Inflation Targeting and Exchange Rate Pass-Through

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Abstract

This paper analyzes how endogenous imperfect exchange rate pass-through affects inflation targeting optimal monetary policies in a New Keynesian small open economy. The paper shows that there exists an inverse relation between the pass-through and the insulation of the economy from foreign and monetary policy shocks, and that imperfect pass-through tends to decrease the variability of the terms of trade. Furthermore, with CPI inflation targeting, in the short run, delayed pass-through constrains monetary policy more than incomplete pass-through and interest rate smoothing amplifies this effect. When the pass-through falls, the variability in economic activity tends to increase and the trade-off between the stabilization of CPI inflation and output worsens depending on how strictly the central bank is targeting CPI inflation. In contrast, with domestic inflation targeting, optimal monetary policy is not constrained and opposite results occur. Finally, with perfect pass-through the choice of flexible CPI inflation targeting seems preferable to flexible domestic inflation targeting while with delayed pass-through the opposite holds.

JEL Classification: E52, E58, F41.
Key Words: Inflation Targeting; Exchange Rate Pass-through; Small open-economy; Direct Exchange Rate Channel; Optimal Monetary Policy.

1 Introduction

What is the appropriate monetary policy response to domestic and foreign shocks with imperfect exchange rate pass-through? How does incomplete or delayed pass-through affect the volatility of the economy? What measure of inflation should a central bank target considering different types of pass-through? In the last few years this type of questions have prompted an increase in the interest on the relationship between the imperfect pass-through of the exchange rate and the working of the economy. This attention is supported by many empirical works spanning over two

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1The expression "exchange rate pass-through" denotes the transmission of a change in import costs to domestic prices of imported goods.
decades and differing for the countries and the industries considered which provide evidence on imperfect pass-through².

The way in which changes in costs pass-through to import price is a complex mechanism, and several factors may play a role in its determination. The positive correlation between inflation and inflation persistence, and the positive impact of the expectations of inflation persistence on the pass-through (via the Taylor staggered price-setting behavior), establish a positive relation from inflation to the degree of pass-through (Taylor, 2000). Also, the firm’s strategy of the pricing to market (PTM) based on international market segmentation and local currency pricing (LCP) lead to incomplete pass-through (Betts and Devereux, 2000).³ Furthermore, the presence of shipping costs and of non-traded distribution services adds to the previous factors (Engel, 2002). Finally, as it has been noted by Obstfeld and Rogoff (2000), studies on PTM have mostly considered exports rather than consumer prices so that the presence of intermediary firms between the exporters and the consumers is likely to reduce the pass-through more.

Taking these factors into account, it has been possible to reach interesting results on the relation between the pass-through and the optimal monetary policy⁴.

In a New Keynesian perspective, considering an emerging market economy with nominal rigidities in both the non-traded goods and import sectors, Devereux and Lane (2001) show that in the case of complete pass-through, targeting non-tradable inflation dominates targeting CPI inflation or an exchange rate peg while, in the case of delayed pass-through, CPI inflation targeting performs better. Devereux (2001) considers a small open-economy with sticky prices in the non-traded goods and import sectors and compares the Taylor rule, a rule that stabilizes non-traded goods inflation, strict CPI inflation targeting and a rule which pegs the exchange rate. He finds that in general, with delayed pass-through, the trade-off between the output and inflation variability is less pronounced; the best monetary policy stabilizes non-traded goods price inflation; and strict CPI inflation targeting performs better with partial pass-through. Smets and Wouters (2002) present a small open-economy model calibrated to euro area data with nominal rigidities in the domestic and imported goods sectors. In this framework, they consider that the welfare costs determined by nominal rigidities in the imported goods sector depend positively on the exchange rate variability. Consequently, they make the point that with delayed pass-through, output gap stabilization is constrained by the minimization of these welfare costs because it leads to a larger exchange rate variability.

²For example, Krugman (1987) considering US import data in the period 1980-1983 finds that, in the machinery and transport sector, 35 to 40 percent of the appreciation of the dollar was not reflected in a decrease of the import prices. Knetter (1989) for the period 1977-1985 finds that US export prices in the destination market currency tend to be either insensitive to exchange rate fluctuations or to amplify their impact, while German export prices tend to stabilize the exchange rate fluctuations. Considering the sample period 1974-1987, Knetter (1993) shows that Japanese export prices adjustments in the destination country currency offset 48 percent of the exchange rate fluctuations while for U.K. and German export prices this fraction reaches 36 percent. More recently, Campa and Goldberg’s (2001) estimation for the period 1975-1999 and a sample of OECD countries supported the complete pass-through hypothesis for the long run but not for the short run.

³LCP, in turn, has been justified in two ways: by a low market share of the exporter country in the foreign market coupled with a low degree of differentiation of its goods (Bacchetta and Wincoop, 2002) and by a greater monetary policy stability of the importing country compared to that of the exporting country (Devereux and Engel, 2001).

⁴See also Lane and Ganelli (2002) for a survey of the implications of different degrees of pass-through when it is considered also the currency denomination of assets contracts.
In a New Classical perspective, Corsetti and Pesenti (2001) show the importance of the degree of pass-through in affecting the trade-off between output gap stabilization and import costs and the implication for the optimal monetary policy. When the pass-through is incomplete because of LCP, exporters’ profits oscillate with the exchange rate, and the hedging behavior of the exporters consequently links the import prices positively to the variability of the exchange rate. Then, if the monetary policy aims to stabilize the output gap, it will increase the variability of the exchange rate and the import prices. Hence, optimal monetary policy has to equate at the margin the cost of the output gap with the cost of a higher import price. It follows that the lower the pass-through, the less the socially optimal output gap stabilization.

These models are characterized by a welfare optimization approach to determine the monetary policy and they consider either delayed or incomplete pass-through. The present study differs from the literature discussed above because it uses inflation-forecast targeting and relies on a more sophisticated transmission mechanism with realistic lags for various channels. Also, it broadens the analysis by considering the role of the type and degree of pass-through in the working of the direct exchange rate channel (henceforth DERC) for an inflation targeting small open-economy. According to the conventional wisdom, and as it is shown in Ball (1998) and Svensson (2000), the DERC, that is, the channel that allows the exchange rate to have an impact on current CPI inflation, plays a prominent role in the transmission of monetary policy. Yet, this channel is considered in these papers with the strict assumption of perfect exchange rate pass-through. The main purpose of this study is to build a simple but sufficiently general model to relax such assumption; thus it is able to compare different inflation targeting monetary policies and related responses of the economy to shocks with endogenous incomplete and/or delayed pass-through. The analysis is based on a dynamic stochastic general equilibrium model built upon Svensson’s (2000) model. The former includes two monopolistically competitive sectors: the domestic goods and the import goods sectors. Both share the same technology but use different inputs and have different firms decision timing.

This model deviates from Svensson’s (2000) in two ways. 1. It provides complete microfoundations, in particular about inertia in the aggregate supply and demand relations following Yun (1996) and Abel (2000), respectively. 2. It generalizes the assumption of perfect pass-through by introducing an import sector that may generate different types and degree of pass-through. This sector is similar to the import sector in Smets and Wouters (2002) in that it derives delayed pass-through from the sticky price assumption modeled in the Calvo’s (1983) style. It is also similar to Erceg and Levine (1995), McCallum and Nelson (1999), Burnstein and Rebelo (2000), Corsetti and Dedola (2002), in that local inputs may be required to bring the foreign goods to domestic consumers; as a result, when this is the case, foreign goods are intermediate goods in the production of the import goods and the pass-through turns out to be incomplete.

This is a notable feature of the model because it allows to consider foreign goods as intermediate goods in the domestic sector but final goods in the import sector or intermediate goods in both the domestic and import sectors. A special attention to the latter case is motivated by the finding of Kara and Nelson (2000) who show that the aggregate supply where imports are modelled as intermediate goods delivers the best approximation of the exchange rate/consumer price relationship.

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5 As to the inflation-forecast targeting procedure, see Svensson (1997) and (1998b).
Such flexibility in the degree of delay and completeness of the pass-through allows a better understanding of the relation between the exchange rate channels and the transmission mechanism of the monetary policy.

A key feature of this model is that it derives structural relations for all the agents in the economy. In particular, the central bank follows a specific targeting rule which, as it has been shown by Svensson (2003), is equivalent to the first order condition equating the marginal rate of substitution and transformation between the loss function variables. The model determines this rule assuming that the central bank minimizes in each period a loss function taking the expectations of the private sector as given and knowing that it will reoptimize in the subsequent periods. Thus the model looks for the Nash equilibrium in the game between the central bank and the private sector which turns out to be characterized by a time invariant reaction function for the central bank.6

With this framework the present study addresses some issues that have been neglected in the literature. First, it analyzes the way in which the pass-through affects the working of the DERC and examines to what extent this latter channel is reliable for the transmission of the monetary impulse in the short run. Such an analysis is important, as this channel is the only one available to stabilize CPI inflation in the short run.

Second, it considers that the DERC is also one of the avenues through which shocks originating in the foreign sector propagate to CPI inflation. Indeed, a shock in foreign output or inflation affects the foreign interest rate, which, in turn, via the interest rate parity condition, propagates to the exchange rate and, finally, hits CPI inflation. Thus, the second question addressed is how the way in which the pass-through occurs affects the degree of insulation of the economy from foreign shocks.

Third, the paper investigates the impact of imperfect pass-through on the volatility of the economy and on the choice of the inflation target.

With regard to inflation targeting effectiveness, the analysis shows that the type and degree of imperfect pass-through adversely affect the capacity of the central bank to stabilize in the short run CPI inflation but not domestic-inflation. More specifically, delayed pass-through turns out to reduce monetary policy effectiveness more than incomplete pass-through. Yet, similarly to domestic inflation targeting, in the medium run, the imperfect pass-through does not significantly constrain CPI inflation targeting.

In relation to the volatility of the economy, this study indicates that, on the one hand, imperfect pass-through tends to decrease the variability of the terms of trade. On the other hand, it tends to stabilize the economy with domestic inflation targeting but to increase its variability with CPI inflation targeting. Consequently, this study suggests that it may be better to target CPI inflation with perfect pass-through and domestic inflation with delayed pass-through.

The model also shows that, with CPI inflation targeting, imperfect pass-through increases the trade-off between CPI inflation and output gap variabilities and that this phenomenon is stronger the more monetary policy is concerned with CPI inflation versus output gap stabilization. In contrast, with domestic inflation targeting, imperfect pass-through tends to reduce this trade-off. Thus, it is important to know

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6 For a further discussion of this type of discretionary equilibrium, a description of the algorithm used to find it and some applications see Oudix and Sachs (1985), Backus and Drifill (1986), Soderlind (1998), Svensson (1994) and (2000).
the type and degree of the pass-through to assess the attainable output gap-CPI inflation variabilities trade-offs.

Finally, interest smoothing constrains the ability of the central bank to stabilize CPI and domestic inflation in the short run.

The paper is organized as follows: section 2 presents the model. Section 3 analyzes the optimal monetary policy; in particular, the reaction functions corresponding to different types of inflation targeting and pass-through and the impulse response functions to domestic and foreign shocks. Section 4 focuses on the relation between the pass-through, the volatility of the economy and the choice of the inflation measure to target. Section 5 concludes and suggests some directions for further research. Appendix A and B present some details of the microfoundations of the model and its state-space form.

2 The model

The model describes a small open economy related to an exogenous rest of the world. All the equations of the model are structural relations derived from equilibrium conditions that characterize optimal private and public sector behaviors.

2.1 The household

The economy is populated by a continuum of unit mass of consumers/producers indexed by \( j \in [0, 1] \) sharing the same preferences and living forever. Intertemporal utility for the representative agent is given by

\[
E_t \sum_{\tau=0}^{\infty} \delta^\tau U(C_{t+\tau}, \bar{C}_{t+\tau-1}),
\]

where \( \delta \) is the intertemporal discount factor, \( C_t \) is total consumption and \( \bar{C}_t \) is the aggregate consumption. Preferences over total consumption feature habit formation which is modeled in the Abel’s (1990) style by the following instantaneous utility function

\[
U(C_t, \bar{C}_t) = \begin{cases} 
\left( \frac{C_{t+\tau}}{\bar{C}_{t+\tau-1}} \right)^{1-\frac{1}{\sigma}} & \sigma \neq 1 \\
\ln \left( \frac{C_{t+\tau}}{\bar{C}_{t+\tau-1}} \right) & \sigma = 1 
\end{cases}
\]

where \( \nu \geq 0 \) captures the willingness of “keeping up with the Joneses” and \( \sigma > 0 \) is the intertemporal elasticity of substitution. This assumption is motivated by the Fuhrer’s (2000) and Banerjee and Batini’s (2003) results which show that the habit formation plays an important role in explaining the inertia in the consumption decisions and so in improving the empirical fit of the sticky prices open economy model.

For sake of simplicity, labor is absent in the preferences of the consumer/producer captured by (1). Yet, as it will be shown later, production implies disutility for the consumer in the form of less consumption available. Indeed, consumption goods are also intermediate goods used in production. Furthermore, since the input requirement

\footnote{Another example of similar preferences is in Svensson (2000).}
function is convex\(^8\), more production implies a smaller share of goods available for consumption. Thus, the utility function (1) can be interpreted as the utility of the yeoman farmer increasing and concave in consumption and decreasing and convex in production.

Total consumption, \(C_t\), is a CES aggregate of two subindices for consumption of the domestic good, \(C_{d,t}\), and import good, \(C_{i,t}\),

\[
C_t \equiv \left[ (1 - w) C_{d,t}^{1-\frac{1}{\theta}} + w C_{i,t}^{1-\frac{1}{\theta}} \right]^{\frac{\theta}{\theta - 1}},
\]

where \(\theta > 0\) is the intratemporal elasticity of substitution between domestic and import goods, \(w\) determines the steady state share of imported goods in total consumption and \(C_{d,t}\), \(C_{i,t}\) are Dixit-Stiglitz aggregates of continuum of differentiated domestic goods and import goods (henceforth indexed with \(d\) and \(i\) respectively),

\[
C_{h,t}^h = \left[ \int \left( C_{h,t}^j \right)^{1- \frac{h}{\vartheta}} dj \right]^{\frac{1}{1- \vartheta}}, \quad h = d, i
\]

where \(\vartheta > 1\) is the elasticity of substitution between any two differentiated goods and, for sake of simplicity, is the same in both sectors.

To avoid the well-known problems of the indeterminacy of the steady state and of the non stationarity of net foreign assets and consumption in a small open economy with incomplete markets I assume (i) zero initial net foreign assets and (ii) that consumers can trade internationally Arrow-Debreu securities. Complete markets is a common hypothesis in the macroeconomic literature on small open economy. By allowing international risk pooling, this hypothesis shuts down the current account as a shock absorber mechanism. As a result, a temporary real shock does not have a permanent effect on the economy (as it occurs in the incomplete markets case) and stationarity is restored\(^9\). Hence, as for example in Woodford (2003), I assume that the representative consumer chooses in period \(t\) a portfolio of state contingent securities with stochastic value \(A_{t+1}\). Then the price of this portfolio is given by

\[
B_t = E_t \left[ \Xi_{t,t+1} A_{t+1} \right],
\]

where \(\Xi_{t,t+1}\) denotes the stochastic discount factor. Furthermore, absence of arbitrage opportunities implies that the nominal interest rate \(I_t\) of a riskless bond satisfies

\[
(1 + I_t)^{-1} = E_t \left( \Xi_{t,t+1} \right).
\]

---

\(^8\)The input requirement function is convex because the production function is assumed to be concave. This assumption, in turn, can be motivated with constant capital.

\(^9\)Complete markets imply the counterfactual prediction of high international consumption correlation. Yet, since the goal of this paper is to study the relationship between the exchange rate pass-through and inflation targeting, the empirical reasonableness of this assumption is of second order. There are other alternatives to the complete markets assumption to avoid the unit-root problem. Schmitt-Grohè and Uribe (2003) compare some stationarity-inducing techniques in the literature based on an endogenous discount factor, a debt elastic interest-rate premium, portfolio adjustment costs and complete markets. Ghironi (2001) presents a model which obtains stationarity via overlapping generations and has the advantage to allow net foreign assets to play a role in shock transmission. Other scholars as Corsetti and Pesenti (2001) obtain stationarity assuming purchasing power parity, unit intratemporal elasticity of substitution between domestic and import good and zero initial net foreign assets.
Thus, the flow budget constraint for consumer $j$ in any period $t$ is given by

$$E_t[\Xi_{t,t+1}A_{t+1}] + P^c_tC_t = A_t + D^d_t + D^i_t,$$

where $D^d_t$ and $D^i_t$ are the dividends distributed by the domestic and the import sector and $P^c_t$ is the overall Dixit-Stiglitz price index for the minimum cost of a unit of $C$ and is given by

$$P^c_t = \left[(1 - w) P^d_t^{(1-\theta)} + w P^i_t^{\theta}\right]^{1/\theta},$$

with $P^d$, $P^i$ denoting, in turn, the Dixit-Stiglitz prices index for goods produced in the domestic and import sector respectively.

To rule out “Ponzi schemes”, I assume that in any period $t$ the consumer chooses the value of the portfolio in $t+1$ such that his borrowing is no larger than the present value of all future dividends

$$A_{t+1} \geq -\sum_{T=t+1}^{\infty} \Xi_{t+1,T} (D^d_T + D^i_T)$$

and that the present value of future dividends is finite.

Since foreign consumers have access to Arrow-Debreu securities too, absence of arbitrage implies that the return of a riskless bond issued in the rest of the world equals the return, in terms of foreign currency, of the portfolio of contingent securities that reproduces the riskless bond. In other words, the following uncovered interest parity holds

$$(1 + I^*_t) = \frac{S_t}{E_t(S_{t+1})} (1 + I_t)$$

where $I^*_t$ is foreign nominal interest rate and $S_t$ is the nominal exchange rate. Then, log-linearizing around steady state values for $(1 + I^*_t)$, $(1 + I_t)$, and $\frac{S_t}{E_t(S_{t+1})}$ yields

$$i_t - i^*_t = s_{t+1|\tau} - s_t$$

where for any variable $x$, the expression $x_{t+\tau|\tau}$ stands for the rational expectation of that variable in period $t + \tau$ conditional on the information available in period $t$ and the variables $i_t$, $i^*_t$ and $(s_{t+1|\tau} - s_t)$ are log-deviations from their respective constant steady state values and.

Utility maximization subject to the budget constraint and the limit on borrowing gives the Euler equation which, considering the equilibrium condition $C_t = \hat{C}_t$, equation (3) and a log-linearization around steady state values results in

$$c_t = \beta c_{t-1} + (1 - \beta) c_{t+1|\tau} - (1 - \beta) \sigma \left(i_t - \pi^c_{t+1|\tau}\right)$$

where $c_t$ is the log aggregate real domestic consumption (measured as a deviation from a constant steady state value), $\beta \equiv \frac{\nu(1-\sigma)}{1 + \nu(1-\sigma)} < 1$ and $\pi^c_t$ denotes log CPI inflation.

### 2.1.1 Domestic consumption of goods produced in the domestic sector

Since aggregate consumption is given by equation (2), the (log deviation of the) domestic demand for goods produced in the domestic sector, $c^d_t$, is given by

$$c^d_t = c_t - \theta \left(p^d_t - p^c_t\right)$$
which, considering the (log-linearized version of the) price index equation (4), can be rewritten as

\[ c_t^d = c_t + wθq_t \]  

(6)

where \( q_t \equiv p_t^d - p_t \) is the terms of trade. As shown in the appendix, solving equation (5) for \( c_t \) and combining it with equation (6) I obtain

\[ c_t^d = -σM_t - σwQ_{t-1} - (σ - θ)wq_t \]  

(7)

where

\[ M_t \equiv \sum_{j=0}^{∞} F_1^j ρ_{t-j|t} \]  

(8)

\( F_1 \) is the smaller root of the characteristic polynomial of equation (5) and \( ρ_{t,j|t} \) can be interpreted as the long real interest rate. Thus, the variable, \( M_t \) is a weighted average of all the previous and current long real interest rates with the weights of the previous rates that decrease exponentially going back in the past. As shown in the appendix, \( M_t \) maps the assumptions of habit formation and forward looking behavior into the effect of monetary policy shocks on the consumption decision. I find convenient to define the variable \( M_t \) because it is more revealing than the alternative lag-lead consumption scheme in showing the relationship between the previous and current monetary policy and the current expenditure decision of the household.

Similarly, I introduce the variable \( Q_t \) defined as \( Q_t \equiv F_1 \sum_{j=0}^{∞} F_1^j q_{t-j} \). \( Q_t \) is a weighted average of all the previous and current real exchange rates and captures the impact of all the shocks that affect the terms of trade (including the monetary policy shocks) on the expenditure decisions of the household.

2.1.2 Aggregate demand for goods produced in the domestic sector

Total aggregate demand for the good produced in the domestic sector is

\[ \tilde{Y}_t^d = C_t^d + Y_t^{d,d} + Y_t^{d,i} + C_t^{*d}, \]

where \( Y_t^{d,d}, Y_t^{d,i} \) and \( C_t^{*d} \) denote, respectively, the quantity of the (composite) domestic good which is used as an input in the domestic sector, as an input in the import sector and which is demanded by the foreign sector.

To specify the quantities of the (composite) domestic good which are used as an input in the domestic and import sector, it is convenient to describe here the production technologies. I assume that both sectors share the same Leontief technology and each one features a continuum of unit mass of firms, indexed by \( j \), that produce differentiated goods \( Y_t^d(j) \) and \( Y_t^i(j) \) in the domestic and import sector respectively. Furthermore, I assume that sectors differ for the input used: the domestic sector uses

\footnote{Under the expectations hypothesis and considering a zero-coupon bond with a finite maturity, the variable \( ρ_t \) is approximately the product of the long real bond rate and its maturity; for details see Svensson (2000).}
a composite input consisting of the domestic (composite) good itself and the (composite) import good produced in the import sector; the import sector uses a composite input consisting of the foreign good $Y^*_i$ and the domestic (composite good). Thus the production functions in the domestic and import sector are given respectively by

$$Y^d_t(j) = f\left[A^d_t\min\left\{\frac{Y^{dd}_t}{1-\mu}, \frac{Y^{id}_t}{\mu}\right\}\right], \quad Y^i_t(j) = f\left[A^i_t\min\left\{\frac{Y^*_t}{1-\mu'}, \frac{Y^{id}_t}{\mu'}\right\}\right] \quad (9)$$

where $f$ is an increasing, concave, isoeconomic function, $A_t$ is an exogenous (sector specific) economy-wide productivity parameter, $\mu$, $\mu' \in [0, 1]$, $(1-\mu)$ and $\mu$ denote, respectively, the shares of domestic good and import good in the composite input required to produce the differentiated domestic good $j$ and $(1-\mu')$ and $\mu'$ denote, respectively, the shares of foreign good and domestic good in the composite input required to produce the differentiated import good $j$.

Thus the quantities of the (composite) domestic good used as an input in the domestic and import sector are $Y^{dd}_t = (1-\mu)f^{-1}\left(\hat{Y}^d_t\right)$ and $Y^{id}_t = \mu f^{-1}\left(\hat{Y}^d_t\right)$, where $\hat{Y}^d_t$ denotes the demand of the import good. Finally, log-linearization around the steady state values yields

$$\hat{y}^d_t = \kappa_1 (\mu^1) c^d_t + \kappa_2 (\mu^1) \hat{y}^d_t + [1 - \kappa_1 (\mu^1) - \kappa_2 (\mu^1)] c^{*d}_t. \quad (10)$$

with $\kappa'_1 < 0$ and $\kappa'_2 > 0$.

Next, I assume, as in Svensson (2000), that $c^{*d}_t$ is exogenous and given by

$$c^{*d}_t = c^*_t + \theta^* w^* q_t$$

$$= \bar{y}^*_q + \theta^* w^* q_t, \quad (11)$$

where $c^*_t$ denotes (log) foreign real consumption, $\theta^*$ and $w^*$ denote, respectively, the foreign atemporal elasticity of substitution between domestic and foreign goods and the share of domestic goods in foreign consumption. Then, assuming that real consumption and aggregate demand are predetermined one period in advance, adding a serially uncorrelated zero-mean demand shock, $\eta_t^{d,n}$, defining the output gap in the domestic sector $\eta_t^d$ as

$$\eta_t^d = \hat{y}^d_t - y_t^{d,n},$$

where $y_t^{d,n}$ denotes the log deviation from the steady state value of the natural output level in the domestic sector and, finally, assuming that the natural output level in both sectors is exogenous, stochastic and follows

$$y^h_{t+1} = \gamma^h y^h_t + \eta^h_{t+1}, \quad 0 \leq \gamma^h < 1, \quad h = d, i$$

where $\eta^h_{t+1}$ is a serially uncorrelated zero-mean shock to the natural output level, I obtain the aggregate demand in the domestic sector in terms of the output gap $\hat{y}^d_t$.

\[11\] Indeed

$$\hat{y}^d_t = \left[\frac{\bar{y}^*(1-(1-\mu)f^{-1}(\bar{y}^*))(1-\mu)f^{-1}(\bar{y}^*)}{\bar{y}^*-(1-\mu)f^{-1}(\bar{y}^*)}\right]^{-1} \frac{\bar{y}^{*d} + \mu^d f^{-1}(\bar{y}^*)}{\bar{y}^* + \mu f^{-1}(\bar{y}^*)} + \left[\frac{\bar{y}^{*d} + \mu^d f^{-1}(\bar{y}^*)}{\bar{y}^* + \mu f^{-1}(\bar{y}^*)}\right]$$
\[ y_{t+1}^d = -\beta_p M_{t+1} - \beta_Q y_{t+1} + \beta_y y_{t+1}^d + \gamma y_{t+1} + \eta_{t+1} - \eta_{t+1} \]

In (12) all the coefficients are positive and functions of the structural parameters of the model and the variable \( y_t^d \) denotes the output gap in the import sector (see appendix for details).

### 2.1.3 Consumption and aggregate demand of goods produced in the import sector

Considering equation (2), the (log) consumption for goods produced in the import sector, \( c^i_t \), is given by

\[ c^i_t = c_t - \theta (p_t^i - p_t^c) = c_t - \theta (1 - w) (p_t^i - p_t^d) . \tag{13} \]

and following the same derivation used for the AD in the domestic sector yields

\[ c^i_t = -\sigma M_t - \sigma w Q_{t-1} - [(\sigma - \theta) w + \theta] q_t \tag{14} \]

Aggregate demand for import goods is given by

\[ \hat{Y}^i_t = C^i_t + Y^i_t \tag{15} \]

where \( Y^i_t \) denotes the amount of the import good used as an input in the domestic sector. Considering the technology in (9), this quantity is given by

\[ Y^i_t = (1 - \mu) f^{-1} (\hat{Y}^d_t) . \]

Log-linearizing (15) around the steady state results in

\[ \hat{y}_t^i = (1 - \kappa) c^i_t + \kappa \hat{y}_t^d \tag{16} \]

Finally, with the same procedure used to complete the derivation of the aggregate demand for the domestic sector goods we get

\[ y_{t+1}^d = -\beta_p M_{t+1} - \beta_Q y_{t+1} + \beta_y y_{t+1}^d + \gamma y_{t+1} + \eta_{t+1} - \eta_{t+1} \tag{17} \]

where all the coefficients are positive and depend on the structural parameters of the model and \( \eta_{t+1} \) is a serially uncorrelated zero-mean demand shock.

Summing up, aggregate demands in both sectors are predetermined one period in advance. Due to the assumptions of habit formation in consumption and rational expectations, they depend on all the previous and expected future monetary policy based on the information available in period \( t \). Due to the use of the output produced in the other sector as an input, they depend also on the demand in the other sector. Since as it will be shown below \( \sigma_{i+1}^d \) is predetermined in period \( t+1 \), monetary policy changes the short real interest rate by changing the instrument \( i_{t+1} \), i.e. the short nominal interest rate, and so affects aggregate demand directly (Aggregate demand channel). Furthermore, a first exchange rate channel, consisting in switching the demand between domestic and foreign goods, is captured here by the terms of trade. Finally, aggregate demand in the domestic sector depends also on foreign output.
2.2 Firms

In both sectors, aggregate supply is derived according to the Calvo (1983) staggered price model and inflation inertia is introduced as indicated by Yun (1996) and also by the presence of the terms of trade as shown by Benigno (2004). Beyond the use of different inputs, the two sectors have different firms decision timing. The derivation of the sectoral aggregate supply is similar to that of Svensson (2000).

2.2.1 Domestic sector

In the domestic sector, the representative consumer/producer \( j \) produces the variety \( j \) of the domestic good, \( Y_{dt}^{d}(j) \), with a composite input whose price is \( W_t \). Since all the varieties use the same technology, there is a unique input requirement function for all \( j \) given by \( f^{-1}\left[ Y_{dt}^{d}(j) \right] / A_t^d \) and the variable cost of producing the quantity \( Y_{dt}^{d}(j) \) is \( W_t f^{-1}\left[ Y_{dt}^{d}(j) \right] / A_t^d \). Furthermore, since there is a Dixit-Stiglitz aggregate of domestic goods, the demand for variety \( j \) is

\[
Y_{dt}^{d}(j) = \hat{Y}_t^{d} \left( \frac{P_{dt}^{d}(j)}{P_t^{d}} \right)^{-\theta} ,
\]

where \( P_{dt}^{d}(j) \) is the nominal price for variety \( j \). As shown in equation (9), the composite input is a convex combination of the Dixit-Stiglitz aggregate of domestic goods and of the Dixit-Stiglitz aggregate of the import goods (with price \( P_t^{i} \) and which will be described below). Thus the price of the input is given by \( W_t = (1-\mu) P_t^{d} + \mu P_t^{i} \).

Then, I assume that the consumer/producer chooses in any period the new price with probability \((1-\alpha)\) or keeps the previous period price indexed to current inflation according to Yun (1996) with probability \(\alpha\) and that the decision taken at period \( t \) refers to the price at period \( t + g \), that is, that the price in \( t \) is predetermined \( g \) periods in advance,

Finally, to connect the profits of the firm with the utility of the household, I use the marginal utility of domestic goods \( \hat{\lambda}_t^d \) which, recalling that consumption decisions are predetermined one period in advance, can be obtained by the following first-order condition with respect to \( C_{t+1}^{d} \)

\[
E_t U_d \left( C_{t+1}^{d}, C_{t+1}^{i} \right) = E_t \left[ \lambda_{t+1} P_{t+1}^{d} \right] \equiv E_t \hat{\lambda}_t^{d},
\]

where, \( \lambda_t \) is the marginal utility of nominal income in period \( t \). Then the decision
problem for firm $j$ is

$$\max_{P_t^{d}} E_t \sum_{\tau=0}^{\infty} \alpha^{\tau} \delta^{\tau} \tilde{\lambda}_{t+\tau}^{d} \left\{ \frac{\tilde{P}_{t+\tau}^{d} \left( \frac{P_{t+\tau+g-1}^{d}}{P_{t+\tau}^{d} + 1} \right)^{\zeta}}{P_{t+\tau+g}^{d}} \tilde{Y}_{t+\tau+g}^{d} \left[ \frac{\tilde{P}_{t+\tau+g}^{d} \left( \frac{P_{t+\tau+g-1}^{d}}{P_{t+\tau+g}^{d} + 1} \right)^{\zeta}}{P_{t+\tau+g+\tau}^{d}} \right]^{\phi} \right\}$$

where $\tilde{P}_{t}^{d}$ and $\zeta$ denote respectively the new price chosen in period $t$ and the degree of indexation to the previous period inflation rate. Assuming that $\delta = 1$ to ensure the natural-rate hypothesis, the log-linearized version of the Phillips curve for the domestic sector turns out to be

$$\pi_{t}^{d} + 2 = \zeta \pi_{t+1}^{d} - \zeta \pi_{t+2}^{d} + \frac{(1 - \alpha)^2}{\alpha (1 + \omega)} \left[ \omega y_{t+2}^{d} + \mu q_{t+2}^{d} \right] + \epsilon_{t+2}, \quad (18)$$

where $\omega$ is the output elasticity of the marginal input requirement function and $\epsilon_{t+2}$ is a zero-mean i.i.d. cost-pust shock that has been added. This relation is derived assuming that pricing decisions are predetermined two periods in advance, i.e. $g = 2^{12}$; it is equal to the Svensson (2000) aggregate supply, except (i) for the inertia in the inflation dynamics which is here also based on the indexation to past inflation and (ii) for the characterization of import goods which in this model are generally different from foreign goods$^{13}$.

According to (18), inflation is a predetermined variable based, on the one hand, on expectations of future inflation, demand and input price relying on the two period ahead information set. On the other hand, is based on previous values of inflation. The relevance of the assumptions of (i) predetermined pricing decision and (ii) of indexation to the previous period inflation is in improving the empirical fit. Indeed, as shown by Woodford (2003), these assumptions eliminate two counterfactual predictions of the basic Calvo model, i.e. the immediate and sharp reaction of inflation to monetary policy shocks.

Equation (18) shows that beyond the aggregate demand and expectations channels, monetary policy affects domestic inflation via the impact of the nominal exchange rate on the real price of the input, which turns out to be equal to $\mu q_{t}^{14}$. This is the second of the three exchange rate channels embedded in this model. The

$^{12}$The assumption that domestic inflation is predetermined is modeled with delayed price changes. For an interesting overview about the motivations and interpretations of this assumption see Woodford (2003).

$^{13}$Here import and foreign goods coincide in the special case of complete pass-through, which is described below.

$^{14}$Indeed, log-linearizing the real price of the composite input $\frac{W_{t}}{P_{t}}$ around the steady state with unit value yields $\mu q_{t}$. 

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strength of this channel depends, on the one hand, on nominal rigidities, imperfect competition and the (degree of) convexity of the input required function captured, respectively, by \( \alpha, \vartheta \) and \( \omega \). On the other hand, it depends on the relevance of the import goods in the production of the domestic goods, which is captured by \( \mu \), and on the characteristics of the pass-through\(^{15}\).

### 2.2.2 Import sector

Similarly to the domestic sector, variety \( j \) of the import goods, \( Y^i_t(j) \), is produced by the representative consumer/producer \( j \) with a composite input whose price is \( F_t \). Furthermore, the input requirement function is \( f^{-1} \left[ Y^i_t(j) \right] / A^i_t \), the variable cost of producing the quantity \( Y^i_t(j) \) is \( F_t f^{-1} \left[ Y^i_t(j) \right] / A^i_t \) and since there is a Dixit-Stiglitz aggregate of import goods with elasticity of substitution \( \vartheta > 1 \), the demand for variety \( j \) is

\[
Y^i_t(j) = \hat{Y}^i_t \left( \frac{P^i_t(j)}{P^i_t} \right)^{-\vartheta},
\]

where \( P^i_t(j) \) is the nominal price for variety \( j \), and \( P^i_t \) is the Dixit-Stiglitz price index for import goods. Since the input is a convex combination of the Dixit-Stiglitz aggregate of domestic goods and of the foreign good, with price \( P^* S_t \), where \( P^* \) is the price in foreign currency of the foreign good, it follows that \( F_t = \mu^d P^d_t + (1 - \mu^d) P^* S_t \).

Now relaxing the assumption that pricing decisions are predetermined \( g \) periods, the problem of the consumer/producer \( j \) is

\[
\max_{F_t} \sum_{\tau=0}^{\infty} \alpha^\tau \delta^\tau \lambda^i_{t+\tau} \left\{ \widetilde{P}^i_t \left( \frac{P^i_{t+\tau-1}}{P^i_{t-1}} \right)^\zeta \widehat{Y}^i_{t+\tau} \left( \frac{P^i_{t+\tau-1}}{P^i_{t+\tau}} \right)^{\zeta} \right\}^{-\vartheta} f^{-1} \left[ \frac{\widetilde{Y}^i_{t+\tau} \left( \frac{P^i_{t+\tau-1}}{P^i_{t+\tau}} \right)^{\zeta}}{A^i_{t+\tau}} \right],
\]

where \( \widetilde{P}^i_t, \lambda^i_t, \alpha^i_t \) have the same meaning of their analogous variables in the domestic sector. Assuming \( g = 0 \) is motivated by the fact that the import sector acts as a retailer sector for the foreign goods and, in practice, retailers do not set their price before they take effect as much as producers do.

Then, the log-linearized version of the Phillips curve in the import sector is given by

\[
\pi^i_t = \frac{1}{1 + \zeta} \left[ \zeta \pi^i_{t-1} + \pi^i_{t+1} + \frac{(1 - \alpha^i)^2}{\alpha^i (1 + \omega \vartheta)} (\omega Y^i_t + q^i_t) \right], \tag{19}
\]

\(^{15}\) The terms of trade \( q_t \) depend on the price level in import sector which, in turn, depends on the pass-through as it will be shown below.
where \( q_i^t \) denotes the price of the composite input in the import sector expressed in terms of the import goods price, \( p^*_i \), and is defined as

\[
q_i^t \equiv (1 - \mu^i) (s_t + p^*_i) + \mu^i p^d_t - p^t,
\]

(20)

where \( p^*_i \) is the (log) foreign price level (measured as the deviation from a constant trend). It is worth noting that the introduction of the variable \( q_i^t \) is a convenient way to obtain an aggregate supply relation in terms of stationary variables.

Equation (19) is derived in a way similar to (18). Here, however, pricing decisions are no longer assumed to be predetermined. As a result, \( \pi_i^t \) is a forward looking variable and we have a third exchange rate channel that exerts a direct effect on \( \pi_i^t \), the DERC. Furthermore, production in the import sector uses a composite input which consists of foreign goods and the goods produced in the domestic sector. The need of distributive services motivates the presence of the goods produced in domestic sector; specifically, it is assumed that to bring one unit of the foreign good to domestic consumers requires some units of a basket of differentiated domestic goods. By introducing a wedge between the price of the foreign goods paid by the domestic consumers and by the retailers, this assumption models the degree of completeness of the pass-through. Specifically, it establishes an inverse relation between the completeness of the pass-through and the need of distribution services captured by the coefficient \( \mu^i \).

A notable feature of this relation is that the stickiness in the price adjustment determines the speed of the pass-through. When \( \alpha^i = 0 \), all the firms in the import sector set in any period their price equal to a mark-up over the marginal cost. Thus a shock to the exchange rate or the foreign price feeds immediately to the price of the import goods. In addition, if we assume also no local inputs, \( \mu^i = 0 \), we obtain the benchmark case of perfect (i.e. complete and immediate) pass-through where the DERC reaches its greatest efficiency.

2.2.3 CPI inflation

Considering the log-linearized version of the CPI price equation (4), CPI-inflation, \( \pi^c_t \), is given by

\[
\pi^c_t = (1 - w) \pi^d_t + w \pi^i_t
\]

(21)

Since \( \pi^c_t \) is predetermined, at time \( t \) monetary policy can affect \( \pi^c_t \) only with \( \pi^i_t \). Specifically, since \( q^i_t \) is predetermined as well, monetary policy can affect \( \pi^c_t \) only via \( q^i_t \) which is a forward looking variable inheriting this feature from the nominal exchange rate. This indicates that the DERC is the only channel which allows monetary policy to have an impact on CPI inflation in the short run.

2.3 Uncovered interest parity in terms of \( q^i \), transmission channels and lags

In order to eliminate the non-stationary nominal exchange rate, it is convenient to express the UIRP in terms of \( q^i_t \) obtaining

\[
q^i_{t+1|t} - q^i_t = (1 - \mu^i) r_t - (1 - \mu^i) \left( i^*_t - \pi^i_{t+1|t} \right) - \left( \pi^i_{t+1|t} - \pi^d_{t+1|t} \right)
\]

(22)

where \( r_t \) is the short term real interest rate defined as \( r_t \equiv i^*_t - \pi^d_{t+1|t} \).
Summing up, the transmission of monetary policy to inflation occurs via the usual aggregate demand and expectations channels and the exchange rate channels. Each channel, other than the DERC, needs some time to convey the monetary policy to CPI-inflation. With the aggregate demand channel there is a first lag to transmit the stimulus to the output-gap through the lagged expectations of both future real interest rate and the terms of trade in (12) and (17). Then, a second lag is required by the output-gap to affect inflation in both sectors via the aggregate supplies (18) and (19). With the expectations channel there is a lag, even though monetary policy can affect domestic inflation expectations immediately. The reason is that the aggregate supply relation for the domestic goods requires a lag to affect inflation via price setting behavior. Also, with the channel that transmits the impact of the exchange rate to the price of the input in the domestic sector, \( \mu q_t \), there is a lag due, again, to the assumption of predetermined inflation. The only channel for which there is no lag is the DERC. In this case, the real interest parity condition (22) conveys the monetary impulse to the real price of the composite input in the import sector, \( q^i_t \), which, in turn, directly hits import sector inflation.

2.4 The public sector

The behavior of the central bank consists of minimizing the following loss function

\[
E_t \sum_{\tau=0}^{\infty} \beta^\tau \left[ \mu^c \pi^2_{t+\tau} + \mu^d \pi^2_{t+\tau} + \lambda y^2_{t+\tau} + \nu (i_{t+\tau} - i_{t+\tau-1})^2 \right],
\]

where \( \mu^d, \mu^c, \lambda \) and \( \nu \) are weights that express the preferences of the central bank for the CPI and domestic inflation targets, the output stabilization target and the instrument smoothing target respectively.

2.5 The rest of the world

I assume stationary univariate AR(1) processes for the exogenous variables foreign inflation and income

\[
\pi^*_t = \gamma^*_\pi \pi^*_t + \varepsilon^*_t, \quad (24)
\]

\[
y^*_t = \gamma^*_y y^*_t + \eta^*_t, \quad (25)
\]

where the coefficients are non-negative and less than unity and the shocks are white noises. Finally, the foreign sector sets the monetary policy according to the following Taylor rule

\[
i^*_t = f^*_\pi \pi^*_t + f^*_y y^*_t + \xi^*_t, \quad (26)
\]

where the coefficients are positive and \( \xi^*_t \) is a white noise.

2.6 Calibration

The choice of the structural parameters values mostly follows Svensson (2000). See the Appendix for the full set of parameters.

\[16\] There is substantial agreement in the literature on the view that the aggregate demand channel affects inflation with a two periods lag.
3 Optimal monetary policy

To recap, the model consists of the maximization of the central bank, firms and households preferences and their optimal behaviors are described by structural relations, namely the reaction function for the central bank, the aggregate supplies for the firms and the aggregate demands for the households.

In this general equilibrium model, the (column) vectors of predetermined, forward-looking variables and innovations to the predetermined variables are, respectively,

\[ X_t = \left( \pi^d_t, \pi^d_{t+1|t}, \pi^i_t, \pi^i_{t-1}, \pi^i_t, y^d_t, y^i_t, i^*_t, y^d_{i,n}, y^i_{i,n}, i_{t-1}, q_{t-1}, q^d_{t-1}, Q_{t-1}, M_{t-1} \right)^\prime, \]
\[ x_t = \left( \pi^i_t, q^i_t, M_t, \pi^d_{t+2|t} \right)^\prime, \]
\[ \nu_t = \left( \varepsilon_t, \zeta^*_t, 0, \varepsilon_t^*, \eta^*_t - \eta^*_t, \eta^*_t - \eta^*_t, \eta^*_t, f^*_t \varepsilon_t^* + f^*_y \eta^*_t + \xi^*_t, \eta^*_t - \eta^*_t, 0, 0, 0, 0 \right)^\prime. \]

In this model the rational expectations equilibrium is defined as the set of plans \( \left\{ i_{t+\tau|t}, \pi^d_{t+\tau|t}, \pi^i_{t+\tau|t}, y^d_{t+\tau|t}, y^i_{t+\tau|t}, q^d_{t+\tau|t} \right\}^\infty_{\tau=0} \) such that, for any given vector of the shocks and set of plans for the exogenous variables, (i) the central bank maximizes its preferences, (ii) the households maximize their utilities and (iii) the firms maximize their profits. Since each agent takes the (optimal) behavior of the other agents as given in his decision process, these plans are also a Nash equilibrium.

Concerning the optimal monetary policy, the model presents a time invariant reaction function which is the first order condition obtained by the intertemporal optimization of the central bank preferences. This function is linear in the vector of the predetermined variables and since the model is linear-quadratic, certainty equivalence holds and it does not depend on the covariance matrix of the shocks. To find this reaction function I used the dynamic programming technique of the linear stochastic regulator with rational expectations and forward-looking variables. For this optimization problem a closed form solution does not exist. Yet, via numerical analysis and using the Backus Driffl algorithm, it has been possible to find the coefficients of the optimal reaction function.

3.1 Domestic and CPI inflation targeting

Table 1 and 2 report the coefficients of the reaction functions for the cases of strict and flexible domestic and CPI inflation targeting under various assumptions on the types and degree of pass-through.

Table 1. Domestic inflation targeting, reaction-function coefficients
\[ \nu = 0.01 \]

\footnotesize{\textsuperscript{17}It is worthwhile pointing out that \( \pi^d_{t+1|t} \) is a predetermined variable. This is apparent if we consider the domestic sector Phillips curve, (17) and take the expectation at time \( t + 1 \) because \( \varepsilon_{t+2|t+1} = 0 \) and \( \pi^d_{t+2|t+1} \) is a function of predetermined variables.

\footnotesuperscript{18}The optimization problem is reported in appendix B.}
First of all, this table shows that both strict and flexible domestic inflation targeting policies are independent on the pass-through. Indeed, changes in the type and degree of pass-through have a negligible impact on the coefficients.

Second, only the coefficients for expected domestic inflation $\pi^d_{t+1}$, the output gap $y^d_t$ (for the flexible case) and the lagged interest rate $i_{t-1}$ are sizeable, with the last one different from zero because of interest rate smoothing. Thus the optimal monetary policy resembles the Taylor rule, differing only for having $\pi^d_{t+1}$ instead of $\pi^f_t$ and different values for the coefficients. This result confirms in a two-sector framework the finding in Svensson (2000) about the possibility of having a reaction function similar to the Taylor rule (but obtained through a targeting rule) with domestic-inflation targeting.

### Table 2. CPI-inflation targeting, reaction-function coefficients $\nu = 0.01$

<table>
<thead>
<tr>
<th></th>
<th>$\pi^d_t$</th>
<th>$\pi^d_{t+1}$</th>
<th>$\pi^i_t$</th>
<th>$\pi^i_{t-1}$</th>
<th>$\pi^s_t$</th>
<th>$y^d_t$</th>
<th>$y^i_t$</th>
<th>$i^*_t$</th>
<th>$i^d_{t,n}$</th>
<th>$i^i_{t,n}$</th>
<th>$i_{t-1}$</th>
<th>$q_{t-1}$</th>
<th>$q^d_{t-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strict CPI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perfect, $\mu^i=0$, $\alpha^i=0.01$</td>
<td>0.04</td>
<td>-2.66</td>
<td>0.00</td>
<td>-0.08</td>
<td>0.00</td>
<td>0.59</td>
<td>0.49</td>
<td>1.00</td>
<td>0.00</td>
<td>0.26</td>
<td>0.80</td>
<td>-0.01</td>
<td>0.80</td>
</tr>
<tr>
<td>Incomplete, $\mu^i=0.5$, $\alpha^i=0.01$</td>
<td>1.47</td>
<td>-4.13</td>
<td>0.00</td>
<td>0.37</td>
<td>0.00</td>
<td>1.17</td>
<td>0.74</td>
<td>0.91</td>
<td>0.02</td>
<td>0.37</td>
<td>0.82</td>
<td>-0.44</td>
<td>0.80</td>
</tr>
<tr>
<td>Delayed, $\mu^i=0$, $\alpha^i=0.5$</td>
<td>2.86</td>
<td>-0.21</td>
<td>0.28</td>
<td>0.42</td>
<td>-0.02</td>
<td>0.16</td>
<td>0.32</td>
<td>0.17</td>
<td>0.18</td>
<td>0.00</td>
<td>0.40</td>
<td>-0.27</td>
<td>0.80</td>
</tr>
<tr>
<td>Del. and Inc., $\mu^i=0.5$, $\alpha^i=0.5$</td>
<td>2.33</td>
<td>0.75</td>
<td>0.20</td>
<td>0.28</td>
<td>0.00</td>
<td>0.13</td>
<td>0.19</td>
<td>0.06</td>
<td>0.12</td>
<td>-0.04</td>
<td>0.51</td>
<td>-0.32</td>
<td>0.80</td>
</tr>
<tr>
<td><strong>Flexible CPI</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Perfect, $\mu^i=0$, $\alpha^i=0.01$</td>
<td>0.75</td>
<td>-1.39</td>
<td>0.00</td>
<td>0.28</td>
<td>0.02</td>
<td>0.58</td>
<td>0.61</td>
<td>0.96</td>
<td>0.30</td>
<td>0.19</td>
<td>0.01</td>
<td>-0.22</td>
<td>0.00</td>
</tr>
<tr>
<td>Incomplete, $\mu^i=0.5$, $\alpha^i=0.01$</td>
<td>1.81</td>
<td>-2.64</td>
<td>0.00</td>
<td>0.50</td>
<td>0.19</td>
<td>1.01</td>
<td>0.70</td>
<td>0.78</td>
<td>0.20</td>
<td>0.25</td>
<td>0.07</td>
<td>-0.54</td>
<td>0.00</td>
</tr>
<tr>
<td>Delayed, $\mu^i=0$, $\alpha^i=0.5$</td>
<td>1.54</td>
<td>-1.28</td>
<td>0.20</td>
<td>0.15</td>
<td>0.55</td>
<td>0.10</td>
<td>0.21</td>
<td>0.13</td>
<td>-0.09</td>
<td>0.03</td>
<td>0.32</td>
<td>0.80</td>
<td>0.00</td>
</tr>
<tr>
<td>Del. and Inc., $\mu^i=0.5$, $\alpha^i=0.5$</td>
<td>0.96</td>
<td>-0.62</td>
<td>0.14</td>
<td>0.09</td>
<td>0.64</td>
<td>0.08</td>
<td>0.15</td>
<td>0.04</td>
<td>-0.14</td>
<td>0.01</td>
<td>0.37</td>
<td>-0.81</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Third, in contrast with the domestic inflation targeting case, Table 2 shows that with strict CPI-inflation targeting the pass-through affects the optimal monetary policy. Here, changes in sign and size of the coefficients stand out and show that incomplete pass-through results in a more aggressive monetary policy. Note also that in the case of flexible CPI, the impact of the pass-through is smaller, and occurs mostly in the size of the coefficients.

Fourth, for almost all the cases reported in Table 2 the coefficient of $\pi^d_{t+1}$ is negative. This result is based on the opposite and symmetric paths of domestic and import goods inflation and on the lag-lead structure of the aggregate supply in
the import sector\(^{19}\). The starting point to explain it is that the DERC allows the monetary policy to stabilize \(\pi^c\) in the short run. This occurs by moving \(q^i_t\) in a way such that inflation in the import sector offsets inflation in the domestic sector. Now, a change of \(\pi^d_{t+1|t}\) transmits to \(i_t\) via \(q^i_t\) and, due to the lag-lead structure of the aggregate supply, this results in a negative impact of \(\pi^d_{t+1|t}\) on \(i_t\).

### 3.2 Impulse responses

In Figures (4-11) the impulse responses for domestic and CPI inflation targeting under different assumptions on the pass-through are reported. They are generated assuming that the economy is in steady state and then is hit by a certain shock whose value is set equal to 1.

In each figure, the first, second, third and fourth column refer, respectively, to the cases of perfect, incomplete, delayed and both incomplete and delayed pass-through. The shock considered are a cost-push shock (figures 4-7) and a foreign inflation shock (figures 8-11). In the various cases the choice of the interest smoothing parameter \(\nu\) balances two contrasting goals: To avoid a completely unrealistic monetary policy, which may occur when values of \(\nu\) are too small and, on the other hand, to avoid an inefficient monetary policy as to the stabilization of CPI inflation, which, instead, occurs when \(\nu\) is not sufficiently small.

#### 3.2.1 Strict domestic inflation targeting, IRF to a cost-push shock

In figure 4, optimal monetary policy is based on the aggregate demand channel and the exchange rate channels other than the DERC.

Monetary policy consists of an initial increase of the nominal interest rate which is gradually taken back to zero (sixth row). Since initially \(i_t\) is larger than \(\pi^d_{t+1|t}\), the real interest rate rises (seventh row) provoking a fall of the output gap in the domestic sector (fourth row); this is the aggregate demand channel.

By keeping constant \(q^i\) (eight row), the inflation in the import sector does not change in the first period (third row). Thus, the terms of trade, \(q\), decreases (ninth row) and, consequently, some demand switches from domestic to import goods. This is the exchange rate channel that adds to the aggregate demand channel. Furthermore, since \(q\) affects also the real price of the input in the domestic sector, there is an additional reduction in domestic inflation via \(q^{t+2}_{t}\) which is still negative. This is the exchange rate channel that works via the production cost in the domestic sector.

When the pass-through is incomplete, delayed, and incomplete and delayed (second, third, and fourth column) the monetary policy and the response of the economy are very similar. With incomplete pass-through (second column), the cost-push shock propagates to \(q^t\) via equation (20) and the monetary policy lets that \(q^t\) slightly increase via the interest parity in terms of \(q^i\). In turn, \(\pi^t\) immediately increases so that the terms of trade decreases less than the case of perfect pass-through. Nevertheless, visual inspection of the figure does not point to any change in the path for domestic inflation.

With delayed pass-through a change in \(q^t\) has a smaller impact on \(\pi^t\). Now only half of the firms in the import sector can update the price fully so that the elasticity

\(^{19}\)About the opposite and symmetric paths of domestic and import goods inflation, see the impulse response functions for the CPI inflation targeting cases.
of inflation to the real price of the input in the import sector is much smaller\textsuperscript{20}. Thus, monetary policy provokes a smaller increase in the import sector inflation which, in turn, determines a larger decrease of the terms of trade. As a result, there are a stronger switching demand effect and fall in the price of the domestic sector input which explain why monetary policy can be slightly more moderate. It is worth noticing that here delayed pass-through reduces the efficiency of the DERC and so allows this channel to absorb some of the monetary policy shock resulting in a smaller increase in the import sector inflation.

3.2.2 Flexible domestic inflation targeting, IRF to cost-push shock

In the flexible domestic inflation targeting cases (figure 5), monetary policy is similar to, but more moderate than, the strict cases. Here the output gap in the domestic sector is completely stabilized at the cost of a slightly longer period to stabilize domestic inflation. Also, the impact of the type and degree of pass-through in the various cases is negligible.

In the case of perfect and incomplete pass-through (first and second columns), the monetary policy shuts down the aggregate demand channel by stabilizing the real interest rate (seventh row) and the terms of trade (ninth row). With delayed pass-through (third row), the same result is obtained by letting the switching demand effect offset the expansionary effect of the negative real interest rate. This policy has the advantage to be more moderate and is feasible because of the reduced efficiency of the DERC captured by the smaller elasticity of $\pi_i^t$ to $q_i^t$.

In summary, in the flexible domestic inflation targeting case, delayed pass-through allows the optimal monetary policy to be more moderate than in the strict case; this is consistent with the reaction functions reported in Table 1-2. Furthermore, the response of the economy to the shock is very similar in the various pass-through cases. In particular, with the exception of the cases of delayed pass-through in flexible inflation targeting, the variability of the nominal exchange rate and the terms of trade seems stable.

3.2.3 Strict CPI inflation targeting, IRF to cost-push shock

With perfect pass-through (first column), optimal monetary policy manages to completely stabilize CPI inflation (first row) after a cost push shock. In the first two periods this shock can be absorbed only via the DERC because domestic inflation is predetermined. As a result, to let inflation in the import sector offset the shock, monetary policy cuts the real interest rate in $t$, increases it sharply in $t+1$ and takes it to zero in the subsequent periods. Such a policy allows $q^t$ to be negative for the first two periods which, in turn, determine the initial desired path for $\pi_i^{t21}$. As to the rest of the economy, the sizable decrease of the terms of trade (ninth row) determines a strong switching demand effect portrayed respectively by the fall and rise of the output gap in the domestic and import sector (fourth and fifth row).

When the pass-through is incomplete (second column), the ability to fully stabilize CPI inflation decreases. Now the real cost of production in the import sector depends

\textsuperscript{20}Note that in the case of immediate pass-through this elasticity tends to infinity so that an infinitesimal change in $q_i^t$ is sufficient to increase $\pi_i^t$.

\textsuperscript{21}With visual inspection it is not possible to see that $q_i^t$ is less than zero, in particular $q_i^t = -0.03$. Furthermore, since $q_i^t < 0$, ($\pi_i^t$ can be negative if and only if $q_i^t < 0$), considering the interest parity in terms of $q^t$ it follows that the initial negative real interest rate is the only way to obtain $q_i^{t+1,t} < 0$. 

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also on local inputs and consequently the DERC is less efficient. Thus, a more aggressive monetary policy is required which, however, is bounded by the interest smoothing constraint.

When the pass-through is delayed (third column) only half of the firms in the import sector is allowed to update the current price of the import. This results in another reduction of the DERC efficiency because now optimal monetary policy can reduce the current cost of production only for half of the firms. As a result, CPI inflation stabilization is reduced.

Finally, when the pass-through is incomplete and delayed (fourth row), these two sources of inefficiency of the DERC add up resulting in a largest variability of CPI inflation. It is interesting to note that delayed pass-through constrains the ability to stabilize CPI inflation more than incomplete pass-through.

### 3.2.4 Flexible CPI inflation targeting, IRF to cost-push shock

Flexible CPI-inflation targeting exhibits an interesting difference with the previous case of strict CPI inflation targeting. Now the DERC is used actively to stabilize $\pi_c$ only in the case of perfect pass-through, as it is shown by the the initial negative value of $\pi_i$ in the first column. Then, the stabilization of $\pi_c$ with imperfect pass-through is based mainly on the aggregate demand and the exchange rate channel, the latter via the production cost in the domestic sector.

### 3.2.5 Strict domestic inflation targeting, foreign inflation shock

It is noteworthy that in this model shocks in foreign inflation or income tend to have a similar qualitative impact on the domestic economy. This is due to the fact that they share, to a large extent, the same transmission mechanism because the foreign economy is assumed to set the monetary policy according to the Taylor rule. Indeed, a change in either foreign inflation or income has the same qualitative impact on the foreign interest rate, and this latter rate, in turn, has the same effect on the domestic interest rate through the uncovered parity condition. In addition, foreign inflation and income have a similar impact on the demand of domestically produced goods via the aggregate demand channel.

Let us consider, for example, a foreign inflation shock. Now domestic inflation is unaffected in the first two periods and from the third period on it depends on the sequence of expectations of the output gap and of the terms of trade taken in $t^{22}$. The shock increases the price of the input in the import sector. When the pass-through is perfect (first column), all the firms in the import sector respond optimally to the shock in period $t$. Since demand is predetermined, the firms in the import sector completely offset the shock by rising their price in period $t$. This determines an increase of the terms of trade (row 8) which, on the one hand, increases the production costs in the domestic sector and, on the other hand, tends to switch the demand from the import to the domestic sector. Therefore, to avoid an upward pressure on domestic inflation, the optimal monetary policy increases the nominal interest rate causing a slight fall of the output gap in the domestic sector which is sufficient to offset the switching demand effect and the increase in the production costs.

---

22 Considering that $\pi_{t+1|t} = 0$, this can be shown by taking the expectation in $t$ of the domestic sector AS and solving it forward.
When the pass-through is incomplete (second column), both foreign good and local input are used in the import sector. Thus the impact of the foreign inflation shock on the production cost in the import sector decreases. As a result the optimal monetary policy and the response of the economy exhibit only a quantitative difference with the perfect pass-through case.

With delayed pass-through (third column), only half of the firms in the import sector can react optimally to the shock. This explains why inflation in the import sector and the terms of trade rise less (third and ninth row) and the real cost of production in the import sector rises more (eight row).

It is interesting to note that the type and degree of pass-through do not affect the ability of the central bank in stabilizing domestic inflation. However, imperfect pass-through tends to shield the economy from the shock in that it reduces the efficiency of the DERC in propagating the shock. This is more apparent in the case of delayed and incomplete pass-through, (fourth column), characterized by less variability of \( \pi_i, \pi_c \) and \( q \).

### 3.2.6 Flexible domestic inflation targeting, foreign inflation shock

With flexible domestic inflation targeting, the objective of output gap stabilization constrains the optimal monetary policy. Specifically, it decreases the use of the output gap contraction in the domestic sector to contrast the increase in the terms of trade. However, in the various cases, concern with output gap stabilization exerts a negligible impact on the monetary policy and the response of the economy, which exhibit the same behaviors described for the cases of strict domestic inflation targeting cases.

### 3.2.7 Strict CPI inflation targeting, foreign inflation shock

For the various cases of pass-through the monetary policy and the response of the economy are similar: the shock exerts a pressure on inflation in the import sector and consequently on CPI inflation. The response of the monetary policy consists of a sharp rise of the instrument \( i_t \) (sixth row) which is then gradually taken back to zero. This policy lets the DERC absorb initially the shock by setting \( q_t^i = 0 \) by means of the nominal exchange rate. This insulates \( \pi_i \) in the first two periods. Then, the aggregate demand channel is available (because the output gap is no longer predetermined) and it carries out the stabilization of \( \pi_i \) in the subsequent periods by a fall in the output gap in the import sector (fifth row). This restrictive monetary policy also determines a fall in the output gap in the domestic sector (forth row) which causes, in turn, a domestic deflation from the second to the forth period (second row). As a result there is a terms of trade increase (ninth row) which tends to switch the demand towards the domestic sector and explains why the output gap in the import sector falls more.

A common feature with the case of strict domestic inflation targeting is that the type and degree of pass-through does not affect the ability of the central bank in stabilizing inflation. A difference is that the pass-through does not affect the variability of \( \pi_c, \pi_i \) and \( q \).

### 3.2.8 Flexible CPI inflation targeting, foreign inflation shock

As expected, now less variability in the output gap is achieved at the cost of more variability in CPI inflation. The various cases reported in Fig. 11 differ with the strict CPI-inflation targeting ones (Fig. 10) for a minor use of both the DERC and the
aggregate demand channel. These changes are reflected for the DERC in a smaller initial appreciation (or even a depreciation) of the nominal exchange rate (tenth row) and a larger inflation in the import sector (third row) and, for the demand channel, in a minor decline of the output gap (fourth row). This result is obtained with a slightly different interest rate plans that, all in all, results in a monetary policy less tight.

4 Imperfect pass-through and volatility in economic activity

This section focuses on the relation between the pass-through and the volatility in economic activity and analyzes how the central bank could use this relation to improve its stabilization task.

4.1 Taylor curves

Figure 1 and 2 show, respectively, the Taylor curves for various degrees of incompleteness and delay of the pass-through when the central bank is following CPI inflation targeting

\[ \nu = 0.01. \]

23 They have been generated assuming that \( \nu = 0.01 \).
These Taylor curves show that the trade-off between the variability of the output gap and CPI inflation worsens when the pass-through is more delayed and/or incomplete. It is noteworthy that the impact of the pass-through tends to be stronger, the more the central bank cares about CPI-inflation stabilization versus output gap stabilization. This is due to the lower efficiency of the DERC which is the only channel available to stabilize CPI inflation in the short run.

The next figure shows the Taylor curve for various degrees of incompleteness of the pass-through when the central bank is following domestic inflation targeting.

\[ \sigma_i = 0.2 \]
\[ \sigma_i = 0.4 \]
\[ \sigma_i = 0.6 \]
\[ \sigma_i = 0.8 \]

Figure 3: Incomplete domestic-inflation targeting

In contrast to the previous CPI-inflation targeting cases, now the trade-off tends to improve because the DERC is less efficient and consequently insulates more the economy from foreign shocks\(^{24}\). On the other hand, the less efficient DERC does not seriously limit the ability of the monetary policy because domestic inflation is predetermined and so the DERC is used less to stabilize it.

This relation between the pass-through and the Taylor curves is even more interesting if one considers the relation between the inflation environment and the pass-through. With respect to the latter, there is a consolidating recent view in the literature for which moving to a lower inflation environment decreases the pass-through. This idea is consistent with the observation of a lower pass-through coupled with a more credible commitment to stabilize inflation that has occurred in the last ten years. Theoretically, Taylor (2000) provided the first motivation for this relation showing how moving to a lower inflation environment reduces the pass-through by decreasing the expected persistence of cost changes. This relation is also supported empirically, for example, in Baililu and Fujii (2004)\(^{25}\). Thus, if we assume following Taylor (2000) that a stable and lower inflation reduces the pass-through, to achieve a lower variability of CPI inflation could turn out to be more costly than expected in terms of output gap variability. A case in point might be a central bank that decides to switch to inflation targeting. Indeed, consider Figure 2 and suppose that due to a pretty high initial inflation the pass-through tends to be immediate, for instance consider the Taylor curve with \( \alpha = 0.25 \). Then suppose that the inflation variability is larger than 1 std and that, on the basis of this Taylor curve, the new inflation target monetary policy aims to a variability of 0.5 std accepting a resulting output

\(^{24}\) Note, however that now the domain and range of this relation are much smaller than before.

\(^{25}\) For other explanations and empirical evidence concerning the relation between the inflation environment and the pass-through see also Coudhry and Hakura (2001), Devereux and Yetman (2002), Gragnon and Ihrig (2002) and Deverux, Engel, and Storgaard (2003).
gap variability of 1.9. Yet, the more CPI inflation variability falls, the worse is the trade-off so that it turns out to be impossible to attain the pair (0.5, 1.9); now, in fact, the pass-through is more delayed (say $\alpha^i = 0.5$) and the 0.5 CPI std target requires 2.3 std in the output gap.

In summary, this analysis leads to two results. The first is that it is important to know the type and degree of the pass-through to assess the attainable output gap-CPI inflation variabilities trade-offs. The second is that, combining this finding with the literature on the relation between the pass-through and the inflation environment, a chosen variability in CPI inflation could be achieved at a output gap variability cost much higher than expected.

These results suggest an extension for further research in introducing endogenously the impact of the monetary policy on the pass-through. This could be done for instance via a Phillips curve that allows the degree of price stickiness to be determined endogenously as in Bakhshi et al. (2004).

### 4.2 Unconditional standard deviations, imperfect exchange rate pass-through and choice of the inflation target

The following table reports the unconditional standard deviations for the main macrovariables in the model.

<table>
<thead>
<tr>
<th>Targeting case</th>
<th>$\pi^c_t$</th>
<th>$\pi^d_t$</th>
<th>$y^d_t$</th>
<th>$q_t$</th>
<th>$i_t$</th>
<th>$r_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.a Strict domestic-inflation (perfect)</strong></td>
<td>1.66</td>
<td>1.08</td>
<td>1.35</td>
<td>5.10</td>
<td>0.70</td>
<td>0.50</td>
</tr>
<tr>
<td><strong>1.b. Strict domestic-inflation (incomplete)</strong></td>
<td>1.33</td>
<td>1.08</td>
<td>1.34</td>
<td>3.37</td>
<td>0.66</td>
<td>0.43</td>
</tr>
<tr>
<td><strong>1.c Strict domestic-inflation (delayed)</strong></td>
<td>0.94</td>
<td>1.08</td>
<td>1.35</td>
<td>2.81</td>
<td>0.73</td>
<td>0.54</td>
</tr>
<tr>
<td><strong>2.a Flexible domestic-inflation (perfect)</strong></td>
<td>1.79</td>
<td>1.12</td>
<td>1.25</td>
<td>5.79</td>
<td>1.10</td>
<td>1.07</td>
</tr>
<tr>
<td><strong>2.b Flexible domestic-inflation (incomplete)</strong></td>
<td>1.39</td>
<td>1.11</td>
<td>1.25</td>
<td>3.74</td>
<td>1.06</td>
<td>1.07</td>
</tr>
<tr>
<td><strong>2.c Flexible domestic-inflation (delayed)</strong></td>
<td>0.99</td>
<td>1.12</td>
<td>1.25</td>
<td>3.11</td>
<td>1.18</td>
<td>1.15</td>
</tr>
<tr>
<td><strong>3.a Strict CPI-inflation (perfect)</strong></td>
<td>0.02</td>
<td>1.28</td>
<td>2.86</td>
<td>6.07</td>
<td>3.20</td>
<td>3.79</td>
</tr>
<tr>
<td><strong>3.b Strict CPI-inflation (incomplete)</strong></td>
<td>0.10</td>
<td>1.29</td>
<td>3.34</td>
<td>5.58</td>
<td>4.77</td>
<td>5.37</td>
</tr>
<tr>
<td><strong>3.c Strict CPI-inflation (delayed)</strong></td>
<td>0.52</td>
<td>1.18</td>
<td>2.33</td>
<td>4.22</td>
<td>3.88</td>
<td>4.05</td>
</tr>
<tr>
<td><strong>4.a Flexible CPI-inflation (perfect)</strong></td>
<td>0.66</td>
<td>1.12</td>
<td>1.53</td>
<td>3.91</td>
<td>2.86</td>
<td>2.94</td>
</tr>
<tr>
<td><strong>4.b Flexible CPI-inflation (incomplete)</strong></td>
<td>0.78</td>
<td>1.10</td>
<td>1.47</td>
<td>3.10</td>
<td>3.29</td>
<td>3.37</td>
</tr>
<tr>
<td><strong>4.c Flexible CPI-inflation (delayed)</strong></td>
<td>0.85</td>
<td>1.11</td>
<td>1.35</td>
<td>3.25</td>
<td>1.91</td>
<td>1.90</td>
</tr>
</tbody>
</table>

**Table 3: Unconditional standard deviations**

First, table 3 shows that the impact of the pass-through on the volatility of the economy is smaller with domestic than with CPI inflation targeting. Indeed, with domestic inflation targeting only the variability of $\pi^c_t$ and $q_t$ decreases when the pass-through is incomplete and/or delayed while the other variables are not affected. In contrast, with CPI inflation targeting, only $\pi^d$ is independent on the pass-through.

Second, imperfect pass-through tends to have opposite effects on the volatility of the economy with the two inflation targets; specifically, with domestic inflation targeting, it reduces the variability of $\pi^c_t$ and $q_t$ and, on the other hand, with CPI
inflation targeting increases the ones of $\pi^c_t$, $i_t$, $r_t$ and in the case of incomplete pass-through also the variability of $y^d_t$.

Third, with any inflation targets, the variability of $q_t$ decreases when the pass-through is imperfect or incomplete.

Finally, it is interesting to compare flexible domestic and CPI-inflation targeting when the pass-through is perfect, cases 2.a and 4.a, and delayed, cases 2.c and 4.c. In order to obtain a clearer comparison, the (loss function) weight on the output gap variability in the CPI cases has been increased to obtain the same variability of $y^d_t$ that we have in the domestic case.

With perfect pass-through, the variability of $\pi^c_t$ and $q_t$ is significantly less following flexible CPI inflation targeting. Thus, considering Benigno (2004) who shows that (a second order approximation of) the utility function depends negatively on the variability of the terms of trade, flexible CPI-inflation targeting dominates flexible domestic inflation targeting.

Repeating the same experiment for the case of delayed pass-through yields similar variabilities of $\pi^c_t$, $\pi^d_t$, $y^d_t$, and a lower variability of $q_t$. Thus, this result suggests that with delayed pass-through the domestic inflation target can be preferable to the CPI.

This analysis suggests further investigation in terms of welfare based on the utility function and leads to the tentative conclusion that it may be better to target CPI inflation with perfect pass-through and domestic inflation with delayed pass-through. This finding is consistent with the previous analysis and relies on the efficiency of the DERC and its role in the transmission mechanism. Thus, depending on the relevance in practice of delayed pass-through, this model may question the general practice of inflation targeting central banks that tend to choose CPI inflation as the inflation measure to target.

## 5 Conclusions

In this paper I have analyzed the relation between the exchange rate pass-through and the optimal monetary policy for a small open-economy pursuing inflation-targeting.

Foremost, the model shows that the type and degree of pass-through play an important role in the capacity of the central bank to stabilize in the short run CPI inflation but not domestic-inflation. With imperfect pass-through and some realistic interest smoothing, optimal monetary policy loses a significant part of its latitude. In particular, delayed pass-through turns out to reduce monetary policy effectiveness more than incomplete pass-through. These results contrast with conventional thinking, according to which the ability to move the exchange rate allows the central bank
to stabilize CPI inflation in the short run. This difference among CPI and domestic inflation targeting about the impact of imperfect pass-through tends to disappear with flexible inflation targeting.

Second I find that generally imperfect pass-through decreases the variability of the terms of trade for CPI and domestic inflation targeting. This outcome is somewhat in contrast with previous findings in the literature where imperfect pass-through leads to a larger exchange rate variability. The intuition for this result is that the inflation forecast targeting procedure allows the monetary policy to optimally choose the various channels in the transmission mechanism. Since with imperfect pass-through the DERC is less efficient, optimal monetary policy tends to replace it with the other channels.

Third, the insulation of the economy from foreign and monetary policy shocks is inversely linked with the degree of pass-through.

Forth, with CPI inflation targeting, the trade-off between CPI inflation and output gap variabilities worsens with imperfect pass-through and this phenomenon is stronger the more monetary policy concerns with CPI inflation versus output gap stabilization. In contrast, with domestic inflation targeting the trade-off tends to improve. Thus, it is important to know the type and degree of the pass-through to assess the attainable output gap-CPI inflation variabilities trade-offs. Furthermore, combining this finding with the literature on the relationship between the pass-through and the inflation environment, a chosen variability in CPI inflation could be achieved at a output gap variability cost much higher than expected.

Fifth, imperfect pass-through tends to reduce the volatility of the economy with domestic inflation targeting but to increase it with CPI inflation targeting; considering the variability of the terms of trade, an implication is that it may be better to target CPI inflation with perfect pass-through and domestic inflation with delayed pass-through.

Finally, interest smoothing constrains the ability of the central bank to stabilize CPI and domestic inflation in the short run.

These findings are all grounded on the fact that the pass-through affects the efficiency of the DERC in the transmission of the monetary impulse and foreign shocks.

A Appendix

A.1 Demand side

A.1.1 Habit formation and monetary policy

To find equation

\[ c_t^d = -\sigma M_t - \sigma wQ_t - (\sigma - \theta) wq_t \]

rewrite equation (5) as

\[ E_t [A(L)c_{t+1}] = r_t^c, \]

where \( L \) is the lag operator, \( r_t^c \equiv \sigma \left( i_t - \pi_{t+1|t}^c \right) \) and

\[ A(L) \equiv 1 - \frac{1}{1-\beta}L + \frac{\beta}{1-\beta}L^2. \]
This lag polynomial can be rewritten as

\[ A(L) = L^2 \left( F^2 - \frac{1}{1-\beta} F + \frac{\beta}{1-\beta} \right), \]

where \( F \equiv L^{-1} \) is the forward operator. Since \( F^2 - \frac{1}{1-\beta} F + \frac{\beta}{1-\beta} \) can be factored as \((F - F_1)(F - F_2)\), where \( F_1 = \frac{\beta}{1-\beta} = 0.15 \), \( F_2 = 1 \) are the roots of \( F^2 - \frac{1}{1-\beta} F + \frac{\beta}{1-\beta} = 0 \), the polynomial \( A(L) \) can be factored as

\[ A(L) = L^2 (F - F_1)(F - F_2) = (1 - F_1 L)(1 - F_2 L). \]

Thus (27) can be rewritten as

\[ E_t [(1 - F_1 L)(1 - F_2 L) c_{t+1}] = r^c_t. \]

Following Woodford (2003), let \( z_t \equiv (1 - F_1 L) c_t \). Then, I obtain

\[ E_t z_{t+1} - z_t = r^c_t. \tag{28} \]

Next, assume that there is a steady state for \( C_t \). Then \( \lim_{\tau \to \infty} c_{t+\tau|t} = 0 \) and \( \lim_{\tau \to \infty} z_{t+\tau|t} = 0 \). Assume also that \( \sum_{\tau=0}^{\infty} r^c_{t+\tau|t} \) converges. Then (28) can be solved forward obtaining

\[ z_t = -\sum_{\tau=0}^{\infty} r^c_{t+\tau|t} \]

or

\[ c_t = -\frac{1}{(1 - F_1 L)} \sum_{\tau=0}^{\infty} r^c_{t+\tau|t} = -\sum_{j=0}^{\infty} F_1^j \sum_{\tau=0}^{\infty} r^c_{t+\tau-j|t} \tag{29} \]

Thus, combining (29) and (6) results in

\[ c^d_t = -\sum_{j=0}^{\infty} F_1^j \sum_{\tau=0}^{\infty} r^c_{t-j+\tau|t} + w\theta q_t \]

\[ = -\sigma \sum_{j=0}^{\infty} \sum_{\tau=0}^{\infty} F_1^j \left( i_{t-j+\tau|t} - \pi^c_{t-j+\tau+1|t} \right) + w\theta q_t \]

\[ = -\sigma \sum_{j=0}^{\infty} F_1^j \rho_{t-j|t} + \sigma w \sum_{j=0}^{\infty} \sum_{\tau=0}^{\infty} F_1^j \left( q_{t-j+\tau+1|t} - q_{t-j+\tau|t} \right) + w\theta q_t \]

where, in the last row, \( q_{t-j+\tau+1|t} - q_{t-j+\tau|t} \) follows from the definition of the terms of trade.

Now I find convenient to define the variable \( M_t \) as

\[ M_t \equiv \sum_{j=0}^{\infty} F_1^j \rho_{t-j|t}. \]
Thus
\[ c_t^d = -\sigma M_t + \sigma w \sum_{j=0}^{\infty} F_1^j \sum_{r=0}^{\infty} (q_{t-j+r+1|t} - q_{t-j+r|t}) + w\theta q_t. \]

Then, noting that
\[ \sum_{r=0}^{\infty} (q_{t-j+r+1|t} - q_{t-j+r|t}) = q_{t-j+1|t} + q_{t-j+2|t} + \ldots - q_{t-j} - q_{t-j+1|t} - \ldots \]
\[ = \lim_{r \to \infty} q_{t-j+r|t} - q_{t-j} \]
\[ = -q_{t-j} \]

assuming \( \lim_{r \to \infty} q_{t-j+r|t} = 0 \), it follows that
\[ c_t^d = -\sigma M_t - \sigma w \sum_{j=0}^{\infty} F_1^j q_{t-j} + w\theta q_t \]
\[ = -\sigma M_t - \sigma w Q_{t-1} - (\sigma - \theta) w q_t \]
where \( Q_{t-1} \equiv F_1 \sum_{j=0}^{\infty} F_1^j q_{t-j-1}. \)

### A.1.2 Aggregate demand for domestic sector goods

Combining equations (7), (10) and (11), we obtain
\[ \hat{y}_t^d = \kappa_1 [-\sigma M_t - \sigma w Q_{t-1} - (\sigma - \theta) w q_t] + \kappa_2 \hat{y}_t + (1 - \kappa_1 - \kappa_2) (\beta_y y_t^* + \theta^* w^* q_t) \]
\[ = -\sigma \kappa_1 M_t - \sigma w \kappa_1 Q_{t-1} - (\sigma - \theta) w \kappa_1 q_t + \kappa_2 \hat{y}_t + (1 - \kappa_1 - \kappa_2) \beta_y y_t^* + (1 - \kappa_1 - \kappa_2) \theta^* w^* q_t \]
\[ = -\beta_p M_t - \beta_Q Q_{t-1} + \beta_q q_t + \kappa_2 \hat{y}_t + \beta_y y_t^* \]
where
\[ \beta_p \equiv \sigma \kappa_1 \]
\[ \beta_Q \equiv \sigma w \kappa_1 \]
\[ \beta_q \equiv [(1 - \kappa_1 - \kappa_2) \theta^* w^* - (\sigma - \theta) w \kappa_1] \]
\[ \beta_y^* \equiv (1 - \kappa_1 - \kappa_2) \beta_y \]

If the same derivation is carried out assuming that real consumption and aggregate demand are predetermined one period in advance and adding a serially uncorrelated zero-mean demand shock, \( \eta_{t+1}^d \), we get
\[ \hat{y}_{t+1}^d = -\beta_p M_{t+1|t} - \beta_Q Q_{t+1|t} + \beta_q q_{t+1|t} + \kappa_2 \hat{y}_{t+1|t} + \beta_y y_{t+1|t} + \eta_{t+1}^d \]
and, finally, in terms of the output gap we obtain
\[ y_{t+1}^d \equiv \hat{y}_{t+1}^d - y_{t+1}^{d,n} \]
\[ = -\beta_p M_{t+1|t} - \beta_Q Q_{t+1|t} + \beta_q q_{t+1|t} + \kappa_2 \hat{y}_{t+1|t} + \beta_y y_{t+1|t} + \eta_{t+1}^d - \gamma_{t+1}^d y_{t+1}^{d,n} + \eta_{t+1}^d - \eta_{t+1}^{d,n} \]
where
\[ \beta_y^i \equiv \kappa_2 \gamma_y^{i,n} \]

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A.1.3 Aggregate demand for goods produced in the import sector

Combining (14) with (16) we get

$$\tilde{y}_t^i = (1 - \tilde{\kappa}) (\sigma M_t - \sigma w Q_{t-1} - [(\sigma - \theta) w + \theta] q_t) + \tilde{\kappa} y_t^d$$

$$= -\beta^i_p M_t - \beta^i_Q Q_{t-1} - \beta^i_q q_t + \tilde{\kappa} y_t^d$$

where

$$\beta^i_p \equiv \sigma (1 - \tilde{\kappa})$$

$$\beta^i_Q \equiv (1 - \tilde{\kappa}) \sigma w$$

$$\beta^i_q \equiv [(\sigma - \theta) w + \theta]$$

If the same derivation is carried out assuming that real consumption and aggregate demand are predetermined one period in advance and adding a serially uncorrelated zero-mean demand shock, $\eta_{t+1}^i$, we obtain

$$\tilde{y}_{t+1}^i = -\beta^i_p M_{t+1|t} - \beta^i_Q Q_t - \beta^i_q q_{t+1|t} + \tilde{\kappa} y_{t+1|t}^d + \eta_{t+1}^i$$

and, finally, in terms of the output gap we obtain

$$y_{t+1}^i \equiv \tilde{y}_{t+1}^i - y_{t+1}^n$$

$$= -\beta^i_p M_{t+1|t} - \beta^i_Q Q_t - \beta^i_q q_{t+1|t} + \tilde{\kappa} y_{t+1|t}^d + \beta^i_q y_{t+1|t}^d - \gamma^i_n y_t^i + \eta_{t+1}^i - \eta_{t+1}^n$$

where

$$\beta^i_q \equiv \tilde{\kappa} y^d$$

A.2 Calibration

Aggregate supplies: $\zeta = 0.4$, $\delta = 1$, $\alpha = 0.5$, $\omega = 0.8$, $\theta = 1.25$, $\mu = 0.1$, $\sigma_x^2 = 1$.

CPI inflation equation: $w = 0.3$,

Aggregate demands: $\tilde{\kappa} = 0.25$, $\theta = 1$, $\sigma = 0.5$, $\tilde{\bar{\nu}} = 0.3$, $\beta^i_y = 0.9$, $\theta^* = 2$,

$$w^* = 0.15$$

$$\gamma^i_n = \gamma^i_y = 0.8$$

$$\sigma^2_{\theta^i} = \sigma^2_{\theta^i_n} = 1$$

$$\sigma^2_{\theta^i_v} = 0.5$$

Foreign sector:

$$y^f = 0.4$$

$$\gamma^i_v = \gamma^i_y = 0.8$$

$$f^* = 1.5$$

$$f^* = 0.5$$

$$\sigma^2_{\xi_v} = 0.5$$

A.3 State-space form of the model

$$\text{Min} \{ \log_{t+\tau|t} \} \sum_{\tau=0}^\infty \beta^\tau Y_{t+\tau}^\tau$$

subject to

$$\begin{bmatrix} X_{t+1}^i \\ x_{t+1|t} \\ y_{t+1|t} \end{bmatrix} = A \begin{bmatrix} X_t \\ x_t \\ y_{t+1} \end{bmatrix} + Bi_t + B_l x_{t+1|t} + Y_{t+1}$$

where $Y_t \equiv C_Z \begin{bmatrix} X_t \\ x_t \end{bmatrix} + C_i x_t$

where
\[ X_t = \left( \pi^d_t, \pi^{d+1}_t, \pi^{i-1}_t, \pi^i_t, y^d_t, y^i_t, \beta^d, \gamma^d_t, y^{d,n}_t, y^{i,n}_t, i_{t-1}, q_{t-1}, Q_{t-1}, M_{t-1} \right), \]

\[ x_t = \left( \pi^d_t, q^i_t, M_t, \pi^{d+2}_t \right). \]

To find the fourth and fifth row of \( A \), take the expectation in period \( t \) of the aggregate demand in the domestic and import sectors to obtain respectively

\[ y^d_t = -\beta_p M_{t+1|t} - \beta_Q Q_t + \beta_y y^*_t + \kappa_2 \gamma^d y^d_t + \beta_y^i y^{i,n}_t, \]

\[ y^i_t = -\beta_p M_{t+1|t} - \beta_Q Q_t - \beta^i y^d_t + \kappa_2 \gamma^i y^{i,n}_t. \]

Next replace \( y^i_t \) in \( y^d_t \) to obtain

\[ y^d_t = -\beta_p M_{t+1|t} - \beta_Q Q_t + \beta_y y^*_t + \kappa_2 \gamma^d y^d_t + \beta_y^i y^{i,n}_t, \]

\[ + \kappa_2 \beta^i y^{i,n}_t - \kappa_2 \gamma^i y^{i,n}_t + \beta_y^i y^{i,n}_t - \gamma^d y^{d,n}_t \]

\[ = \frac{1}{1 - \kappa_2 \beta^i} \left[ - (\beta_p + \kappa_2 \beta^i) M_{t+1|t} - (\beta_Q + \kappa_2 \beta^i) Q_t + (\beta_y + \kappa_2 \beta_y^i) y^d_t \right] \]

\[ + \beta_y^i y^{i,n}_t + (\beta_y^i - \kappa_2 \gamma^i y^{i,n}_t - (\gamma^d y^{d,n}_t - \kappa_2 \beta^i) y^{i,n}_t \]

\[ = y^d_t \]

\[ y^i_t = y^i_t \]

Finally substituting

\[ q_{t+1|t} = q_t + \pi^{i,t+1|t} - \pi^{d,t+1|t} \]

we obtain the fourth and fifth row of \( A \).

To find the 15th row recall that

\[ Q_t = F_1 \sum_{j=0}^{\infty} F_1^j q_{t-j}, \quad Q_{t-1} = F_1 \sum_{j=0}^{\infty} F_1^j q_{t-j-1} \]

\[ Q_t = F_1 (q_t + F_1 q_{t-1} + \ldots) \]

\[ = F_1 q_t + F_1 [F_1 (q_{t-1} + F_1 q_{t-2} + \ldots)] \]

\[ = F_1 q_t + F_1 Q_{t-1} \]

To find the 19th row note that

\[ M_{t+1|t} = F_1 M_t = \rho_{t+1|t} \]

and

\[ \rho_{t+1|t} = \rho_t + \pi^{d,t+1|t}. \]

Then, it follows that
\[ M_{t+1|t} - F_1 M_t = M_t - F_1 M_{t-1} - \pi_{t+1|t}^d \]
\[ M_{t+1|t} = (1 + F_1) M_t - F_1 M_{t-1} - \pi_{t+1|t}^d. \]

To find the last row, first take the expectation in period $t$ of equation (18) and solve it for $\pi_{t+3|t}^d$:
\[ \pi_{t+3|t}^d = (1 + \zeta) \pi_{t+2|t}^d - \zeta \pi_{t+1|t}^d - \frac{(1 - \alpha)^2}{(1 + \theta)} \left[ \omega y_{t+2|t} + \mu q_{t+2|t} \right] \quad (30) \]

then, lead $(y_{t+1|t}^d)$, $(M_{t+1|t})$ and $(y_{t+1|t}^d)$ one period, take the expectation in period $t$ and combine them to obtain $y_{t+2|t}^d$:
\[ M_{t+1|t} = (1 + F_1) M_t - F_1 M_{t-1} - \pi_{t+1|t}^d \]
\[ y_{t+2|t}^d = \frac{1}{(1 - \kappa_2 \kappa)} \left[ (\beta_p + \kappa_2 \beta_p^i) \left( (1 + F_1) M_{t+1|t} - F_1 M_t - \pi_{t+1|t}^d \right) - (\beta Q + \kappa_2 \beta Q^i) Q_{t+1|t}^d \right] + (\beta_y + \kappa_2 \beta Q^i) q_{t+2|t} + \beta_y \gamma y_{t+1|t} + (\beta y - \kappa \beta y) y_{t+1|t} - (\gamma y - \kappa \beta y^i) y_{t+1|t} \quad (31) \]

Similarly, lead $(q_{t+1|t})$ and $(\pi_{t+1|t}^i)$ one period, take the expectation in period $t$, and combine them with $(q_{t+1|t})$ to obtain $q_{t+2|t}$:
\[ q_{t+2|t} = q_{t+1|t} + \pi_{t+2|t}^i - \pi_{t+2|t}^d \]
\[ \pi_{t+2|t}^i = -\frac{(1 - \alpha)^2}{\alpha^2 (1 + \theta)\theta} q_{t+1|t} - \frac{(1 - \alpha)^2}{\alpha^2 (1 + \theta)\theta} y_{t+1|t} - \zeta \pi_{t+1|t}^i + (1 + \zeta) \pi_{t+1|t}^i, \]
and
\[ q_{t+2|t} = q_{t+1|t} - \frac{(1 - \alpha)^2}{\alpha^2 (1 + \theta)\theta} q_{t+1|t} - \frac{(1 - \alpha)^2}{\alpha^2 (1 + \theta)\theta} y_{t+1|t} - \zeta \pi_{t+1|t}^i + (1 + \zeta) \pi_{t+1|t}^i - \pi_{t+2|t}^d \]
\[ = q_{t+1|t} - \pi_{t+1|t}^i - \pi_{t+1|t}^d - \frac{(1 - \alpha)^2}{\alpha^3 (1 + \theta)\theta} q_{t+1|t} - \frac{(1 - \alpha)^2}{\alpha^3 (1 + \theta)\theta} y_{t+1|t} - \zeta \pi_{t+1|t}^i + (1 + \zeta) \pi_{t+1|t}^i - \pi_{t+2|t}^d \quad (32) \]

Finally, lead $(Q_t = F_1 Q_{t-1} + F_1 q_t)$ one period, take the expectation in period $t$ and combine it with $(q_{t+1|t})$ to obtain
\[ Q_{t+1|t} = F_1 Q_t + F_1 \left( q_{t+1|t} - \pi_{t+1|t}^d \right) \quad (33) \]

Now I combine equations (30-33) to obtain
\[ \pi_{t+3|t}^d = \frac{1}{\alpha(1+\vartheta\omega)(1-\kappa_2\kappa)} \left[ (1-\alpha)^2\omega(\kappa_2\beta_\rho + \beta_\rho)\pi_{t+1|t}^d + F_1 M_t - (1+F_1)M_{t+1|t} \right] 
\]

Finally, considering equations (24-26) and adding trivial equations for the lagged variables \( i_{t-1}, q_{t-1}^i \) and \( M_{t-1} \) we obtain

\[ A = \begin{bmatrix}
  e_{20} \\
  e_{20} \\
  e_{n+1} \\
  \gamma_n e_4 \\
  \frac{1}{(1-\kappa_2\kappa)} \left[ - (\beta_\rho + \kappa_2\beta_\rho) A_{n+3} - \left( \beta_Q + \kappa_2\beta_Q \right) A_{15} + \left( \beta_Q + \kappa_2\beta_Q \right) (A_{13} + A_{n+1} - A_1) \\
  + \beta y \cdot A_7 + \left( \beta y - \kappa_2\gamma y^n \right) e_{11} - \left( \gamma d,n - \kappa_2\beta y't \right) e_{10} \right] \\
  \frac{1}{(1-\kappa_2\kappa)} \left[ - (\beta y + \kappa\beta y) A_{n+3} - \left( \beta_Q + \kappa\beta_Q \right) A_{15} + \left( \beta Q + \kappa\beta Q \right) (A_{13} + A_{n+1} - A_1) \\
  + \kappa\beta y \cdot A_7 + \left( \beta y - \kappa y d,n \right) e_{10} - \left( \gamma i,n - \kappa\beta y \right) e_{11} \right] \\
  \gamma y^e_7 \\
  f_x^y \gamma^e_4 + f_x^y \gamma^e 7 \\
  \gamma y e_9 \\
  \gamma d,n^y e_{10} \\
  \gamma i,n^y e_{11} \\
  e_0 \\
  e_{13} + A_3 - e_1 \\
  e_{n+1} \\
  F_1 e_{15} + F_1 A_{13} \\
  \frac{1}{(1-\alpha^2)} e_{n+3} + \frac{(1-\alpha^2)\omega}{(1+\vartheta\omega)} e_6 - \zeta e_3 + (1+\zeta) e_{n+1} \\
  e_{n+2} + \mu e_2 - A_{n+1} - (1-\mu^2) (e_8 - A_4) - (1-\mu^2) e_9 \\
  (1+F_1) e_{n+3} - F_1 e_{n+1} + e_2 \\
  A_{20}
\end{bmatrix} \]

where, using the Svensson’s definitions, \( e_j, \ j = 0, \ldots, 16 \) stands for a 1x16 row vector.
that for $j = 0$ has all the elements equal to zero and for $j \neq 0$ has element $j$ equal to unity and all other elements equal to zero; $A_j$ stands for row $j$ of the matrix $A$.

where

$$A_{20} = \frac{1}{\alpha(1 + \vartheta \omega)(1 - \kappa \tilde{\kappa})} \left[ (1 - \alpha)^2 \omega (\kappa_2 \beta_p^q + \beta_q) \right] (i_{d+1} + F_1 e_{n_1+3} - (1 + F_1) A_{n_1+3})$$
$$+ \left[ (-1 + \kappa \tilde{\kappa}) \left( \mu + \alpha^2 \mu - \alpha (\zeta + 2 \mu + \vartheta \omega) \right) - (1 + \alpha)^2 \omega (\kappa_2 \beta_q^q + \beta_q - F_1 \kappa_2 \delta_Q^q + \beta_Q) \right] e_2$$
$$+ \left[ (1 + \kappa \tilde{\kappa}) \left( \mu + \alpha (1 + \zeta + (-2 + \alpha) \mu + \vartheta \omega + \zeta \vartheta \omega) \right) - (1 + \alpha)^2 \omega (\kappa_2 \beta_q^q + \beta_q + \beta_p) \right] e_{n_1+4}$$
$$+ \left[ (-1 + \alpha)^2 [$$
$$+ \zeta \left( -1 + \kappa \tilde{\kappa} \right) \mu - \omega (\kappa_2 \beta_q^q + \beta_q) \right] e_{n_1+1}$$
$$+ \left[ (2 + \zeta) (-1 + \kappa \tilde{\kappa}) \mu + \kappa_2 (2 + \zeta) \omega \beta_q^q - F_1 \kappa_2 \omega \beta_Q^q + (2 + \zeta) \omega \beta_q - F_1 \omega \beta_Q \right] A_{n_1+1}$$
$$+ \left[ (-1 + \kappa \tilde{\kappa}) \mu + \omega (\kappa_2 \beta_q^q - F_1 \kappa_2 \beta_Q^q + \beta_q - F_1 \beta_Q) \right] A_{13}$$
$$+ \omega (\kappa_2 \beta_q^q - \gamma^d_{y^m}) A_{10} - \omega F_1 (\kappa_2 \beta_Q^q + \beta_Q) A_{15} + \omega (\beta_q^q - \kappa_2 \gamma^d_{y^m}) A_{11} + \omega \beta_q^q \gamma^*_y A_7$$
$$- \frac{(-1 + \alpha)^2 (\mu - \kappa \tilde{\kappa} \mu + \kappa_2 \omega \beta_q^q + \omega \beta_q)}{(1 + \vartheta \omega \alpha^4)} \left( A_{n_1+2} + \omega A_6 \right) \right]$$

Finally the vectors $B$ and $B^1$ are given by

$$B = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ \frac{1}{(1 - \kappa \tilde{\kappa})} (\beta_q + \kappa \beta_p^q) \\ \frac{1}{(1 - \kappa \tilde{\kappa})} (\beta_p^q + \kappa \beta_p) \\ 0 \\ 0 \\ 0 \\ 0 \\ 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ (1 - \mu^4) \end{bmatrix}$$

$$B^1 = \begin{bmatrix} -\alpha (1 + \vartheta \omega)(1 - \kappa \tilde{\kappa}) \left[ (1 - \alpha)^2 \omega (\kappa_2 \beta_p^q + \beta_p) (1 + F_1) \\ \frac{1}{(1 + \vartheta \omega \alpha^4)} \right] \\
\frac{1}{(1 - \kappa \tilde{\kappa})} \left[ (1 - \alpha)^2 \omega (\kappa_2 \beta_p^q + \beta_p) (1 + F_1) \\ \frac{1}{(1 + \vartheta \omega \alpha^4)} \right] (1 - \mu^4) + \omega \frac{1}{(1 - \kappa \tilde{\kappa})} (\beta_p^q + \kappa \beta_p) \end{bmatrix}$$
\[
B^1 = \begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\frac{1}{\alpha(1+\vartheta\omega)(1-\kappa^2)}(1-\alpha)^2 \omega(\kappa^2 \beta_i \rho + \beta \rho) & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
\]

and the matrix $K$ is a diagonal matrix with $(\mu^c, \mu^d, \lambda, \nu)$ along the main diagonal.

At this point the algorithm used by Oudiz and Sachs (1985) as well as by Backus and Driffill (1986) for the solution of the optimization problem in the dynamic programming framework is applied and a detailed description is provided by Soderlind (1998) and (1999). For the problem raised by the presence of future controls, see the working paper version of Svensson (2000).

References


Figure 4. Strict domestic inflation targeting. IRF to a cost-push shock. $\nu = 0.005$.
In the first, second, third and fourth column, $\alpha^i$ and $\mu^i$ are equal, respectively, to
$(0.01, 0)$, $(0.01, 0.5)$, $(0.5, 0)$ and $(0.5, 0.5)$. 

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Figure 5. Flexible domestic inflation-targeting. IRF to a cost-push shock. 
\( \nu = 0.005 \). In the first, second, third and fourth column, \( \alpha^i \) and \( \mu^i \) are equal, respectively, to (0.01, 0), (0.01,0.5), (0.5,0) and (0.5,0.5).
Figure 6: Strict CPI-inflation targeting. IRF to a cost-push shock. $\nu = 0.05$. In the first, second, third and fourth column $\alpha^i$ and $\mu^i$ are equal, respectively, to (0.01, 0), (0.01, 0.5), (0.5, 0) and (0.5, 0.5)
Figure 7: Flexible CPI inflation-targeting. IRF to a cost-push shock. $\nu = 0.05$. In the first, second third and fourth column $\alpha^i$ and $\mu^i$ are equal, respectively, to (0.01, 0), (0.01, 0.5), (0.5, 0) and (0.5, 0.5).
Figure 8: Strict domestic-inflation targeting. IRF to a foreign inflation shock.

\( \nu = 0.05 \). In the first, second, third and fourth column \( \alpha \) and \( \mu \) are equal, respectively, to \( (0.01, 0) \), \( (0.01, 0.5) \), \( (0.5, 0) \) and \( (0.5, 0.5) \).
Figure 9: Flexible domestic-inflation targeting. IRF to a foreign inflation shock. 
\( \nu = 0.05 \). In the first, second, third and fourth column \( \alpha^d \) and \( \mu^d \) are equal, respectively, to (0.01, 0), (0.01, 0.5), (0.5, 0) and (0.5, 0.5).
Figure 10: Strict CPI-inflation targeting. IRF to a foreign inflation shock.
\( \nu = 0.001 \). In the first, second, third and fourth column \( \alpha^i \) and \( \mu^i \) are equal, respectively, to (0.01, 0), (0.01, 0.5), (0.5, 0) and (0.5, 0.5).
Figure 11: Flexible CPI-inflation targeting. IRF to a foreign inflation shock. $\nu = 0.001$. In the first, second, third and fourth column $\alpha^i$ and $\mu^i$ are equal, respectively, to $(0.01, 0)$, $(0.01, 0.5)$, $(0.5, 0)$ and $(0.5, 0.5)$. 