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Monetary Policy under Alternative Asset Market Structures: the Case of a Small Open Economy

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Abstract
Can the structure of asset markets change the way monetary policy should be conducted? Following a linear-quadratic approach, the present paper addresses this question in a New Keynesian small open economy framework. Our results reveal that the configuration of asset markets significantly affects optimal monetary policy and the performance of standard policy rules. In particular, when comparing complete and incomplete markets, the ranking of policy rules is entirely reversed, and so are the policy prescriptions regarding the optimal level of exchange rate volatility.

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1 Introduction

How does the structure of international asset markets affect monetary policy? The debate surrounding optimal monetary policy in open economies has been extensive over the past decade. Many works have emphasized that optimal monetary policy in an open economy may be influenced the presence of a "terms of trade externality". Part of the literature highlights the fact that the presence of such an externality can affect the optimality of inward looking policies. But are these policy incentives affected by the degree of international risk sharing? The current paper characterizes a utility-based loss function for a small open economy under different asset market structures and derives the corresponding optimal monetary policy. Our analysis shows that the degree of risk sharing can significantly affect the optimal policy prescription and the performance of standard policy rules.

Early contributions on optimal monetary policymaking in an open economy, such as Clarida et al. (2001) and Gali and Monacelli (2005), show the policy problem in an open economy may be isomorphic to the one in a closed economy environment. Their results suggest that policymakers in an open economy should follow a purely inward looking policy, responding solely to movements in domestic prices (or producer prices). Hence, there is no role for exchange rate stabilization, even if movements in the exchange rate affect consumer prices.

However, recent theoretical literature on policy objectives in open economies suggests that this result is not a robust one. As emphasized in Obstfeld and Rogoff (1998), welfare in an open economy can be influenced by a "terms of trade externality". This externality arises because imported goods may not be perfect substitutes to goods produced domestically. This fact implies that a social planner in an open economy may wish to exploit a certain degree of monopoly power.[1] Corsetti and Pesenti (2001) analyze welfare and monetary policy in a setting characterized by this external distortion - related to the country's monopoly power in trade - and an internal distortion – related to monopolistic supply in the domestic market. The internal distortion implies that monetary surprises can increase output towards its efficient level. But in open economies these surprises also reduce domestic consumers' purchasing power internationally. Because of the latter effect, expansionary policies can reduce welfare. As emphasized in Tille (2001), the overall impact of such shocks depends on the relative size of these two distortions.[2]

In a complete markets setting, Benigno and Benigno (2003) explore the consequences of such internal and external distortions for monetary policy cooperation in a stochastic two-country framework. De Paoli (2009) analyzes optimal monetary policy in a small open economy setting.[3] These studies show that, if policymakers in different countries act independently, they may have an incentive to affect the terms of trade in their own advantage. If domestic and foreign goods are close substitutes, an improvement in the terms of trade can induce agents to consume more imported goods (that is, terms of trade improvements have a so-called expenditure-switching effect). These consumers are better off, since they can reduce their labor effort without a corresponding fall in their consumption levels. A terms of trade improvement (or a real exchange rate appreciation) ceases to be welfare improving when these elasticities are small, and the terms of trade cannot divert consumption towards foreign goods. In this case, a more depreciated real exchange rate on average can be welfare improving. Moreover, unless countries are insular to terms of trade movements, domestic inflation targeting is no longer the policy choice of individual countries.

The present paper evaluates whether or not the above policy incentives are influenced by the degree of international risk sharing. Our analysis confirms that, under complete markets and a *high* elasticity of substitution between domestic and foreign, there is a policy incentive to engineer a terms of trade improvement (or a real exchange rate ap-

[1] This externality is also discussed in the trade theory context. The literature on trade policy points out that imposing taxes on exports might be welfare improving because, due to imperfect substitutability between the domestic and foreign goods, it is in the country's interest to behave like a monopolist and restrict its supply of exports.

[2] Tille (2001) shows that the overall impact of changes in money supply depends on the degree of substitutability between goods produced within a country and the degree of substitutability between goods produced in different countries.

[3] Many other studies analyze welfare and monetary policy in different open economy settings. For alternative works investigating the case for exchange rate stabilization see, for example, Devereux and Engel (2003), Corsetti and Pesenti (2005), Sutherland (2005), Benigno and Benigno (2006). Note that there is an earlier literature, based on models without explicit intertemporal microfoundations, which already spell out that terms of trade spillovers can create an externality and, thus, scope for monetary policy coordination. See Canzoneri and Henderson (1991) for an exposition.

preciation). Moreover, in this case, a exchange rate peg can outperform (that is, lead to higher welfare) a policy that focus on domestic price stabilization. This is because a fixed exchange rate regime ties policymakers hands who, for this reason, under-stabilize output relative to the flexible price allocation. When compared with price stability, this regime is associated with a lower level of output and a more appreciated real exchange rate on average.

However, the results are different in the case of imperfect risk sharing. Whereas efficient risk sharing severs the link between domestic consumption and domestic production, with incomplete markets these are more tightly related. Under financial autarky, for example, consumption has to be fully financed by domestic output. So, while in the complete markets setting, optimal risk sharing prevents home agents from suffering negative income effects if they were to reduce domestic production and engineer a terms of trade improvement, this is no longer the case under incomplete markets. That is, under imperfect risk sharing it may no longer be possible to decrease agent's disutility from producing domestically without decreasing their utility from consumption. In fact, under incomplete markets, a policy of exchange rate stabilization would only be beneficial if the degree of substitutability between home and foreign good is *low*. This is because a low elasticity of substitution between imported and domestic goods reduces the negative income effect of terms of trade improvement on consumption.

Therefore, our welfare comparison highlights that while an exchange rate peg may outperform a domestic inflation targeting regime when asset markets are complete and domestic and imported goods are substitutes, the opposite holds when asset markets are incomplete. Our results suggest that optimal monetary policymaking in a small open economy crucially depend on the degree of substitutability between goods and the degree of international risk sharing.

In terms of our modelling approach, we characterize a small open economy framework as a limiting case of a two-country dynamic general equilibrium model. The baseline framework features monopolistic competition, nominal rigidities and home bias in consumption. In our analysis we consider three different asset markets specification: complete asset markets (optimal international risk sharing), incomplete asset markets (sub-optimal international risk sharing) and financial autarky (absence of international risk sharing).

Our policy evaluation methodology follows the linear quadratic approach developed by Benigno and Woodford (2005) and Sutherland (2002), and characterizes a utility-based loss function for the different asset market settings. The method delivers an analytical representation of the policy problem that is similar to the one used in the traditional literature on monetary policy evaluation (that is, policymakers minimize a quadratic loss function subject to linear constraints). But the utility-based loss function for the small open economy depends not only on the volatility of output and domestic inflation but also on the real exchange rate volatility. Moreover, the weights of these variables in the loss function depend on the form of asset markets. Finally, we derive the optimal monetary policy for the different settings and represent it in terms of a targeting rule *à la* Svensson (2003).

The remainder of the paper is structured as follows. Section 2 introduces the model. The system of log-linearized equilibrium conditions is presented in Section 3. In Section 4 we derive welfare and Subsection 4.1 presents the linear-quadratic loss function. The analysis of monetary policy under different asset market structure is illustrated in Section 5. Finally, Section 6 concludes.

2 The Model

The framework consists of a small open economy setup derived from two-country dynamic general equilibrium model. The baseline framework is fairly standard, following the work of Gali and Monacelli (2005) and De Paoli (2009). Nevertheless, in our analysis, we consider three different asset market specifications. These are presented in Subsection 2.1.

In the model deviations from purchasing power parity arise from the existence of home bias in consumption. This bias depends on the degree of openness and the relative size of the economy. The specification allows us to characterize the small open economy by taking the limit of the home economy size to zero. Prior to applying the limit, we derive the optimal equilibrium conditions for the general two-country model. After the limit is taken, the two countries, Home and Foreign, represent the small open economy and the rest of the world, respectively.

Monopolistic competition and sticky prices are introduced in order to address issues of monetary policy. We further assume that home price setting follows a Calvo-type contract, which introduces richer dynamic effects of monetary policy than in a setup where prices are set one period in advance. Moreover, we abstract from monetary frictions by considering a cashless economy as in Woodford (2003, Chapter 2).

Preferences

We consider two countries, H (Home) and F (Foreign). The world economy is populated with a continuum of agents of unit mass, where the population in the segment $[0, n)$ belongs to country H and the population in the segment $(n, 1]$ belongs to country F. The utility function of a consumer j in country H is given by[4]

$$U_t = E_t \sum_{s=t}^{\infty} \beta^{s-t} \left[U(C_s) - \frac{1}{n} \int_0^n V(y_s^j, \xi_s) dj \right], \tag{1}$$

Households obtain utility from consumption $U(C^j)$ and contribute to the production of all domestic goods y^j attaining disutility $\frac{1}{n}\int_0^n V(y_s^j, \xi_s)dj$. Risk is pooled internally to the extent that agents participate in the production of all goods and receive an equal share of production revenue. Productivity shocks are denoted by ξ_s, and C is a C.E.S. (constant elasticity of substitution) aggregate of home and foreign goods, defined by

$$C = \left[v^{\frac{1}{\theta}} C_H^{\frac{\theta-1}{\theta}} + (1-v)^{\frac{1}{\theta}} C_F^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}. \tag{2}$$

The parameter $\theta > 0$ is the intratemporal elasticity of substitution between home and foreign-produced goods, C_H and C_F. As in Sutherland (2005), the parameter determining home consumers' preferences for foreign goods, $(1 - v)$, is a function of the relative size

[4]In the subsequent sections, we assume the following isoelastic functional forms: $U(C_t) = \frac{C_t^{1-\rho}}{1-\rho}$ and $V(y_t, \varepsilon_{Y,t}) = \frac{\varepsilon_{Y,t}^{-\eta} y_t^{1+\eta}}{1+\eta}$, where ρ is the coefficient of relative risk aversion and η is equivalent to the inverse of the elasticity of labor supply.

of the foreign economy, $(1-n)$, and of the degree of openness, λ; more specifically, $(1-v)=(1-n)\lambda$.

Similar preferences are specified for the rest of the world

$$C=\left[v^{*\frac{1}{\theta}}C_H^{*\frac{\theta-1}{\theta}}+(1-v^*)^{\frac{1}{\theta}}C_F^{*\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}}, \tag{3}$$

with $v^*=n\lambda$. That is, foreign consumers' preferences for home goods depend on the relative size of the home economy and the degree of openness. Note that the specification of v and v^* generates a home bias in consumption.

The sub-indices C_H (C_H^*) and C_F (C_F^*) are Home (Foreign) consumption of the differentiated products produced in countries H and F. These are defined as follows

$$C_H=\left[\left(\frac{1}{n}\right)^{\frac{1}{\sigma}}\int_0^n c(z)^{\frac{\sigma-1}{\sigma}}dz\right]^{\frac{\sigma}{\sigma-1}}, \qquad C_F=\left[\left(\frac{1}{1-n}\right)^{\frac{1}{\sigma}}\int_n^1 c(z)^{\frac{\sigma-1}{\sigma}}dz\right]^{\frac{\sigma}{\sigma-1}}, \tag{4}$$

$$C_H^*=\left[\left(\frac{1}{n}\right)^{\frac{1}{\sigma}}\int_0^n c^*(z)^{\frac{\sigma-1}{\sigma}}dz\right]^{\frac{\sigma}{\sigma-1}}, \qquad C_F^*=\left[\left(\frac{1}{1-n}\right)^{\frac{1}{\sigma}}\int_n^1 c^*(z)^{\frac{\sigma-1}{\sigma}}dz\right]^{\frac{\sigma}{\sigma-1}}, \tag{5}$$

where $\sigma>1$ is the elasticity of substitution across the differentiated products. The consumption-based price indices that correspond to the above specifications of preferences are given by

$$P=\left[vP_H^{1-\theta}+(1-v)\left(P_F\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}, \tag{6}$$

and

$$P^*=\left[v^*P_H^{*1-\theta}+(1-v^*)\left(P_F^*\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}, \tag{7}$$

where P_H (P_H^*) is the price sub-index for home-produced goods expressed in the domestic (foreign) currency and P_F (P_F^*) is the price sub-index for foreign produced goods expressed in the domestic (foreign) currency:

$$P_H=\left[\left(\frac{1}{n}\right)\int_0^n p(z)^{1-\sigma}dz\right]^{\frac{1}{1-\sigma}}, P_F=\left[\left(\frac{1}{1-n}\right)\int_n^1 p(z)^{1-\sigma}dz\right]^{\frac{1}{1-\sigma}}, \tag{8}$$

$$P_H^*=\left[\left(\frac{1}{n}\right)\int_0^n p^*(z)^{1-\sigma}dz\right]^{\frac{1}{1-\sigma}}, P_F^*=\left[\left(\frac{1}{1-n}\right)\int_n^1 p^*(z)^{1-\sigma}dz\right]^{\frac{1}{1-\sigma}}. \tag{9}$$

We assume that the law of one price holds, so

$$p(h)=Sp^*(h) \text{ and } p(f)=Sp^*(f), \tag{10}$$

where the nominal exchange rate, S_t, denotes the price of foreign currency in terms of domestic currency. Equations (6) and (7), together with condition (10), imply that $P_H=SP_H^*$ and $P_F=SP_F^*$. However, as Equations (8) and (9) illustrate, the home bias specification leads to deviations from purchasing power parity; that is, $P\neq SP^*$ For this reason, we define the real exchange rate as $Q\equiv\frac{SP^*}{P}$.

From consumers' preferences, we can derive the total demand for a generic good h, produced in country H, and the demand for a good f, produced in country F

$$y_t^d(h) = \left[\frac{p_t(h)}{P_{H,t}}\right]^{-\sigma} \left\{ \left[\frac{P_{H,t}}{P_t}\right]^{-\theta} \left[vC_t + \frac{v^*(1-n)}{n} \left(\frac{1}{Q_t}\right)^{-\theta} C_t^* \right] + G_t \right\}, \tag{11}$$

$$y_t^d(f) = \left[\frac{p_t(f)}{P_{F,t}}\right]^{-\sigma} \left\{ \left[\frac{P_{F,t}}{P_t}\right]^{-\theta} \left[\frac{(1-v)\,n}{1-n} C_t + (1-v^*) \left(\frac{1}{Q_t}\right)^{-\theta} C_t^* \right] + G_t^* \right\}, \tag{12}$$

where G_t and G_t^* are the country-specific government shocks. We assume that the public sector in the Home (Foreign) economy only consumes Home (Foreign) goods and has preferences for differentiated goods analogous to the ones of the private sector (given by Equations 4 and 5). The government budget constraints in the Home and Foreign economy are respectively given by

$$\tau_t \int_0^n p_t(h) y_t(h) dh = n P_{H,t}(G_t + Tr_t) \tag{13}$$

and

$$\tau_t \int_n^1 p_t^*(f) y_t^*(f) dh = (1-n) P_{F,t}(G_t^* + Tr_t^*). \tag{14}$$

Fluctuations in proportional taxes, τ_t (τ_t^*), or government spending, G_t (G_t^*), are exogenous and completely financed by lump-sum transfers, Tr_t (Tr_t^*), made in the form of domestic (foreign) goods.

Finally, to portray our small open economy, we use the definition of v and v^* and take the limit for $n \to 0$. Consequently, conditions (11) and (12) can be rewritten as

$$y^d(h) = \left[\frac{p_t(h)}{P_{H,t}}\right]^{-\sigma} \left\{ \left[\frac{P_{H,t}}{P_t}\right]^{-\theta} \left[(1-\lambda)C_t + \lambda \left(\frac{1}{Q_t}\right)^{-\theta} C_t^* \right] + G_t \right\}, \tag{15}$$

$$y^d(f) = \left[\frac{p_t^*(f)}{P_{F,t}^*}\right]^{-\sigma} \left\{ \left[\frac{P_{F,t}^*}{P_t^*}\right]^{-\theta} C_t^* + G_t^* \right\}. \tag{16}$$

Equations (15) and (16) show that external changes in consumption affect demand in the small open economy, but the opposite is not true. Moreover, movements in the real exchange rate do not affect the rest of the world's demand.

Price-setting Mechanism

Prices follow a partial adjustment rule *à la* Calvo (1983). Producers of differentiated goods know the form of their individual demand functions (given by Equations (15) and (16)), and maximize profits taking overall market prices and products as given. In each period a fraction, $\alpha \in [0, 1)$, of randomly chosen producers is not allowed to change the nominal price of the goods they produce. The remaining fraction of firms, given by $(1-\alpha)$, chooses prices optimally by maximizing the expected discounted value of profits. The optimal choice of producers that can set their price $\tilde{p}_t(j)$ at time T is, therefore

$$E_t \left\{ \sum (\alpha\beta)^{T-t} U_c(C_T) \left(\frac{\tilde{p}_t(j)}{P_{H,T}}\right)^{-\sigma} Y_{H,T} \left[\frac{\tilde{p}_t(j)}{P_{H,T}} \frac{P_{H,T}}{P_T} - \frac{\sigma V_y\left(\tilde{y}_{t,T}(j), \varepsilon_t\right)}{(1-\tau_T)(\sigma-1)U_c(C_T)} \right] \right\} = 0. \tag{17}$$

Monopolistic competition in production leads to a wedge between marginal utility of consumption and marginal disutility of production. We allow for fluctuations in this wedge by assuming a time-varying proportional tax τ_t. Hereafter, we refer to these fluctuations as markup shocks $\mathcal{M}_t$, where $\mathcal{M}_t = \frac{\sigma}{(1-\tau_t)(\sigma-1)}$.[5]

Given the Calvo-type setup, the price index evolves according to the following law of motion,

$$(P_{H,t})^{1-\sigma} = \alpha P_{H,t-1}^{1-\sigma} + (1-\alpha)\left(\tilde{p}_t(h)\right)^{1-\sigma}. \quad (18)$$

The rest of the world has an analogous price setting mechanism.

2.1 Asset Markets

The structure of financial markets can significantly alter the way idiosyncratic shocks affect consumption, output and other macroeconomic variables. As described in Obstfeld and Rogoff (1996, Chapter 5), *"The presence of international markets for risky assets weakens and may sever the link between shocks to a country's output or factor productivity and shocks to its resident's income. Sophisticated international financial markets thus force us to rethink the channels through which macroeconomic shocks impinge on the world economy."*

In this Section, we introduce three different specifications for asset market structure. First, we present the scenario in which international financial markets are incomplete, by assuming that agents can internationally trade nominal riskless bonds subject to intermediation costs. Then we describe two benchmark cases of asset market structure: at one extreme, we analyze the case of financial autarky, in which the small open economy has no access to international financial markets; at the other, we examine the most developed form of capital markets, in which households have access to a complete set of contingent claims.

Incomplete Markets

We characterize the environment of incomplete markets by assuming that agents can trade nominal riskless bonds denominated in *Home* and *Foreign* currency. We consider that home-currency denominated bonds are only traded domestically. Moreover, following Turnovsky (1985), the international trade of foreign currency-denominated bonds is subject to intermediation costs.[6] This cost is proportional to the country's aggregate net foreign asset position. If the small open economy is a net debtor, its agents pay a premium on the foreign interest rates when borrowing from abroad. On the other hand, if the country is a net creditor, households lending in foreign currency receive a rate of return lower than foreign interest rates. The spread is the remuneration of international intermediaries, and is assumed to be rebated equally among foreign households.

The intermediation cost assumption is introduced for technical reasons: it solves the stationarity problem in the style of Obstfeld and Rogoff (1995).[7] By ensuring that the

[5] Time-varying taxes introduce inefficient fluctuations in the marginal rate of substitution between consumption and goods production. We interpret them as markup shocks since, effectively, changes in taxes are passes from firms to consumers as changes in firms' markup over their marginal cost. Note that we could have obtained the same source of disturbances if, for example, we had introduced a time-varying elasticity of substitution σ (as in Clarida et al (2002)), or a time-varying monopoly power of wage setters (as Woodford (2003)).

[6] This specification was also recently used in Benigno (2001).

[7] See Ghironi.(2006) for a comprehensive discussion.

model is stationary, this assumption guarantees the precision of any quantitative exercises involving a log linear version of the model. In addition, it allows for the examination of the second moments of macroeconomic variables. Nevertheless, for some of our qualitative analysis, we consider the case of zero intermediation costs. This is done in order to simplify the analytical derivation of the optimal plan and improve our intuition on the policy prescriptions under incomplete markets.

We can write the household's budget constraint at Home as follows:

$$P_tC_t+\frac{B_{H,t}}{(1+i_t)}+\frac{S_tB_{F,t}}{(1+i_t^*)\psi\left(\frac{S_tB_{F,t}}{P_t}\right)}\leq B_{H,t-1}+S_tB_{F,t-1}+\frac{(1-\tau_t)\int_0^n p_t(h)y_t(h)dh}{n}+P_{H,t}Tr_t, \tag{19}$$

where $B_{H,t}$ and $B_{F,t}$ denote domestic-currency and foreign-currency denominated nominal bonds and Tr_t are government transfers, made in the form of domestic goods. The function $\psi(\cdot)$ represents the cost from international borrowings and it is increasing in the aggregate level of foreign debt: $\psi'(.)<0$. We further assume a zero steady-state risk premium by setting $\psi\left(\overline{B}_F\right)=1$. Moreover, in specifying the budget constraint (19), we also assume that households in a given country produce all goods and share the revenues from production in equal proportions. So, given that idiosyncratic risk is pooled among domestic households, and foreign households only trade foreign-currency denominated bonds, domestic-currency denominated bonds are in zero net supply. That is, in reality only foreign-currency denominated bonds are traded in equilibrium.[8] As a result, defining the intermediation costs over the foreign currency bond only is sufficient to pin down the overall steady-state net foreign asset position.

We also consider the case in which the initial wealth of all households within a country are equal. In effect, households in the same country face the same budget constraints in every period and state of the world. That is, we can consider a representative consumer for each economy. But even though idiosyncratic risk is pooled among households from the same country, there is imperfect risk sharing across borders.

Foreign households are assumed to trade only in foreign currency bonds. Thus, their budget constraint can be written as

$$P_t^*C_t^{*i}+\frac{B_{F,t}}{(1+i_t^*)}\leq B_{F,t-1}+\frac{(1-\tau_t^*)\int_{1-n}^1 p(f)y_t(f)dh}{1-n}+P_t^*Tr_t^*+\frac{K}{1-n}. \tag{20}$$

The intermediation profits K, which are shared equally among foreign households, can be written as

$$K=\frac{B_{F,t}}{P_t^*\left(1+i_t^*\right)}\left[1-\frac{Q_t}{\psi\left(\frac{S_tB_{F,t}}{P_t}\right)}\right]. \tag{21}$$

Given the above specification, we can write the consumer's intertemporal optimal choices as

$$U_C\left(C_t\right)=(1+i_t)\beta E_t\left[U_C\left(C_{t+1}\right)\frac{P_t}{P_{t+1}}\right], \tag{22}$$

$$U_C\left(C_t^*\right)=(1+i_t^*)\beta E_t\left[U_C\left(C_{t+1}^*\right)\frac{P_t^*}{P_{t+1}^*}\right], \tag{23}$$

[8]The present framework does not include a portfolio problem for households. For recent contributions on optimal international portfolios in incomplete markets settings, see, for example, Devereux and Sutherland (2007) and Evans and Hnatkovska (2005).

and

$$U_C\left(C_t\right) = (1+i_t^*)\psi\left(\frac{S_t b_t}{P_t}\right)\beta E_t\left[U_C\left(C_{t+1}\right)\frac{S_{t+1}P_t}{S_t P_{t+1}}\right], \tag{24}$$

where Equation (22) results from the small open economy optimal choice of home-currency denominated bonds. Equations (23) and (24) are Foreign and Home Euler equations derived from the optimal choice of foreign-currency denominated bonds. Moreover, Equations (22) and (24) imply that there is an interest rate differential across countries.

Financial Autarky

In this setup, the economy does not have access to international borrowing or lending. Consequently, there is no risk sharing across borders. As in the case of incomplete markets, we assume that there is a symmetric initial distribution of wealth across domestic agents.

The household budget constraints, at Home and abroad, can be written as

$$P_t C_t \leq \frac{(1-\tau_t)\int_0^n p_t(h) y_t(h) dh}{n} + P_{H,t} Tr_t \tag{25}$$

and

$$P_t^* C_t^{*i} \leq \frac{(1-\tau_t^*)\int_{1-n}^1 p(f) y_t(f) dh}{1-n} + P_t^* Tr_t^*. \tag{26}$$

Under financial autarky, the value of domestic production has to be equal to the level of public and private consumption in nominal terms. Aggregating private and public budget constraints, we have:

$$P_H(Y_t - G_t) = P_t C_t \tag{27}$$

The inability to trade bonds with the rest of the world imposes that the value of imports should equal the value of exports:

$$(1-n) S_t P_{H,t}^* C_{H,t}^* = n P_{F,t} C_{F,t}. \tag{28}$$

Complete Markets

Following Chari *et al* (2002), the complete market environment is introduced by assuming that agents in the small open economy have access to state contingent claims that allow them to optimally share risk with the rest of the world. In particular, we assume that agents meet and trade state contingent financial assets before monetary policy decisions are made. In our setting, agents have access to a full set of claims, contingent on all possible states of nature (resulting from different realizations of shocks and policy decisions). Thus, in effect, agents are insured against the uncertainty implied by the choice of monetary regime. This asset market structure implies the following risk sharing condition

$$\frac{U_C\left(C_t^*\right)}{U_C\left(C_t\right)} = \frac{S_t P_t^*}{P_t}. \tag{29}$$

But as shown in Senay and Sutherland (2007), if one considers a setup in which asset are traded after policy takes place and individuals cannot insure against policy choices, the above condition no longer holds. Moreover, the authors show that the timing of asset trades can have significant implication for policy analysis. In the current work we maintain the assumption that assets are traded before policy throughout the text, but we recognize that relaxing this assumption can have interesting implications for the analysis of monetary policy under alternative asset market structures. More specifically, if we assumed an alternative setting in which assets were traded after policy, we would be effectively changing the level of insurance financial markets provide. So, this setting could lead to economic dynamics which are closer to the ones obtained under incomplete markets or financial autarky.[9] This fact could, in turn, reduce the differences in the optimal policy prescriptions under alternative asset market specifications. We, nevertheless, leave the formal analysis of this specification for future research.

3 Log-linearized equilibrium conditions

In the current Section we present a summary of the model's equilibrium conditions in log-deviations from steady state. In the previous section we present a general version of the model, while the log-linearized system of equilibrium conditions described below imposes some restrictions on parameter values and steady-state conditions. In particular, we assume a log-utility function (i.e. $\rho = 1$). Moreover, we consider the case of a symmetric steady state which implies a zero steady-state net foreign asset position (that is, $\bar{B}_F = 0$, where upper-bar indicates a steady-state condition). The implication of these restrictions are discussed in Section 5.1.2, where such assumptions are relaxed.

The system of equilibrium conditions for the small open economy can be described by an aggregate supply, an aggregate demand and an equilibrium condition(s) implied by the financial market structure. These can be found in Tables 1, 2 and 3, which represent, respectively, the case of complete markets, financial autarky and incomplete markets.

Lower case variables are expressed in log deviations from steady-state, $g_t \equiv \log(G_t/\bar{Y})$ and $\mu_t \equiv \log(\mathcal{M}_t)$. In summary: c_t and c_t^* denote domestic and foreign consumption, y_t denotes domestic output, q_t denotes the real exchange rate, b_t represents net foreign assets (expressed in real terms) and π_t represents domestic (or producer price) inflation. The stochastic environment is characterized by the presence of productivity shocks ε_t, fiscal shocks g_t, and markup shocks μ_t. The parameters of the model are described in Table 4.

Equation (AS) represents the small open economy's Phillips curve. Note that the flexible price allocation is identical to the equilibrium allocation that would prevail were policymakers to target domestic inflation. That is, the case in which $\alpha \to 0$ and, therefore, $k \to \infty$, is equivalent to the case in which $\pi_t = 0$, ∇t. Equation (AD) illustrates

[9] In Senay and Sutherland (2007) the assumption that assets are traded after policy decisions are made implies that, ex-ante, the value of domestic consumption has to be financed by domestic consumption – condition which holds ex-post under financial autarky. This can be verified by inspection of equation (3) and (6) in the referred paper.

how the demand for the small open economy's products depends on foreign and domestic consumption. Equation (CM) in Table 1 is derived from the complete market assumption, and represents the optimal risk sharing agreement between agents in the small economy and agents in the rest of the world. In Table 2, which summarizes the equilibrium conditions under financial autarky, Equation (FA) represents the aggregate resource constraint. This Equation illustrates that under financial autarky, domestic consumption has to be fully financed by domestic production. Finally, in the case of market incompleteness (Table 3), combining domestic and foreign Euler equations, we derive Equation (IM). Moreover, in this setup, the aggregate budget constraint of the small open economy can be written as (IM′).

Given domestic exogenous shocks ε_t, g_t, and μ_t, and external conditions, c_t^*, the small open economy system of equilibrium conditions is closed by specifying the monetary policy rule. In the next sections we examine different specifications for this rule. Apart from analyzing the optimal monetary policy regime, we evaluate the performance of alternative policy rules such as an exchange rate peg, and both consumer price index (CPI) and producer price index (PPI) inflation targeting regimes.

Foreign dynamics are governed by foreign supply and demand conditions (AS* and AD*):

The specification of the foreign policy rule completes the system of equilibrium conditions which determine the evolution of y_t^*, c^* and π_t^*. For simplicity, and without loss of generality, we assume that the foreign economy targets domestic inflation (i.e. sets $\pi_t^* = 0$, ∇t).[10] We should note that the dynamics of the rest of the world are not affected by *Home* variables. Therefore, the small open economy can treat c_t^* as an exogenous shock.

4 Welfare

In this Section we present the objective function and the optimal monetary policy plan for the small open economy, under the different asset market structures. We should note that, for clarity of the exposition, in the sections to follow we assume a specific level for this markup (in particular, we set $\bar{\mathcal{M}} = (1-\lambda)^{-1}$, as in Gali and Monacelli (2005)). This parameterization guarantees that the steady state is efficient when the elasticity of intratemporal and intertemporal substitution are unitary, or when the economy is closed. We relax this assumption in Section 5.1.2.

In a microfounded model, welfare can be directly obtained from households' utility. Therefore, we obtain the monetary authority's objective function, which should reflect the economy's level of welfare, from a second-order Taylor expansion of this utility:

$$L_{to} = (1-\lambda)U_c\bar{C}E_{t_0}\sum\beta^t\left[d_t + \frac{1}{2}(\eta+1)(y_t - y_t')^2 + \frac{1}{2}\frac{\sigma}{k}(\pi_t)^2\right] + t.i.p + \mathcal{O}(||\xi||^3). \quad (30)$$

[10]Since the policy choice in the rest of the world determines how the endogenous variables respond to structural shocks, it may also affect the correlation between c_t^* and π_t^*. But in the case of a symmetric steady state, the system of equilibrium conditions in the small open economy is only affected by c_t^*. Thus, in this case, the policy choice of the rest of the world is irrelevant for the dynamics of the small open economy.

The term $t.i.p.$ stands for terms independent of policy (in particular, these refer to exogenous shocks that are not affected by the policy choice) and $\mathcal{O}(||\xi||^3)$ refers to terms of order strictly higher than two. In addition, we define $d_t \equiv y_t - \frac{1}{(1-\lambda)}c_t$ and $y_t' \equiv \frac{\eta}{(\eta+1)}\varepsilon_t$. Note that, in the case of a closed economy, in which $\lambda = 0$, the term d_t is eliminated from the above expression. Moreover, when markup shocks are absent, y_t' coincides with the flexible price allocation, or equivalently, the equilibrium allocation that would prevail if a policy of price stability is implemented. In other words, in this specification of a closed economy, there is no trade-off between stabilizing inflation and the output gap.

But as described in Obstfeld and Rogoff (1998) and Corsetti and Pesenti (2001), in an open economy welfare is influenced by an external distortion that gives rise to a terms of trade externality. Such a distortion arises because imported goods are not perfect substitutes to goods produced domestically, and, as a result, a social planner in an open economy may wish to exploit a certain degree of monopoly power. Thus, apart from nominal rigidities, welfare in our small open economy is affected an internal monopolistic distortion as well as an external distortion. The presence of these distortions can be illustrated by the term d_t in the loss function.

Importantly, the implication of these distortions depends on the asset market structure. We can illustrate this fact by comparing the complete markets specification with the case of financial autarky. By inspection of Table 1 and Table 2 we can see that while under complete markets the term d_t can be written as a function of $E[(1-\theta)q_t]$, under financial autarky, this term depends on $E[(\theta-1)q_t]$.[11] Therefore, while a more appreciated real exchange rate on average is welfare improving under complete markets and substitute goods ($\theta > 1$), the opposite holds under financial autarky.[12]

Under complete markets, when domestic and foreign goods are substitutes in the utility an real exchange rate appreciation can improve welfare by decreasing the disutility of producing at home without an equivalent reduction in the utility of consumption. But while the complete markets assumption prevents agents in the small economy from experiencing negative income effects (were they to reduce their production levels), under financial autarky this would no longer be the case. When domestic agents have no access to international asset markets, domestic agents borrowing constraints imply a tight link between domestic consumption and income. In this case, if goods are substitutes an appreciated real exchange rate is actually welfare inferior, as it induces a lower demand for domestic goods and, thus, lower domestic income. Lower domestic income, in turn, decreases consumption and welfare.

On the other hand, when goods are complements in the utility (i.e. when $\theta < 1$), under complete markets a more depreciated unconditional mean of the real exchange rate increases welfare by creating a rise in consumption utility larger than the rise in labor disutility. And, in this case, an appreciated exchange rate could improve welfare under financial autarky. For small values of θ, output would fall little relative the movement in

[11] Using a first-order approximation of demand equation and the risk sharing condition, we can write d_t as a function of θ and q_t. However, the full welfare implications of the linear term can only be accessed when this term is approximated to second order. This is properly taken into account in the loss function derivation presented in the next Section.

[12] In the case of log utility, when $\theta > 1$ the marginal utility of consuming domestic goods increases with the consumption of foreign goods (and vice-versa). Thus, these goods are "substitutes in the utility". When $\theta < 1$, domestic and foreign goods are "complements in the utility", as the marginal utility of consuming one good falls with the consumption of the other good. But in the general case of CRRA utility, this condition also depends on the coefficient of risk aversion ρ. In particular, goods are substitutes (complements) in the utility when $\rho\theta > 1$ ($\rho\theta < 1$).

real exchange rate, and the effect of the appreciation on agents' purchasing power would outweigh the reduction in output.

In the knife-edge case in which the marginal utility of consuming one good does not depend on the consumption of the other good (i.e. when $\theta = 1$), welfare would not depend on the level of the real exchange rate. Under this specification, the economy never experiences trade imbalances and the dynamics of the current account and the asset market structure are irrelevant.[13] As a result, the welfare characterization is also independent of the degree of risk sharing. Furthermore, the real exchange rate externality is eliminated and the utility-based loss function becomes isomorphic to the one in a closed economy.

4.1 The Linear-quadratic Loss Function

In order to obtain an approximation of the optimal plan that is fully accurate to second-order, we follow the linear-quadratic approach of Benigno and Woodford (2005) and Sutherland (2002).[14] We eliminate the linear term d_t in the Taylor expansion, using a second-order approximation of the model's equilibrium conditions. Because alternative asset market characterizations imply different equilibrium conditions, the final expression for welfare varies according to the structure of the asset market. The resulting objective function can be expressed as

$$L_{to} = U_c\bar{C}E_{t_0}\sum\beta^t\left[\begin{array}{c}\frac{1}{2}l^m_{yy}y_t^2 + l^m_{yq}y_tq_t + \frac{1}{2}l^m_{qq}q_t^2 + \frac{1}{2}l^m_{\pi}\pi_t^2 \\ +L^{m'}_{ey}e_ty_t + L^{m'}_{eq}e_tq_t\end{array}\right] + t.i.p^m + \mathcal{O}(||\xi||^3).^{15} \quad (31)$$

The weights $l^m_{yy}, l^m_{qq}, l^m_{yq}, l^m_{\pi}$, and the vectors L^m_{ey} and L^m_{eq} depend on the structural parameters of the model and on the asset market configuration. In what follows we let the superscript $m = c$ represent the case of complete markets, while $m = fa$ is the financial autarky setup and the incomplete market case is denoted by $m = i$. The vector of exogenous variables, e_t, is defined as:

$$e_t = \left[\begin{array}{cccc}\varepsilon_t & \mu_t & g_t & c_t^*\end{array}\right],$$

Even though the weights in the loss function are a complex function of structural parameters, we can show that when domestic and foreign goods are substitutes (complements) in the utility function, inflation variability is less (more) costly if asset markets are complete. In particular, the weight of inflation in the loss function, l_π, can be expressed as:

[13] The irrelevance of the asset market structure under this specification has been extensively discussed in the literature (e.g. Cole and Obstfeld (1991), Obstfeld and Rogoff (1995) and Benigno (2001), among others).

[14] Chari et al. (1994, 1995) suggest that the linear-quadratic approach may lead to an inaccurate approximation of the optimal policy problem. However, as explained in Benigno and Woodford (2006a, 2006b), their analysis is based on a "naïve" linear-quadratic approximation of the policy problem. As emphasized by Judd (1996, 1999), in order to obtain an approximation of the optimal plan that is fully accurate to second-order, the effect of second moments on the mean of the variables should be taken into account. The linear-quadratic approach adopted in this paper incorporates these effects by obtaining a purely quadratic approximation for the policy objective. Indeed, Benigno and Woodford (2006a, 2006b) demonstrate that a purely quadratic representation of the loss function leads to the correct local approximation of the problem for small enough disturbances.

[15] The second order approximation of the model and the full derivation of the loss function can be found in our Technical Appendix, which is available upon request. This appendix also contains a detailed derivation of the complete markets specification and the full derivation of the optimal monetary plan.

$$l^i_\pi = l^{fa}_\pi = \frac{\sigma(1-\lambda)}{k}\left(1 + l\frac{\lambda}{(l+1)(1-\lambda)}\right)$$

and

$$l^c_\pi = \frac{\sigma(1-\lambda)}{k}\left(1 - l\frac{\lambda(\eta+1)}{(1+\eta)+\eta\lambda l}\right)$$

where $l = (\theta-1)(2-\lambda)$. Therefore, $l^i_\pi = l^{fa}_\pi > l^c_\pi$ when $\theta > 1$ and $l^i_\pi = l^{fa}_\pi < l^c_\pi$ when $\theta < 1$.

5 Monetary Policy under Alternative Asset Market Structures

We proceed by characterizing the optimal plan under the assumption that policymakers can commit to maximizing the small open economy's welfare. The policy problem consists of minimizing the loss function given the equilibrium conditions and the initial conditions π_{t_0} and y_{t_0}.[16] In the case of complete markets and financial autarky, the policymakers choose the path of $\{\pi_t, y_t, c_t, q_t\}$ in order to minimize (31), subject to the equilibrium conditions given by Tables 1 and 2, respectively. The first order conditions to the minimization problem can be written in the form of the following targeting rules:

$$Q^c_y \Delta(y_t - y^{T,c}_t) + Q^c_q \Delta(q_t - q^{T,c}_t) + Q^c_\pi \pi_t = 0 \tag{32}$$

and

$$Q^{fa}_y \Delta(y_t - y^{T,fa}_t) + Q^{fa}_q \Delta(q_t - q^{T,fa}_t) + Q^{fa}_\pi \pi_t = 0, \tag{33}$$

where Δ denotes first difference operator, the superscript c denotes the complete market case and fa refers to the financial autarky setting. The above targeting rules set the objectives for monetary policy. This is done by specifying the targets y^T_t and q^T_t as functions of the different shocks.

In the case of incomplete markets, the policy problem consists of choosing the path of $\{\pi_t, y_t, c_t, q_t, b_t\}$ in order to minimize (31) subject to the equations specified in Table 3. The characterization of the optimal policy under incomplete markets is more complicated because of the intertemporal representation of the constraints (IM) and (IM$'$). The presence of intermediation costs also adds to the complexity of the problem. Nevertheless, in the special case in which there are no intermediation costs involved in the international trade of bonds (i.e. $\delta = 0$), the first order conditions of the policy problem imply

$$Q^i_y E_t \Delta(y_{t+1} - y^{T,i}_{t+1}) + Q^i_q E_t \Delta(q_{t+1} - q^{T,i}_{t+1}) + Q^i_\pi E_t \pi_{t+1} = 0.^{17} \tag{34}$$

The general formulation of the optimal rule is similar under the different asset market structures. According to these rules, policymakers should respond to real exchange rate

[16] In effect, the constraints on the initial conditions impose that the first order conditions to the problem are time invariant. This method follows Woodford's (1999) timeless perspective approach and ensures that the policy prescription does not constitute a time inconsistent problem.

[17] We should note that Equation (34) is not a targeting rule, since economic dynamics are not *determined* under this rule. The monetary policy plan which determines the optimal evolution of variables under incomplete markets is given by the first order conditions of the policy problem.

and output movements, as well as inflation. Nevertheless, the coefficients Q_y, Q_q and Q_π vary with the structure of the asset market. Such coefficients depend on the weights of output, the real exchange rate and inflation in the loss function, which, in turn depend on the asset market structure.

However, as previously stated, when the elasticity of intratemporal substitution is unitary, the dynamics of the small open economy are independent of the asset market structure. Under this specification, the first order conditions of the policy problem - for every asset market structure - can be expressed as:

$$0 = \Delta(y_t - y_t') + \sigma\pi_t \tag{35}$$

where y_t' coincides with the flexible price allocation for output when markup shocks are absent. Therefore, under this parameterization, a policy of complete domestic price stabilization closes the welfare relevant output gap. In other words, it is optimal to target producer price inflation regardless of the asset market structure. This result would not hold in the presence of markup shocks, since, as emphasized in the closed economy literature, these shocks introduce inefficiencies in the flexible price allocation.[18]

5.1 Evaluating monetary policy

After presenting the formulation of the optimal monetary policy analytically, we now evaluate the performance of optimal policy numerically. In particular, we examine how the degree of exchange rate and price stabilization prescribed by the optimal policy varies with the asset market specification. Since the implementation of the optimal rule may not be straightforward in practice (either because the targets are difficult to monitor - i.e. y_t^T and q_t^T depend on unobservable shocks - or because the weights are complex functions of structural parameters), we also evaluate the performances of simple policy rules. Table 6 presents the benchmark specification for the parameter values used in our numerical exercises.

Figures 1-3 shows the response of output, real exchange rate, consumption and inflation following a productivity shock, for the different asset market structures. Impulse responses are shown for the case in which the monetary authority is following the optimal plan (darker lines) and the case in which the central bank is targeting domestic inflation (lighter lines). In all cases, the increase in productivity leads to a higher output and a depreciation of the real exchange rate (as domestic goods become relatively cheaper in the face of higher supply). International risk sharing implies that consumption increases less then output. The difference between output and consumption is larger under financial autarky, given that in this case risk sharing only occurs via international relative prices.

The plots demonstrate that, even though quantitatively optimal policy deviations from price stability are quite small, there are some interesting qualitative differences. Under complete markets, relative to a policy of price stability, optimal monetary policy restricts movement in output and reduces the necessary movements in real exchange rate when goods are substitutes in the utility ($\theta > 1$). The opposite is true when goods are complements in the utility ($\theta < 1$). In this case, the level of exchange rate stabilization is higher than under price stability.

[18] See Woodford (2003) for a discussion.

The results are completely reversed when risk sharing is not optimal. Under incomplete markets or financial autarky, optimal policy reduces the volatility of the real exchange rate, relative to a policy that targets producer price inflation, when goods are complements rather than substitutes in the utility. These findings are summarized in Table 7, which compares the volatility of the real exchange rate under the optimal rule and under a policy of domestic price stability for the different asset market specifications.

5.1.1 Understanding the results

The economic rationale for these results is similar to the one presented in Section 4. In this section we have seen that an appreciated real exchange rate on average can have a positive effect on welfare when asset markets are complete and the elasticity of substitution is high or when asset markets are incomplete and this elasticity is low. So, in order to understand the results above, we need to spell out how stabilization policy affects the average level of the real exchange rate. A second order approximation of the equilibrium conditions can provide an analytical solution of how the first moment (or the mean) of variables is affected by the second moment (or the variance) of these variables. In effect, these approximations can pin down the implications of policies with different degrees of inflation and exchange rate volatility for the mean of the real exchange rate.

It follows that, regardless of the asset market structure, a policy that lowers the volatility of the real exchange rate at the expense of higher inflation volatility tends to be associated with a lower level of output and a more appreciated real exchange rate on average. Why? One of the reasons is given by the fact that a less volatile real exchange rates tends to increase demand for imports relative to domestic goods. This link between demand and the variance of the real exchange rate can be seen by inspection of the second order approximations of the demand. But the definite link between stabilization policy and the average level of the real exchange rate, also depends on how the degree of exchange rate/inflation volatility affects the price index, supply and risk sharing conditions. Figure 4 illustrate this relationship numerically for the case of complete markets and financial autarky. It confirms that the mean of the real exchange rate, $E(q)$, falls (appreciates) when the central bank (following a rule of the type $\pi_t + \chi \Delta q_t$) raises the degree of real exchange rate stabilization (i.e. χ increases).

So, as Figure 1 demonstrates, when asset markets are complete and goods are substitutes, optimal policy over-stabilizes the real exchange rate relative to its flexible price allocation. A less volatile real exchange rate tends to increase demand for imports relative to domestic goods. In equilibrium, the small open economy experiences lower domestic demand, lower output and a more appreciated exchange rate on average. The policy effectively diverts some output production to the foreign economy and therefore reduces the disutility of producing at home. At the same time, *the complete market specification ensures that consumption at home does not suffer significantly with the policy of diverting production.*

Moreover, when domestic and foreign goods are close substitutes to each other, the decrease in output and production disutility will be larger and the welfare benefits for the real exchange rate stabilization policy higher. This reasoning explains why, as shown in Table 8, when the elasticity of substitution between the goods is large enough, a policy that completely stabilize the nominal exchange rate a policy can outperform an inflation targeting regime. But when goods are complements, however, it is no longer possible to shift consumption towards foreign goods by inducing a greater appreciation in the exchange rate. In this case, domestic inflation targeting is the preferred policy rule

In the case of incomplete markets, there is a greater link between consumption and output. In the extreme case of financial autarky, for example, consumption has to be fully financed by domestic production. Consequently, a policy that tries to reduce the disutility of production will inevitably reduce consumption utility. When the elasticity of substitution between the goods is high, restricting the exchange rate movements (and engineering a more appreciated real exchange rate on average) has a strong impact on output and, consequently, on consumption. Therefore, it does not lead to welfare gains. In this case, as also illustrated Table 8, a policy that focus on stabilizing inflation and on minimizing the distortions that price dispersion brings, leads to higher welfare then a policy that perfectly stabilizes the nominal exchange rate.

On the other hand, lowering the degree of substitutability between the goods reduces output sensitivity to real exchange rate movements. Hence, the income effect on consumption of the appreciation is smaller. In addition, a relatively appreciated exchange rate can improve the small open economy's purchasing power under market incompleteness (see equations (FA) and (IM)). When the elasticity of substitution between goods is sufficiently low, the income effect in consumption is small and therefore its negative impact on welfare is smaller than the positive welfare effect from an improvement in purchasing power. Hence, in this case, an exchange rate peg outperforms a domestic inflation target.

Note that the findings presented in Tables 7 and 8 are entirely consistent with the results shown in Section 4.1. In this section we demonstrate that, when home and foreign goods are substitutes in utility, the coefficient of inflation variability in the loss function is smaller under perfect risk sharing than it is under incomplete markets, while the opposite holds when the goods are complementary to one another. The numerical value of these coefficients are presented in Table 9.

5.1.2 Quantifying the results

In this section we aim at quantifying the significance of the results presented above. In particular, we compare the welfare costs of different policy rules, conduct sensitivity analyses considering different parameter values, and evaluated the robustness of specific policy rules.[19] Moreover, we contrast the performance of domestic inflation targeted with

[19] Note that in what follows we compare welfare between different policy specifications, conditional on a given asset market specification. Our aim is not to compare welfare between different asset market structures. For a study that does that in a monetary union setting, see Auray and Eyquem (2008). A similar welfare comparison in a small open economy setting requires a careful analysis of the welfare approximation, as illustrated in Kim and Kim (2003). Although our fully quadratic characterization of the loss function allows for this analysis, we leave it for future research.

the optimal policy, and evaluate how significant are the differences in optimal policy across asset market structures.

First, we examine the relative performance of simple policy rules under alternative asset market structures. In particular, we present the differences in welfare, measured as percentage of a permanent shift in steady-state consumption, between a policy that targets domestic (or PPI) inflation and one that follows a fixed exchange rate regime (or PEG). We do not show the performance of CPI targeting given that this policy is not the preferred one in any calibration considered. As in Table 8, we consider values for the elasticity of intertemporal substitution ranging from 0.5 to 6. Although most of the recent literature tend to consider an elasticity of intratemporal substitution above unit, there is still some mixed evidence in the literature. For example, Rabanal and Tuesta (2006) and Lubik and Schorfheide (2005) estimate, using Bayesian techniques, values for elasticity of substitution well below unity. Heathcote and Perri (2002) estimate a value of 0.9. On the other hand, in Broda and Weinstein (2005) the mean estimates are between 4 and 6. Also, recent work by Imbs and Mejean (2009), suggests that evidence from disaggregated data points to estimates of around 5.[20]

As Table 8 illustrates, when asset markets are complete, an exchange rate PEG can lead to higher welfare when the elasticity of substitution is significantly high. But the quantitative results presented in Table 10 show that the differences in welfare associated with a PPI relative to a PEG are of, at most, 0.02% of steady state consumption (this is the case when the elasticity of intratemporal substitution is set to 6). When risk-sharing is suboptimal, a PEG outperforms a PPI targeting regime when the elasticity of substitution between goods is low, and the difference in welfare reaches 0.138% of steady state consumption when the elasticity of intratemporal substitution is 0.5.

In our benchmark calibration, we consider a logarithm utility function - that is, we assume that the coefficient of risk aversion, denoted by ρ, is unitary. While this assumption is somewhat common in the real business cycle literature, the literature suggests a larger number for this coefficient (for example, Chari at al (2002) consider a value as large as 6). Therefore, given that our welfare derivations assume a general constant relative risk aversion (CRRA) utility function, we can conduct further sensitivity analysis for higher values of the coefficient of risk aversion. As shown in Table 11, since increasing the degree of risk aversion raises the costs of economic fluctuations, it increases the welfare losses associated with inferior rules (that is, it raises the absolute values of the numbers presented in Table 11).[21]

As emphasized in Woodford (2003) and Benigno and Woodford (2005), changing the degree of inefficiency in steady-state output created by monopolistic competition can alter the design of monetary policy in closed economies. So our sensitivity analysis

[20] See Bodenstein (2008) for a comprehensive discussion on this empirical literature.

[21] As previously discussed, when utility is not log, goods are substitutes (complements) in the utility when $\theta > 1$ ($\theta < 1$). But in the general case of CRRA utility, this condition also depends on ρ. So changing the degree of risk aversion can also change the ranking of policy rules. For example, some further sensitivity tests suggest that if markets are complete and ρ takes a value of 4 or 6, in contrast with the results of Table 8, a PEG might outperform a PPI even if θ is as low as 2.

also considers different levels of steady-state markup $\bar{\mu}$. Table 11 illustrates that the welfare benefit of restricting exchange rate movements tends to fall (and the relative performance of PPI relative to PEG tends to improve) with the level of steady state markup. This is because, a higher level of steady-state markup increases the size of the internal monopolistic distortion and the degree of inefficiency in the level of output supplied by firms. So, as in a closed economy, increasing $\bar{\mu}$ raises the policy incentives to engineer a higher level of output as to offset the internal monopolistic distortion. As discussed in the open economy literature (see, for example, Tille (2001)), these incentives then counterbalance the ones coming from the presence of the external distortion. That is, the welfare gains from offsetting the internal distortion counterbalance the benefits of inducing an equilibrium allocation in which the real exchange rate is more appreciated (and, in which, output would be lower). As a result, increasing $\bar{\mu}$ reduces the net benefits from restricting exchange rate movements.

Table 11 also examines the implications for the performance of policy rules of lower levels of the elasticity of labour supply, i.e. higher values of η. Our benchmark calibration assumes $\eta = 0.47$, as in Rotemberg and Woodford (1997), but works such as Canzoneri, Cumby and Diba (2008) point to values as high as 6. Our results reveal that the relative performance of PPI increases with η. The previous section highlights that a policy of restricting exchange rate movements (and switching consumption towards foreign goods) can improve welfare by reducing the disutility of producing domestically. But as labour becomes more inelastic, this effect dissipates, and the performance of a policy that concentrates on domestic price stability improves.[22] Finally, as shown in Table 11, reducing the degree of openness also decreases the incentive to exploit the terms of trade externality and improves the performance of an inward looking policy such as PPI relative to PEG.[23]

The results above suggest that domestic inflation targeting tends to outperform a PEG for most parameter values considered, unless the degree of substitutability between the goods takes values close to the bounds of the range considered. Moreover, the relative performance of PPI improves if we consider larger distortions in output due to monopolistic competition, less elastic labour supply, or lower degrees of openness. But how does domestic inflation targeting performs relative to the optimal policy?

As previously illustrated in Figures 1-3, although the optimal policy plan and a PPI inflation targeting regime imply different levels of exchange rate stabilization, these policies lead to very similar economic dynamics following productivity shocks. In line with these results, Table 12 shows that the welfare costs of implementing a policy that targets PPI inflation rather than the optimal policy are smaller than 0.0004% of steady-state consumption. So these findings generalize the results illustrated in Figures 1-3, suggesting that PPI inflation targeting lead to small welfare costs when the economy is subject to all types of shocks.[24] We should note, however, that the welfare losses presented in

[22] This result is consistent with the findings of Cova and Søndergaard (2004).

[23] We have also conducted some sensitivity analysis varying the level of steady state net foreign assets in the case of incomplete markets. Nevertheless, these did not have notable implications for the ranking performance of different policy rules.

[24] Note that Table 12, as well as the other tables assessing the performance of different rules, assumes that the stochastic environment is characterized by the presence of all shocks. But the same qualitative results would hold if we rank policy rules conditional on the presence of only productivity shocks, only fiscal shocks or only external shocks. Markup shocks effectively introduce inefficient fluctuations in the marginal rate of substitution between consumption and goods production, so stabilizing such fluctuations is another objective of stabilization policy. Thus, the presence of such shocks tends to deteriorate the

Tables 10-12 are of a similar order of magnitude as the costs of business cycles reported by Lucas (1987), and are comparable to others found in similar exercises in the literature (see, for example Benigno (2009)).

Our final exercise evaluates the welfare implications of designing policies under incorrect assumptions for level of asset market sophistication. For example, suppose that the small open economy is initially operating under financial autarky and the monetary authority is using the optimal policy designed for this asset market specification. The economy then opens up to international asset trading, and nominal bonds become traded, but monetary policy remains the same. How big is the loss from not changing the optimal policy to take into account that agents can trades bonds? This is shown in the first column of Table 13. The next column than compares the welfare costs of maintaining a policy designed for financial autarky, in an economy with access to a complete set of contingent claims. Finally, the final column analyze the opposite scenario. Again, the implications of adopting suboptimal policies for welfare are quantitatively small. This result is not surprising given that, under the calibrations considered in Table 13, optimal policy resembles closely a policy of producer price inflation targeting, regardless of the asset market structure.[25]

6 Concluding Remarks

In this work, we formalize the dynamics of the small open economy under different degrees of international risk sharing and show that these have direct implications for monetary policy. Optimal monetary policy is independent of the financial market structure only when the latter is entirely irrelevant for the economy's dynamics. This is the case when trade imbalances are ruled out and the steady-state level of net foreign assets is zero. Under this specification, and provided there are no markup shocks or steady-state inefficiencies in output, domestic price stability coincides with the optimal plan, regardless of the degree of risk sharing.

But in general the optimal level of stabilization of domestic prices or exchange rates varies with the asset market structure and the degree of substitutability between goods. When a country can optimally share risk with the rest of the world, and home and foreign goods are substitutes, restricting real exchange rate volatility may improve its welfare. But under imperfect risk sharing, these results are entirely reversed.

These findings suggest that countries with differences import profiles and different asset market characteristics could benefit from different policy specifications. Having said that, our results suggest that, although qualitatively interesting, the quantitative implications of these factors for the performance of different policies are not large. In particular, our numerical results suggest that welfare costs of adopting a domestic inflation targeting appear to be small for most parameter values considered. But, as underlined in Lucas (1987), small welfare costs of macroeconomic fluctuations appear to be a feature of most models of this class.

performance of simple rules relative to the optimal policy.

[25] We do not present quantitative assessments of the optimal rule for extreme values of θ because, in these cases, the second order conditions of the optimal policy problem may not be satisfied.

Tables and Figures

Table 1: Equilibrium Conditions under Complete Markets

$\pi_t = k(c_t + \eta y_t + \frac{\lambda}{1-\lambda} q_t - \eta \varepsilon_t + \mu_t) + \beta E_t \pi_{t+1}$	AS
$y_t = (1-\lambda)c_t + \lambda c_t^* + \gamma q_t + g_t$	AD
$c_t = c_t^* + q_t$	CM

Table 2: Equilibrium Conditions under Financial Autarky

$\pi_t = k(c_t + \eta y_t + \frac{\lambda}{1-\lambda} q_t - \eta \varepsilon_t + \mu_t) + \beta E_t \pi_{t+1}$	AS
$y_t = (1-\lambda)c_t + \lambda c_t^* + \gamma q_t + g_t$	AD
$y_t - \frac{\lambda}{1-\lambda} q_t = c_t$	FA

Table 3: Equilibrium Conditions under Incomplete Markets

$\pi_t = k(c_t + \eta y_t + \frac{\lambda}{1-\lambda} q_t - \eta \varepsilon_t + \mu_t) + \beta E_t \pi_{t+1}$	AS
$y_t = (1-\lambda)c_t + \lambda c_t^* + \gamma q_t + g_t$	AD
$E_t(c_{t+1} - c_t) = E_t(c_{t+1}^* - c_t^*) + E_t \Delta q_{t+1} - \delta b_t$	IM
$\beta b_t = b_{t-1} + y_t - c_t - \frac{\lambda}{1-\lambda} q_t$	IM′

Table 4: Model parameters

θ	Intratemporal elasticity of substitution
η^{-1}	Elasticity of labor production
λ	Degree of openness
β	Subjective discount factor
σ	Elasticity of substitution across the differentiated products
δ	Sensitivity of intermediation costs to the level of foreign debt
k	$(1-\alpha\beta)(1-\alpha)/\alpha(1+\sigma\eta)$
γ	$\theta\lambda(2-\lambda)/(1-\lambda)$

Table 5: Foreign Equilibrium Conditions

$\pi_t^* = k(c_t^* + \eta y_t^* - \eta \varepsilon_t^* + \mu_t^*) + \beta E_t \pi_{t+1}^*$	AS*
$y_t^* = c_t^* + g_t^*$	AD*

Table 6: Parameter values used in the quantitative analysis

Parameter	Value	Notes:
β	0.99	Specifying a quarterly model with 4% steady-state real interest rate
η	0.47	Following Rotemberg and Woodford (1997)
λ	0.25	(unless specified otherwise)
α	0.66	Characterizing an average length of price contract of 3 quarters
σ	10	Following Benigno and Woodford (2005)
θ	1.5	(unless specified otherwise)
δ	0.01	Benigno (2009)
$sdv(\hat{\varepsilon})$	0.0071	Consistent with Gali and Monacelli (2005) and Kehoe and Perri (2002)
$sdv(\hat{g})$	0.0062	Following Lubik and Schorfheide (2005)
$sdv(\hat{\mu})$	0.0013	Consistent with Adolfson at al (2007) and Smets and Wouters (2003)
$sdv(\hat{C}^*)$	0.0129	Following Lubik and Schorfheide (2007)
$\kappa^{(\varepsilon)}$, $\kappa^{(C^*)}$	0.66	Following Gali and Monacelli (2005)
$\kappa^{(g)}$	0.94	Following Lubik and Schorfheide (2005)
$\kappa^{(\mu)}$	0.99	Following Adolfson at al (2007)

Productivity shocks			
	Optimal risk sharing	Sub-optimal risk sharing	
	Complete Markets	Incomplete Markets	Financial Autarky
$\theta = 2$	$\text{var}^{opt}(Q_t) < \text{var}^{ppi}(Q_t)$	$\text{var}^{opt}(Q_t) > \text{var}^{ppi}(Q_t)$	$\text{var}^{opt}(Q_t) > \text{var}^{ppi}(Q_t)$
$\theta = 0.8$	$\text{var}^{opt}(Q_t) > \text{var}^{ppi}(Q_t)$	$\text{var}^{opt}(Q_t) < \text{var}^{ppi}(Q_t)$	$\text{var}^{opt}(Q_t) < \text{var}^{ppi}(Q_t)$

Table 7: Volatility of the Real Exchange Rate under the Optimal Rule vs. Producer Price Inflation Targeting

Welfare ranking				
		Optimal risk sharing	Sub-optimal risk sharing	
		Complete Markets	Incomplete Markets	Financial Autarky
Substitute Goods	$\theta = 6$	PEG	PPI	PPI
	$\theta = 4$	PEG	PPI	PPI
	$\theta = 2$	PPI	PPI	PPI
	$\theta = 1$	PPI	PPI	PPI
Complementary Goods	$\theta = 0.8$	PPI	PPI	PPI
	$\theta = 0.7$	PPI	PPI	PPI
	$\theta = 0.6$	PPI	PEG	PEG
	$\theta = 0.5$	PPI	PEG	PEG

Table 8: Welfare ranking of producer price inflation (PPI) targeting, consumer price inflation (CPI) targeting and fixed exchange rate regime (or PEG), when the economy is subject to productivity, markup, fiscal and external shocks.

Complete Markets	l_π^c	Incomplete Markets	l_π^i	Financial Autarky	l_π^{fa}
$\theta = 0.8$	217	$\theta = 0.8$	131	$\theta = 0.8$	131
$\theta = 1$	191	$\theta = 1$	191	$\theta = 1$	191
$\theta = 2$	89	$\theta = 2$	270	$\theta = 2$	270

Table 9: Loss function coefficients

Welfare costs: Producer Price Inflation Targeting vs Exchange rate Peg				
		Optimal risk sharing	Sub-optimal risk sharing	
		Complete Markets	Incomplete Markets	Financial Autarky
Substitute Goods	$\theta = 6$	0.019	-0.026	-0.011
	$\theta = 4$	0.008	-0.028	-0.016
	$\theta = 2$	-0.011	-0.032	-0.024
	$\theta = 1$	-0.027	-0.027	-0.027
Complementary Goods	$\theta = 0.8$	-0.031	-0.020	-0.020
	$\theta = 0.7$	-0.034	-0.010	-0.008
	$\theta = 0.6$	-0.036	0.014	0.023
	$\theta = 0.5$	-0.038	0.097	0.138

Table 10: Preferred Policy Rule following a Productivity Shock

Welfare costs: Producer Price Inflation Targeting vs Exchange rate Peg				
		Optimal risk sharing	Sub-optimal risk sharing	
		Complete Markets	Incomplete Markets	Financial Autarky
Risk Aversion	ρ= 1	-0.019	-0.031	-0.027
	ρ= 2	-0.024	-0.066	-0.043
	ρ= 3	-0.031	-0.115	-0.059
	ρ= 4	-0.038	-0.178	-0.075
Steady-state Markup	$\bar{\mu}$= 1	-0.014	-0.031	-0.026
	$\bar{\mu}$= 1.66	-0.019	-0.031	-0.027
	$\bar{\mu}$= 2	-0.020	-0.032	-0.027
Labor Supply Elasticity	η^{-1}= 1/0.47	-0.019	-0.031	-0.027
	η^{-1}= 1	-0.028	-0.046	-0.041
	η^{-1}= 1/3	-0.071	-0.109	-0.102
	η^{-1}= 1/6	-0.139	-0.210	-0.199
Openness	λ= 0.4	-0.019	-0.031	-0.027
	λ= 0.2	-0.031	-0.036	-0.030
	λ= 0.1	-0.039	-0.039	-0.031

Table 11: Preferred Policy Rule following a Productivity Shock

Welfare costs: Optimal Policy vs Producer Price Inflation Targeting			
	Optimal risk sharing	Sub-optimal risk sharing	
	Complete Markets	Incomplete Markets	Financial Autarky
$\theta = 2$	-0.0004	-0.0001	-0.0001
$\theta = 0.8$	-0.00004	-0.0001	-0.0002

Table 12: Welfare costs of PPI inflation targeting relative to the optimal policy regime

Welfare costs of suboptimal policies			
	$L^{Incomp.}_{Incomp.} - L^{Incomp.}_{F.\ Aut.}$	$L^{Comp.}_{Comp.} - L^{Comp.}_{F.\ Aut.}$	$L^{F.\ Aut.}_{F.\ Aut.} - L^{F.\ Aut.}_{Comp.}$
$\theta = 2$	-0.0002	-0.0003	-0.0009
$\theta = 0.8$	-0.00003	-0.0003	-0.0001

Table 13: L^A_B indicates the loss function of an economy under asset market structure A that uses a policy designed for an economy under asset market structure B.

Figure 1: Impulse responses, Complete Markets Case

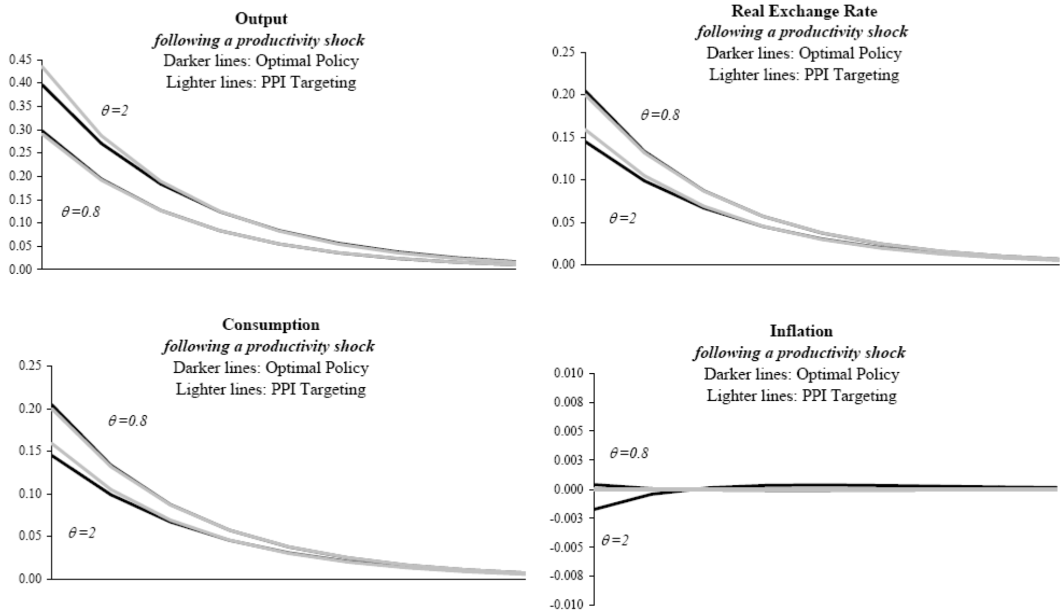


Figure 2: Impulse responses, Incomplete Markets Case

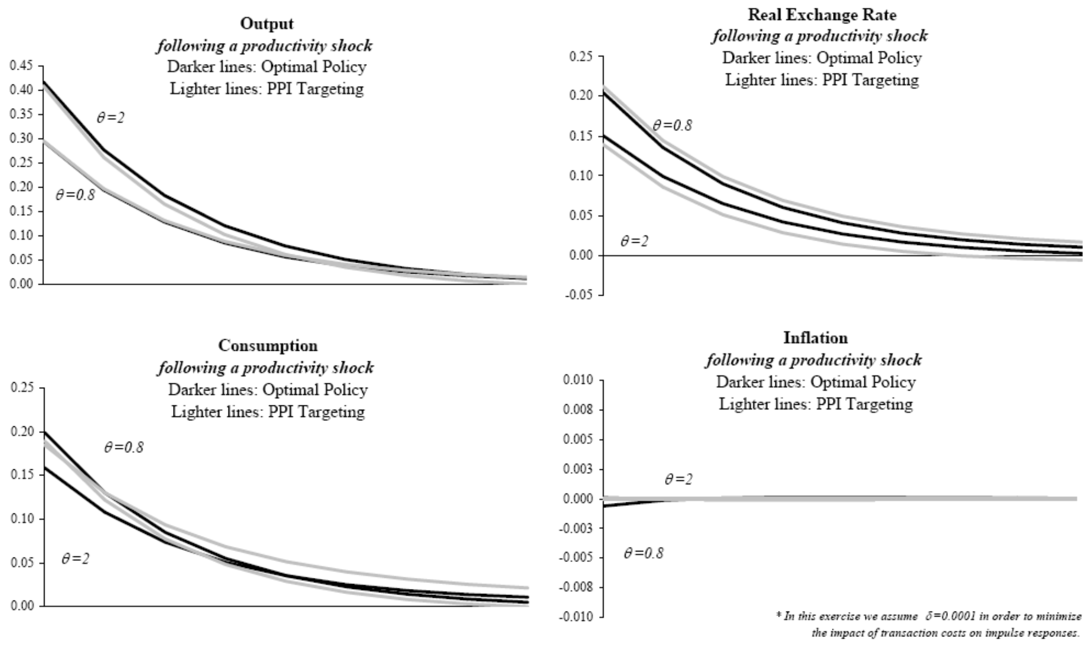


Figure 3: Impulse responses, Financial Autarky Case

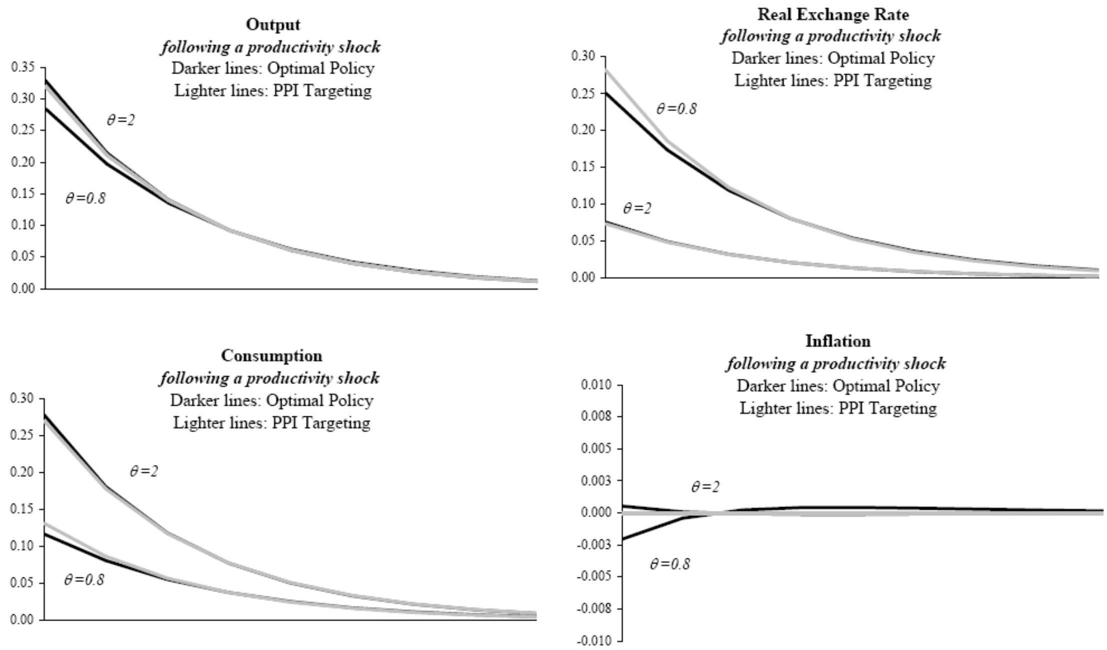
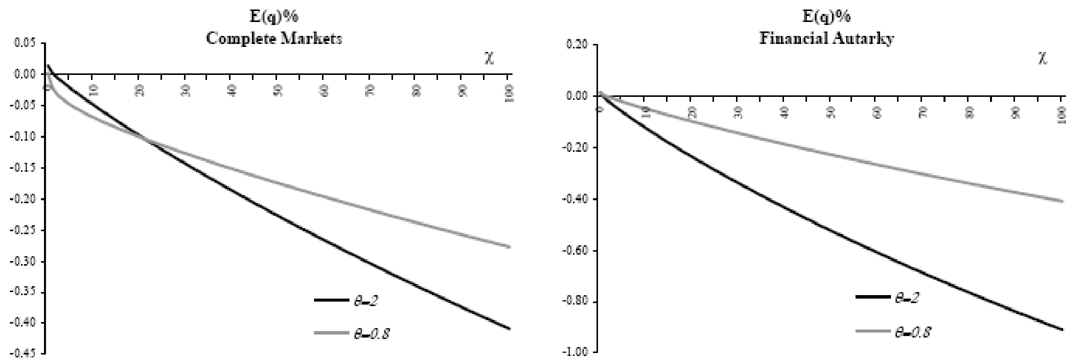


Figure 4: Average Real Exchange Rate. The stochastic environment is characterized by the presence of productivity, markup, fiscal and external shocks.



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