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NON-TRADED GOODS AND MONETARY POLICY TRADE-OFFS IN A SMALL OPEN ECONOMY

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Resumen
En este trabajo desarrollo un modelo para una economía abierta y abierta con dos sectores domésticos. Junto con un sector que produce bienes transables (exportable) existe un sector que produce bienes no transables. En ambos sectores los precios son rígidos, y cada uno está sujeto a choques de productividad específicos. En este marco, la asignación de recursos que surgiría bajo precios flexibles no se puede replicar por medio de un único instrumento de política monetaria. Por lo tanto, la autoridad monetaria se ve enfrentada a un *trade-off* entre estabilizar la inflación en el sector transable o en el sector no transable. En este contexto, y cuando el tamaño del sector no transable no es muy grande, una regla de Taylor simple entrega un mejor resultado que un régimen estricto de metas de inflación. Sin embargo, ambas reglas de política son dominadas por una regla que mueve agresivamente la tasa de interés en respuesta a desviaciones de la inflación subyacente respecto a su meta. Por otro lado, si el tamaño del sector no transable el grande entonces la economía converge hacia una economía cerrada. En este caso, si no existen choques de costos exógenos (*cost push shocks*) entonces lo óptimo es estabilizar completamente la inflación de IPC.

Abstract
In this paper I develop a small open economy model that is characterized by existence of two domestic sectors. Together with a home traded goods sector we incorporate a non-traded goods sector. In both sectors prices are sticky, and each one is subject to a specific productivity shock. In this setup the flexible price allocation can not be reached by means of a single monetary policy instrument. Therefore, the central bank faces a trade-off between stabilizing inflation in the Non-traded sector and in the home goods sector. In this context, and when the share of non-traded goods is not too high, a simple Taylor rule outperforms a strict inflation-targeting regime. However, both policy rules are dominated by a rule that moves aggressively the interest rate in response to deviation in core inflation. On the other hand, if the share of non-traded goods is high then the model converges to the closed economy case, and, in absence of an exogenous cost push shock, the optimal policy is to completely stabilize consumer price inflation.

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1 Introduction

What are the potential trade-offs faced by the monetary authority of a small country when different domestic sectors respond asymmetrically to shocks? Typically, when deciding its monetary policy a central bank faces a trade-off between stabilizing output and inflation. This has been widely explored on recent literature that analyzes monetary policy in both open and closed economies. In much of this literature a trade-off among different objectives of the monetary authority is introduced in an ad-hoc way, by assuming an exogenous cost push that affects the position of the Phillips curve.

In this paper I develop a small open economy model that is characterized by the existence of two domestic sectors. Together with a sector that produces internationally traded goods (Home goods) there is a sector that produces non-traded goods. Each sector is subject to a specific productivity shock, and within each one of them firms adjust prices in a staggered way. As long as productivity shocks are not perfectly correlated across sectors, the flexible price allocation can not be reached by means of a single monetary policy instrument. Therefore, the central bank faces a trade-off between stabilizing inflation in the non-traded sector and in the Home goods sector. Moreover, the trade-off arises endogenously because of the asymmetries in both sectors.[1]

Using this framework I compare three alternative monetary policy regimes: A baseline Taylor rule, where the central bank adjusts the interest rate in response to inflation and output gap; a strict inflation targeting regime; and a *core* inflation targeting regime, where the central bank aggressively adjusts the interest rate in response to deviations of *core* or domestic inflation from its target.

The model does not allow us to develop a welfare function derived from first principles. Therefore, our criterion to compare the three different monetary regimes is based on the idea that welfare losses are associated with price dispersion. We define an ad-hoc welfare loss function that depends on the variances of both, Home goods and non-traded goods inflation.

I show that a policy rule that aggressively adjusts the interest rate in response to fluctuations in *core* inflation reduces deviations of output from its natural level. At the same time, when the share of non-traded goods is not too high, a "flexible" inflation targeting regime -a Taylor rule- outperforms a strict inflation targeting regime. On the other hand, if the share of non-

[1] Recently, Monacelli (2002) and Smets and Wouters (2002) have shown that imperfect pass-through arising from sticky deviations of the law of one price also generate and endogenous trade-off for the monetary policy.

traded goods is high, then the model converges to a closed economy case, and, in absence of an exogenous cost push shock, the optimal policy is to completely stabilize consumer price inflation.

Finally, all three regimes imply a positive correlation between domestic and foreign interest rate. Therefore, in all three cases there is some exchange rate smoothing. However, of all three regimes *core* inflation targeting is the one that entails more exchange rate volatility. On the contrary, the correlation between domestic and foreign interest rate under strict inflation targeting is close to 1. In other words, under this regime the exchange rate exhibits excess smoothness.

The paper is structured as follows: In section 2 the main equations of the model are displayed. Section 3 presents the model in its log-linear version. Section 4 discusses three alternative monetary regimes. Section 5 presents impulse responses to different productivity shocks, and compares the variance of several macro variables under the three alternative monetary regimes. In this case, it is also evaluated how the share of non-traded goods affects the implied volatility of the alternative regimes. Finally, some welfare implications are discussed briefly. Section 6 concludes.

2 The Model

In this section we describe a small open economy model with two domestic sectors. The main feature of the model is the coexistence of a sector that produces non-traded goods together with a sector that produces traded goods (Home goods) that are consumed domestically as well as exported. Additionally, assets markets are complete and labor is perfectly mobile across sectors.

2.1 Households

The domestic economy is inhabited by an continuous number of households indexed by $j \in [0, 1]$. Present discounted expected utility of household j is given by:

$$U_t^j = E_t \sum_{i=0}^{\infty} \beta^i \left\{ \frac{\sigma}{1-\sigma} (C_{t+i}^j)^{\frac{\sigma-1}{\sigma}} + \frac{a}{u} \left(\frac{M_{t+i}^j}{P_{t+i}} \right)^u - \frac{\kappa}{v+1} \left(N_{t+i}^j \right)^{v+1} \right\} \quad (1)$$

where N_t^j is total labor effort, and C_t^j represents a consumption bundle defined below.

We assume that each households supplies simultaneously labor to both the non-traded and the Home goods sectors. Therefore, total labor effort is the sum of labor devoted to both sectors:

$$N_t^j = N_{Nt}^j + N_{Ht}^j$$

The consumption buddle C_t includes both, a composite of non-traded goods, C_N, and a bundle of internationally traded goods C_T:

$$C_{t+i}^j = \left[\gamma^{\frac{1}{\theta}}(C_{N,t+i}^j)^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}}(C_{T,t+i}^j)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \tag{2}$$

Parameter θ corresponds to the intratemporal elasticity of substitution between traded and non-traded goods, and γ defines the share of non-traded goods in steady state (see Appendix D). I restrict this parameter to lay on the interval $[0,1)$.

The consumption basket of internationally traded goods is composed by Home goods, C_{Ht}, and Foreign consumption goods, C_{Ft}:

$$C_{Tt+i}^j = \left[\frac{1}{2}^{\frac{1}{\eta}}(C_{H,t+i}^j)^{\frac{\eta-1}{\eta}} + \frac{1}{2}^{\frac{1}{\eta}}(C_{F,t+i}^j)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{3}$$

where η corresponds to the intratemporal elasticity of substitution between Home and Foreign goods. Here it is assumed, for simplicity, that in steady state the share of Home goods is 1/2. This means that there is no Home goods bias in consumption of traded goods.

The bundles of non-traded and Home goods are composed by a continuum of differentiated varieties, each one indexed between 0 and 1. Both consumption bundles are defined as follows:

$$C_{N,t}^j = \left(\int_0^1 C_{N,t}^j(z_N)^{\frac{\epsilon_N-1}{\epsilon_N}} dz_N\right)^{\frac{\epsilon_N}{\epsilon_N-1}}, \tag{4}$$

$$C_{H,t}^j = \left(\int_0^1 C_{H,t}^j(z_H)^{\frac{\epsilon_H-1}{\epsilon_H}} dz_H\right)^{\frac{\epsilon_H}{\epsilon_H-1}} \tag{5}$$

where ϵ_N and ϵ_H correspond to the elasticities of substitution across varieties in the bundles of non-traded and Home goods, respectively. Cost minimizations implies the following individual demand for varieties z_N and z_H:

$$C_{N,t}^j(z_N) = \left(\frac{P_{N,t}(z_N)}{P_{N,t}}\right)^{-\epsilon_N} C_{N,t}^j, \quad C_{H,t}^j(z_H) = \left(\frac{P_{H,t}(z_H)}{P_{H,t}}\right)^{-\epsilon_H} C_{H,t}^j \tag{6}$$

Analogously, foreign households consume a bundle of Home goods that is equivalent to the one defined in (5). Foreign household j´s demand for a particular variety z_H is given by:

$$C^{*j}_{H,t}(z_H) = \left(\frac{P^*_{H,t}(z_H)}{P^*_{H,t}}\right)^{-\epsilon_H} C^{*j}_{H,t}. \tag{7}$$

The optimal composition of the aggregate consumption bundle is obtained by minimizing the cost of consumption subject to (2) and (3). From this cost minimization we obtain the demand for each type of goods:

$$C^j_{N,t} = \gamma \left(\frac{P_{N,t}}{P_t}\right)^{-\theta} C^j_t \tag{8}$$

$$C^j_{H,t} = (1-\gamma)\frac{1}{2}\left(\frac{P_{H,t}}{P_{Tt}}\right)^{-\eta}\left(\frac{P_{T,t}}{P_t}\right)^{-\theta} C^j_t \tag{9}$$

$$C^j_{F,t} = (1-\gamma)\frac{1}{2}\left(\frac{P_{F,t}}{P_{Tt}}\right)^{-\eta}\left(\frac{P_{T,t}}{P_t}\right)^{-\theta} C^j_t \tag{10}$$

2.1.1 Asset Market Structure and Budget Constraint

In this economy, asset markets are complete: There are complete, contingent one-period bonds denominated in the domestic currency. Let $B^j_t(s_{t+1})$ denote the domestic consumer's holding of a bond purchased in period t with payoffs contingent in some particular state s_{t+1} at $t+1$. One unit of this bond pays one unit of the home currency in period $t+1$ if the particular state s_{t+1} occurs and 0 otherwise. Let $d(s_{t+1} \mid s^t)$ denote the price of one unit of that bond in period t and history s^t. Household j maximizes utility subject to the sequence of budget constraints,

$$\frac{M^j_t}{P_t} + \sum_{s_{t+1}} d(s_{t+1} \mid s^t)\frac{B^j_t(s_{t+1})}{P_t} \leq \frac{M^j_{t-1}}{P_t} + \frac{B^j_{t-1}}{P_t} + \frac{W^j_t}{P_t}N^j_t + \frac{\Pi^j_t}{P_t} - C^j_t + \tau^j_t$$

where τ^j_t are net transfers from the government, Π^j_t are profits received from firms, P_t is the consumer price index defined below, and W^j_t is the nominal wage rate which is the same in both the non-traded and the Home goods sectors.[2]

[2] As we said, labor is mobile across sectors. Therefore, the wage rate must be the same in both of them.

2.1.2 Optimal Conditions

From the first order conditions for labor effort and consumption we obtain the following expressions:

$$\frac{\kappa}{2}\frac{N_t^{v}}{C_t^{-1/\sigma}} = \frac{W_t}{P_t} \tag{11}$$

$$\beta\varphi(s_{t+1}|s^t)\frac{P_t}{P_{t+1}}\left(\frac{C_t}{C_{t+1}}\right)^{-\frac{1}{\sigma}} = d(s_{t+1}|s^t), \tag{12}$$

where, for convenience, we have suppressed the upper index j.[3] Equation (11) is the labor supply schedule. The RHS corresponds to the marginal rate of substitution between labor and consumption. At the optimum, this rate must be equal to the real wage received by the worker.

Expression (12) is the Euler equation between any state at time t and state s_{t+1} at date $t+1$. The term $\varphi(s_{t+1}|s^t)$ corresponds to the probability of state s_{t+1} given history s^t. Aggregating over all possible states s_{t+1} we can express the Euler equation as a function of the risk free interest rate:[4]

$$1 = (1+i_{t+1})\,\beta E_t\frac{P_t}{P_{t+1}}\left(\frac{C_t}{C_{t+1}}\right)^{\frac{1}{\sigma}}. \tag{13}$$

Let Q_t be the real exchange rate at time t. It is easy to show that under complete assets market the following risk sharing condition is satisfied (see Chari, Kehoe and McGrattan, 2002):

$$\frac{C_t}{C_t^*} = \vartheta Q_t^{\sigma} \tag{14}$$

where ϑ is a constant that depends on the initial conditions in both economies (the initial levels of the exchange rate and the relative price level across countries).

2.2 Firms

2.2.1 Non-traded Sector

Following the New Keynesian literature prices in this economy are sticky (Yun, 1996). Domestic firms producing non-traded goods face a constant

[3] Consumption and labor supply decisions are symmetric across households.

[4] The risk free interest rate satisfies, in equilibrium, the following relationship:

$$1+i_{t+1} = \frac{1}{\sum_{s_{t+1}} d(s_{t+1} \mid s^t)}.$$

probability $1-\phi_N$ of adjusting prices each period. Therefore, when optimizing a firm that produces variety z_N will set a new price in order to maximize its expected present discounted stream of profits:

$$E_t\left\{\sum_{i=0}^{\infty}(\phi_N\beta)^i\,\Lambda_{t,t+i}\frac{P_{N,t}(z_N)-MC_{Nt+i}(z_N)}{P_{t+i}}Y_{N,t+i}(z_N)\right\}$$

subject to the demand for its product:

$$Y_{N,t}(z_N)=\left(\frac{P_{N,t}(z_N)}{P_{N,t}}\right)^{-\epsilon_N}C_{N,t}, \tag{15}$$

and the following production technology:

$$Y_{N,t}(z_N)=A_{Nt}N_{Nt}(z_N).$$

Variable $MC_{Nt}(z_N)$ represents the nominal marginal cost faced by a firm producing z_N, $N_{Nt}(z_N)$ is the labor input utilized in production, and A_{Nt} is a technological parameter common to all firms producing non-traded goods.

The optimal resetting price is the following:

$$P_{Nt}^{new}(z_N)=\frac{\epsilon_N}{\epsilon_N-1}\frac{\sum_{i=0}^{\infty}(\phi_N\beta)^iE_t\left\{\Lambda_{t,t+i}MC_{Nt+i}(z_N)\frac{Y_{N,t+i}(z_N)}{(P_{N,t+i})^{\epsilon_N}}\right\}}{\sum_{i=0}^{\infty}(\phi_N\beta)^iE_t\left\{\Lambda_{t,t+i}\frac{Y_{N,t+i}(z_N)}{(P_{N,t+i})^{1-\epsilon_N}}\right\}}$$

Once a firm sets a price it stands ready to satisfy demand at the ongoing price.

Total output in the non-traded goods sector is obtained by using the following aggregator:

$$Y_{N,t}\equiv\left(\int_0^1 Y_{N,t}(z_N)^{\frac{\epsilon_N-1}{\epsilon_N}}dz_N\right)^{\frac{\epsilon_N}{\epsilon_N-1}} \tag{16}$$

This definition of total output in the non-traded sector, and the fact that each firm satisfies demand implies that the following equilibrium relation is always met:

$$Y_{N,t}=C_{N,t} \tag{17}$$

2.2.2 Home Goods Sector

A firm producing Home traded goods faces each period a constant probability $1-\phi_H$ of adjusting its price. When the firm adjusts its price its choose a new price in order to maximize:

$$E_t \left\{ \sum_{i=0}^{\infty} (\phi_H \beta)^i \, \Lambda_{t,t+i} \frac{P_{H,t}(z_H) - MC_{Ht+i}(z_H)}{P_{t+i}} Y_{H,t+i}(z_H) \right\}$$

subject to total demand for its product:

$$Y_{H,t}(z_H) = \left(\frac{P_{H,t}(z_H)}{P_{H,t}} \right)^{-\epsilon_H} C_{H,t} + \left(\frac{P^*_{H,t}(z_H)}{P^*_{H,t}} \right)^{-\epsilon_H} C^*_{H,t}, \qquad (18)$$

and the following production technology:

$$Y_{H,t}(z_H) = A_{Ht} N_{Ht}(z_H).$$

As before, the variable $MC_{Ht}(z_H)$ represents the nominal marginal cost faced by firm z_H, $N_{Ht}(z_H)$ is the labor input utilized by the firm, and A_{Ht} is a technological parameter common to all firms producing Home goods.

We assume that the law of one price (LOP) holds for Home goods sold abroad. Under this assumption the foreign currency price of variety z_H is given by $P^*_{H,t}(z_H) = \frac{P_{H,t}(z_H)}{\mathcal{E}_t}$, where $\mathcal{E}_t$ is the nominal exchange rate. With this assumption, the demand faced by firm z_H can be rewritten as:

$$Y_{H,t}(z_H) = \left(\frac{P_{H,t}(z_H)}{P_{H,t}} \right)^{-\epsilon_H} \left(C_{H,t} + C^*_{H,t} \right). \qquad (19)$$

The optimal resetting price in this case is the following:

$$P^{new}_{Ht}(z_H) = \frac{\epsilon_H}{\epsilon_H - 1} \frac{\sum_{i=0}^{\infty} (\phi_H \beta)^i E_t \left\{ \Lambda_{t,t+i} MC_{Ht+i}(z_H) \frac{Y_{H,t+i}(z_H)}{(P_{H,t+i})^{\epsilon_H}} \right\}}{\sum_{i=0}^{\infty} (\phi_H \beta)^i E_t \left\{ \Lambda_{t,t+i} \frac{Y_{H,t+i}(z_H)}{(P_{H,t+i})^{1-\epsilon_H}} \right\}}.$$

Aggregate output in the Home goods sector is obtained by using the following aggregator:

$$Y_{H,t} \equiv \left(\int_0^1 Y_{H,t}(z_H)^{\frac{\epsilon_H - 1}{\epsilon_H}} dz_H \right)^{\frac{\epsilon_H}{\epsilon_H - 1}}. \qquad (20)$$

Again, given the fact that each firm satisfies demand, and given the definition of total output in the Home goods sector, the following equilibrium relation is always satisfied:

$$Y_{H,t} = C_{H,t} + C^*_{H,t}. \qquad (21)$$

2.3 Prices

Let $P_{T,t}$ be the price index of traded goods and let $P_{N,t}$ be the price index of non-traded goods. The price of the consumption basket in the domestic economy (the Consumer Price Index, CPI), P_t, is defined as follows:

$$P_t = \left[\gamma {P_{N,t}}^{1-\theta} + (1-\gamma){P_{T,t}}^{1-\theta}\right]^{\frac{1}{1-\theta}}.$$

The price index of traded goods, P_{Tt}, is given by:

$$P_{Tt} = \left[\frac{1}{2}{P_{H,t}}^{1-\eta} + \frac{1}{2}{P_{F,t}}^{1-\eta}\right]^{\frac{1}{1-\eta}}.$$

Usually, in models with only one domestic sector the terms of trade and the real exchange rate are the same variable. Here, with two domestic sectors we can differentiate these two variables and characterize the behavior of each one separately.

The terms of trade are defined as the ratio between the domestic currency price of Foreign goods (imported goods) and the price of Home goods (exported goods):

$$TT_t = \frac{P_{F,t}}{P_{H,t}}. \tag{22}$$

Here an increase in TT_t represents a deterioration of the terms of trade for the domestic economy.

We assume that the LOP also holds for foreign goods sold domestically. Under this assumption the real exchange rate is given by:

$$Q_t \equiv \frac{\mathcal{E}_t P_t^*}{P_t} \tag{23}$$

where $\mathcal{E}_t P_t^* = \left[\zeta^* P_{F,t}^{1-\eta} + (1-\zeta^*)P_{H,t}^{1-\eta}\right]^{\frac{1}{1-\eta}}$. Here, parameter ζ^* corresponds to the share of Foreign goods in the steady-state consumption basket of foreign households. Since the domestic economy is a small economy, we assume that the consumption basket abroad includes only a negligible portion of Home goods. In other words ζ^* is close to 1.

Keeping all the rest constant, a change in the price of non-traded goods will affect only the real exchange rate but not the terms of trade. On the contrary, changes in the Home goods price will affect both, the terms of trade and the real exchange rate.

3 Linearized Model

This section describes the model in its linearized version. Lowercase characters represent log-deviations from steady state of the corresponding variables. In order to ensure the uniqueness of the steady state I restrict the analysis to the case where $\theta = \eta$. In the Appendix D I show that under this assumption the steady state is in fact unique.

The output gap in this economy given by the difference between current output and natural output:

$$x_t \equiv y_t - \widetilde{y}_t \tag{24}$$

where natural output, $\widetilde{y}_t$, corresponds to the log-deviation of output from steady-state under flexible prices.

3.1 Output and Aggregate Demand

Aggregate demand in the small economy is driven by the real exchange rate through the risk sharing condition for consumption. From equation (14) we have,

$$c_t = \sigma q_t + c_t^* \tag{25}$$

where $q_t \equiv \log(Q_t)$ is the real exchange rate and $c_t = \log(C_t/C)$.

To obtain a measure of total domestic output we need to aggregate output produced in both, the non-traded and Home sectors. Let P_{N0} and P_{H0} be the price index of non-traded and Home goods in a particular base year. Thus, total output expressed in terms of prices of the base year is given by:

$$P_{Y0}Y_t = P_{N0}Y_{N,t} + P_{H0}Y_{H,t} \tag{26}$$

where P_{Y0} is the GDP deflator in the base year. We assume that the base year is a year in which the economy is at its steady state. In the Appendix D I show that labor mobility across sectors implies that in steady state $P_{N0} = P_{H0}$. Moreover, by normalizing $P_{Y0} = P_{H0}$ the following expression for real aggregate output is obtained:

$$Y_t = Y_{N,t} + Y_{H,t} \tag{27}$$

In the Appendix D it also is shown that in steady-state there is no net accumulation of foreign assets. This implies that the current account is zero and the following relations hold: $\frac{Y_N}{Y} = \gamma$ and $\frac{Y_H}{Y} = 1 - \gamma$. The log-linear version of (27) is, thus, given by:

$$y_t = \gamma y_{Nt} + (1 - \gamma)\, y_{Ht} \tag{28}$$

where $y_t = \log(Y_t/Y)$, $y_{Nt} = \log(Y_{Nt}/Y_N)$, $y_{Ht} = \log(Y_{Ht}/Y_H)$, and where Y, Y_N and Y_H are the steady state level of aggregate output, non-traded goods output and Home goods output, respectively.

In the short-run output in both sectors is demand determined. Equilibrium in the non-traded sector implies

$$y_{Nt} = c_{Nt}. \tag{29}$$

Analogously, the equilibrium condition in the domestic traded sector can be stated as follows:

$$y_{Ht} = \frac{C_H}{Y_H} c_{H,t} + \frac{C_H^*}{Y_H} c_{H,t}^* \tag{30}$$

where from the steady state we have that: $\frac{C_H}{Y_H} = \frac{C_H^*}{Y_H} = \frac{1}{2}$.

From (8), (9) and (10) we can establish the following relationships between consumption of the different types of goods, the terms of trade and the real exchange rate:

$$c_{N,t} = -\theta \frac{1-\gamma}{\gamma} \left(\zeta^* - \frac{1}{2} \right) \delta_t + \theta \frac{1-\gamma}{\gamma} q_t + c_t \tag{31}$$

$$c_{H,t} = \theta \zeta^* \delta_t - \theta q_t + c_t \tag{32}$$

$$c_{F,t} = \theta \left(\zeta^* - 1 \right) \delta_t - \theta q_t + c_t \tag{33}$$

where δ_t is the log-deviation from the steady state of the terms of trade. Keeping all the rest constant, a real depreciation of the exchange rate unambiguously raises domestic consumption of non-traded goods and reduces consumption of both Home and Foreign goods. On the contrary, a worsening of the terms of trade (a rise in δ_t) lowers consumption of non-traded goods and raises consumption of Home goods. To understand this, notice that the following relationship between the terms of trade and the real exchange rate holds:

$$\left(\zeta^* - \frac{1}{2} \right) \delta_t = \gamma \left(p_{Nt} - p_{Tt} \right) + q_t$$

In order to have a worsening of the terms of trade with q_t constant it is necessary that either p_{Nt} rises or p_{Tt} falls. A fall in p_{Tt} with a simultaneous rise in δ_t is only possible if the price of Home goods fall. This, in turn, implies a reduction in the relative price of Home goods, which in turn raises the demand for this type of goods.

As long as $\zeta^* < 1$ the effect of movements in the terms of trade on consumption of Foreign goods is negative. The same happen with a real deprecition of the exchange rate.

Analogously, foreign consumption of Home goods can be expressed as

$$c_{H,t}^* = \theta\zeta^*\delta_t + c_t^* \tag{34}$$

The magnitude of the expenditure switching effect, in this case, depends on the intratemporal elasticity of substitution between Home and Foreign goods abroad (which I assume is the same as in the domestic economy). The larger θ, the larger the response of foreign consumption of Home goods to a deterioration of the terms of trade.

From (28), (29), (30) (31), (32), and (34) we obtain the following expression for aggregate output:

$$y_t = \left(\sigma - \frac{1-\gamma}{2}(\sigma - \theta)\right) q_t + \left(\frac{1-\gamma}{2}\right)\theta\delta_t + c_t^* \tag{35}$$

Notice that when $\theta = \eta$ parameter ζ^* is not relevant to define aggregate output in the domestic economy. In this case, when $\gamma = 0$ then terms of trade are proportional to the real exchange rate, $\delta_t = 2q_t$, and output is given by: $y_t = \frac{1}{2}(3\theta + \sigma) q_t + c_t^*$. This corresponds to the canonical model described in Galí and Monacelli (2002). On the contrary, when $\gamma \to 1$, output converges to the following value $\sigma q_t + c_t^*$.[5] In this case θ plays no role since the model converges to a closed economy model.

3.2 Marginal Cost and Aggregate Supply

From the first order conditions for the optimal re-setting price in the non-traded sector we obtain the following relationship between non-traded good inflation and the relevant marginal cost in this sector:

$$\pi_{Nt} = \lambda_N mc_{N,t} + \beta E_t \{\pi_{Nt+1}\} \tag{36}$$

where $\lambda_N = \frac{(1-\phi_N)(1-\beta\phi_N)}{\phi_N}$. The log-linear deviation of marginal cost from steady state is given by:

$$\begin{aligned} mc_{Nt} &= (w_t - p_{Nt}) - a_{Nt} \\ &= (w_t - p_t) + \frac{1-\gamma}{\gamma} q_t - \frac{1-\gamma}{\gamma}\left(\zeta^* - \frac{1}{2}\right)\delta_t - a_{Nt}. \end{aligned} \tag{37}$$

Notice that the relevant marginal cost is the real unitary labor cost in terms of units of the of the good the firm produces. Thus, for a given real

[5] Notice that the limit case when $\gamma = 1$ is not well defined in this model with perfect risk sharing.

wage in terms of the consumption basket, a real depreciation of the exchange rate raises the marginal cost faced by firms producing non-traded goods. On the contrary, a worsening of the terms of trade, keeping q_t constant, lowers mc_{Nt}.

Analogously, the optimal re-setting price for firms producing Home goods defines the relation between inflation in the Home goods sector and marginal cost:

$$\pi_{Ht} = \lambda_H mc_{H,t} + \beta E_t \{\pi_{Ht+1}\} \tag{38}$$

where $\lambda_H = \frac{(1-\phi_H)(1-\beta\phi_H)}{\phi_H}$. The log-linear deviation of marginal cost from steady state in this sector is given by:

$$\begin{aligned} mc_{Ht} &= (w_t - p_{Ht}) - a_{Ht} \\ &= (w_t - p_t) - q_t + \zeta^* \delta_t - a_{Ht}. \end{aligned} \tag{39}$$

From the technological restriction the demands for labor in each sector are given by:[6]

$$n_{Nt} = y_{Nt} - a_{Nt}, \tag{40}$$

$$n_{Ht} = y_{Ht} - a_{Ht}. \tag{41}$$

Linearizing the FOC for labor (11), and from the risk sharing condition (25), and labor demands (40), (41), we obtain the following equilibrium relationship between the real wage, output, the real exchange rate and exogenous shocks:

$$w_t - p_t = v y_t + q_t + \frac{1}{\sigma} c_t^* - v a_t \tag{42}$$

where $a_t = \gamma a_{Nt} + (1-\gamma) a_{Ht}$ is a weighted average productivity in the domestic economy.

It is important to note that a productivity shock in either sector will affect the real wage in the whole economy. For instance, a rise in productivity in the non-traded sector will reduce labor demand in this sector. Since each worker simultaneously works in both sectors, a reduction in labor demand in one particular sector implies that total labor effort falls. Therefore, in equilibrium the real wage must fall. Moreover, since labor is mobile across

[6] If we linearize the sectorial demand for labor we obtain:

$$\begin{aligned} n_{Nt} &= y_{Nt} - a_{Nt} + u_{Nt}, \\ n_{Ht} &= y_{Ht} - a_{Ht} + u_{Ht}, \end{aligned}$$

where $u_{Nt} = \log \int \frac{Y_{Nt}(z_N)}{Y_{Nt}} dz_N$ and $u_{Ht} = \log \int \frac{Y_{Ht}(z_H)}{Y_{Ht}} dz_H$. However, these two terms are of second order. Then, equations (40) and (41) are valid up to a first order approximation.

sectors the real wage must be the same in both of them. The same logic applies for the effect of foreign consumption on the real wage in (42).

The positive effect of the real exchange rate on the real wage is explained as follows: an increase in the real exchange rate raises domestic consumption (because of complete markets). More consumption reduces the marginal rate of utility of consumption and raises the marginal rate of substitution between labor and consumption. Therefore, real wage must increase.

Replacing (42) into (37) and (39) we obtain the following expressions for the marginal cost in both, the non-traded and the Home sectors:

$$mc_{Nt} = vx_t + \frac{1}{\gamma}q_t - \frac{1-\gamma}{\gamma}\left(\zeta^* - \frac{1}{2}\right)\delta_t + \frac{1}{\sigma}c_t^* + v\widetilde{y}_t - va_t - a_{Nt}, \quad (43)$$

$$mc_{Ht} = vx_t + \zeta^*\delta_t + \frac{1}{\sigma}c_t^* + v\widetilde{y}_t - va_t - a_{Ht}. \quad (44)$$

Equations (43) and (44) are two important relations in this model. First, notice that marginal cost in both domestic sectors are not orthogonal. In particular, changes in q_t and δ_t have asymmetric effects on mc_{Nt} and mc_{Ht}. Second, notice that a productivity shock in the non-traded (Home) sector has also an effect on the marginal cost faced by firms producing in the Home (non-traded) sector. Thus, productivity shocks in either sector will affect inflation in both sectors simultaneously.

3.3 Inflation

From the definition of the consumer price index, the consumer price index (CPI) inflation corresponds to a weighted average of non-traded goods inflation and Home goods inflation:

$$\pi_t = \gamma\pi_{Nt} + (1-\gamma)\,\pi_{Tt} \quad (45)$$

where $\pi_{Tt} = \frac{1}{2}\left(\Delta e_t + \pi_t^*\right) + \frac{1}{2}\pi_{Ht}$.

An alternative measure of inflation is the *core* inflation. In our case we define this variable as a weighted average of the inflation of domestically produced goods:

$$\pi_t^c = \gamma\pi_{Nt} + \frac{(1-\gamma)}{2}\pi_{Ht} \quad (46)$$

With this definition of *core* inflation, CPI inflation can be expressed as $\pi_t = \pi_t^c + \frac{1-\gamma}{2}\left(\Delta e_t + \pi_t^*\right)$

3.4 Interest parity, Terms of Trade, and the Real Exchange Rate

Without further distortions in the international capital market, the uncovered interest rate parity condition must hold:

$$i_t - i_t^* = E_t \Delta e_{t+1} \tag{47}$$

Solving forward for the exchange rate we obtain:

$$e_t = i_t^* - i_t - E_t \left(\sum_{i=1}^{\infty} i_{t+i} - i_{t+i}^* \right) \tag{48}$$

Notice that the precise path for the exchange rate depends not only on the current interest rate differential between domestic and foreign interest rates, but also on the future path of this differential. Thus, a reduction in the domestic interest at time t does not necessarily imply a depreciation of the exchange rate if future interest rate rises.

Finally, the terms of trade and real exchange rate evolve according to the following expressions:

$$\delta_t = \delta_{t-1} + \Delta e_t + \pi_{Ft}^* - \pi_{Ht} \tag{49}$$

$$q_t = q_{t-1} + \Delta e_t + \pi_t^* - \pi_t \tag{50}$$

where π_{Ft}^* is Foreign goods inflation expressed in terms of the foreign currency.

3.5 External Sector

Foreign households maximize an expected utility function analogous to (1). In this case, the consumption bundle is defined as follows:

$$C_{t+i}^* = \left[(\zeta^*)^{\frac{1}{\theta}} \left(C_{F,t+i}^* \right)^{\frac{\theta-1}{\theta}} + (1-\zeta^*)^{\frac{1}{\theta}} \left(C_{H,t+i}^* \right)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \tag{51}$$

It is assumed that the domestic economy is small relative to the rest of the world (represented by the foreign economy). This assumption is captured by setting parameter ζ^* close to 1. In other words, the share of Home goods in the foreign household consumption bundle is negligible. Using the risk sharing condition, foreign demand for Home goods is given by:

$$C_{H,t+i}^* = (1-\zeta^*) \left(\frac{P_{Ht}}{P_t} \right)^{-\theta} Q_t^{\theta} C_t^*$$

Notice that no claim about foreign output is made. What is relevant to characterize the dynamics of the small domestic economy is foreign consumption and the foreign interest rate. Let c_t^* be the log-deviation of foreign consumption from steady-state. It is assumed that c_t^* follows an autorregresive exogenous process:

$$c_t^* = \rho^* c_{t-1}^* + \varepsilon_t^* \tag{52}$$

where $0 < \rho^* < 1$, and ε_t^* is and $i.i.d$ processes.

In order to simplify the model, it is also assumed that foreign currency prices of Foreign goods are flexible. Therefore, foreign inflation is given by:

$$\begin{aligned} \pi_t^* &= (1-\zeta^*)\pi_{Ht}^* \\ &= (1-\zeta^*)\left(\pi_{Ht} - \Delta e_t\right) \end{aligned} \tag{53}$$

From the linearized version of the Euler equation for the representative foreign household, and utilizing (52) and (53), the following expression for the foreign interest rate is obtained:

$$i_t^* = (1-\zeta^*)E_t\left(\pi_{Ht+1} - \Delta e_{t+1}\right) - \frac{1}{\sigma}\left(1-\rho^*\right)c_t^* \tag{54}$$

Notice that since the term $1-\zeta^*$ is close to zero, Home goods inflation and the exchange rate have a negligible effect on i^*.

A consumption shock abroad is transmitted on the domestic economy through two different channels: aggregate demand and relative price. For instance, a rise in foreign consumption boosts domestic demand according to the risk sharing condition (25). At the same time, foreign interest rate falls and the exchange rate tends to appreciate. This entails a change in relative prices turning demand away from domestically produced goods (both non-traded and Home goods). Therefore, the overall effect of this shock on the domestic economy is in principle ambiguous. It depends, on how sensitive is the interest rate differential to foreign consumption, and on the response of domestic consumption to changes in relative prices (the expenditure switching effect).

3.6 Flexible Prices

The flexible price allocation in the domestic economy is the allocation that would be reached if prices in both the non-traded goods and the traded Home sectors were flexible. This implies that at any moment t inflation in both sectors is zero.

Imposing in $\pi_{Nt} = 0$ and $\pi_{Ht} = 0$ in (43) and (44), respectively, and using (35) we obtain the following expression for natural output:

$$\widetilde{y}_t = \frac{\omega v \gamma}{1+\omega v}\left(1+\frac{Y_q}{\omega v}\right)(a_{Nt}-a_{Ht}) + \omega\frac{1+v}{1+\omega v}a_{Ht} + \frac{1}{\sigma}\frac{\sigma-\omega}{1+\omega v}c_t^* \tag{55}$$

where $\omega = \left(\sigma - \frac{1-\gamma}{2}(\sigma-\theta)\right)\left(\frac{1+\gamma}{2}\right) + \left(\frac{1-\gamma}{2}\right)\theta$. Notice that when $\gamma = 0$ productivity shocks in the non-traded sector have no effect on natural output. On the other hand, when $\gamma \longrightarrow 1$ then $\omega \longrightarrow \sigma$ and $\widetilde{y}_t \longrightarrow \frac{\sigma(v+1)}{1+v\sigma}a_{Nt}$. This corresponds precisely to the natural output in a closed economy (see Clarida, Galí and Gertler, 2000).

The corresponding expressions for the log-deviation from steady state of the terms of trade and the real exchange under flexible prices are given by:

$$\widetilde{\delta}_t = -v\widetilde{y}_t - \frac{1}{\sigma}c_t^* + v(a_{Nt}-a_{Ht}) + (1+v)a_{Ht}, \tag{56}$$

$$\widetilde{q}_t = \left(\frac{1+\gamma}{2}\right)\widetilde{\delta}_t + \gamma(a_{Nt}-a_{Ht}). \tag{57}$$

Notice that if productivity shocks in the two domestic sectors were completely correlated then the real exchange rate would just be proportional to the terms of trade. As long as a_{Nt} differs from a_{Nt} then also the real exchange rate will differ from $\widetilde{\delta}_t$.

From the Euler equation we obtain an expression for the interest rate that would prevail if prices in both domestic sectors were flexible:

$$\widetilde{i}_t = i_t^* + \frac{2}{1+\gamma}\Delta\widetilde{q}_{t+1} \tag{58}$$

This interest rate corresponds to the natural interest rate in Benigno (2002). It is important to notice that causality here goes from the flexible price allocation to the natural interest rate, but not the other way. In other words, if the central bank replicates (58), this does not imply that the flexible price allocation would be reached.

Finally, we assume that productivity in each sector follows a stationary AR(1) process:

$$a_{Nt} = \rho_N a_{Nt-1} + \varepsilon_t^N \tag{59}$$

$$a_{Ht} = \rho_H a_{Ht-1} + \varepsilon_t^H \tag{60}$$

where ε_t^N, and ε_t^H are *i.i.d* processes.

4 Monetary Policy

To close the model we define the monetary regime followed by the authority. It is assumed that the monetary authority controls only one instrument. In other words, the central bank has the ability of defining the path of one of the variables of the system. Three alternative monetary regimes are considered.

4.1 Benchmark Case

In the benchmark case the Central Bank controls the interest rate through a specific rule. The policy rule is a modified Taylor rule, where the Central Bank adjusts the interest rate in response to both, inflation and output gap fluctuations. However, there is some inertia in the adjustment of the interest rate. The rule is the following:

$$i_t = \rho_i i_{t-1} + (1 - \rho_i)\,\psi_\pi \pi_t + (1 - \rho_i)\,\psi_x x_t. \qquad (61)$$

where ρ_i is an autorregresive coefficient that captures the inertia in the policy rule, and were ψ_π, and ψ_x are the weights associated to inflation and the output gap, respectively. This inertia in the interest rate has been widely documented (see Galí and Gertler (1999) for the U.S. economy) and could be explained by the desire of the central bank to smooth interest rate fluctuations, or by the fact that changes in the monetary instrument are slowly pass through to market interest rates (see evidence in Bondt, G. (2002), and Borio, C. and W. Fritz (1995)).

4.2 CPI Inflation Targeting

Under CPI inflation targeting the central bank defines a path for the rate of CPI inflation. In particular, it is assumed that the monetary authority completely stabilizes the consumer price index:

$$\pi_t = 0 \qquad (62)$$

Given the rates of inflation of non-traded and Home traded goods, the central bank must adjust the exchange rate in order to obtain the desired path for π_t. This implies that the exchange rate is given by:

$$\Delta e_t = -2\frac{\gamma}{1-\gamma}\pi_{Nt} - \pi_{Ht}$$

In other words, CPI targeting can be interpreted as a managed exchange rate regime where the Central Bank actively adjusts the exchange rate to reach its target defined by (62). From the parity condition (47) we can obtain a path for the nominal interest rate that would lead to the allocation that results from this monetary regime.

4.3 *Core* Inflation Targeting

In the literature on optimal monetary policy for open economies it has been emphasized that under certain conditions the optimal policy stabilizes domestic inflation (Galí and Monacelli, 2002). In our case the flexible price allocation is reached if both π_{Nt} and π_{Ht} are, simultaneously, zero. However, since the central bank controls only one instrument this allocation can not be reached by using the monetary policy. Moreover, it is not possible to completely stabilize prices on either of the two domestic sectors. To see that, suppose the Central Bank gives up controlling the interest rate and defines, instead, a path for π_{Nt} (or π_{Ht}). This implies that the equation defining the interest rate disappears and that the uncovered interest parity condition is no longer enough to pin down the nominal exchange rate. The system becomes undetermined.

Given this, a *core* inflation targeting regime is defined as the following feedback rule for the interest rate:

$$i_t = \psi_{\pi^c} \pi_t^c \tag{63}$$

where we assume $\psi_{\pi^c} \to \infty$.[7] In other words, under *core* inflation targeting the Central Bank adjusts its monetary instrument in an aggressive way in response to any deviation of *core* inflation from its target (which is zero in the model). Notice that stabilizing *core* inflation does not guarantee that the flexible price allocation is reached. In fact, there are infinite paths for π_{Nt} and π_{Ht} that satisfy (46) with $\pi_t^c = 0$.

The model is fully characterized by equations (24), (35), (36), (38), (43), (44), (45), (47), (49), (50), the law of motion of the exogenous variables (52), (60), and (59) , and the monetary regime. The full model cannot be solved analytically. Therefore, results are based on a numerical solution. The next section presents the baseline calibration of the model, and describes the main results.

[7] In the simulations below ψ_{π^c} is just a large number.

5 Results

The model is parameterized using some standard parameters in the RBC literature and some figures consistent with the features of the Chilean economy for quarterly data. In particular, for the impulse-response function discussed below we assume that $\gamma = 0.6$, which is consistent with a share of non-traded goods in GDP of about 60%. The probability that a particular firm keeps its price until the next period is assumed to be equal across sectors: $\phi_N = \phi_H = 0.75$. This value implies that firms reset prices every four periods on average.

Two key parameters are the intertemporal elasticity of substitution, σ, and the intratemporal elasticity of substitution, θ.[8] First, I assume that $\sigma = 1$, which corresponds to a log utility specification. Second, the intratemporal elasticity of substitution is set to 1.5. This corresponds to the value utilized by Galí and Monacelli (2002), and Backus, et al. (1994).

Other parameters of the model are the elasticity of labor supply, v, and the autorregresive coefficients for the exogenous processes, and the monetary policy rule. I assumed that $v = 2$, which corresponds to an elasticity of labor supply of $\frac{1}{2}$. This is consistent with the parameter used by Smets and Wouters (2001) among others.

The smoothing parameter for the baseline monetary policy rule is 0.7. This number corresponds to the value estimated by Galí and Gertler for the U.S. economy and also by Caputo (2002) and Parrado (1999) for the Chilean economy. Two other parameters in the baseline rule are: $\psi_\pi = 1.5$, and $\psi_x = 0.5$. The feedback parameter for the interest rate in the *core* inflation targeting regime is $\psi_{\pi^c} = 500$. Finally, it is assumed that the autorregresive parameter for the two productivity shocks and for foreign consumption is 0.9.

5.1 Impulse-response Functions

Figures 1 to 3 present impulse-responses functions for the three exogenous shocks. Figure 1 presents impulse-responses of a number of macro variables to a productivity shock in the non-traded sector, a_{Nt}.[9] The solid line corresponds to the benchmark policy, the dotted line corresponds to the CPI inflation targeting, and line with the triangles represents the responses under *core* inflation targeting.

[8] Remember that it is assumed that $\eta = \theta$.

[9] The shock corresponds to a 1% deviation of productivity from its steady state value.

It can be seen that under the three regimes a productivity shock depreciates the real exchange rate. However, the response of this variable is larger under *core* inflation targeting than under the baseline rule or CPI inflation targeting. Under all three regimes the central bank responds to the shock by expanding the monetary stance, which induces a depreciation of the nominal exchange rate. With sticky prices the nominal depreciation leads to an increase in the real exchange rate. Under *core* inflation targeting the monetary authority reduces the interest rate in a more aggressive way. Therefore, both the nominal and the real exchange rate depreciate by more than in the other two cases. Notice that under this regime the initial depreciation of the nominal exchange rate (plus the increase in Home goods inflation) raises CPI inflation on impact. In the case of the baseline policy, despite of the nominal depreciation of the exchange rate, there is a mild fall in CPI inflation. The reason is that one of the main effects of the productivity shock is to reduce inflation in the non-traded goods sectors. Given our baseline parametrization -where inflation in the non-traded sector represents 60% of CPI inflation- this effect dominates over the effect of the nominal exchange rate on inflation. This fall in inflation also contributes to the rise in the real exchange rate. Notice that in the case of CPI inflation targeting, by construction CPI inflation remains unchanged.

Initially, under the three regimes the terms of trade rise in response to the shock. This is a result of the depreciation of the nominal exchange rate which increases the domestic currency price of Foreign goods. However, under all the three regimes there is, simultaneously, an increase in Home goods inflation. Over time, the increment in the price of Home goods dominates the effect of the nominal exchange rate on the price of Foreign goods, and the terms of trade fall bellow zero on their transition to the steady state.

For all the three regimes the real depreciation of the exchange rate induces an expenditure switching effect that boosts output. Again, here we can notice how the more expansive policy followed under *core* inflation targeting results in a larger output response. Under this regime the expansion in output is large enough to let output gap rise after the shock. On the contrary, under the baseline case and under CPI inflation targeting the expenditure switching effect is not large enough to raise output above its natural level (which also rises with the shock). As a result, in these two cases the output gap falls.

The response of non-traded goods inflation is negative under all three regimes. This is a direct consequence of the negative impact of productivity on the marginal cost in this sector. On the contrary, under the three policy regime Home goods inflation rises with the shock. In the three cases the worsening of the terms of trade increases the marginal cost in this sector. This, in turn, boosts Home goods inflation.

The trade-off faced by the central bank is clear: If the monetary authority would try to completely stabilize inflation in the non-traded sector it would have to induce an even larger depreciation of the nominal exchange rate (larger than the depreciation induced under *core* targeting). This would worsen the terms of trade more than in any of the three regimes above. As a result, the rise in Home goods inflation would by even larger.

Figure 2 presents the impulse responses to a productivity shock in the Home goods sector, a_{Ht}. As in the previous case, under the three monetary regimes this shock depreciates the real exchange rate and worsens the terms of trade. However, since this shock affects the price of Home goods directly -and the price of non-traded goods only indirectly- the real depreciation of the exchange rate is smaller and the worsening in the terms of trade is larger than in the previous case.

The transmission mechanisms at work, in this case, are similar to the ones in the previous case. First, the shock lowers marginal cost in the Home goods sector and inflation in this sector falls. Under the three monetary regimes the central bank responds by expanding the economy and the nominal exchange rate depreciates. Both, the fall in the price of Home goods together with the nominal depreciation of the exchange rate, worsen the terms of trade, and the real exchange rate depreciates.

Notice that the response of the terms of trade to the shock is larger under CPI inflation targeting than under the other two regimes. Under CPI inflation targeting the monetary authority is less aggressive in reducing the interest rate. As a result, the drop in Home goods inflation and the deterioration of the terms of trade are larger under this regime.

In all three cases, and despite the increase in output, the initial response of the output gap is negative. However, under CPI inflation targeting the larger increase in the terms of trade that occurs after some periods, leads to an also larger expansion in output. As a result, the output gap rises above its steady state after some periods and it converges back to the steady state from above.

Figure 3 presents the responses to a foreign consumption shock. Remember that this type of shock simultaneously raises foreign consumption and lowers the interest rate abroad. There are two opposite effects on output: On the one hand, the increase in foreign consumption raises domestic demand through the risk sharing condition. However, at the same time there is a real depreciation of the exchange rate and the terms of trade fall. As a result foreign goods become relatively cheaper and demand moves away from domestically produced goods. The overall effect on output depends on the different elasticities and the response of the monetary authority to the shock.

Under CPI inflation targeting the monetary authority prevents a large swing in relative prices by stabilizing the exchange rate. This is reflected in the trajectory of the nominal interest rate which falls in response to the shock. As a result, the expenditure switching effect is minimized and the positive direct effect of foreign consumption dominates the response of domestic output to the shock. As a consequence, both output and the output gap have a transitory increase in response to the shock.

Under both the benchmark policy rule and *core* inflation targeting the central bank allows a larger appreciation of the exchange rate. This leads to a fall in CPI inflation. In both cases the expenditure switching effect compensates the aggregate effect of the shock and the response of the output gap is nil.

Notice that under *core* inflation targeting a foreign shock has no impact neither on Home goods inflation nor on non-traded goods inflation. On the contrary, under CPI inflation targeting the initial increase in output raises marginal cost and inflation increases in both sectors.

As a summary, under CPI inflation targeting the central bank is less aggressive in adjusting the interest rate in response to domestic productivity shocks, and it allows a more expansive policy in response to foreign shocks. On the contrary, under *core* inflation targeting the monetary authority follows a more expansive policy to accommodate domestic productivity shocks and it is less active with respect to foreign shocks.

5.2 Non-traded Goods and Macroeconomic Volatility

In this section we analyze how volatility of different variables is affected by the existence of a non-traded sector. In Figure 4 we show the standard deviation of a set of variables for different values of γ. Again, the solid line corresponds to the baseline case, the dotted line the CPI inflation targeting and the line with the triangles represents the *core* inflation targeting regime.

Obviously, of all three regimes, and for any value of γ, the *core* inflation targeting regime delivers the lowest *core* inflation volatility. However, if we compare individually non-traded and Home goods inflation, we see that this regime does not necessarily reduce the volatility of these two variables. In fact, when the economy has a very small share of non-traded goods the baseline Taylor rule induces a smaller inflation in the non-traded goods sector. On the contrary, when the share of non-traded goods is large then also the baseline case delivers the lowest inflation volatility in the Home goods sector.

When comparing the CPI inflation targeting regime with the baseline rule, in terms of *core* inflation volatility, the former regime provides more stability only when the share of non-traded goods is high. Home goods inflation volatility is lower under the Taylor rule than under CPI inflation targeting for any value of γ. non-traded goods inflation is also lower under the Taylor rule than under CPI inflation targeting for low values of γ. However, as the share of non-traded goods increases the volatility of inflation in this sector under CPI inflation targeting decreases. In fact, in the limit as γ goes to 1, both non-traded goods inflation and *core* inflation volatility converges to zero under this regime. As we saw, when the share of non-traded goods is large then the economy converges to a closed economy. In this case, non-traded inflation tends to coincide with CPI inflation. Therefore, if the central bank stabilizes CPI inflation then it stabilizes non-traded goods inflation at the same time. Moreover, in the limiting case when $\gamma \to 1$ there is no trade-off for the central bank and both, inflation and the output gap, can be completely stabilized, as shown in the figure.

The fact that under the three regimes, and for any value of γ different from 0 or 1, the volatility the output gap is positive, is a consequence of the incapacity of the monetary policy to replicate the flexible price allocation. However, a tough response of the monetary authority to *core* inflation fluctuations, as in the *core* inflation targeting regime, reduces the volatility of the output gap. The reason is simple: When the share of non-traded goods is large then fluctuations in *core* inflation will reflect basically fluctuations in non-traded goods inflation. Thus, while stabilizing *core* inflation, the *core* inflation targeting regime will simultaneously stabilize non-traded goods inflation. The fact that the volatility of Home goods inflation is increased is not relevant as long as γ is large. The opposite is true for low values of γ.

If we compare the baseline rule and CPI inflation targeting we observe that, in general, the output gap is more stable under the former rule. However, this is not true for large values of γ. As we saw, when the share of non-traded goods is large stabilizing CPI inflation implies stabilizing the non-traded sector. Moreover, since the non-traded sector represents a large share of aggregate output this policy approaches output to its natural level.

Notice that under the three policy regimes, the volatility of the real exchange rate increases with the share of non-traded goods. This is consistent with the evidence in Hau (1999), where he shows that the volatility of the real exchange rate is a decreasing function of the degree of openness of a country.[10]

Of all three monetary regime *core* inflation is the one that entails most exchange rate volatility, for any value of γ. Figure 5 presents the correlation coefficient between domestic and foreign interest rate for different shares of non-traded goods. From the figure is clear that all three regimes imply a positive correlation between the domestic and the foreign interest rate. Therefore, there is some exchange rate smoothing. However, the correlation between these interest rates varies considerably across monetary regimes. Under both, the core inflation targeting regime and the baseline case, the domestic interest rate tends to be uncorrelated with the foreign interest rate as γ increases. Instead, under CPI inflation targeting the correlation between these two variables remains high for any value of γ.

5.3 Welfare Analysis

In this economy there are two sources of inefficiency: the monopoly power excised by domestic producers, and price stickiness. The first source of inefficiency can be alleviated with a proper scheme of taxes and subsidies (see Benigno, 2001). Once this is done, the first best policy for the monetary authority implies replicating the flexible price allocation, which is given by equations (55), (56) and (57). However, the Central Bank has control over only one instrument. As we said, this implies that the monetary authority can not replicate the flexible price allocation.[11]

In this version of the paper we do not determine the optimal policy. Instead we are interested in ranking the different policy rules according to a particular welfare criterion. A welfare function derived from first principles, as in Woodford (2002) or Benigno (2001), is not feasible in our setup.[12] Instead, it is assumed here that welfare is directly affected by the distortions created by price dispersion on consumption, measured by the volatility of inflation in both, the non-traded goods and Home goods sectors (Smets and Wouters (2002)). The loss function that define welfare is given by:

$$\mathbb{W}_t = -\left\{\alpha_N Var\left(\pi_{Nt}\right) + \alpha_H Var\left(\pi_{Ht}\right)\right\} \tag{64}$$

[10] Hau measures openness by the share of imports in total GDP. In this paper, the degree of openness is measured by the share of Non-traded goods in total consumption.

[11] In a standard microfunded one-sector sticky-price open economy model, without further distortions (i.e. without an ad-hoc cost push shock or incomplete pass-through) the flexible price allocation could be reach with one instrument.

[12] Gali and Monacelli (2002) present a welfare function for a small open economy that is derived from first principles. However, in order to obtain such a function they had to restrict the value of key parameters to a particular case.

where $\alpha_N = \gamma$ and $\alpha_H = \frac{1-\gamma}{2}$. These weights correspond to the share of non-traded and Home goods in the steady-state consumption bundle.

This welfare function can be rationalized as follows: given the fact that prices in each sector are sticky, fluctuation in inflation cause price dispersion. This, in turn, represents a change in relative prices across individual producers that reduces welfare.

Figure 6 displays the loss function (64) for various values of γ. This figure summarizes the relationships between the share of non-traded goods and the volatility of the two domestic inflations described in the previous section.

Despite the fact that *core* inflation targeting does not completely stabilize non-traded and Home goods inflation simultaneously, this regime delivers the lowest welfare loss for any value of γ. Moreover, as $\gamma \to 0$ or $\gamma \to 1$ the allocation under this monetary regime corresponds to the optimal allocation.

When comparing CPI inflation targeting with the baseline Taylor rule we see that the former carries a lower welfare loss only when the share of non-traded goods is high. This is due to the fact that when γ is high the volatility of π_{Nt} under CPI inflation targeting is lower than under the Taylor rule. In the limiting case when $\gamma \to 1$, CPI inflation targeting coincide with *core* inflation targeting and the value of the loss function tends to zero.

In the other extreme case, when γ is low, CPI inflation targeting is outperformed by the Taylor rule. Remember that CPI inflation targeting implies completely stabilizing CPI inflation. When foreign shocks are present the expenditure switching mechanism helps stabilizing output around its flexible price level. However, when γ is low, fluctuations in the exchange rate have a larger weight on CPI inflation. Thus, under CPI inflation targeting the central bank is more active in stabilizing the exchange rate, and the expenditure switching effect is reduced. As a result, output over expands in response to foreign shocks. The same happens with marginal costs in both, the Home goods and non-traded goods sectors. This induces larger swings in sectorial inflation.

5.4 Correlated Shocks

Here we relax the assumption that shocks are uncorrelated. In particular we allow productivity in both the non-traded and the Home goods sectors to be correlated. We also allow productivity in the Home goods sector to be positively correlated with foreign consumption.[13]

In Figure 7 we present the welfare loss function under the three monetary regimes for different values of γ and for different degrees of correlations across shocks. In general, the results are similar to the case where shocks are uncorrelated. In all cases, *core* inflation targeting is the best of all three regimes according to our welfare criterion. Also, the Taylor rule outperforms a CPI inflation targeting regime when the share of non-traded goods is not to high. An exception to this is when productivity in the Home goods sector is perfectly correlated with the foreign shock. In this case CPI inflation targeting outperforms the Taylor rule for any value of γ. The reason is that under this regime the effects of both shocks on Home goods inflation compensate one to the other.

Notice also that when the correlation between non-traded and Home goods productivity is 1 then *core* inflation corresponds to the optimal monetary policy

6 Conclusions

This paper develops a small open economy model that is characterized by existence of two domestic sectors: a Home traded goods sector and a non-traded goods sector. In both sectors prices are sticky, and each one is subject to a specific productivity shock.

In this setup the flexible price allocation can not be reached by means of a single monetary policy instrument. Therefore, the central bank faces a trade-off between stabilizing inflation in the non-traded sector and in the Home goods sector. In this context, when the share of non-traded goods is not too high, a simple Taylor rule (a feedback rule for the interest rate that depends on inflation and output gap) outperforms a strict inflation targeting regime. However, both policy rules are dominated by a rule that moves the interest rate aggressively in response to deviation in domestic *core* inflation. On the other hand, if the share of non-traded goods is high then the model converges to a closed economy case, and, in absence of an exogenous cost push shock, the optimal policy is to completely stabilize consumer price inflation.

[13] This can be justified by assuming that foreign consumption responds to a world productivity shock that also affects domestic production of Home goods.

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Appendix: Steady State

Here I describe the equations that characterize the steady-state of the economy, and I discuss the existence and uniqueness of such steady-state.

Aggregate domestic demands for the two domestically produced goods are by

$$C_N = \gamma \left(\frac{P_N}{P} \right)^{-\theta} C \tag{65}$$

$$C_H = (1-\gamma) \frac{1}{2} \left(\frac{P_H}{P} \right)^{-\theta} C \tag{66}$$

At the same time, foreign demand for Home goods is given by:

$$C_H^* = (1-\zeta^*) \left(\frac{P_H}{P} \right)^{-\theta} Q^\theta C^* \tag{67}$$

where Q is the steady state level of the real exchange rate.

Given C* the steady state level of consumption in the domestic economy, C, is given by the risk sharing condition:

$$C = \alpha Q^\sigma C^* \tag{68}$$

where α is a parameter that depends on the initial conditions in both economies.

There are different ways aggregate output in the domestic economy. For simplicity I use a linear aggregator, where real domestic output is just the sum of Non-traded output and output produced in the traded sector:

$$Y_t \equiv Y_{Nt} + Y_{Ht} \tag{69}$$

I assume that in the steady state productivity levels in both domestic sector are $A_N = A_H = 1$. Moreover, I assume that the elasticity of subtitution across varieties in both sector is the same, $\epsilon_N = \epsilon_H = \epsilon$. This implies that steady state markups in both sectors are also the same. Therefore, steady state prices of the two domestically produced goods are given by:

$$\begin{aligned} P_N &= \Phi W, \\ P_H &= \Phi W \end{aligned} \tag{70}$$

where $\Phi = \frac{\epsilon}{\epsilon - 1}$ is the steady state markup. Real exchange rate in steady state satisfies the following expression:

$$Q \equiv \frac{\mathcal{E} P^*}{P} = \left(\frac{1-\zeta^* + \zeta^* TT^{1-\theta}}{1-\widetilde{\gamma} + \widetilde{\gamma} TT^{1-\theta}} \right)^{\frac{1}{1-\theta}} \tag{71}$$

where $\widetilde{\gamma} = \frac{1-\gamma}{2}$ and TT are the steady state terms of trade. Notice that if $\frac{\zeta^*}{1-\zeta^*} > \frac{\widetilde{\gamma}}{1-\widetilde{\gamma}}$, then $Q_{TT} > 0$. In other words, if ζ^* is large enough then the real exchange rate is positively related to the terms of trade In fact, given any value of $\gamma \in [0,1]$ the previous condition is satisfied if $\zeta^* > 1/2$.

From the Household´s maximization problem for labor effort we have the following relationship:

$$\frac{k}{2} N^v C^{1/\sigma} = \frac{W}{P} = \frac{1}{\Phi} \frac{P_H}{P}.$$

where the relative price of Home goods satisfies: $\frac{P_H}{P} = \left[(1-\widetilde{\gamma}) + \widetilde{\gamma} TT^{1-\theta}\right]^{-\frac{1}{1-\theta}}$. Using the risk sharing condition (68) we obtain:

$$\frac{k}{2} \Phi N^v Q \left(\alpha C^*\right)^{1/\sigma} = \frac{P_H}{P} \tag{72}$$

Using (69) plus labor demands in each one of the two domestic sector, $N_N = Y_N$ and $N_H = Y_H$, we obtain:

$$N = Y \tag{73}$$

Combining (73) with (72) we obtain the following expression:

$$Y = \left(2\frac{\Phi^{-1}}{k}\right)^{\frac{1}{v}} \left(\alpha C^*\right)^{-\frac{1}{v\sigma}} \left(\frac{P_H}{P}\frac{1}{Q}\right)^{\frac{1}{v}} \equiv L\left(TT, C^*\right) \tag{74}$$

Is easy to show that given C^*, $L_{TT} < 0$ for al TT. Moreover, if $\theta > 1$ then,

$$\lim_{TT \to \infty} L\left(TT, C^*\right) = \left(2\frac{\Phi^{-1}}{k}\right)^{\frac{1}{v}} \left(\alpha C^*\right)^{-\frac{1}{v\sigma}} \left(1-\zeta^*\right)^{\frac{v}{\theta-1}},$$

and,

$$\lim_{TT \to 0} L\left(TT, C^*\right) = \infty.$$

Analogously, if $\theta < 1$ then:

$$\lim_{TT \to \infty} L\left(TT, C^*\right) = 0,$$

and,

$$\lim_{TT \to 0} L\left(TT, C^*\right) = \left(2\frac{\Phi^{-1}}{k}\right)^{\frac{1}{v}} \left(\alpha C^*\right)^{-\frac{1}{v\sigma}} \left(\frac{1}{1-\zeta^*}\right)^{\frac{v}{1-\theta}}.$$

Market clearing condition implies the following relation between nominal output and the demands for domestically produced goods:

$$Y = (C_N + C_H + C_H^*)$$

Notice that I have used the fact that in steady state $P_Y = P_N = P_H$.

Using (65), (66), and (67), and the risk sharing condition we can express aggregate nominal output as follows:

$$Y = (1-\widetilde{\gamma})\left(\frac{P_H}{P}\right)^{-\theta}\alpha Q^{1/\sigma}C^* + (1-\zeta^*)\left(\frac{P_H}{P}\right)^{-\theta}Q^{\theta}C^* \equiv H\left(TT, C^*\right) \tag{75}$$

It is easy to see that for of any level of TT, $H_{TT} > 0$. Moreover, if $\theta > 1$

$$\lim_{TT\to\infty} H = \left(\alpha\left(1-\widetilde{\gamma}\right)^{\frac{\sigma-1}{(1-\theta)\sigma}}\left(1-\zeta^*\right)^{\frac{1}{(1-\theta)\sigma}} + \left(1-\zeta^*\right)^{\frac{1}{1-\theta}}\right)C^*,$$

and,

$$\lim_{TT\to 0} H = 0.$$

Analogously, if $\theta < 1$ then the following is true:

$$\lim_{TT\to\infty} H = \infty,$$

and,

$$\lim_{TT\to 0} H = \left(\alpha\left(1-\widetilde{\gamma}\right)^{\frac{\sigma-1}{(1-\theta)\sigma}}\left(1-\zeta^*\right)^{\frac{1}{(1-\theta)\sigma}} + \left(1-\zeta^*\right)^{\frac{1}{1-\theta}}\right)C^*.$$

Uniqueness of the steady-state is guarantee by the fact that for all TT, $L_{TT} < 0$ and $H_{TT} > 0$. To prove existence we have to consider two cases:

Case (a): $\theta > 1$ In this case we have to show that the following condition is satisfied:

$$\left(2\frac{\Phi^{-1}}{k}\right)^{\frac{1}{v}}\alpha^{-\frac{1}{v\sigma}}\left(C^*\right)^{-\frac{1+v\sigma}{v\sigma}} < \alpha\left(1-\widetilde{\gamma}\right)^{\frac{1-\sigma}{(\theta-1)\sigma}}\left(1-\zeta^*\right)^{-\frac{1+v}{(\theta-1)\sigma}} + \left(1-\zeta^*\right)^{-\frac{1+v}{\theta-1}} \tag{76}$$

Notice that the LHS is just a constant, while the RHS of this expression is *increasing* in ζ^*. Moreover, the RHS goes to infinity as $\zeta^* \to 1$. Therefore, there exist a $\overline{\zeta}^* \in [0,1]$ such that for any $\zeta^* > \overline{\zeta}^*$ condition (76) is satisfied.

Case (*b*): $\theta < 1$ Here we have to show that the following relation holds:

$$\left(2\frac{\Phi^{-1}}{k}\right)^{\frac{1}{v}} \alpha^{-\frac{1}{v\sigma}} \left(C^*\right)^{-\frac{1+v\sigma}{v\sigma}} > \alpha \left(1-\widetilde{\gamma}\right)^{\frac{\sigma-1}{(1-\theta)\sigma}} \left(1-\zeta^*\right)^{\frac{1+v\sigma}{(1-\theta)\sigma}} + \left(1-\zeta^*\right)^{\frac{1+v}{1-\theta}} \tag{77}$$

Again, the LHS of this expression is a positive constant. The RHS is a decreasing function of ζ^*, and it goes to 0 as $\zeta^* \to 1$. Therefore, there exist a $\widetilde{\zeta}^*$ such that for all $\zeta^* > \widetilde{\zeta}^*$ condition (77) is satisfied. Therefore, existence is guarantee provided that $\zeta^* > \max\left(\overline{\zeta}^*, \widetilde{\zeta}^*\right)$.

For convenience, and without lose of generality, I assume that initial condition are such that $\alpha = 2\frac{1-\zeta^*}{1-\gamma}$. In this case the steady state is characterized by $TT = Q = 1$ and $Y = C = \alpha C^*$

Figure 1: Impulse-response to a Non-traded goods productivity shock

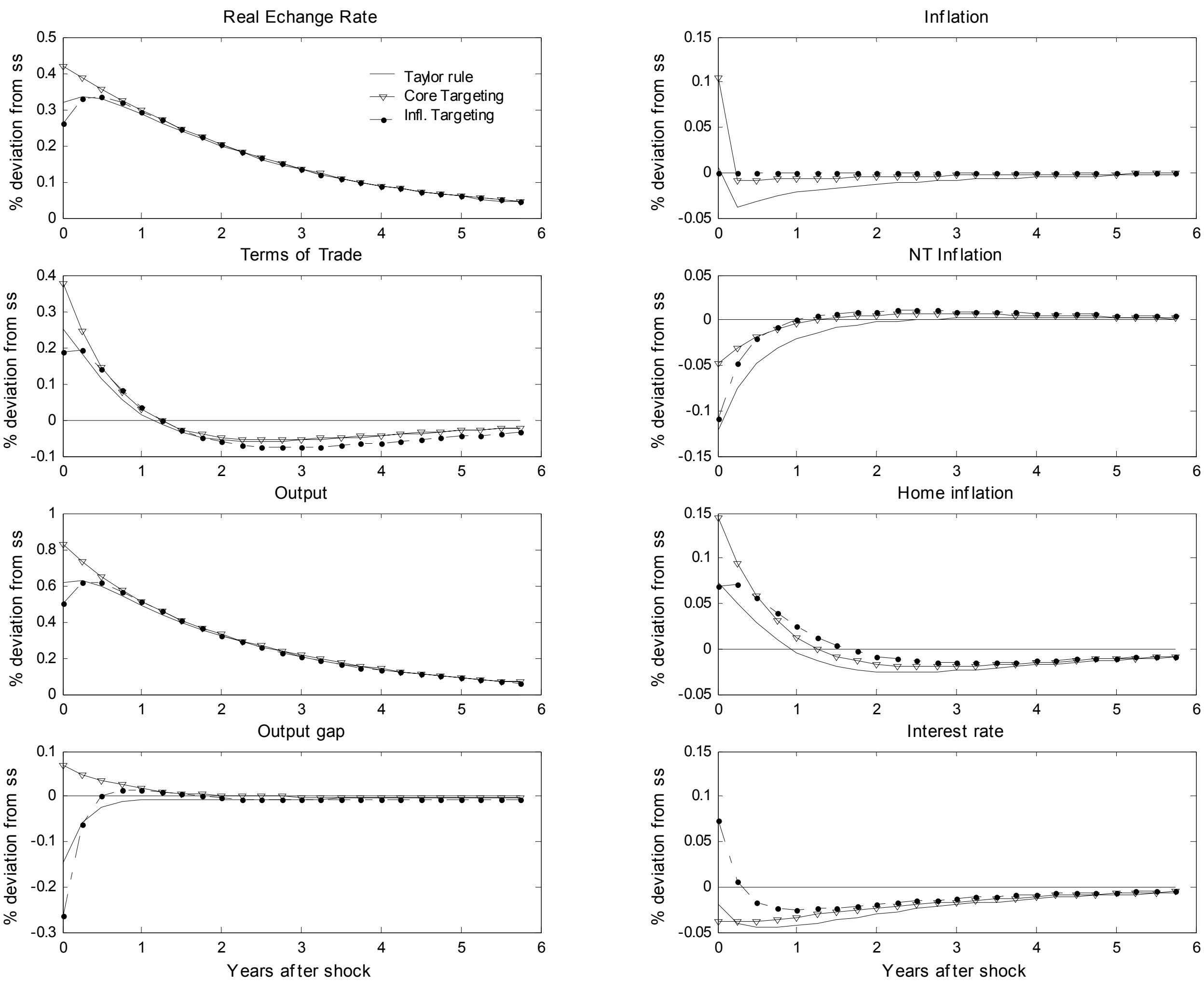


Figure 2: Impulse-response to a Home goods productivity shock

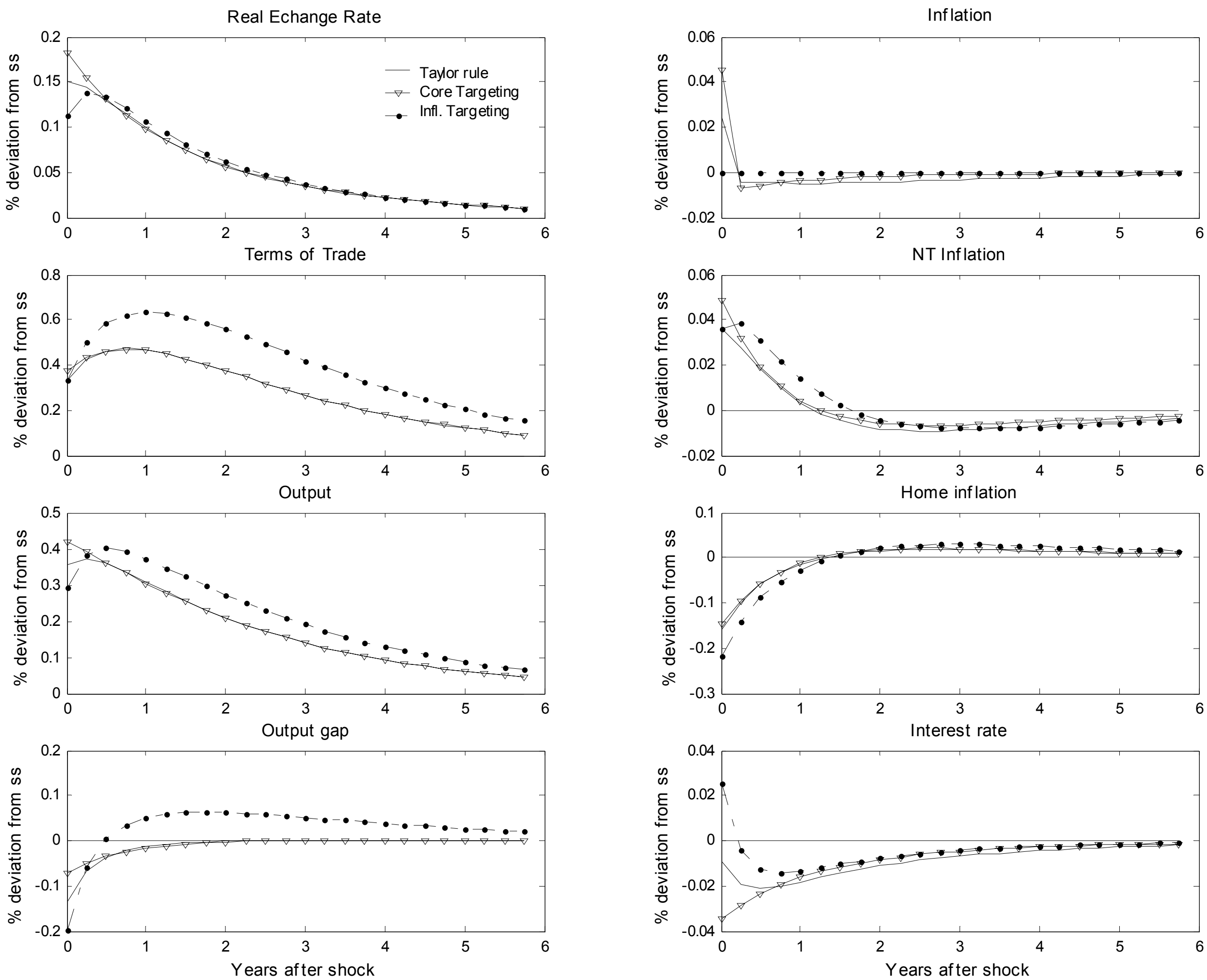


Figure 3: Impulse-response to a Foreign shock

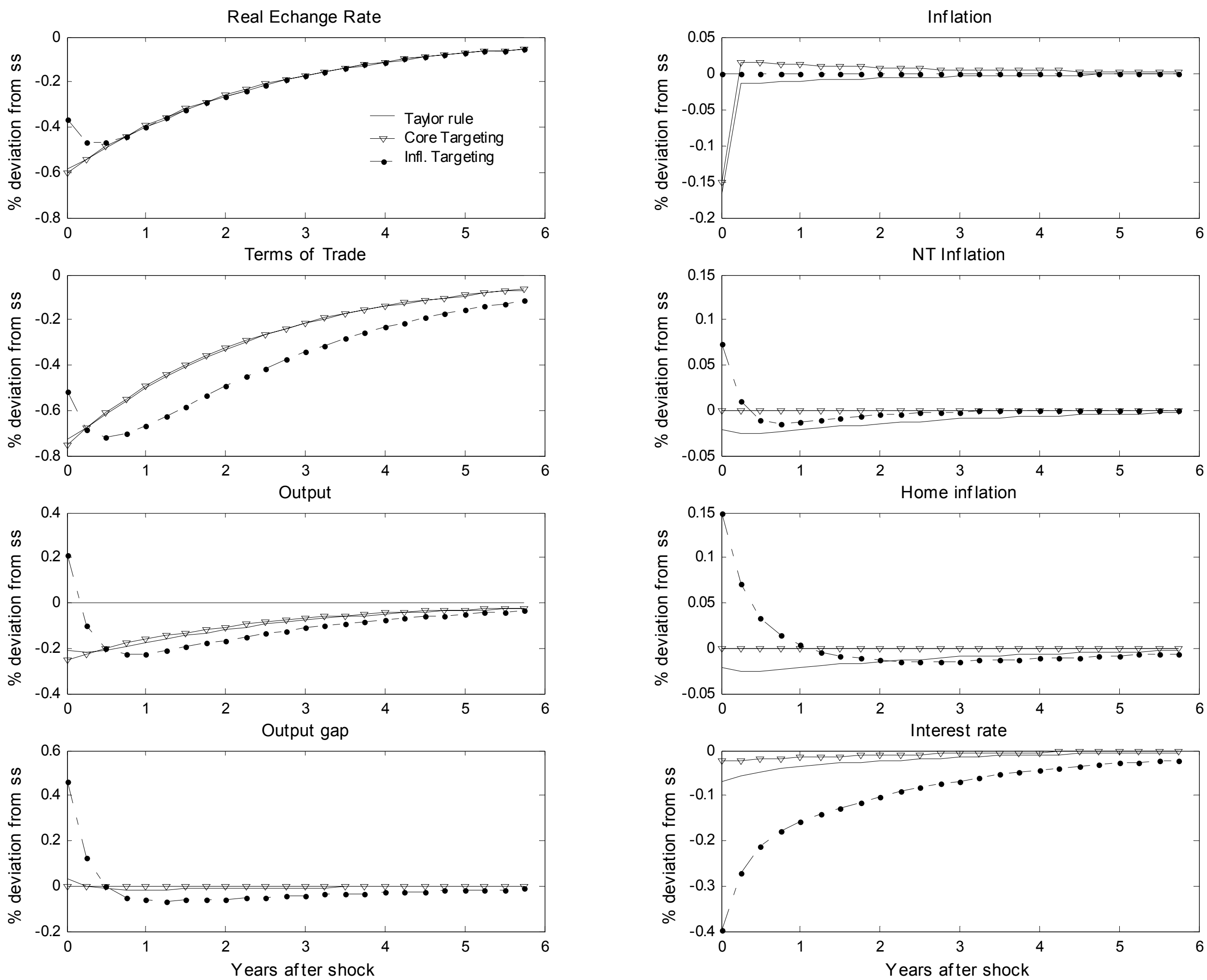


Figure 4: Non-traded goods and Volatility

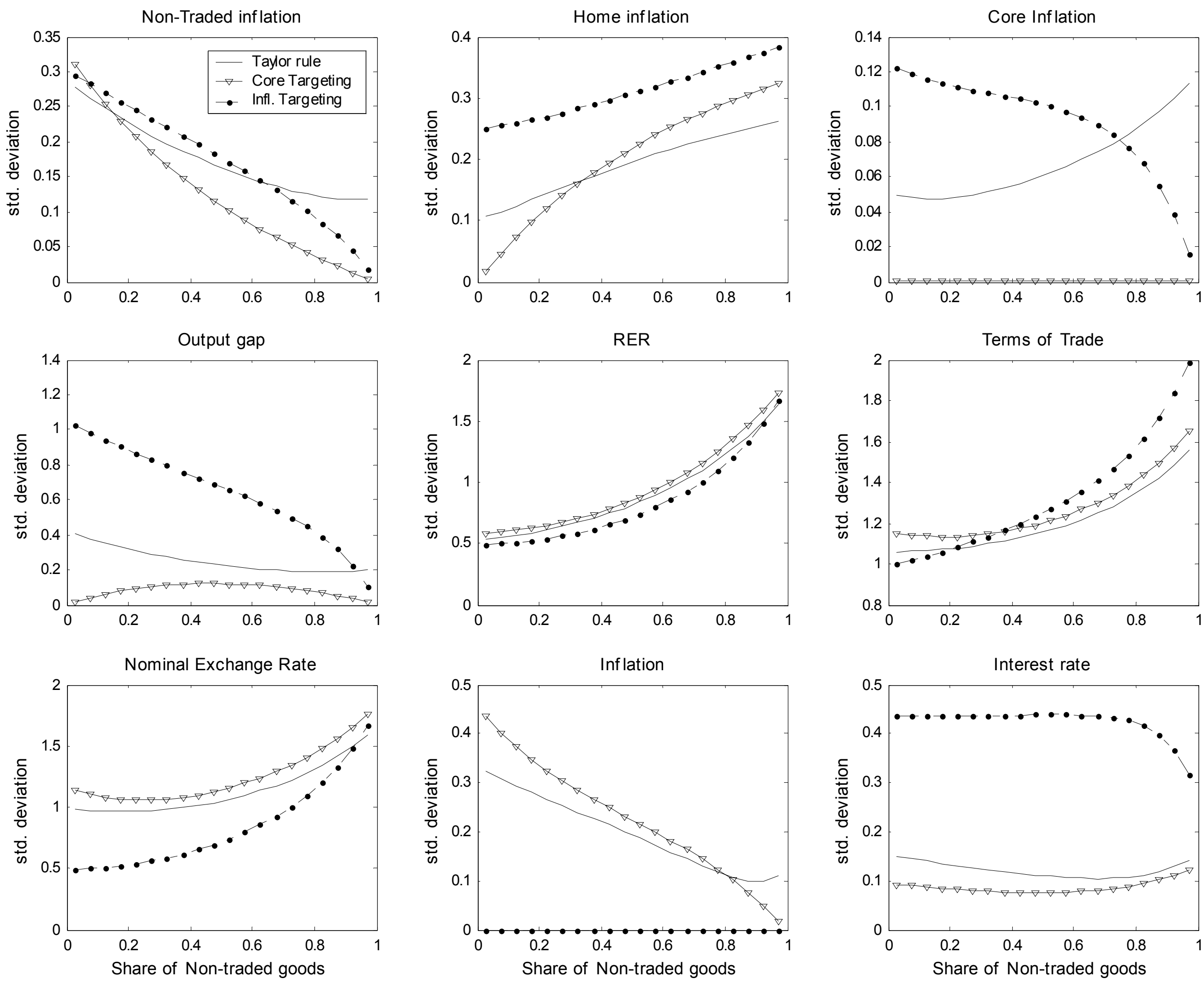


Figure 5: Non-traded goods and policy response to Foreign interest rate

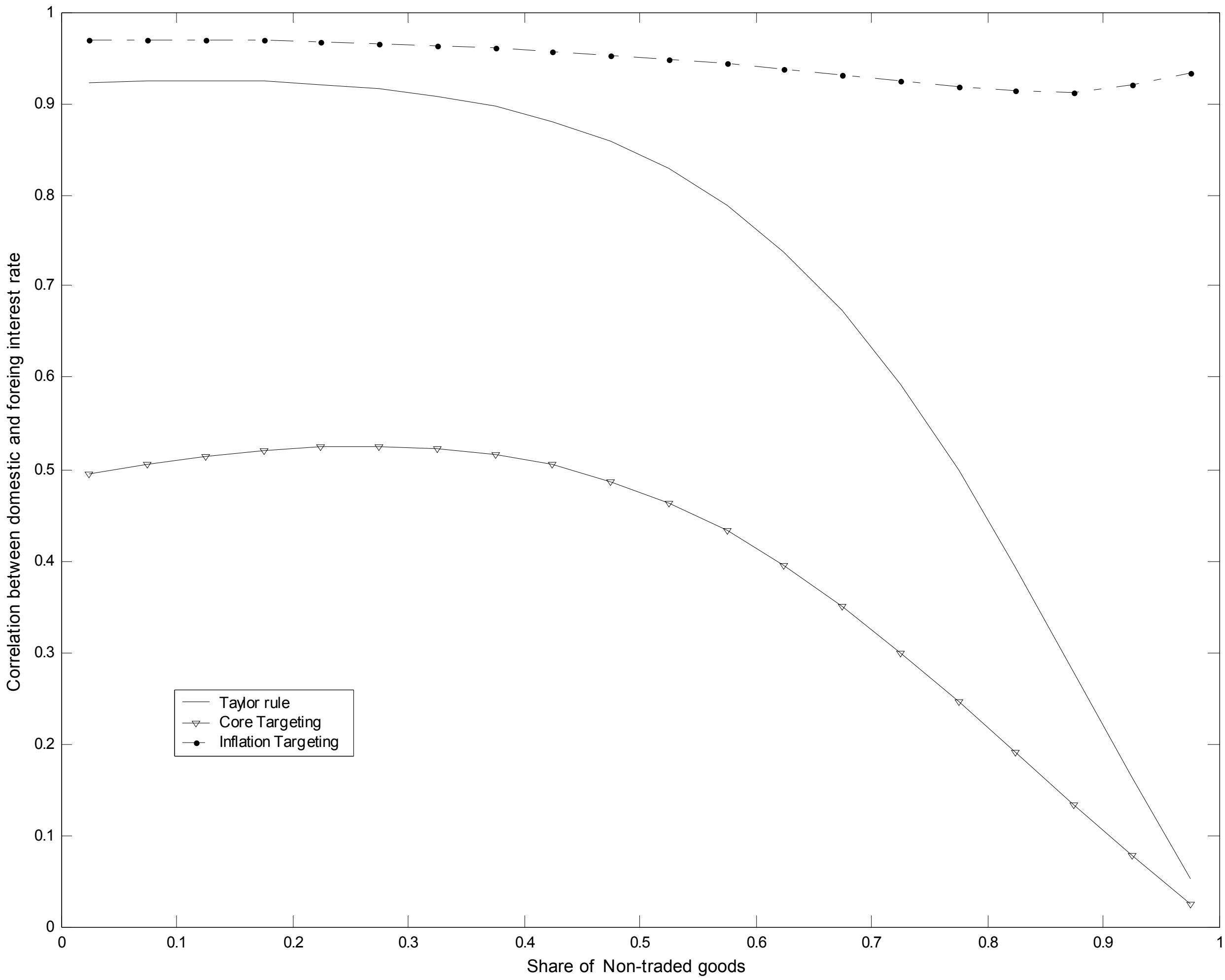


Figure 6: Non-traded goods and Welfare

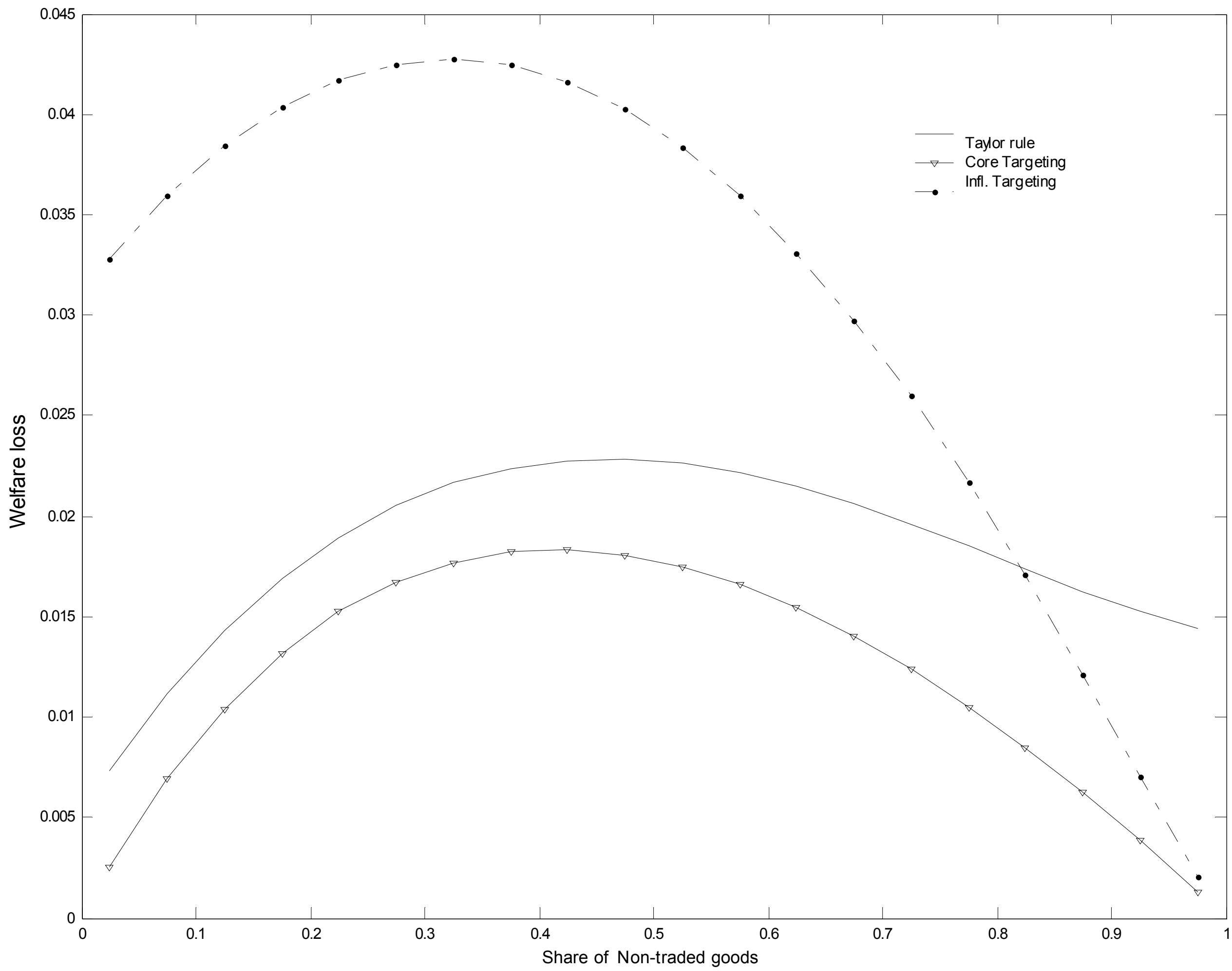
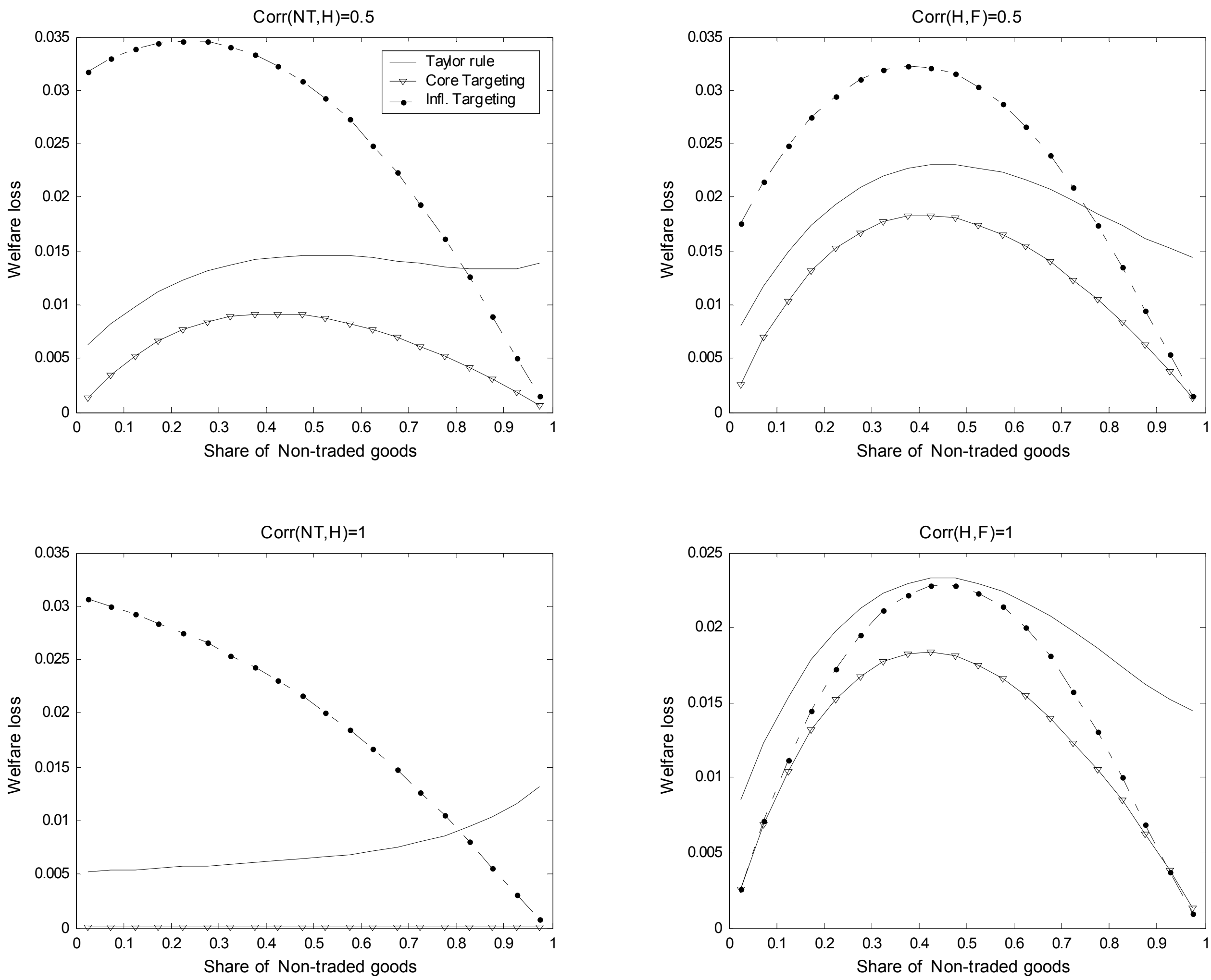


Figure 7: Welfare under correlated shocks



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