\{ \frac{C_t^{1-\sigma}}{1-\sigma} + N_t \frac{\xi_1}{1-\eta} (1-h_t)^{1-\eta} + (1-N_t) \frac{\xi_2}{1-\eta} (1)^{1-\eta} + \beta E_t V^H(\Theta_{t+1}) \right\}$$

$$\text{s.t.} \begin{cases} S_t D_{t+1}^d - B_{t+1}^d + (1+i_t)B_t - (1+i_t^*)S_{t-1}D_t - P_t C_t \\ + W_t h_t N_t + T_t + \Pi_t - P_t \frac{\psi_d}{2} \left(\frac{D_{t+1}^d S_t}{P_t} - \bar{d} \right)^2 = 0 \quad (x_t) \\ (1-s)N_t + \psi_t(1-N_t) - N_{t+1} = 0 \quad (y_t) \end{cases}$$

with the state vector variables $\Theta_t = (B_t, D_t, N_t)$.

Let define $\lambda_t = x_t P_t$ and the inflation rate $1 + \pi_t = \frac{P_t}{P_{t-1}}$. The optimality conditions are given by:

$$C_t^{-\sigma} - \lambda_t = 0 \quad (18)$$

$$\lambda_t - \beta E_t \left\{ \left(\frac{1+i_{t+1}}{1+\pi_{t+1}} \right) \lambda_{t+1} \right\} = 0 \quad (19)$$

$$\lambda_t - \beta E_t \left\{ \left(\frac{1+i_{t+1}^*}{1+\pi_{t+1}} \right) \frac{S_{t+1}}{S_t} \lambda_{t+1} \right\} - \lambda_t \psi_d \left(\frac{S_t D_{t+1}}{P_t} - \bar{d} \right) = 0 \quad (20)$$

The envelop condition employment writes:

$$D_3 V^H(\Theta_t) = \frac{\xi_1}{1-\eta} (1-h_t)^{1-\eta} - \frac{\xi_2}{1-\eta} + \lambda_t \frac{W_t}{P_t} h_t + (1-s-\psi_t) \beta E_t D_3 V^H(\Theta_{t+1}) \quad (21)$$

2.4 Firms

2.4.1 The intermediate goods sector

An intermediate good is produced by a representative firm through labor. The production technology is represented by the following function :

$$H_t = A_H (h_t N_t)^\alpha - \omega V_t \quad \text{with } \alpha \in]0, 1[\quad (22)$$

H_t is the amount of intermediate goods produced, $h_t N_t$ is the labor input and A_H is a scale parameter.

The intermediate good is sold both to the firms producing the non-traded final goods and to the export goods. Let $P_{H,t}$ be the price of a unit of intermediate good and W_t the nominal wage. Prior to hiring a worker, the firm must post a vacant job. Posting a vacancy incurs in a cost ω expressed in terms of intermediate good. A vacant job is filled with a probability Φ_t which is taken as given by the firm. The employment evolution followed by the firm is thus:

$$N_{t+1} = (1-s)N_t + \phi_t V_t \quad (23)$$

The manager of the firm has to choose a sequence of vacancies and a sequence of employments that maximize the expected discount profit flows. The problem of the firm is as follows :

$$\max_{\mathbf{D}_t} E_0 \sum_{t=1}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left[\frac{P_{H,t}}{P_t} (A_H (h_t N_t)^\alpha - \omega V_t) - \frac{W_t}{P_t} h_t N_t \right]$$

$$\text{s.t. } (1-s)N_t + \phi_t V_t - N_{t+1} = 0$$

where $\mathbf{D}_t = (N_{t+1}, V_t)$. The intermediate goods' market is competitive. The firm takes the prices as given. Wages W_t and the working time h_t will also be given and will be determined through a Nash bargaining process.

The above problem can be rewritten recursively as follows :

$$V^I(\Delta_t) = \max_{\mathbf{D}_t} \left\{ \frac{P_{H,t}}{P_t} (A_H (h_t N_t)^\alpha - \omega V_t) - \frac{W_t}{P_t} h_t N_t + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} V^I(\Delta_{t+1}) \right) \right\}$$

$$\text{s.t. } (1-s)N_t + \phi_t V_t - N_{t+1} = 0 \quad (q_t)$$

with the state vector variables $\Delta_t = (N_t)$.

We obtain the following set of optimality conditions:

$$D_1 V^I(\Delta_t) = \frac{P_{H,t}}{P_t} \alpha A_H h_t (h_t N_t)^{\alpha-1} - \frac{W_t}{P_t} h_t + (1-s) \frac{P_{H,t}}{P_t} \frac{\omega}{\phi_t} \quad (24)$$

$$\lambda_t \frac{P_{H,t}}{P_t} \frac{\omega}{\phi_t} - \beta E_t \left\{ \lambda_{t+1} \left(\frac{P_{H,t+1}}{P_{t+1}} A_H \alpha h_{t+1} (h_{t+1} N_{t+1})^{\alpha-1} - \frac{W_{t+1}}{P_{t+1}} h_{t+1} + (1-s) \frac{P_{H,t+1}}{P_{t+1}} \frac{\omega}{\phi_{t+1}} \right) \right\} = 0 \quad (25)$$

2.4.2 Wage and hours determination

Wage and hours are determined through a Nash bargaining process. When a match is done, the worker and the employer bargain to share the joint surplus of the match. The marginal value of employment (equation 21) will lead us to the household's expected return (in terms of utility) of the job, whereas the intermediate goods' firm's marginal value of employment (equation 24) leads us to the firm's expected return from a job. Thus, the joint surplus of a new job, in terms of utility, is given by $D_3 V^H(\Theta_t) + \lambda_t D_1 V^I(\Delta_t)$. The outcome of the bargaining process is given by the solution of the following maximization problem :

$$\max_{W_t, h_t} (D_3 V^H(\Theta_t))^{1-\gamma} (\lambda_t D_1 V^I(\Delta_t))^\gamma$$

We deduce that the hourly real wage and the amount of worked hours are given by :

$$\lambda_t \frac{W_t}{P_t} h_t = (1 - \gamma) \lambda_t \left(\frac{P_{H,t}}{P_t} A_H \alpha h_t (h_t N_t)^{\alpha-1} + \psi_t \frac{P_{H,t}}{P_t} \frac{\omega}{\phi_t} \right) + \gamma \left(\xi_1 \frac{(1 - h_t)^{1-\eta}}{1 - \eta} - \frac{\xi_2}{1 - \eta} \right) \quad (26)$$

$$\xi_1 (1 - h_t)^{-\eta} = \lambda_t \frac{P_{H,t}}{P_t} A_H \alpha (h_t N_t)^{\alpha-1} \quad (27)$$

2.4.3 The non-traded goods sector

There is a continuum of non-traded goods indexed by $z \in [0, 1]$. Each good z is produced by a unique firm also indexed by z . Each firm produces final goods with a single input, which are the intermediate goods. The production technology is linear in the intermediate goods. That is :

$$Y_{N,t}(z) = A_N H_{N,t}(z)$$

where $Y_{N,t}$ is the amount of goods z produced by the firm, $H_{N,t}(z)$ is the amount of intermediate goods used in the production process and A_N is a scale parameter.

The non-traded goods' market is monopolistic in the line of Blanchard and Kiyotaki (1987). The consumption of goods z is denoted by $C_{N,t}(z)$. Let $C_{N,t}$ represent the aggregate consumption of non-traded goods. The aggregation technology implies :

$$C_{N,t} = \left(\int_0^1 C_{N,t}(z)^{\frac{\lambda-1}{\lambda}} dz \right)^{\frac{\lambda}{\lambda-1}} \quad (28)$$

$\lambda > 0$ is the elasticity of substitution between the differentiated goods. Let $P_{N,t}(z)$ be the differentiated goods' z price and $P_{N,t}$ the aggregate goods' price. The household's demand for goods z is :

$$C_{N,t}(z) = \left(\frac{P_{N,t}(z)}{P_{N,t}} \right)^{-\lambda} C_{N,t}$$

The aggregate price index P_t is given by :

$$P_{N,t} = \left(\int_0^1 P_{N,t}(z)^{1-\lambda} dz \right)^{\frac{1}{1-\lambda}}$$

A firm z faces a demand constraint given by :

$$Y_{N,t}(z) \leq C_{N,t}(z) = \left(\frac{P_{N,t}(z)}{P_{N,t}} \right)^{-\lambda} C_{N,t}$$

where $C_{N,t}(z)$ is the maximum demand addressed to the firm z .

Even though firms choose their prices optimally, we suppose a stochastic price adjustment scheme in the line of Calvo (1983). At each date, a firm can choose to optimally adjust its price with probability $1 - \kappa$. Moreover, $1 - \kappa$ also represents the proportion of firms, at each date, that optimally adjust their prices. On the other hand, non-adjusting firms will increase their prices at a rate equal to π_N .

It is worthwhile to introduce the following notations: $P_{N,t}(z)$, the price billed by the firm z at date t is denoted $P_{N,t}^t(z)$ had the firm optimally adjusted today. If the firm z does not optimally adjust today but adjusted j periods ago, the price billed is denoted $P_{N,t}^{t-j}(z)$ with $P_{N,t}^{t-j}(z) = (1 + \pi_N)P_{N,t-1}^{t-j}(z)$.

Firms maximize the present discount value of their profits. Instantaneous profits are $P_{N,t}(z)Y_{N,t}(z) - P_{H,t}H_{N,t}(z)$. The firms' discount rate is as follows :

$$R_{t+1/t}(z) = \beta \frac{x_{t+1}}{x_t} = \beta \frac{1}{1 + \pi_{t+1}} \frac{\lambda_{t+1}}{\lambda_t}$$

Let ϑ_t^{t-j} represent the value of a firm that has optimally adjusted its price j periods ago. The problem of an adjusting firm takes the following recursive form :

$$\begin{aligned} \vartheta_t^t(z) = & \max_{P_{N,t}^t(z)} \left\{ P_{N,t}^t(z)Y_{N,t}^t(z) - P_{H,t}H_{N,t}^t(z) \right. \\ & \left. + \beta E_t \left[\frac{1}{1 + \pi_{t+1}} \frac{\lambda_{t+1}}{\lambda_t} \left((1 - \kappa)\vartheta_{t+1}^{t+1}(z) + \kappa\vartheta_{t+1}^t(P_{N,t+1}^t(z)) \right) \right] \right\} \\ \text{s.t. } & \begin{cases} Y_{N,t}^t(z) = \left(\frac{P_{N,t}^t(z)}{P_{N,t}} \right)^{-\varepsilon} C_{N,t} \\ Y_{N,t}^t(z) = A_N H_{N,t}^t(z) \\ P_{N,t+1}^t(z) = (1 + \pi_N)P_{N,t}^t(z) \end{cases} \end{aligned}$$

Finally, the value of a non-adjusting firm writes :

$$\begin{aligned} \vartheta_t^{t-j}(P_{N,t}^{t-j}(z)) = & P_{N,t}^{t-j}(z)Y_{N,t}^{t-j}(z) - P_{H,t}H_{N,t}^{t-j}(z) \\ & + \beta E_t \left[\frac{1}{1 + \pi_{t+1}} \frac{\lambda_{t+1}}{\lambda_t} \left((1 - \kappa)\vartheta_{t+1}^{t+1}(z) + \kappa\vartheta_{t+1}^{t-j}(P_{N,t+1}^{t-j}(z)) \right) \right] \\ \text{with } & \begin{cases} Y_{N,t}^{t-j}(z) = \left(\frac{P_{N,t}^{t-j}(z)}{P_{N,t}} \right)^{-\varepsilon} C_t \\ Y_{N,t}^{t-j}(z) = A_N H_{N,t}^{t-j}(z) \\ P_{N,t+1}^{t-j}(z) = (1 + \pi_N)P_{N,t}^{t-j}(z) \end{cases} \end{aligned}$$

The optimality condition that determines the optimal price $\frac{P_{N,t}^t(z)}{P_{N,t}}$ takes the

following recursive form :

$$Q_{N,t} = \frac{1}{A_N} \frac{W_t}{P_t} \frac{P_t}{P_{N,t}} C_{N,t} + \kappa \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{(1 + \pi_N)^{1-\lambda} (1 + \pi_{N,t+1})^\lambda}{1 + \pi_{t+1}} Q_{N,t+1} \right\} \quad (29)$$

$$R_{N,t} = C_{N,t} + \kappa \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{(1 + \pi_N)^{-\lambda} (1 + \pi_{N,t+1})^{\lambda+1}}{1 + \pi_{t+1}} R_{t+1} \right\} \quad (30)$$

with :

$$\frac{P_{N,t}^t}{P_{N,t}} = \frac{\lambda}{\lambda - 1} \frac{Q_{N,t}}{R_{N,t}} \quad (31)$$

At the date t , $1 - \kappa$ firms adjust their prices, $\kappa(1 - \kappa)$ adjusted their prices one period and more generally, $\kappa^j(1 - \kappa)$ firms adjusted their prices j periods ago. The expression that gives the aggregate price can then be computed :

$$\begin{aligned} P_{N,t}^{1-\lambda} &= \int_0^1 P_{N,t}(z)^{1-\varepsilon} dz = \sum_{j=0}^{\infty} (1 - \kappa) \kappa^j P_{N,t}^{t-j} 1^{-\lambda} \\ &= (1 - \kappa) P_{N,t}^{1-\lambda} + \kappa (1 + \pi_N)^{1-\lambda} P_{N,t-1}^{1-\lambda} \end{aligned}$$

That is :

$$1 = (1 - \kappa) \left(\frac{P_{N,t}^t}{P_{N,t}} \right)^{1-\lambda} + \kappa (1 + \pi_N)^{1-\lambda} (1 + \pi_{N,t})^{\lambda-1} \quad (32)$$

2.4.4 The export goods sector

There is an export good ($Y_{X,t}$) produced with both the domestic intermediate goods ($H_{X,t}$) and the imported intermediate goods ($I_{M,t}$). The production technology has a constant-elasticity-of-substitution and is given by :

$$Y_{X,t} = \left[\vartheta (A_X H_{X,t}^{\frac{\varphi-1}{\varphi}} + (1 - \vartheta) (I_{M,t}^{\frac{\varphi-1}{\varphi}}) \right]^{\frac{\varphi}{\varphi-1}} \quad (33)$$

with $\vartheta, \varphi \in]0, 1[$ and $A_X > 0$.

Let $P_{X,t}$ and $P_{1M,t}$ be, respectively, the price of the export goods and the price of the imported intermediate goods (in domestic currency). The firm is in a competitive environment, it thus takes as given the input prices and the export goods' price. The optimality conditions of the profit maximization problem of the firm may be written as follows :

$$\frac{P_{X,t}}{P_t} \vartheta A_X \left(\frac{Y_{X,t}}{A_X H_{X,t}} \right)^{\frac{1}{\varphi}} = \frac{W_t}{P_t} \quad (34)$$

$$(1 - \vartheta) \left(\frac{Y_{X,t}}{I_{M,t}} \right)^{\frac{1}{\varphi}} = \frac{P_{1M,t}^*}{P_{X,t}^*} \quad (35)$$

2.4.5 The import consumption goods and local pricing

As for the non-traded goods, there is a continuum of import consumption goods indexed by $z \in [0, 1]$. In the foreign country, the price of a unit of good z is $P_{M,t}^*$. Note that in the foreign country, the price of a unit of good will thus not depend on the type z of the good. For each good z , there is a local retailer importing the goods z at price $P_{M,t}^* S_t$. Let $Y_{M,t}(z)$ be the amount of goods z imported by the retailer.

The local import goods market is monopolistic. The consumption of goods z is denoted by $C_{M,t}(z)$. Let $C_{M,t}$ be the aggregate consumption of import goods. The aggregation technology provides :

$$C_{M,t} = \left(\int_0^1 C_{M,t}(z)^{\frac{\lambda-1}{\lambda}} dz \right)^{\frac{\lambda}{\lambda-1}}$$

$\lambda > 0$ is the elasticity of substitution between the differentiated goods. Let $P_{M,t}(z)$ be the differentiated goods' z price and $P_{M,t}$ the aggregate goods' price. The household's demand for goods z is :

$$C_{M,t}(z) = \left(\frac{P_{M,t}(z)}{P_{M,t}} \right)^{-\lambda} C_{M,t}$$

The aggregate price index $P_{M,t}$ is :

$$P_{M,t} = \left(\int_0^1 P_{M,t}(z)^{1-\lambda} dz \right)^{\frac{1}{1-\lambda}}$$

A firm z faces a demand constraint given by :

$$Y_{M,t}(z) \leq C_{M,t}(z) = \left(\frac{P_{M,t}(z)}{P_{M,t}} \right)^{-\lambda} C_{M,t}$$

where $C_{M,t}(z)$ is the maximum demand addressed to the firm z .

In relation to the non-traded goods' price setting, we suppose a stochastic price adjustment scheme. At each date, a firm will be allowed to optimally adjust its price with probability $1 - \kappa^*$. At each date $1 - \kappa^*$ also represents the proportion of firms that optimally adjust their prices. The firms who do not optimally adjust prices increase their prices at a rate equal to π_M .

The price billed by a firm that optimally adjusts itself at date t is denoted $P_{M,t}^t(z)$. Finally, the price billed by a firm that optimally adjusted itself j periods ago is denoted $P_{M,t}^{t-j}(z)$ with $P_{M,t}^{t-j}(z) = (1 + \pi_M) P_{M,t-j}^{t-j}(z)$.

Firms maximize the present discount value of their profits. Instantaneous profits are $P_{M,t}(z) Y_{M,t}(z) - P_{M,t}^* S_t Y_{M,t}(z)$. The firm's discount rate writes as follows :

$$R_{t+1/t}(z) = \beta \frac{x_{t+1}}{x_t} = \beta \frac{1}{1 + \pi_{t+1}} \frac{\lambda_{t+1}}{\lambda_t}$$

Let Υ_t^{t-j} be the value of a firm that has optimally adjusted its price j periods ago. The problem of an adjusted firm takes the following recursive form :

$$\begin{aligned} \Upsilon_t^t(z) &= \max_{P_{M,t}^t(z)} \left\{ P_{M,t}^t(z) Y_{M,t}^t(z) - P_{M,t}^* S_t Y_{M,t}^t(z) \right. \\ &\quad \left. + \beta E_t \left[\frac{1}{1 + \pi_{t+1}} \frac{\lambda_{t+1}}{\lambda_t} \left((1 - \kappa^*) \Upsilon_{t+1}^{t+1}(z) + \kappa^* \Upsilon_{t+1}^t(P_{M,t+1}^t(z)) \right) \right] \right\} \\ \text{s.t. } &\begin{cases} Y_{M,t}^t(z) = \left(\frac{P_{M,t}^t(z)}{P_{M,t}} \right)^{-\varepsilon} C_{M,t} \\ P_{M,t+1}^t(z) = (1 + \pi_M) P_{M,t}^t(z) \end{cases} \end{aligned}$$

Finally, the value of a non-adjusted firm writes :

$$\begin{aligned} \Upsilon_t^{t-j}(P_{M,t}^{t-j}(z)) &= P_{M,t}^{t-j}(z) Y_{M,t}^{t-j}(z) - P_{M,t}^* S_t Y_{M,t}^{t-j}(z) \\ &\quad + \beta E_t \left[\frac{1}{1 + \pi_{t+1}} \frac{\lambda_{t+1}}{\lambda_t} \left((1 - \kappa^*) \Upsilon_{t+1}^{t+1}(z) + \kappa^* \Upsilon_{t+1}^{t-j}(P_{M,t+1}^{t-j}(z)) \right) \right] \\ \text{with } &\begin{cases} Y_{M,t}^{t-j}(z) = \left(\frac{P_{M,t}^{t-j}(z)}{P_{M,t}} \right)^{-\varepsilon} C_{M,t} \\ P_{M,t+1}^{t-j}(z) = (1 + \pi_M) P_{M,t}^{t-j}(z) \end{cases} \end{aligned}$$

The optimality condition that determines the optimal price $\frac{P_{M,t}^t(z)}{P_{M,t}}$ takes the following recursive form :

$$Q_{M,t} = \frac{P_{X,t}}{P_t} \frac{P_t}{P_{M,t}} \frac{P_{M,t}^*}{P_{X,t}^*} C_{M,t} + \kappa^* \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{(1 + \pi_M)^{1-\lambda} (1 + \pi_{M,t+1})^\lambda}{1 + \pi_{t+1}} Q_{M,t+1} \right\} \quad (36)$$

$$R_{M,t} = C_{M,t} + \kappa^* \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{(1 + \pi_M)^{-\lambda} (1 + \pi_{M,t+1})^{\lambda+1}}{1 + \pi_{t+1}} R_{M,t+1} \right\} \quad (37)$$

with :

$$\frac{P_{M,t}^t}{P_{M,t}} = \frac{\lambda}{\lambda - 1} \frac{Q_{M,t}}{R_{M,t}}$$

At date t , $1 - \kappa^*$ firms adjust their prices, $\kappa^*(1 - \kappa^*)$ adjusted their prices one period ago and more generally, $\kappa^{*j}(1 - \kappa^*)$ firms adjusted their prices j periods ago. The expression that gives the aggregate price can then be computed :

$$\begin{aligned} P_{M,t}^{1-\lambda} &= \int_0^1 P_{M,t}(z)^{1-\varepsilon} dz = \sum_{j=0}^{\infty} (1 - \kappa^*) \kappa^{*j} P_{M,t}^{t-j} 1^{1-\lambda} \\ &= (1 - \kappa^*) P_{M,t}^{t-1-\lambda} + \kappa^* (1 + \pi_M)^{1-\lambda} P_{M,t-1}^{1-\lambda} \end{aligned}$$

That is :

$$1 = (1 - \kappa^*) \left(\frac{P_{M,t}^t}{P_{M,t}} \right)^{1-\lambda} + \kappa^* (1 + \pi_M)^{1-\lambda} (1 + \pi_{M,t})^{\lambda-1}$$

2.5 The equilibrium

2.5.1 Market clearing condition

Market clearing conditions on government bonds market, foreign bonds market (debt), intermediate goods market and non-traded goods markets are given by :

$$B_{t+1} = B_{t+1}^d \quad (38)$$

$$D_{t+1} = D_{t+1}^d \quad (39)$$

$$H_t = H_{X,t} + H_{N,t} \text{ with } H_{N,t} = \int_0^1 H_{N,t}(z) dz \quad (40)$$

$$Y_{N,t}(z) = C_{N,t}(z) \forall z \in [0, 1] \quad (41)$$

2.5.2 Price distortions

Considering the non-traded goods' production technologies and the market equilibrium conditions, the following equality is obtained :

$$\int_0^1 Y_{N,t}(z) dz = A_N \int_0^1 H_{N,t}(z) dz = A_N H_{N,t}$$

substituting $Y_{N,t}(z) = \left(\frac{P_{N,t}(z)}{P_{N,t}}\right)^{-\lambda} C_{N,t}$ in the above equation gives :

$$C_{N,t} \int_0^1 P_{N,t}^\lambda P_{N,t}(z)^{-\lambda} dz = A_N H_{N,t}$$

Defining the distortion index $D_{N,t} \equiv \int_0^1 P_{N,t}^\lambda P_{N,t}(z)^{-\lambda} dz$ we can now rewrite the above expression as :

$$C_{N,t} D_{N,t} = A_N H_{N,t}$$

The distortion index (non-traded goods prices) takes the following recursive form :

$$\begin{aligned} D_{N,t} &= \int_0^1 P_{N,t}^\lambda P_{N,t}(z)^{-\lambda} dz = \sum_{j=0}^{\infty} (1 - \kappa) \kappa^j P_{N,t}^\lambda P_{N,t}^{t-j-\lambda} \\ &= (1 - \kappa) \left(\frac{P_{N,t}^t}{P_{N,t}}\right)^{-\lambda} + \kappa (1 + \pi_N)^{-\lambda} (1 + \pi_{N,t})^\lambda D_{N,t-1} \end{aligned} \quad (42)$$

Finally, we can define a distortion index of the the import consumption goods' prices: $D_{M,t} \equiv \int_0^1 P_{M,t}^\lambda P_{M,t}(z)^{-\lambda} dz$. It takes the following recursive form :

$$D_{M,t} = (1 - \kappa^*) \left(\frac{P_{M,t}^t}{P_{M,t}} \right)^{-\lambda} + \kappa^* (1 + \pi_M)^{-\lambda} (1 + \pi_{M,t})^\lambda D_{M,t-1} \quad (43)$$

and satisfies :

$$\int_0^1 C_{M,t}(z) dz = \int_0^1 \left(\frac{P_{M,t}(z)}{P_{M,t}} \right)^{-\lambda} C_{M,t} dz = C_{M,t} D_{M,t}$$

2.5.3 Debt evolution

Using household budget constraint, the government budget constraint and the market clearing conditions, we get :

$$S_t D_{t+1} - (1 + i_t^*) S_{t-1} D_t - P_t C_t + W_t h_t N_t + \Pi_t - P_t \frac{\psi_d}{2} \left(\frac{D_{t+1} S_t}{P_t} - \bar{d} \right)^2 = 0$$

The total profit Π_t distributed to the household is the sum of the profits made by the different firms, that is : $\Pi_t = \Pi_{H,t} + \Pi_{N,t} + \Pi_{X,t} + \Pi_{M,t}$. Note that $\Pi_{H,t}$, $\Pi_{X,t}$, $\Pi_{N,t}$ and $\Pi_{M,t}$ represent, respectively, the profits of the intermediate goods' firm, the export goods' firm, the non-traded goods' firms and the import consumption goods' retailers. They satisfy :

$$\begin{aligned} \Pi_{H,t} &= P_{H,t}(H_{X,t} + H_{N,t}) - P_{H,t}\omega V_t - W_t h_t N_t \\ \Pi_{X,t} &= P_{X,t} Y_{X,t} - W_t H_{X,t} - P_{1M,t} I_{M,t} = 0 \\ \Pi_{N,t} &= \int_0^1 \Pi_{N_t}(z) dz = P_{N,t} C_{N,t} - W_t H_{N,t} \\ \Pi_{M,t} &= \int_0^1 \Pi_{M_t}(z) dz = P_{M,t} C_{M,t} - S_t P_{M,t}^* \int_0^1 C_{M_t}(z) dz \\ &= P_{M,t} C_{M,t} - S_t P_{M,t}^* C_{M,t} D_{M,t} \end{aligned}$$

Substituting in the household budget constraint provides :

$$\begin{aligned} & - \frac{S_t D_{t+1}}{P_t} + \frac{1 + i_t^*}{1 + \pi_t} \frac{S_t}{S_{t-1}} \frac{S_{t-1} D_t}{P_{t-1}} - \left(\frac{P_{X,t}}{P_t} Y_{X,t} - \frac{P_{X,t}}{P_t} \frac{P_{1M,t}^*}{P_{X,t}^*} I_{M,t} - \frac{P_{X,t}}{P_t} \frac{P_{M,t}^*}{P_{X,t}^*} C_{M,t} D_{M,t} \right) \\ & + \frac{\psi_d}{2} \left(\frac{S_t D_{t+1}}{P_t} - \bar{d} \right)^2 = 0 \end{aligned} \quad (44)$$

2.5.4 Definition of the equilibrium

Before defining the equilibrium, it is necessary to give some caveats concerning the law of motion of prices. The aggregate consumption good is taken as currency. All the prices are thus deflated by P_t . Relative prices evolve according to the following law of motion :

$$\frac{P_{N,t}}{P_t} = \frac{1 + \pi_{N,t}}{1 + \pi_t} \frac{P_{N,t-1}}{P_{t-1}} \quad (45)$$

$$\frac{P_{M,t}}{P_t} = \frac{1 + \pi_{M,t}}{1 + \pi_t} \frac{P_{M,t-1}}{P_{t-1}} \quad (46)$$

$$(1 + \pi_t) \frac{P_{X,t}}{P_t} \frac{P_{t-1}}{P_{X,t-1}} = \frac{S_t}{S_{t-1}} \pi^* \exp(v_{P^*,t}) \quad (47)$$

Definition 1 We define the competitive equilibrium as a sequence of prices and quantities $\frac{S_{t-1}D_t}{P_{t-1}}, \frac{S_t}{S_{t-1}}, \frac{P_{X,t}}{P_t}, \frac{P_{N,t}}{P_t}, \frac{P_{M,t}}{P_t}, \frac{W_t}{P_t}, \frac{P_{H,t}}{P_t}, \pi_t, \pi_{N,t}, \pi_{M,t}, Y_{X,t}, C_t, C_{N,t}, C_{M,t}, I_{M,t}, V_t, N_t, h_t, H_t, H_{X,t}, H_{N,t}, \phi_t, \psi_t, D_{N,t-1}, D_{M,t-1}, R_{N,t}, Q_{N,t}, R_{M,t}, Q_{M,t}, \frac{P_{N,t}^*}{P_t}, \frac{P_{M,t}^*}{P_t}, \lambda_t$ satisfying equations 11-12, 15-17, 18-20, 22, 23, 25, 26-27, 29-31, 32,33, 34-35, 36-38, 39, 40, 41, 42, 43, 44 and 45-47, for a given interest rate process i_t and for a given exogeneous stochastic process $\frac{P_{X,t}^*}{P_{M,t}^*}, \frac{P_{X,t}}{P_{1M,t}^*}, i_t^*, v_t, v_{M,t}, v_{1M,t}$ and $v_{P^*,t}$ [equations 1, 4, 7 and 8],

2.5.5 Monetary policy rules

The monetary authority chooses the short-run interest rate i_t . We study the dynamic and quantitative properties of the model under two alternative interest rate determinations. The monetary authority may follow a feedback rule or solve a Ramsey problem providing an optimal sequence of interest rate.

The Taylor rule The monetary authority follows a feedback rule given by :

$$1 + i_{t+1} = \left(\frac{1 + \pi_t}{1 + \bar{\pi}} \right)^{\mu_\pi} \left(\frac{C_t}{\bar{C}} \right)^{\mu_Y} \left(\frac{S_t}{\bar{S}} \right)^{\mu_S} (1 + \bar{i}) \quad (48)$$

where \bar{i} , $\bar{\pi}$, \bar{S} and \bar{C} are respectively the steady state values of the domestic interest rate, the inflation rate, the nominal exchange rate and consumption.

Parameters μ_π , μ_Y and μ_S denote, respectively, the degree to which the monetary authority tries to control variations in inflation, the output and the exchange rate. In order to avoid indeterminacy, μ_π and μ_Y will take the traditional values of 0.5 and 1.5. Parameter μ_S plays an important role and experiments will be made with different values. Three critical values will be considered. If $\mu_S = 0$, the monetary authority does not try to stabilize the nominal exchange rate (floating exchange rate). Conversely, if $\mu_S \rightarrow \infty$, the authorities fully stabilize the exchange rate (fix exchange rate). Finally, we will consider a case with $\mu_S = 1$ corresponding to an intermediary regime.

The Ramsey equilibrium The Ramsey policy is the monetary policy under commitment that maximizes the intertemporal welfare of the representative household.

Definition 2 *The Ramsey equilibrium is a sequence of prices and quantities $i_t, \frac{S_{t-1}D_t}{P_{t-1}}, \frac{S_t}{S_{t-1}}, \frac{P_{X,t}}{P_t}, \frac{P_{N,t}}{P_t}, \frac{P_{M,t}}{P_t}, \frac{W_t}{P_t}, \frac{P_{H,t}}{P_t}, \pi_t, \pi_{N,t}, \pi_{M,t}, Y_{X,t}, C_t, C_{N,t}, C_{M,t}, I_{M,t}, V_t, N_t, h_t, H_t, H_{X,t}, H_{N,t}, \phi_t, \psi_t, D_{N,t-1}, D_{M,t-1}, R_{N,t}, Q_{N,t}, R_{M,t}, Q_{M,t}, \frac{P_{N,t}^t}{P_t}, \frac{P_{M,t}^t}{P_t}, \lambda_t$ maximizing the representative agent life-time utility :*

$$E_t \sum_{j=0}^{\infty} \beta^j \left[\frac{C_{t+j}^{1-\sigma}}{1-\sigma} + N_{t+j} \frac{\xi_1}{1-\eta} (1-h_{t+j})^{1-\eta} + (1-N_{t+j}) \frac{\xi_2}{1-\eta} \right]$$

subject to the equilibrium conditions 11-12, 15-17, 18-20, 22, 23, 25, 26-27, 29-31, 32, 33, 34-35, 36-38, 39, 40, 41, 42, 43, 44 and 45-47 and given the exogenous stochastic processes $\frac{P_{X,t}^}{P_{M,t}^*}, \frac{P_{X,t}^*}{P_{1M,t}^*}, i_t^*, v_t, v_{M,t}, v_{1M,t}$ and $v_{P^*,t}$ [equations 1, 4, 7 and 8].*

We assume that the government chooses the optimal policy respecting past commitments. Thus, following Woodford (2003), we compute the timeless optimal monetary policy.

3 Calibration

Since there are no analytical solutions, we use a linear approximation of the model around the deterministic steady state in order to assess the predictions of the model. The calibration of the model is described in Table 1 and tries to replicate the behavior of Latin American countries and, where possible, to match the empirical regularities of Argentina. Because of the lack of data for these economies we have in some cases been forced to use a standard calibration.

As far as the consumptions goes, it is assumed that the intertemporal elasticity of the substitution in consumption is 0.5 (which implies $\sigma = 2$). This calibration is within the range of the literature. Following Devereux et al. (2006), we set the elasticity of the substitution between non-traded and imported goods in consumption to unity. The parameter a corresponds to the share of the non-traded goods in the consumer price index. Following Gumus (2005) we found that the average share of non-traded goods in the total household consumption expenditures in Argentina was of 71% during the period 1980–98.

The elasticity of labor supply is also set to unity, following Christiano et al. (1997) and set h to 1/3, and $\psi = 2$ for elasticity 1. In addition, the elasticity of substitution between varieties of non-tradable goods determines the average price/cost mark-up in the non-tradable sector. We follow standard estimates from the literature in setting a 10% mark-up, so that $\lambda = 11$. (we assume the same value for the elasticity of substitution between varieties of imports).

The usual assumption of a steady state with zero consumption growth leads us to a world interest rate equal to the rate of time preference. We set the world

| Description | Parameter | Value |
|---|------------|----------|
| Discount factor | β | 0.99 |
| Inverse of elasticity of substitution in consumption | σ | 2 |
| Inverse of Intertemporal elasticity of leisure | ψ | 2 |
| Elasticity of substitution between non-traded goods and import goods in consumption | ρ | 1 |
| Elasticity of substitution between varieties of goods (same across sectors) | λ | 11 |
| Share on non-traded goods in the consumption price index | a | 0.71 |
| Probability that the price of import intermediary firms remains unchanged | κ^* | 0 - 0.75 |
| Bond adjustment cost | ψ_D | 0.0007 |
| Steady-state debt-GDP ratio | χ_2 | 0.32 |
| Share of consumption good in total imports | χ_3 | 0.28 |
| Labor Market | | |
| Vacancy cost parameter | τ_V | 0.05 |
| Bargaining Power of firms | θ | 0.5 |
| Bargaining Power of workers | γ | 0.5 |
| Elasticity in the matching Function | α | 0.64 |
| Job separation rate | s | 0.15 |
| Average Duration of a job vacancy (quarters) | ϕ_s | 0.6 |

Table 1: Calibration

interest rate equal to 4% annually - an approximate number used in the macro-RBC literature - so that, at the quarterly level, this implies a value of 0.99 for the discount factor. We set χ_2 so that the steady state debt is 32% of GDP to match the debt burden of Argentina. χ_3 represents the share of consumption goods in total imports. By fixing the ratio debt-GDP and the share of import goods in total imports we calculate the long term D , and the term of trade.

With respect to the bond adjustment cost we follow the estimate of Schmitt-Grohe and Uribe (2003) to set $\psi_D = 0.0007$.

The degree of nominal rigidity in the model is set by κ , the speed of adjustment in non-traded goods. We follow Devereux (2003) and set $\kappa = 0.75$ for a price-adjustment process of approximately four quarters. On the other hand, k^* represents the degree to which exchange rate and foreign prices shocks are passed through to imported domestic goods' prices.

As far the calibration of the labor market in emerging economies is concerned, there is almost no empirical literature that would allow us to thoroughly calibrate our model economy in order to match it with the Latin American data. Scale parameters ξ_1 and ξ_2 have been recalculated. The vacancy cost parameter ω_V , is set to 5% of intermediary good production, thus $\frac{\omega_V}{A_H(\bar{H}\bar{N})^\alpha} = 0,05$. We set $N = 87$ implying an unemployment rate of 13% for Argentina. We set the separation rate s to 0.1 and the elasticity of new matches with respect to the number of searching workers to be $\theta = 0.5$. Then, we set the probability ϕ that

a firm fills a vacancy to 0.6. The probability ψ that a worker finds a job is calculated from the steady state relationships to be equal to 0.25. These values imply that the average time in which a vacancy is filled and a worker finds a job are about 1.5 and 4 quarters, respectively. Finally, we obtain the value of the parameter from the steady state calculation. The lower is the value of the bargaining power η , the lower is the volatility of the bargained wage. Since the Hosios condition is satisfied, the bargaining powers γ and θ equal to 0.5.

4 External shocks under alternative monetary rules

In this section we explore the impact of the shocks under three alternative monetary rules that represent three exchange rate arrangements. We will also analyze the optimal response of the monetary authority in terms of the Ramsey allocation. We consider two types of shocks to this economy: world interest rate and terms of trade shocks. This is likely to be the best representation of the emerging markets' external environment.

4.1 Taylor's rules

4.1.1 Interest rate shocks

Figure 3 shows the dynamic response of the model economy to a foreign interest rate shock when the pass-through from the exchange rates to the imported goods' prices is delayed ($\kappa^* = 0.75$).

The response to a foreign interest rate shock generates both an internal and an external reallocation of resources. The interest rate shock reduces the domestic consumption, thus generating a trade balance surplus. The fall in absorption also induces a nominal exchange rate depreciation followed by a real exchange rate depreciation. This, in turn, leads to a reallocation of factors from the non-traded to the export goods' production. In consequence, there is both an internal and an external transfer. At the same time, the shock also impacts on the real economy by increasing the unemployment. This response-pattern is observed under the three types of monetary rule. These results are similar to those obtained by Devereux (2003) and Devereux et al. (2006). However, the magnitude of the response depends largely on the monetary rule followed by the monetary authority.

Evidently, the consumption falls much more under a pegged exchange rate or in the case of an intermediate exchange rate arrangement. With delayed pass-through, changes in exchange rates feed into the CPI only at the rate of an overall price adjustment. Under these two types of exchange rate regimes, the inflation rate is effectively stabilized. Thus, the real interest rate rises by

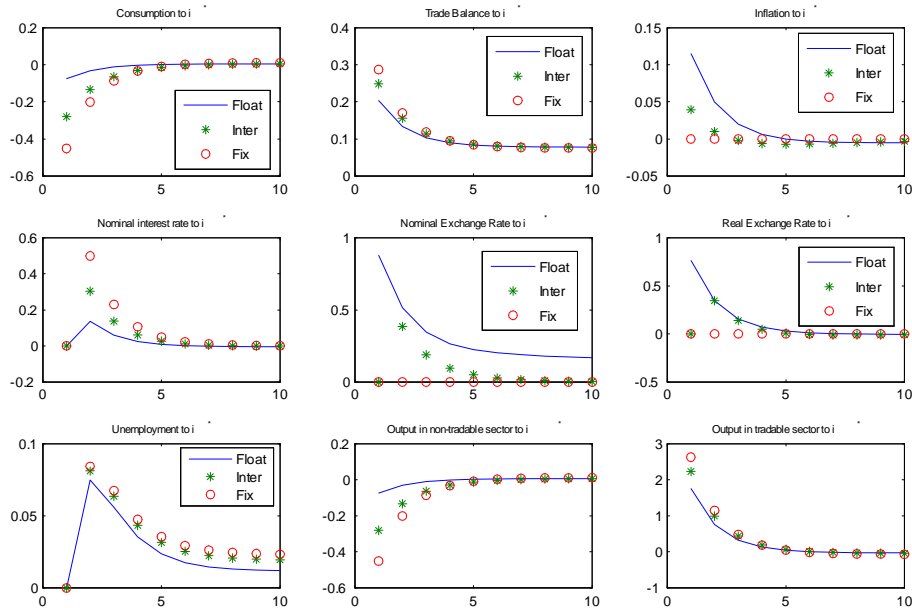


Figure 1: Impulse response to i^* : Delayed Pass-through

the same magnitude as the foreign interest shock. As far as the floating exchange rate is concerned, the nominal exchange rate movements help cushion the domestic economy and the real interest rate remains almost unchanged.

It should be noted that, since the exchange rate movements affect only gradually the domestic inflation, the impact on the internal relative prices reduces the degree of expenditure switching and leads to a smaller contraction in non-traded good's production. For the same reason, the lower response of inflation allows for a lower real interest rate response to the foreign interest rate shock.

Under this setup, the limited pass-through model delivers low aggregate inflation while still allowing a significant movement in the nominal exchange rate. This entails that the monetary authority's goal of price stability is consistent with a lower nominal and real interest rate response to the shock.

Figure 2 illustrates the case of a complete pass-through ($\kappa^* = 0$). In this case, movements in the exchange rate pass through into import prices immediately. Since the degree of pass-through does not affect the fixed exchange rates, the results will be identical to those in Figure 1.

However, for intermediate and floating exchange rate arrangements, the higher exchange rate pass-through directly affects the response of inflation and the expenditure switching mechanism. Indeed, the full pass-through model delivers more aggregate inflation while allowing less exchange rate response. This entails that the monetary authority's goal of price stability is less consistent

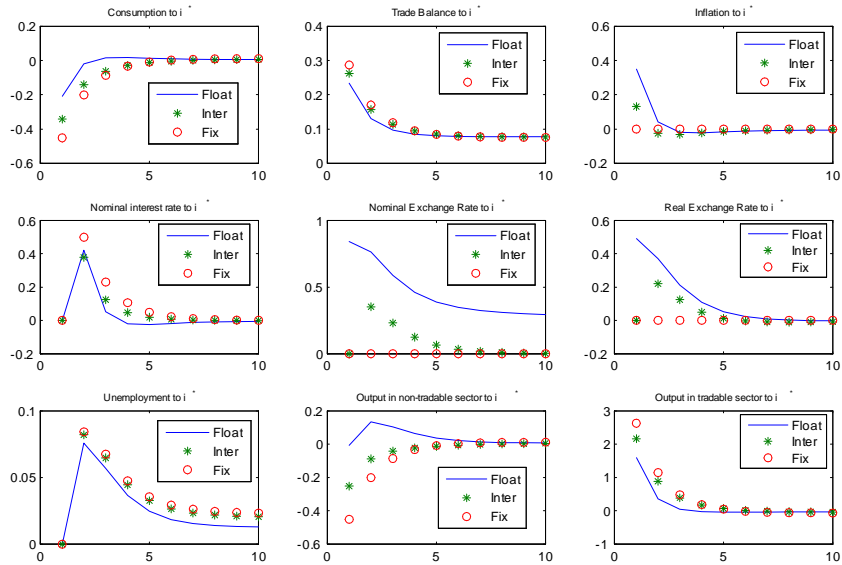


Figure 2: Impulse response to i^* : Full Pass-through

with a lower nominal and real interest rate response to the shock. In consequence, the output under floating and intermediate exchange rate arrangements is much more variable than the pegged exchange rate rule.

It should be clear by now that the monetary rules that provide stability in the real economy do so at the expense of the inflation stability. Both an intermediate and a floating exchange rate arrangement deliver lower output volatility but require a highly volatile overall price level. There is a trade-off between output stability and inflation stability.

The main conclusion is that there is a clear trade-off between the output stability and the inflation stability. With limited pass-through a flexible exchange rate regime can cushion the output response to an external interest rate shock without requiring more inflation instability thus lowering the trade-off. On the contrary, in the presence of full pass-through of exchange rate changes to import prices, this trade-off is significantly amplified and thus leads policymakers to less volatile exchange rate arrangements. These results help us understand why the optimal response of the monetary authority is to stabilize the nominal exchange rate.

4.1.2 Terms of trade shocks

We turn now to the analysis of a shock to terms of trade. Figure 3 shows the response of the economy to the terms of trade shocks. As in the previous

case, we see that the main conclusions apply. The shock leads to a fall in the consumption and, since it is equivalent to a negative income shock in the traded sector, output in this sector will fall, producing an internal reallocation from the traded to the non-traded sector. The expenditure switching effect will be higher in the case of a full pass-through. As in the previous case, in the case of a full pass-through there will be a sharp decline in consumption and a higher magnitude of inflation. This will produce a serious impact on the real exchange rate. As was the case for interest rate shocks, note that with delayed pass-through the exchange rate responds by substantially more while inflation reacts by substantially less. This strongly changes the trade-off faced by the monetary authority.

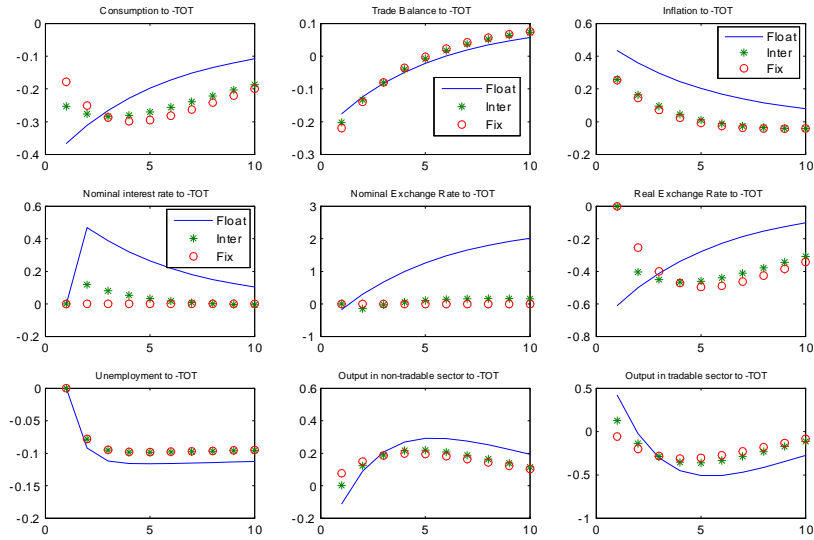


Figure 3: Impulse response to -TOT: Delayed Pass-through

4.2 Optimal monetary policy

As explained in the introduction, our framework integrates real rigidities into the model. Even though in previous sections the Hosios condition was satisfied by assumption, there is no theoretical or empirical reasons stating that the parameters affecting the bargaining power of workers and firms should be equal. In order to analyze the effects of labor-market distortion, we take different values of the worker's bargaining power γ while keeping all other parameters the same as in the standard calibration. As proved by Tang (2006) once the Hosios condition is not satisfied and hence the steady state not efficient, the optimal response may differ and complete inflation stabilization may not be optimal. Figure 5 reports how the model reacts of different levels of γ .

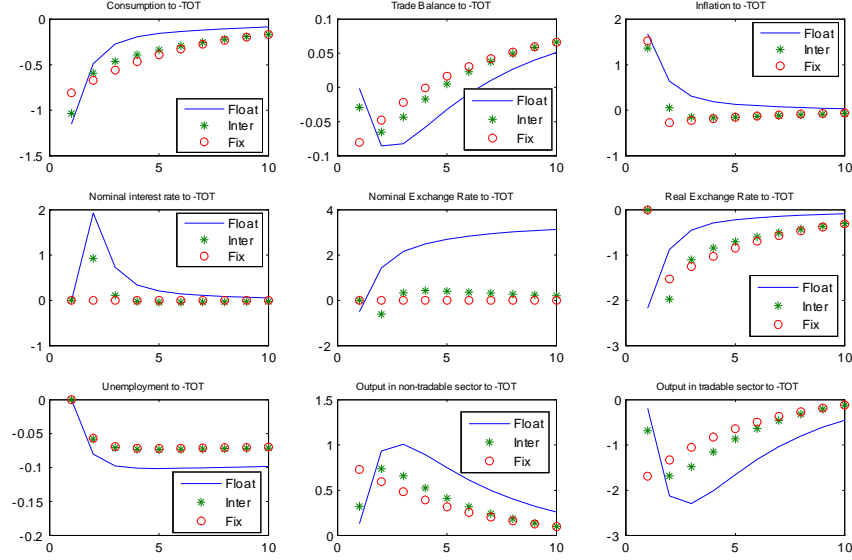


Figure 4: Impulse response to -TOT: Full Pass-through

In general, we see that when the Hosios condition is not satisfied ($\gamma \neq 0.5$) the response of the variables to a shock is magnified for the inflation, nominal exchange rate and unemployment. Regarding the inflation and the nominal exchange rate, the response is greater when the workers' bargaining power is lower. However, in the case of $\gamma = 0.4$, the dynamic of the response is quite different given that we observe an appreciation of the exchange rate whereas there is a depreciation in all other cases. Finally, in the case of a greater bargaining power of workers, we see a larger response of unemployment.

We set γ at 0.4 since we consider that in Latin America worker's bargaining power is lower than that of firms. This may be due to a number of reasons including weak unions, high unemployment and high poverty rates.

Figure 6 shows the optimal response to the shock under a Ramsey allocation in both a complete and a delayed exchange rate scenario. The general behaviour will be the same regardless of the degree of pass-through. The degree of expenditure switching will be similar to that of Taylor's rules. In either case, the monetary authority will almost fully stabilize the inflation by greater nominal interest rate adjustments. In consequence, the optimal response is to fully stabilize both the nominal and the real exchange rate.

Figure 7 shows the optimal response of the monetary authority. Contrarily to what happens in the case of an interest rate shock, it seems that the monetary authority adopts a non-monotonic response to a term of trade shock. In the case of a delayed exchange rate pass-through, the optimal response will be that of stabilizing inflation while allowing greater nominal exchange rate volatility. On

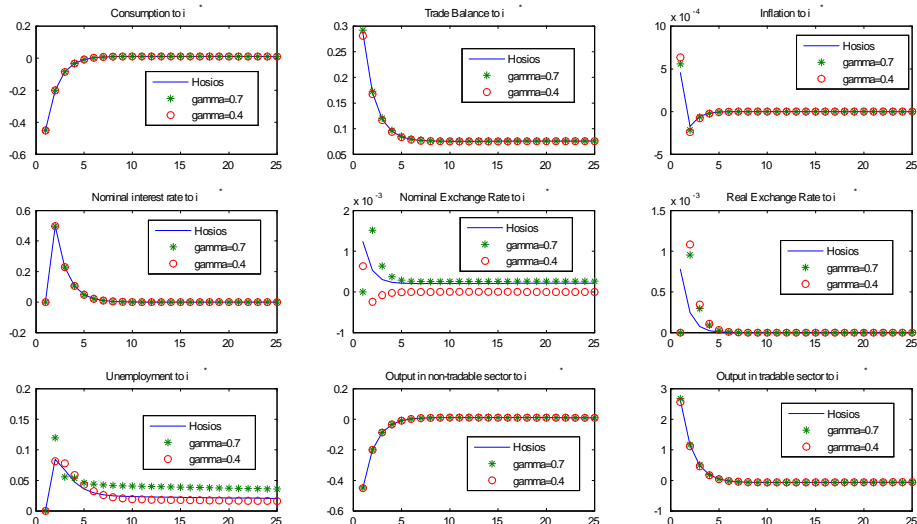


Figure 5: Optimal response to i^* : alternative values of γ

the contrary, when faced to a high exchange rate pass-through, the Ramsey planner will have the incentive to fully stabilize the nominal exchange rate. These results support our intuition.

5 Overall regime evaluation

In order to evaluate the difference between the two monetary policies, we make a welfare evaluation of the alternative monetary policies. More precisely, for each alternative policy we compute the fraction of consumption that should be added to attain the welfare level that corresponds to the Ramsey allocation.

Tables 2-4 report welfare costs calculations and the volatility of key macroeconomic variables³ for alternative values of workers' bargaining power. The top section of the tables show the results in the case of a full pass-through whereas the bottom section shows the case of a delayed pass-through. The welfare results are consistent with the discussion held in previous sections. In both cases - complete and delayed pass-through - the intermediate regime delivers the highest utility. In all cases we have less volatility in macro variables under a delayed pass-through. Inflation volatility increases significantly in the case of a full pass-through except in the case of an intermediate regime. Furthermore there is an inverse relationship between output and inflation stabilization, stat-

³See Annex 1 for further details on welfare's computation.

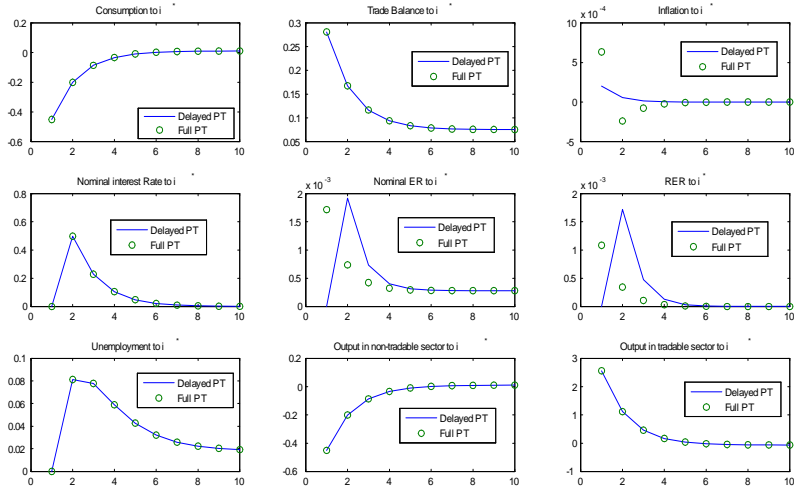


Figure 6: Impulse response to i^* : Ramsey allocation

ing that there is a clear trade-off when comparing the scenarios of delayed and complete pass-through.

Regarding the different values of workers' bargaining power, γ , we see that overall, the performance and the ranking of preference of the different exchange rate arrangements is the same. However we see that volatilities in general are reduced in the case of a γ equal to 0,3.

6 Conclusion

This paper has addressed an old theme in open macroeconomics: the optimal choice of the exchange rate regime. However, we have turned the focus towards the behaviour of emerging markets and, more precisely, towards Latin American countries. We have developed a dynamic stochastic general-equilibrium (DSGE) model of a small open economy where the economy faces a high exchange rate pass-through and a non-walrasian labor market. In order to assess the role of the exchange rate pass-through, the model economy was subject to foreign interest rate, and to shocks of the terms of trade. The model helped us understand why there is a predominance of "fear of floating" in emerging markets' economies and how they empirically tend to intervene in the foreign exchange market in order to limit the nominal exchange rate volatility.

We have found that the degree in which exchange rate movements affect the domestic prices is central when it comes to determining the optimal exchange rate regime. The main conclusion of this paper is that there is a trade-off

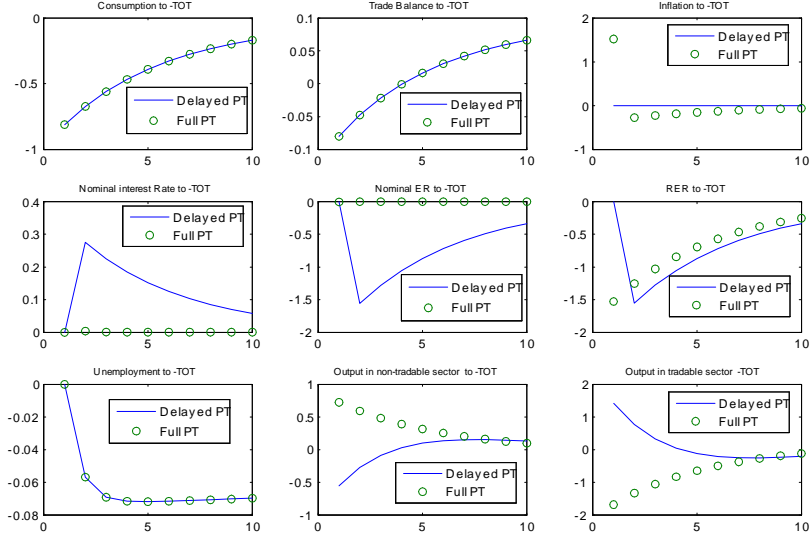


Figure 7: Impulse response to -TOT: Ramsey Allocation

between the output stability and the inflation stability. With limited pass-through a flexible exchange rate regime can cushion the output response to an external interest rate shock without requiring more inflation instability and thus lowering the trade-off. On the contrary, in the presence of a full pass-through of exchange rate changes to import prices, this trade-off is significantly amplified and thus leads policymakers to less volatile exchange rate arrangements.

As far as the optimal monetary policy is concerned we showed that when the Hosios condition is not satisfied, the optimal response of inflation and the nominal exchange rate both in terms of magnitude and dynamics is quite different. We also showed that the response of the Ramsey Planner to a foreign interest rate shock is to fully stabilize the exchange rate, both in the case of a full and a delayed pass-through. Finally, when the economy faces a term of trade shock, the optimal response depends again on the degree of the exchange rate pass-through. The results under Taylor's rules seem to be confirmed as an optimal response since, in the case of a full pass-through, the monetary authority stabilizes the nominal exchange rate.

Regarding the role of labor market rigidities we showed that they didn't play a significant role in shaping the response of the Taylor's rules. Contrarily, the incorporation of search played a non-trivial role in the optimal monetary policy since inflation and the nominal exchange rates had a different dynamics. Nevertheless the incorporation of real rigidities did not alter the predictions of the model.

In the light of the above discussion, we argue that in an economy that

Table 2: Standard deviations — welfare cost ($\gamma = 0.5$)

| | Cons | Nom IR | Inflation | Empl | Hours | Exp utility | Cons cost |
|--------|------|--------|-----------|------|-------|-------------|-----------|
| FP | | | | | | | |
| Ramsey | 8.31 | 4.20 | 4.39 | 2.10 | 15.71 | -971.17 | |
| Float | 4.99 | 5.95 | 5.60 | 2.03 | 15.68 | -1033.21 | 0.1632 |
| Inter | 5.13 | 1.32 | 2.42 | 2.03 | 15.66 | -977.84 | 0.0168 |
| Fix | 5.13 | 0.57 | 2.60 | 2.03 | 15.66 | -978.51 | 0.0185 |
| DP | | | | | | | |
| Ramsey | 8.31 | 3.04 | 0.0026 | 2.10 | 15.71 | -977.09 | |
| Float | 4.68 | 5.46 | 4.17 | 2.02 | 15.69 | -1044.80 | 0.1769 |
| Inter | 4.99 | 1.01 | 1.08 | 2.03 | 15.66 | -977.89 | 0.002 |
| Fix | 5.01 | 0.57 | 1.06 | 2.03 | 15.66 | -979.54 | 0.0061 |

Table 3: Standard deviations — welfare cost ($\gamma = 0.3$)

| | Cons | Nom IR | Inflation | Empl | Hours | Exp utility | Cons cost |
|--------|------|--------|-----------|------|-------|-------------|-----------|
| FP | | | | | | | |
| Ramsey | 8.26 | 4.20 | 4.38 | 2.41 | 15.22 | -983.46 | |
| Float | 4.93 | 5.90 | 5.54 | 2.31 | 15.21 | -1042.98 | 0.1551 |
| Inter | 5.06 | 1.32 | 2.42 | 2.32 | 15.66 | -990.43 | 0.0175 |
| Fix | 5.06 | 0.57 | 2.60 | 2.31 | 15.19 | -991.08 | 0.0191 |
| DP | | | | | | | |
| Ramsey | 8.26 | 3.03 | 0.0037 | 2.41 | 15.71 | -989.25 | |
| Float | 4.61 | 5.41 | 4.12 | 2.31 | 15.23 | -1053.93 | 0.1671 |
| Inter | 4.92 | 1.01 | 1.08 | 2.32 | 13.85 | -990.55 | 0.0032 |
| Fix | 4.94 | 0.57 | 1.06 | 2.32 | 15.19 | -992.10 | 0.0070 |

faces both real and nominal rigidities, the trade-off faced by industrial countries will be different to that faced by the emerging markets. Emerging markets exhibit a higher degree of exchange rate pass-through, which implies a greater impact of exchange rate movements in the domestic prices. After a shock, an economy of this type with a floating exchange rate arrangement will have an important expenditure switching effect, a greater decline in both consumption and output and a greater impact on inflation. This may help us understand why the emerging markets tend to choose de facto intermediary exchange rate arrangements.

7 Annex

7.1 Welfare Evaluation

Let \mathcal{W}_t^* be the conditional welfare under the Ramsey allocation and let C_t^a , N_t^a and h_t^a denote the allocation obtained under the Taylor rule. The welfare cost Ψ is obtained by solving the following equation :

Table 4: Standard deviations — welfare cost ($\gamma = 0.6$)

| | Cons | Nom IR | Inflation | Empl | Hours | Exp utility | Cons cost |
|--------|------|--------|-----------|------|-------|-------------|-----------|
| FP | | | | | | | |
| Ramsey | 8.35 | 4.20 | 4.39 | 1.88 | 15.87 | -968.02 | |
| Float | 5.04 | 5.98 | 5.63 | 1.81 | 15.83 | -1032.01 | 0.1687 |
| Inter | 5.18 | 1.32 | 2.42 | 1.82 | 15.68 | -974.42 | 0.0162 |
| Fix | 5.18 | 0.57 | 2.60 | 1.81 | 15.81 | -975.13 | 0.0180 |
| DP | | | | | | | |
| Ramsey | 8.34 | 3.04 | 0.0020 | 1.88 | 15.87 | -974.04 | |
| Float | 4.72 | 5.50 | 4.21 | 1.81 | 15.85 | -1044.12 | 0.1835 |
| Inter | 5.04 | 1.01 | 1.08 | 1.82 | 16.70 | -974.38 | 0.0009 |
| Fix | 5.05 | 0.57 | 1.06 | 1.82 | 15.81 | -976.18 | 0.0053 |

$$\mathcal{W}_t^* = E_t \sum_{j=0}^{\infty} \beta^j \left[\frac{[(1 + \Psi)C_{t+j}^a]^{1-\sigma}}{1-\sigma} + N_{t+j}^a \frac{\xi_1}{1-\eta} (1 - h_{t+j}^a)^{1-\eta} + (1 - N_{t+j}^a) \frac{\xi_2}{1-\eta} \right] \quad (49)$$

Ψ can be written as follows :

$$\Psi = \left(\frac{\mathcal{W}_t^* - \mathcal{W}_{N,t}^a}{\mathcal{W}_{C,t}^a} \right)^{\frac{1}{1-\sigma}} - 1$$

with :

$$\mathcal{W}_{C,t}^a = E_t \sum_{j=0}^{\infty} \beta^j \left[\frac{[C_{t+j}^a]^{1-\sigma}}{1-\sigma} \right]$$

$$\mathcal{W}_{N,t}^a = E_t \sum_{j=0}^{\infty} \beta^j \left[N_{t+j}^a \frac{\xi_1}{1-\eta} (1 - h_{t+j}^a)^{1-\eta} + (1 - N_{t+j}^a) \frac{\xi_2}{1-\eta} \right]$$

Ψ is numerically computed using a second order approximation (see Schmitt-Grohé and Uribe (2004)). Tables 2-4 report welfare costs calculations and the volatility of key macroeconomic variables under alternative values of γ .

7.2 Steady state computation

The steady state employment and hours levels (\bar{N} and \bar{h}) and the probability to fill a vacancy ($\bar{\phi}$) are given. The share of the vacancy costs also takes a given level $\tau_V = \frac{\omega \bar{V}}{A_H (\bar{h} \bar{N})^\alpha}$. We easily deduce $\bar{H} = (1 - \tau_V) A_H (\bar{h} \bar{N})^\alpha$, $\bar{M} = s \bar{N}$, $\bar{V} = \frac{\bar{M}}{\bar{\phi}}$, $\psi = \frac{\bar{M}}{1 - \bar{N}}$ and $\omega = \frac{\tau_V A_H (\bar{h} \bar{N})^\alpha}{\bar{V}}$.

The rates to which firms adjust their prices are set to 0 ($\pi_N = \pi_M = 0$). We also suppose that the steady state foreign inflation level π^* is equal to 0.

The stationary foreign nominal interest rate i^* (thus equal to the real one) is supposed to satisfy $i^* = \frac{1-\beta}{\beta}$. The domestic inflation rates satisfy $\bar{\pi} = \bar{\pi}_N = \bar{\pi}_M = 0$. The steady state nominal exchange rate growth factor is equal to 1 (The steady state nominal exchange rate \bar{S} is normalized to 1) and the steady state interest rate⁴ \bar{i} takes the value of $\frac{1-\beta}{\beta}$. Finally, the distortion indexes and the optimal prices respectively satisfy $\bar{D}_N = \bar{D}_M = 1$ and $\frac{\bar{P}_N^t}{\bar{P}_N} = \frac{\bar{P}_M^t}{\bar{P}_M} = 1$.

Let χ_1 be the ratio of foreign debt to output ($\frac{\bar{d}}{\bar{C}}$, equation 44 evaluated at the steady state provides :

$$\frac{\bar{P}_H}{\bar{P}} \bar{H}_X - \frac{\bar{P}_X}{\bar{P}} \frac{\bar{P}_M^*}{\bar{P}_X^*} \bar{C}_M = \frac{1-\beta}{\beta} \chi_1 \bar{C}$$

From equations 15, 16, 29 - 31, 36 - 38, 40, and 41, the following relations are easily deduced :

$$C = a \frac{\bar{P}_N}{\bar{P}} \bar{C}_N \quad (50)$$

$$\frac{\bar{P}_M}{\bar{P}} \bar{C}_M = \frac{1-a}{a} \frac{\bar{P}_N}{\bar{P}} \bar{C}_N \quad (51)$$

$$\bar{H}_X = \bar{H} - \bar{H}_N \quad (52)$$

$$A_N \frac{\bar{P}_N}{\bar{P}} = \frac{\lambda}{\lambda-1} \frac{\bar{P}_H}{\bar{P}} \quad (53)$$

$$\bar{C}_N = A_N \bar{H}_H \quad (54)$$

$$\frac{\bar{P}_M}{\bar{P}} = \frac{\lambda}{\lambda-1} \frac{\bar{P}_X}{\bar{P}} \frac{\bar{P}_M^*}{\bar{P}_X^*} \quad (55)$$

Substituting in equation ?? yields the value of \bar{H}_N , that is :

$$\bar{H}_N = \frac{a \bar{H}}{\frac{\lambda}{\lambda-1} \frac{1-\beta}{\beta} \chi_1 + 1}$$

The share of the import consumption goods in the total import expenditures is set to χ_2 . One has :

$$\chi_2 = \frac{\frac{\bar{P}_X}{\bar{P}} \frac{\bar{P}_M^*}{\bar{P}_X^*} \bar{C}_M}{\frac{\bar{P}_X}{\bar{P}} \frac{\bar{P}_M^*}{\bar{P}_X^*} \bar{I}_M + \frac{\bar{P}_X}{\bar{P}} \frac{\bar{P}_M^*}{\bar{P}_X^*} \bar{C}_M}$$

⁴If the nominal interest rate is set according to a Taylor rule, it is supposed the monetary authority chooses $\bar{i} = \frac{1-\beta}{\beta}$. It follows that $\bar{\pi} = \bar{\pi}_N = \bar{\pi}_M = 0$ and the steady state nominal exchange rate growth factor is equal to 1. If the monetary authority solves a Ramsey problem, the same steady states values are obtained.

Let define $\chi_1 = \frac{\bar{P}_H \bar{H}_X}{\bar{P}_X \bar{Y}_X}$.

Equation ?? and equations 50 - 55, after some manipulations, provide :

$$\chi_3 = \frac{\frac{\lambda}{\lambda-1} \frac{1-\beta}{\beta} \chi_1 + 1 - a}{\frac{1-\chi_2}{\chi_2} (1-a) + 1 - a + \frac{1-\beta}{\beta} \chi_1 \frac{\lambda}{\lambda-1}}$$

It is then easy to deduce the value of \bar{Y}_X , \bar{I}_M and $\frac{\bar{P}_X^*}{\bar{P}_{1M}^*}$, that is :

$$\begin{aligned} \bar{Y}_X &= \bar{H}_X A_X \left(\frac{\chi_3}{\vartheta} \right)^{\frac{\varphi}{1-\varphi}} \\ \bar{I}_M &= \left[\frac{1}{1-\vartheta} \left(1 - \vartheta \left(\frac{\bar{A}_X \bar{H}_X}{\bar{Y}_X} \right)^{\frac{\varphi-1}{\varphi}} \right) \right]^{\frac{\varphi}{\varphi-1}} \bar{Y}_X \\ \frac{\bar{P}_X^*}{\bar{P}_{1M}^*} &= \frac{1}{1-\vartheta} \left(\frac{\bar{Y}_X}{\bar{I}_M} \right)^{\frac{-1}{\varphi}} \end{aligned}$$

We also suppose that $\frac{\bar{P}_X^*}{\bar{P}_{1M}^*} = \frac{\bar{P}_X^*}{\bar{P}_M^*}$.

After some algebra, one gets the value of \bar{C}_M , that is :

$$\bar{C}_M = \frac{\frac{\lambda-1}{\lambda} \frac{\bar{P}_X^*}{\bar{P}_M^*} \bar{Y}_X}{\frac{1-\chi_2}{\chi_2} \frac{\lambda-1}{\lambda} + \frac{\lambda-1}{\lambda} + \frac{1-\beta}{\beta} \chi_1 \frac{1}{1-a}}$$

The other steady state values are easily deduced.

$$\begin{aligned}
\bar{C} &= \left(\frac{\bar{C}_N}{a}\right)^a \left(\frac{\bar{C}_M}{1-a}\right)^{1-a} \\
\bar{d} &= \chi_1 \bar{C} \\
\frac{\bar{P}_N}{\bar{P}} &= a \frac{\bar{C}}{\bar{C}_N} \\
\frac{\bar{P}_M}{\bar{P}} &= (1-a) \frac{\bar{C}}{\bar{C}_M} \\
\frac{\bar{P}_H}{\bar{P}} &= \frac{\lambda-1}{\lambda} A_H \frac{\bar{P}_N}{\bar{P}} \\
\bar{R}_N &= \frac{\bar{C}_N}{1-\beta\kappa} \\
\bar{Q}_N &= \frac{\lambda-1}{\lambda} \bar{R}_N \\
\bar{R}_M &= \frac{\bar{C}_M}{1-\beta\kappa^*} \\
\bar{Q}_M &= \frac{\lambda-1}{\lambda} \bar{R}_M \\
\frac{\bar{P}_X}{\bar{P}} &= \frac{\lambda-1}{\lambda} \frac{\bar{P}_X^*}{\bar{P}_M^*} \frac{\bar{P}_M}{\bar{P}} \\
\bar{\lambda} &= \bar{C}^{-\sigma}
\end{aligned}$$

Finally, we compute the steady state value of the real wage $\frac{\bar{W}}{\bar{P}}$, the values of the preferences parameters ξ_1 and ξ_2 and the matching function scale parameter χ . That is :

$$\begin{aligned}
\frac{\bar{W}}{\bar{P}} &= \frac{1}{\beta\bar{h}} \left(\beta \frac{\bar{P}_H}{\bar{P}} A_H \alpha \bar{h} (\bar{h}\bar{N})^{\alpha-1} - (1-\beta(1-s)) \frac{\bar{P}_H}{\bar{P}} \frac{\omega}{\phi} \right) \\
\xi_1 &= \frac{\bar{\lambda} \frac{\bar{P}_H}{\bar{P}} A_H \alpha (\bar{h}\bar{N})^{\alpha-1}}{(1-\bar{h})^{-\eta}} \\
\xi_2 &= \left[\bar{\lambda} \frac{\bar{W}}{\bar{P}} \bar{h} - (1-\gamma) \bar{\lambda} \left(\frac{\bar{P}_H}{\bar{P}} A_H \alpha \bar{h} (\bar{h}\bar{N})^{1-\alpha} + \bar{\psi} \frac{\bar{P}_H}{\bar{P}} \frac{\omega}{\phi} \right) \right. \\
&\quad \left. - \gamma \xi_1 \frac{(1-\bar{h})^{1-\eta}}{1-\eta} \right] \frac{1-\eta}{-\gamma} \\
\chi &= \frac{\bar{M}}{\bar{V}^\theta (1-\bar{N})^{1-\theta}}
\end{aligned}$$

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