ENDOGENOUS EXCHANGE-RATE PASS-THROUGH AND SELF-VALIDATING EXCHANGE RATE REGIMES

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A long-standing question in open-macro macroeconomics concerns the choice of currency denomination of nominal prices and contracts. A firm serving the export market may choose to set prices in its domestic currency, the destination market currency, or a vehicle currency, possibly indexing these prices —fully or partially— to exchange-rate movements.[1] To the extent that nominal prices remain sticky, the choice among these alternatives has crucial consequences for the design of stabilization policy —by determining the degree of exchange rate pass-through on export/import prices[2]. However, the causal relation may also go in the opposite direction as the currency denomination choice may itself depend, among other factors, on the stabilization strategy pursued by policymakers.

In this paper, we analyze the interaction between firms' export pricing and monetary policy, and discuss its potential macroeconomic implications for business cycle synchronization and an exchange-rate regime choice. In the framework of a highly stylized monetary model, we first provide an analytical characterization of the optimal export pricing by imperfectly monopolistic firms subject to nominal rigidities. We show that, when choosing the currency denomination of exports (and/or the degree of indexation to the exchange rate), firms optimize over the covariance between the exchange rate (log) and the markup (inverse). Intuitively, the currency denomination of exports affects the exposure of firms' marginal revenue to the shocks moving the exchange rate and demand in the destination markets. Depending on the covariance of these shocks with the shocks affecting marginal costs, firms can optimize their profit stream from the export markets in the face of production and demand risk (including monetary policy risk).

For example, consider a firm producing in a country where monetary policy is relatively noisy, that is, frequent nominal shocks tend to simultaneously raise nominal wages and depreciate the exchange rate. In this environment, by choosing to preset prices in foreign currency, a firm can rest

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[1] For a review of the empirical evidence, see Goldberg and Knetter (1997), Goldberg and Tille (2008), Gopinath and Rigobon (2008) among others.
[2] See Betts and Devereux (2000), Obstfeld and Rogoff (2000), Engel (2002), Corsetti and Pesenti (2005). Corsetti. Dedola and Leduc (2010) provide a synthesis of the debate.

assured that whenever an unexpected monetary expansion causes nominal wages and, thus, its marginal cost to rise, its export revenues in domestic currency will correspondingly increase per effect of the nominal depreciation, with clear stabilizing effects on the firm's markup. The opposite will hold true for a foreign firm exporting to the same country. By choosing to preset prices in local currency, this firm can insulate its revenue and, hence, its markup from monetary noise.

In the second part of the paper, we turn to the analysis of optimal monetary policy, building on the well-known result that the design of optimal monetary rules in open economies crucially depends on the degree of exchange rate pass-through, i.e., whether firms invoice their exports in their own currency (the hypothesis of producer currency pricing, or PCP, in which case the pass-through of exchange rate into import prices is full) or in local currency (the hypothesis of local currency pricing, or LCP, corresponding to zero pass-through). Since firms in our model take monetary policy into account when choosing optimal pass-through, in equilibrium, monetary policy and firms' pricing strategies depend on each other. We show that this two-way interaction raises the possibility of equilibria in which the choice of the exchange-rate regime and export pricing becomes self-validating in the sense that central banks and firms adopt optimal policies conditional on beliefs about each other's behavior.

Our findings warn against reliance on the conventional view that business cycle synchronization and macroeconomic convergence are pre-conditions to the implementation of a currency area, as they crucially reduce the costs of giving up national monetary policy —i.e., giving up the ability to deliver differentiated policy responses to country-specific disturbances hitting the economy. In our model, the private sector responds to a credible adoption of an exchange-rate peg by choosing pricing strategies that are optimal in the absence of exchange-rate flexibility. Conditional on central banks' beliefs that firms set export prices in foreign currency, a fixed exchange rate turns out to be the (conditionally) optimal monetary regime from the vantage point of the national policymakers as well. Specifically, national outputs become more correlated for any given stochastic pattern of the shocks to fundamentals, thus reducing the (perceived) need for differentiated national monetary policies. Despite the absence of structural changes, economies that adopt a fixed exchange-rate regime may end up satisfying the criteria for an Optimum Currency Area (henceforth OCA) according to the theory spelled out by the classic contributions of Mundell (1961), McKinnon (1963), Kenen (1969) and Ingram (1973).[3]

In the vast literature on this subject, early arguments for an endogenous OCA emphasize that the change in the monetary regime could act as a catalyst of business cycle synchronization through trade integration. For instance, Frankel and Rose (1998) stress that the reduction of foreign exchange

[3] Modern applications and revisions include, among others, Eichengreen (1990; 1992), Dowd and Greenaway (1993), Tavlas (1993), Bayoumi and Eichengreen (1994), Melitz (1996), Bayoumi (1997), and Alesina and Barro (2002). See Buiter, Corsetti and Pesenti (1998), ch.10, for a critical survey of the literature.

transaction costs associated with the adoption of a common currency promotes cross-border trade. To the extent that the process of integration enhances intra-industry trade rather than product specialization, national business cycles can become more synchronized, driven by sectoral demand shocks and productivity innovations affecting all countries simultaneously. Higher national output correlation then reduces the need for exchange-rate adjustments to stabilize national employment and prices, and minimizes the welfare costs of giving up national currencies.[4]

Our characterization of endogenous currency areas is different. Namely, we show that it is still possible for a monetary union to satisfy the OCA criterion ex-post even if monetary integration fails to boost economic convergence and intra-industry trade. To distinguish our theory from arguments to increase economic symmetry resulting from economic integration, throughout our analysis, we assume that countries are perfectly specialized in the production of one type of good independent of the exchange-rate regime.

In our stochastic setting, national welfare is measured by the expected utility of the representative household. The adoption of such non-arbitrary metrics allows us to rank equilibria in welfare terms. The result is that a fixed exchange rate and currency union are Pareto-inferior to the Friedman-style optimal float. Although in our model the private and public sector do the right thing; in terms of policy and pricing strategies, once the equilibrium without exchange-rate flexibility is selected, there is still room for welfare improvement by creating conditions for relative price adjustment through changes in the exchange rate. A move toward more volatile rates and less synchronized business cycles would bring about the appropriate change in firms' pricing and pass-through strategies, which in turn would validate the floating regime as optimal.

While the model considered in this paper is highly stylized, in part reflecting the advantages of working with closed-form solutions in levels rather than relying on linear approximations, the principle it illustrates is more general. The literature provides examples of the potential range of applications of our analysis, as in Chang and Velasco (2006)'s model of optimal currency denomination of debt contracts, once again, regulated by an assessment of the covariance between contractual payment and revenues expressed in the same currency. A related analysis by Goldberg and Tille (2008) extends the choice of currency denomination of exports to multiple currencies, thus including vehicle currencies.

Our contribution is related to a small but influential piece of literature modeling the specific determinants of the currency denomination of exports as an endogenous choice. Namely, Bacchetta and van Wincoop (2005), Devereux, Engel and Stoorgard (2004), and Friberg (1998) develop models where firms can choose to price exports in domestic or foreign currency, knowing that price updates

[4] Not everyone agrees with this argument: For instance, Eichengreen (1992) and Krugman (1993) stress that monetary integration could lead to greater specialization in production, thus lowering output correlation and making regions more vulnerable to local shocks. On an empirical basis however, the evidence presented by Frankel and Rose (1998) supports the view that trade links raise income correlations. Moreover, Rose and Engel (2000) show that membership in a common currency area increases international business cycle correlations by a significant amount.

will be subject to frictions. As emphasized by this literature, a rich set of factors, from the market share of exporters to the incidence of distribution and the availability of hedging instruments, potentially play a crucial role in this choice (see Engel (2006) for a synthesis). Relative to this literature, our contribution emphasizes the covariance between exchange rates and markups as the key elements of optimal strategies of currency denomination and pricing rather than the variance of the exchange rate. Also, in our model, firms are allowed to index, if only imperfectly, their export prices to the exchange rate (say, by posting an exchange rate clause in their catalog markets for overseas sales). This modeling choice enhances the flexibility and generality of the pricing framework, allowing for a clear and transparent analytical characterization of the equilibrium.

This paper is organized as follows: Section 2 develops the model. Section 3 studies price-setters' optimal behavior and endogenous pass-through strategies for given monetary policies. Section 4, in contrast, focuses on optimal monetary policies given firm pricing strategies. The previous two analyses are brought together in section 5 where we characterize the equilibrium of the economy. The final section discusses our main results.

1. The Model

Our model shares the standard elements in modern monetary analysis: imperfect competition in production, nominal rigidities in the goods markets, and forward-looking price-setting behavior by firms (although we do not assume staggered price setting).[5] Drawing on Corsetti and Pesenti (2005), our setup allows for imperfect pass-through of exchange rates on export prices. In contrast to our earlier contribution, here we further study how the degree of pass-through is endogenously chosen ex-ante by exporters on the basis of information on shocks and policy rules in the form of a limited-price flexibility rule contingent on exchange-rate movements. Taking firms' pass-through strategies as given, we characterize state-contingent monetary policy rules. In a world equilibrium, both the degree of pass-through and monetary policy are jointly determined by optimizing agents.

1.1 Consumer Optimization

We model a world economy with two countries, H (home) and F (foreign), each specialized in one type of traded good. Each good is produced in a number of varieties, defined over a continuum of unit mass. Varieties are indexed by h in the home country and f in the foreign country. Each country is populated by households defined over a continuum of unit mass. Households are indexed by j in the home country and j^* in the foreign country.

[5] Related contributions in recent literature include Obstfeld and Rogoff (2000; 2002), Devereux and Engel (2003), Corsetti and Pesenti (2001; 2005), Benigno (2004), Canzoneri, Cumby and Diba (2004).

Home agent j's lifetime expected utility $\mathcal{W}$ is defined as follows:

$$\mathcal{W}_{t-1}(j) \equiv E_{t-1} \sum_{\tau=t}^{\infty} \beta^{\tau-t} [lnC_{\tau}(j) - \kappa \ell_{\tau}(j)] \quad 0 < \beta < 1 \,, \kappa > 0 \tag{1}$$

where β is the discount rate. The instantaneous utility is a positive function of the consumption index $C(j)$, and a negative function of labor effort $\ell(j)$. Foreign agents' preferences are similarly defined: the discount rate is the same as in the home country, while κ^*, in the foreign country, need not coincide with κ in the home country.

$C(j)$ and its foreign analog are Cobb-Douglas baskets of the home and foreign goods:

$$C_t(j) \equiv C_{H,t}(j)^{\gamma} C_{F,t}(j)^{1-\gamma}, \quad C_t^*(j^*) \equiv C_{H,t}^*(j^*)^{\gamma} C_{F,t}^*(j^*)^{1-\gamma} \quad 0 < \gamma < 1 \tag{2}$$

where the weights γ and $1 - \gamma$ are identical across countries. $C_{H,t}(j)$ and $C_{(F,t)}(j)$ are CES baskets of home and foreign varieties, respectively:

$$C_{H,t}(j) = \left(\int_0^1 C_t(h,j)^{1-\frac{1}{\theta}} dh \right)^{\frac{\theta}{\theta-1}} , \quad C_{F,t}(j) = \left(\int_0^1 C_t(f,j)^{1-\frac{1}{\theta^*}} df \right)^{\frac{\theta^*}{\theta^*-1}} \tag{3}$$

where $C_t(h,j)$ and $C_t(f,j)$ are, respectively, consumption of home variety h and foreign variety j by home agent j at time t. Each home variety is an imperfect substitute for all other home varieties, with constant elasticity of substitution across varieties θ. We assume that θ is larger than the elasticity of substitution between home and foreign types. Similarly the elasticity of substitution among foreign varieties is $\theta^* > 1$. The consumption indexes in the foreign country, $C_{H,t}^*(j^*)$ and $C_{F,t}^*(j^*)$, are analogously defined.

We denote the prices of varieties h and f in the home market (thus expressed in the home currency) as $p(h)$ and $p(f)$, and the prices in the foreign market (in foreign currency) as $p^*(h)$ and $p^*(f)$. For given prices of the individual varieties, we can derive the utility-based price indexes P_H, P_F, P and their foreign analogs.[6] In particular, the utility-based CPIs are:

[6] For instance, the utility-based price index $P_{H,t}$ is defined as the minimum expenditure required to buy one unit of the composite good $C_{H,t}$ and is derived as $P_{H,t} = \left[\int_0^1 p_t(h)^{1-\theta} dh \right]^{\frac{\theta}{1-\theta}}$.

(4) $$P_t = \frac{P_{H,t}^{\gamma} P_{F,t}^{1-\gamma}}{\gamma_W}, \quad P_t^* = \frac{\left(P_{H,t}^*\right)\left(P_{F,t}^*\right)^{1-\gamma}}{\gamma_W} \quad \gamma_W \equiv \gamma^{\gamma}(1-\gamma)^{1-\gamma}$$

Home households hold the portfolio of home firms, and two international bonds, B and B^*, denominated in home and foreign currency, respectively. Both international bonds are in zero net supply. Households receive wages and profits from the firms. The individual flow budget constraint for agent j in the home country is:

(5) $$B_t(j) + \varepsilon_t B_t^*(j) \leq (1 + i_{t-1})B_{t-1}(j) + (1 + i_{t-1}^*)\varepsilon_t B_{t-1}^*(j) + W_t \ell_t(j) + \int_0^1 \pi_t(h)dh - \int_0^1 p_t(h)\, C_t(h,j)dh - \int_0^1 p_t(f) C_t(f,j)df$$

In the expression above, the nominal yields i_t and i_t^* are paid at the beginning of period $t+1$ and are known at time t. Taking prices as given, home household j maximizes (1) subject to (5) with respect to consumption, labor effort, and bond holdings. A similar optimization problem is solved by foreign household j^*.

Agent j's optimal demand for varieties h and f is a function of the relative price and total consumption of home and foreign goods, respectively:

(6) $$C_t(h,j) = \left(\frac{p_t(h)}{P_{H,t}}\right)^{-\theta} C_{H,t}(j), \quad C_t(f,j) = \left(\frac{p_t(f)}{P_{F,t}}\right)^{-\theta^*} C_{F,t}(j)$$

and, similarly, the demand for home and foreign consumption goods is a constant fraction of agent j's total consumption expenditure:

(7) $$P_t C_t(j) = \frac{1}{\gamma} P_{H,t} C_{H,t}(J) = \frac{1}{1-\gamma} P_{F,t} C_{F,t}(j)$$

The intertemporal allocation is determined according to the Euler equation:

(8) $$1 = (1 + i_t) E_t Q_{t.t+1}(j)$$

where $Q_{t,t+1}(j)$ is agent j's stochastic discount rate:

(9) $$Q_{t,t+1}(j) \equiv \beta \frac{P_t C_t(j)}{P_{t+1} C_{t+1}(j)}$$

The condition for optimal labor effort equates the real wage to the marginal rate of substitution between consumption and leisure:

(10) $$W_t = \kappa P_t C_t(j)$$

The above equation implies that consumption and discount rates are equalized across agents, so that $Q_{t,t+1}(j) = Q_{t,t+1}$

1.2 Nominal Rigidities, Exchange Rate Pass-Through and Price Setting

Each variety h is produced by a single home firm and sold in both countries under conditions of monopolistic competition. Output is denoted Y. Technology is linear in household's h labor, $\ell(h)$:

(11) $$Y_t(h) = Z_t \ell_t(h)$$

where Z is a country-specific productivity shock. Similarly, output of foreign variety f is a function of foreign labor $\ell^*(f)$ and the productivity shock in the foreign country Z^*.

Home firms take the nominal price of labor W_t as given. The nominal marginal cost MC_t is identical across firms:

(12) $$MC_t(h) = MC_t = W_t / Z_t$$

and home firms' nominal profits Π_t are defined as:

(13) $$\Pi_t(h) = (p_t(h) - MC_t) \int_0^1 C_t(h,j) dj + (\varepsilon_t p_t^*(h) - MC_t) \int_0^1 C_t^*(h,j^*) dj^*$$

where E is the nominal exchange rate expressed as home currency per unit of foreign currency. Foreign variables are similarly defined.

It is assumed that individual firms set the nominal price of their product one period in advance, and stand ready to meet demand at given prices for one period. In terms of our notation, home firms selling in the home market choose $p_t(h)$ at time $t-1$ by maximizing the present discounted value of profits:

(14) $$p_t(h) = \arg\max E_{t-1} Q_{t-1,t} \pi_t(h),$$

accounting for (6). Domestic firms optimally set prices equal to expected nominal marginal cost appropriately discounted and augmented by the equilibrium markup $\theta/(\theta-1)$:

(15) $$p_t(h) = \frac{\theta}{\theta-1} \frac{E_{t-1}(MC_t Q_{t-1,t}\, p_t(h)^{-\theta} P_{H,t}^{\theta} C_{H,t})}{E_{t-1}(Q_{t-1,t}\, p_t(h)^{-\theta} P_{H,t}^{\theta} C_{H,t}}$$

Accounting for (7) and (9), the previous expression can be rewritten as:

(16) $$p_t(h) = P_{H,t} = \frac{\theta}{\theta-1} E_{t-1} MC_t = \frac{E_{t-1}(P_t C_t / Z_t)}{\Phi}$$

Where we define $\Phi \equiv (\theta-1)/\theta\kappa$. As we will see below, the constant Φ measures the expected level of labor effort in the home country.

Home firms selling abroad also set nominal prices one period in advance. In contrast to most models in the literature, we do not impose a priori restriction that export prices are set in home currency, implying that all unexpected fluctuations in the exchange rate are "passed through" one-to-one on export prices in foreign currency (in the literature this scenario is referred to as "Producer Currency Pricing" or PCP). Furthermore, we do not impose the opposite restriction that export prices are set in foreign currency, implying that foreign-currency prices of home goods do not respond at all to unexpected exchange-rate fluctuations (i.e. the case of "Local Currency Pricing" or LCP). Instead, we consider the more general case in which home firms preset export prices in foreign currency, but are able to modify them after observing exchange-rate changes, following Corsetti and Pesenti (2005) and Obstfeld (2002). In our setup, the extent to which the foreign currency prices of home exports adjust, contingent on the realization of the exchange rate, is a choice variable determined by home firms at time $t-1$. In other words, the elasticity of exchange rate pass-through can endogenously be zero, as in the LCP case; one, as in the PCP case; or any intermediate number.

Formally, by definition of pass-through elasticity $\eta_t^* \equiv \delta \ln p_t^*(h) / \delta \ln(1/\varepsilon_t)$, foreign-currency prices of home varieties are:

(17) $$p_t^*(h) \equiv \frac{\tilde{p}_t(h)}{\varepsilon_t^{\eta_t^*}} \qquad 0 \le \eta_t^* \le 1$$

where $\tilde{p}_t(h)$ is the predetermined component of the foreign-currency price of good h that is not adjusted to variations of the exchange rate during period t.[7] At time t, home firms choose $\tilde{p}_t(h)$ and η_t^* one period in advance in order to maximize expected discounted profits (14) accounting for foreign demand —i.e., the foreign analog of (6). The actual $p_t^*(h)$ however, depends on the realization of the exchange rate at time t.[8]

In equilibrium we obtain:

$$p_t^*(h) = \frac{\theta}{\theta - 1} \frac{1}{\varepsilon_t^{\eta^*}} \frac{E_{t-1}(MC_t Q_{t-1,t}\, p_t^*(h)^{-\theta} P_{H,t}^{*\theta} C_{H,t}^*)}{E_{t-1}(Q_{t-1,t}\, p_t^*(h)^{-\theta} P_{H,t}^{*\theta} C_{H,t}^* \varepsilon_t^{1-\eta^*})} \quad (18)$$

Using (7) and (9) and letting $\Theta \equiv \gamma/(1-\gamma)(P_t^* C_t^* \varepsilon_t / P_t C_t)$, we can also write:

$$p_t^*(h) \equiv P_{H,t}^* = \frac{\tilde{p}_t(h)}{\varepsilon_t^{\eta_t^*}} = \frac{\theta}{\theta - 1} \frac{E_{t-1}\left(\frac{MC_t \Theta_t}{\varepsilon_t^{1-\eta^*}}\right)}{\varepsilon_t^{\eta^*} E_{t-1}\Theta_t} = \frac{E_{t-1}\left(\frac{P_t C_t \Theta_t}{Z_t \varepsilon_t^{1-\eta^*}}\right)}{\Phi \varepsilon_t^{\eta^*} E_{t-1}\Theta_t} \quad (19)$$

Analogous expressions can be derived for the prices set by foreign firms in the foreign and home markets. In the case of foreign exports the notation is:

$$p_t(f) = \tilde{p}_t^*(f) \varepsilon_t^{\eta_t}, \quad 0 \leq \eta_t \leq 1 \quad (20)$$

where the degree of pass-through in the home country η_t need not be equal to that in the foreign country η_t^*. The optimal pricing strategy is:

$$P_{F,t}^* = \frac{\theta^*}{\theta^* - 1} E_{t-1}(MC_t^*), \quad P_{F,t} = \frac{\theta^*}{\theta^* - 1} \varepsilon_t^{\eta_t} \frac{E_{t-1}(MC_t^* \varepsilon_t^{1-\eta_t}/\Theta_t)}{E_{t-1}(1/\Theta_t)} \quad (21)$$

Clearly, home firms are willing to supply goods at given prices as long as their ex-post markup does not fall below one:

$$P_{H,t} \geq MC_t, \quad P_{H,t}^* \geq \frac{MC_t}{\varepsilon_t} \quad (22)$$

[7] For instance, if $\eta^* = 1$, pass-through in the foreign country is complete —as in the PCP case. If $\eta^* = 0$ we have $p_t^*(h) = \tilde{p}_t(h)$ which coincides with the price chosen by the home producer in the LCP case.

[8] The optimal degree of pass-through may well vary over time. The model could be easily extended to encompass the case in which the pass-through elasticity is a non-linear function of the exchange rate (e.g., η^* is close to zero for small changes of the exchange rate E but close to one for large exchange rate fluctuations). The key results of our analysis would remain unchanged.

Otherwise, agents would be better off by not accommodating shocks to demand. In what follows, we restrict the set of shocks so that the "participation constraint" (22) and its foreign analog are never violated.

1.3 Monetary Policy

The government controls the path of short-term rates i and provides a nominal anchor for market expectations. To characterize monetary policy, it is analytically convenient to introduce a forward-looking measure of monetary stance μ_t, defined as:

$$\frac{1}{\mu_t} = \beta(1+i_t)E_t\left(\frac{1}{\mu_{t+1}}\right) \tag{23}$$

or integrating forward as:

$$\frac{1}{\mu_t} = E_t \lim_{N\to\infty} \beta^N \frac{1}{\mu_{t+N}} \prod_{\tau=0}^{N-1}(1+i_{t+\tau}) \tag{24}$$

Monetary policy is assumed to make the variable μ_t/mu_{t-1} stationary around a constant long-run inflation target $1+\pi$. In a non-stochastic steady state μ grows at the rate $1+\pi$, and the steady-state nominal interest rate is $1+i=(1+\pi)/\beta$. Home monetary easing at time t (μ_t temporarily above trend) reflects a temporary interest-rate cut (i.e., $1+i_t<(1+\pi)/\beta$).

Note that in equilibrium, μ_t is equal to P_tC_t (and μ_t^* is equal to $P_t^*C_t^*$). A monetary expansion delivers increased nominal spending.[9] A monetary union in our framework is defined as a regime in $i_t = i_t^*$ for all t. If both countries adopt the same numeraire, this implies $\mu_t=\mu_t^*$.

1.4 Market Clearing and the Closed-Form Solution

The resource constraint for variety h is:

$$Y_t(h) \geq \int_0^1 C_t(h,j)dj + \int_0^1 C_t^*(h,j^*)dj^* \tag{25}$$

while the resource constraint in the home labor market is:

[9] This result can be obtained by comparing (23) with the home Euler equation under logarithmic utility (8), i.e. $1/P_tC_t = \beta(1+i_t)E_t(1/P_{t+1}C_{t+1})$

(26) $$\int_0^1 \ell_t(j)dj \geq \int_0^1 \ell_t(h)dh$$

The resource constraint for foreign variety f and foreign labor are similarly defined. Finally, international bonds are in zero net supply:

(27) $$\int_0^1 B_t(j)dj + \int_0^1 B_t(j^*)dj^* = \int_0^1 B_t^*(j)dj + \int_0^1 B_t^*(j^*)dj^*$$

In our analysis below, we focus on symmetric equilibria in which, at some initial point in time $t = 0$, agents worldwide have zero net financial wealth. As shown in Corsetti and Pesenti (2001; 2005), in equilibrium, both net wealth and the current account are endogenously zero at any subsequent point in time: home imports from abroad are always equal in value to foreign imports from home. Since agents are equal within countries (though not necessarily symmetric across countries) we can drop the indexes j and j^* and interpret all variables in per-capita (or aggregate) terms. As trade and the current account are always balanced, countries precisely consume their aggregate sales revenue:

(28) $$\Theta_t = 1, \quad (1-\gamma)P_t C_t - \gamma \varepsilon_t P_t^* C_t^* = 0$$

Table 1 presents the general solution of the model in which all endogenous variables, (29) through (39), are expressed in closed form as functions of real shocks (Z_t and Z_t^*) and monetary stances (μ_t and μ_t^*).[10]

Table 1: The Closed-Form Solution of the Model

(29)	$\varepsilon_t = \frac{1-\gamma}{\gamma}\frac{\mu_t}{\mu_t^*}$
(30)	$MC_t = \kappa\mu_t / Z_t$
(31)	$MC_t^* = \kappa^*\mu_t^* / Z_t^*$
(32)	$P_{H,t} = \frac{\theta}{\theta-1} E_{t-1}(MC_t)$
(33)	$P_{F,t} = \frac{\theta^*}{\theta^*-1} \varepsilon_t^{\eta_t} E_{t-1}\left[MC_t^* \varepsilon_t^{1-\eta_t}\right]$
(34)	$P_{H,t}^* = \frac{\theta}{\theta-1} \frac{E_{t-1}\left[MC_t / \varepsilon_t^{1-\eta_t^*}\right]}{\varepsilon_t^{\eta_t^*}}$

[10] Algebraic details can be found in the Appendix of Corsetti and Pesenti (2004). Note that the solution does not hinge upon any specific assumptions or restriction on the nature of the shocks.

(35)	$$P^*_{F,t} = \frac{\theta}{\theta - 1} E_{t-1}(MC^*_t)$$
(36)	$$C_t = \frac{\gamma_W \left(\frac{\theta - 1}{\theta}\right)^{\gamma} \left(\frac{\theta^* - 1}{\theta^*}\right)^{1-\gamma} \mu_t \varepsilon_t^{-\eta_t(1-\gamma)}}{[E_{t-1}(MC_t)]^{\gamma} \left[E_{t-1}\left(MC^*_t \varepsilon_t^{1-\eta_t}\right)\right]^{1-\gamma}}$$
(37)	$$C^*_t = \frac{\gamma_W \left(\frac{\theta - 1}{\theta}\right)^{\gamma} \left(\frac{\theta^* - 1}{\theta^*}\right)^{1-\gamma} \mu^*_t \varepsilon_t^{\eta^*_t \gamma}}{\left[E_{t-1}\left(MC_t / \varepsilon_t^{1-\eta^*_t}\right)\right]^{\gamma} [E_{t-1}(MC^*_t)]^{1-\gamma}}$$
(38)	$$\ell_t = \left(\frac{\theta - 1}{\theta \kappa}\right) \left[\gamma \frac{MC_t}{E_{t-1}(MC_t)} + (1-\gamma) \frac{MC_t / \varepsilon_t^{1-\eta^*_t}}{E_{t-1}\left[MC_t / \varepsilon_t^{1-\eta^*_t}\right]}\right]$$
(39)	$$\ell^*_t = \left(\frac{\theta^* - 1}{\theta^* \kappa^*}\right) \left[(1-\gamma) \frac{MC^*_t}{E_{t-1}(MC^*_t)} + \gamma \frac{MC^*_t / \varepsilon_t^{1-\eta_t}}{E_{t-1}\left[MC^*_t \varepsilon_t^{1-\eta_t}\right]}\right]$$

Interpreting Table 1: since the equilibrium current account is always balanced (see (28) above) and the demand for imports is proportional to nominal expenditures $P_t C_t$ and $P^*_t C^*_t$, the nominal exchange rate E_t in (29) is proportional to $P_t C_t / P^*_t C^*_t$, that is, a function of the relative monetary stance. Relations (30) and (31) link marginal costs to macroeconomic shocks and monetary policy. Domestic prices of domestic goods are predetermined according to (32) and (35), while import prices vary with the exchange rate, depending on the degree of exchange rate pass-through according to (33) and (34). Equilibrium consumption is determined in (36) and (37). Finally, employment and output levels are determined according to (38) and (39).

2. The Choice of Currency Denomination of Exports and Optimal Exchange Rate Pass-Through

What is the optimal degree of exchange rate pass-through on export prices of home goods in the foreign market? Taking monetary stances and policy rules as given, home firms choose η^*_t to maximize expected discounted profits. In a symmetric environment with $p^*_t(h) = P^*_{h,t}$ the first order condition is:[11]

[11] The optimal pass-through maximizes $E_{t-1}[Q_{t-1}, \Pi_t(h)]$, thus maximizes the expression:

$$E_{t-1}[Q_{t-1,t}\left(\tilde{p}_t(h)/P^*_{H,t}\right)^{-\theta} C^*_{H,t} \left\{\tilde{p}_t(h)\varepsilon_t^{1-\eta^*_t+\theta^*_t+\theta\eta^*_t} - MC_t \varepsilon_t^{\theta\eta^*_t}\right\}]$$

The first order condition yields:

$$0 = E_{t-1}[Q_{t-1,t}\left(\tilde{p}_t(h)/(\varepsilon_t^{\eta^*_t} P^*_{H,t})\right)^{-\theta} C^*_{H,t} \ln\varepsilon_t\{(\theta - 1)\tilde{p}_t(h)\varepsilon_t^{1-\eta^*_t} - \theta MC_t\}]$$

And accounting for the equilibrium expressions Q, P^*_H, C^*_H and MC, as well as (28), it is possible to rewrite the first order condition above as in (40).

(40) $$1 = \frac{\theta_k}{\theta - 1} \frac{E_{t-1}[\ln \varepsilon_t (P_t^* C_t^* / Z_t)/P_{H,t}^*]}{E_{t-1}(\ln \varepsilon_t)} \frac{\gamma}{1-\gamma}$$

Comparing (40) with (18) and (29), it follows that the optimal pass-through η_t^* is such that:

(41) $$E_{t-1}\left[\frac{\mu_t}{Z_t \varepsilon_t^{1-\eta_t^*}}\right] E_{t-1}(\ln \varepsilon_t) = \left[E_{t-1} \ln \varepsilon_t \left(\frac{\mu_t}{Z_t \varepsilon_t^{1-\eta_t^*}}\right)\right]$$

that is:

(42) $$Cov_{t-1}\left(MC_t/\varepsilon_t^{1-\eta_t^*}, \ln \varepsilon_t\right) = 0$$

This is a critical condition. At an optimum, the markup (reciprocal) in the export market must be uncorrelated with the exchange rate (log). Trivially, if E_t is constant or fully anticipated, any degree of pass-through is consistent with the previous expression. But if E_t is not perfectly predictable, the optimal degree of pass-through will depend on the expected monetary policies and the structure of the shocks. By the same token, the optimal pass-through chosen by foreign firms selling in the home market requires the following:

(43) $$Cov_{t-1}\left(MC_t^* \varepsilon_t^{1-n_t}, \ln(1/\varepsilon_t)\right) = 0$$

To build intuition, observe that in equilibrium, home ex-post real profits in the foreign market[12] are proportional to $\tilde{p}_t(h) - MC_t/E_t^{1-\eta_t^*}$, that is, they are a concave function of E_t for $\eta_t < 1$.[13] This implies that, keeping everything else constant, exchange-rate shocks reduce expected profits from exports. In general, however, to assess the overall exposure of profits to exchange rate uncertainty, it is crucial to know whether the underlying shocks make marginal costs and exchange rate co-vary positively.

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[12] Ex-post real profits from selling in the foreign market are $Q_{t-1,t}\left(\varepsilon_t p_t(h) \varepsilon_t^{-\eta^*} - MC_t\right) C_{H,t}^*$. Using the equilibrium expression for C_H^*, E, and Q, the previous expression can be rewritten as:

$$\beta(1-\gamma) \frac{\mu_{t-1}}{\tilde{p}_t(h)} \left(\tilde{p}_t(h) - MC_t/\varepsilon_t^{1-\eta_t^*}\right).$$

Recall that E is proportional to μ_t/μ_t^*, $Q_{t-1,t}$ is proportional to $1/\mu_t$, MC_t is proportional to μ_t/Z_t and $C_{H,t}^*$ is proportional to $\mu_t^* E_t^{\eta_t^*}$.

[13] This result does not rely on the linearity of labor effort disutility. Suppose that the latter is nonlinear, say in the form $-\ell^v/v$. It can be shown that profits are concave in the nominal exchange rate for any $v \geq 1$.

Suppose, for instance, that there are no productivity shocks. If exogenous monetary shocks in the home country μ_t are the only source of uncertainty, condition (42) becomes:

$$Cov_{t-1}(\mu_t^{\eta_t^*}, \ln \mu_t) = 0 \quad (44)$$

which is solved by $\eta_t^* = 0$. Home monetary shocks symmetrically affect home marginal costs MC_t and the home discount rate Q_t, leaving their product unchanged. They also affect the exchange rate: E_t depreciates in those states of nature in which μ_t increases. Currency depreciation increases home firms' nominal sales revenue per unit of exports (by a factor $1 - \eta_t^*$) and increases foreign demand for home goods (by a factor η_t^*). By setting a zero degree of pass-through, or $\eta_t^* = 0$, home exporters insure that both their export markup and the relevant demand curve for their products abroad are unaffected by monetary shocks.

Instead, if the only source of uncertainty is μ^*, condition (42) becomes:

$$Cov_{t-1}\left((\mu_t^*)^{\eta_t^*-1}, -\ln \mu_t^*\right) = 0 \quad (45)$$

which is solved by $\eta_t^* = 1$. Home marginal costs are uncorrelated with the exchange rate. By choosing full pass-through and letting export prices absorb exchange-rate changes, home firms can insulate their export sales revenue from currency fluctuations and avoid any uncertainty of markup and profitability in the foreign market. Note that these examples shed light on the reason why countries with high and unpredictable monetary volatility should also exhibit a high degree of pass-through, and vice versa —a view emphasized, for instance, by Taylor (2000).[14]

The same intuition carries over to the case in which there is both monetary and real uncertainty. In this case, patterns of endogenous intermediate pass-through can emerge, as the following example illustrates. If the home monetary authority adopted the policy $\mu_t = Z_t^2/\mu_t^*$, then it would be optimal for home firms to choose $\eta_t^* = 0.5$. Abroad, we would need $MC_t^* E_t^{1-\eta_t}$ to be uncorrelated with the exchange rate. This would be the case, for instance, if $\mu_t^* = (Z_t^*)^5/Z_t^4$ and $\eta_t = 0.6$.

In the literature that analyzes the currency denomination of exports as an endogenous choice by profit maximizing firms —see Bacchetta and Van Wincoop (2005), Devereux, Engel and Stoorgard (2004), and Friberg (1998), among others— this choice is influenced by a number of factors ranging from the market share of exporters to the incidence of distribution and the availability of hedging instruments (see Engel (2006) for a synthesis). Relative to this literature however, condition (42)

[14] When monetary policy is exogenous (suboptimal) and firms are only allowed to choose between zero and 100 percent pass-through (that is, between local-currency and producer-currency pricing), the results above are consistent with the analysis of Devereux, Engel, and Stoorgard (2004), and Bacchetta and Van Wincoop (2004).

emphasizes how the focus of the analysis should be shifted from the variance of the exchange rate towards the co-movements between the exchange rates on the one hand, and marginal revenues and marginal costs on the other.

Our framework naturally lends itself to the task of exploring the interactions between the choice of currency denomination of exports and monetary policy. Regarding this interaction, an early hypothesis was put forward by Taylor (2000), who specifically links low pass-through to a low trend-inflation environment (see Campa and Goldberg (2005) for evidence). Our analysis suggests that systematic effects of monetary policy stabilization indeed work through the covariance between exporters' marginal costs and their revenues from the foreign market.

Intuitively, consider a firm producing in a country where monetary policy is relatively noisy; that is, frequent nominal shocks tend to simultaneously raise nominal wages and depreciate the exchange rates. In this environment, by choosing LCP, a firm can be certain that, whenever an unexpected monetary expansion causes nominal wages and thus its marginal cost to rise, its export revenues in domestic currency will correspondingly increase per effect of the nominal depreciation — with clear stabilizing effects on the firm's markup. The opposite will be true for a foreign firm exporting to the same country. By choosing PCP, this firm can insulate its revenue, and therefore its markup, from monetary noise.

3. OPTIMAL MONETARY POLICY FOR GIVEN EXCHANGE RATE PASS-THROUGH

Consider now the policymakers' problem in a world Nash equilibrium where national monetary authorities are able to commit to preannounced rules. In specifying this equilibrium, we assume that policy makers take each other's monetary stance as given, as well as the degree of exchange rate pass-through on export pricing. We motivate the latter assumption by observing that central bankers may rely on a vast body of empirical findings that point to a low elasticity of import prices to the exchange rate (see Corsetti, Dedola and Leduc (2008) for a theoretical assessment of these studies). Nonetheless, it is worth stressing from the start that, as a consequence of this assumption, the Nash equilibrium we solve for is conditional on policymakers' beliefs concerning equilibrium pass-through. A different allocation would follow, for instance, if we posited that policymakers take equilibrium prices, rather than pass-through, as given. We will return to this point below.[15]

In our Nash equilibrium, the home monetary authority seeks to maximize the indirect utility of the home representative consumer (1) with respect to $\{\mu_{t+\tau}\}_{\tau=0}^{\infty}$, given $\{\mu_\tau^*, Z_\tau, Z_\tau^*, \eta_\tau, \eta_\tau^*\}_{\tau=t}^{\infty}$. The foreign authority faces a similar problem. Table 2 presents the closed-form reaction functions, the solution of which is the global Nash equilibrium "up". Each reaction function is written in two ways: as a function

[15] For an analysis of optimal monetary behavior under discretion see Corsetti and Pesenti (2005).

of marginal costs and markups, or as a function of employment gaps and deviations from the law of one price.

The optimal policy requires that the home monetary stance be eased (μ increases) in response to a positive domestic productivity shock (Z rises). Without a policy reaction, a positive productivity shock would create both an output and an employment gap. In fact, ℓ would fall below $\Phi = (\theta - 1)/(\theta\kappa)$. Actual output Y would not change, but potential output, defined as the equilibrium output with fully flexible prices, would increase. In light of this, optimal monetary policy leans against the wind and moves to close the employment and output gaps.

In general, however, the optimal response to a home productivity shock will not close the output gap completely. Home stabilization policy, in fact, induces fluctuations in the exchange rate uncorrelated with foreign marginal costs. For the reasons seen above, these exchange-rate shocks reduce foreign firms' expected profits in the home market. When pass-through in the home market is incomplete, the elasticity of foreign profits relative to the exchange rate is decreasing in $\tilde{p}^*(f)$. Then, charging a higher price $\tilde{p}^*(f)$ is a way for foreign exporters to reduce the sensitivity of their export profits to exchange-rate variability. But the higher average export prices charged by foreign firms translate into higher average import prices in the home country, reducing home residents' purchasing power and welfare.

This is why the home monetary stance required to close the domestic output gap is not optimal when pass-through is incomplete. Relative to such a stance, domestic policymakers can improve utility by adopting a policy that equates, at the margin, the benefit from exchange-rate flexibility (that is, from keeping domestic output close to its potential level) with the loss from exchange-rate volatility (that is, the fall in purchasing power and real wealth due to higher average import prices)

Table 2: Monetary Authorities' Optimal Reaction Functions

(46)
$$\gamma + (1-\gamma)(1-\eta_t) = \frac{\gamma MC_t}{E_{t-1}(MC_t)} + \frac{(1-\gamma)(1-\eta_t)MC_t^*\varepsilon_t^{1-\eta_t}}{E_{t-1}\left(MC_t^*\varepsilon_t^{1-\eta_t}\right)} = \frac{\gamma\frac{\theta\kappa}{\theta-1}\ell_t}{\gamma + (1-\gamma)\frac{P_{\mathrm{H},t}}{\varepsilon_t P_{\mathrm{H},t}^*}} + \frac{(1-\gamma)(1-\eta_t)\frac{\theta^*\kappa^*}{\theta^*-1}\ell_t^*}{\gamma + (1-\gamma)\frac{P_{\mathrm{F},t}}{\varepsilon_t P_{\mathrm{F},t}^*}}$$

(47)
$$1-\gamma + \gamma(1-\eta_t^*) = \frac{(1-\gamma)MC_t^*}{E_{t-1}(MC_t^*)} + \frac{\gamma(1-\eta_t^*)MC_t/\varepsilon_t^{1-\eta_t^*}}{E_{t-1}(MC_t/\varepsilon_t^{1-\eta_t^*})}$$

$$= \frac{(1-\gamma)\frac{\theta^*\kappa^*}{\theta^*-1}\ell_t^*}{1-\gamma+\gamma\frac{\varepsilon_t P_{F,t}^*}{P_{F,t}}} + \frac{\gamma(1-\eta_t^*)\frac{\theta\kappa}{\theta-1}\ell_t}{1-\gamma+\gamma\frac{\varepsilon_t P_{H,t}^*}{P_{H,t}}}$$

As long as η is below one, the home monetary stance tightens when productivity worsens abroad, and loosens otherwise. Rising costs abroad (a fall in Z^*) lower the markup of foreign goods sold at home. If home policymakers were not expected to stabilize the markup by raising rates and appreciating the exchange rate, foreign firms would charge higher prices on home consumers. Only when $\eta = 1$ do foreign firms realize that any attempt by the home authorities to stabilize the markup is bound to fail, as both P_F and the exchange rate fall in the same proportion.

With complete pass-through in both countries, the policies in a Nash equilibrium satisfy:

(48) $$\frac{\mu_t}{Z_t} = E_{t-1}\left(\frac{\mu_t}{Z_t}\right) \qquad \mu_t^*/Z_t^* = E_{t-1}(\mu_t^*/Z_t^*)$$

The optimal policy consists in a commitment to provide a nominal anchor for the economy,[16] and to deviate from such stance only when productivity shocks in the economy threaten to destabilize marginal costs and move employment and output far from their potential levels. Output gaps are fully closed and employment remains unchanged at the potential level Φ or Φ^*. Both domestic and global consumption endogenously co-move with productivity shocks. Thus, the Nash optimal monetary policy leads to the same allocation that would prevail were prices fully flexible. This result restates to the case for flexible exchange rates made by Friedman (1953): even without price flexibility, monetary authorities can engineer the right adjustment in relative prices through exchange rate movements. In our model with PCP, expenditure-switching effects make exchange rate and price movements perfect substitutes.

However, the Nash equilibrium will not coincide with a flexible-price equilibrium when the pass-through is less than perfect in either market. Consider the case of LCP. Here, the optimal monetary policy in each country cannot be inward looking, but must respond symmetrically to shocks anywhere in the world economy —the optimal monetary policies in table 2 can be written as:

[16] As is well known (see e.g. Woodford (2003)), rules such as (48) define the monetary stances up to the scale of nominal variables. In fact, the equations of (48) are solved by $\mu_t = \alpha_t Z_t$, and $\mu_t^* = \alpha_t^* Z_t^*$ where α_t and α_t^* are variables forecastable at time $t-1$, pinning down nominal expectations in each country. In models with one-period nominal price rigidities, the variables α_t and α_t^* are arbitrary. Under the assumption that the policymakers target the CPI inflation rate π, we would have

$$\alpha_t = P_{t-1}(1+\pi)$$

For an analysis of the conditions for a unique equilibrium, see Adao, Correia, and Teles (2011).

(49) $$\mu_t = \left[\gamma \frac{1/Z_t}{E_{t-1}(\mu_t/Z_t)} + (1-\gamma)\frac{1/Z_t^*}{E_{t-1}(\mu_t/Z_t^*)}\right]^{-1}$$

(50) $$\mu_t^* = \left[\gamma \frac{1/Z_t}{E_{t-1}(\mu_t^*/Z_t)} + (1-\gamma)\frac{1/Z_t^*}{E_{t-1}(\mu_t^*/Z_t^*)}\right]^{-1}$$

expressions which imply $\mu = \mu^*$.[17]

In our model, the exchange rate is a function of the relative monetary stance μ_t/μ_t^*. Our analysis then suggests that exchange rate volatility will be higher in a world economy close to purchasing power parity, and lower in a world economy where changes in the exchange rate generate large deviations from the law of one price.[18] In fact, if the exposure of firms' profits to exchange rate fluctuations were limited, inward-looking policymakers would assign high priority to stabilizing domestic output and prices, with 'benign neglect' of exchange rate movements. Otherwise, policymakers 'think globally', taking into account the repercussions of exchange rate volatility on consumer prices; hence, the monetary stances in the world economy come to mimic each other, reducing currency volatility.

The characterization of a *conditionally* optimal monetary union (or conditionally optimal fixed exchange-rate regime) is a simple corollary of the analysis above. We define a monetary union $\mu_t = \mu_t^*$ as optimal if the single monetary stance μ_t is optimal for both countries. It is straightforward to show that when shocks are perfectly correlated, the optimal allocation is such that $MC_t = E_{t-1}(MC_t)$ and $MC_t^* = E_{t-1}(MC_t^*)$ regardless of the degree of pass-through. Optimal monetary policies support a fixed exchange-rate regime and an optimal monetary union while fully closing the national output gaps. If shocks are asymmetric, a monetary union is optimal only when both countries find it optimal to choose a symmetric monetary stance, that is, when pass-through is zero worldwide according to (49) and (50).

4. Endogenous Exchange Rate Regimes

The conventional wisdom about the choice of exchange rate regime is that asymmetries in business cycles weaken the case for fixed exchange rates or the adoption of a single currency. With domestic monetary authorities unable to use differentiated policy responses due to the disturbances hitting the economy, business cycle synchronization and macroeconomic convergence are emphasized

[17] Once again, these rules define the monetary stances up to the scale of nominal variables. Note that in a monetary union, goods prices cannot diverge and the nominal anchors mentioned in the footnote above must satisfy $\alpha_t = \alpha_t^*$.
[18] This result has been stressed by Devereux and Engel.

as pre-conditions to the implementation of single currency areas, as they obviously reduce the costs of giving up national monetary policy.

In what follows, we build on our model to provide an instance of an economy in which a move toward symmetric monetary policy endogenously increases business cycle synchronization and convergence even if there is no change in the magnitude and sign of fundamental shocks. In other words, independent of any structural change in the economy, the adoption of a credible fixed exchange-rate regime can be supported in equilibrium as a self-validating optimal monetary arrangement, in the sense that endogenous changes in private agents' expectations and behavior eliminate all the (perceived) incentives for monetary authorities to pursue independent strategies of national output stabilization in response to asymmetric shocks.

We show that, conditional on beliefs about exchange rate pass-through, the model admits two equilibria. While exporters could in principle choose any intermediate level of pass-through, in equilibrium, pass-through is either 100 percent or zero as profit maximization turns out to require "corner" pricing strategies.[19] There is one equilibrium in which firms choose to preset prices in domestic currency, and let the foreign price adjust according to the law of one price. With complete pass-through, monetary policies are fully inward looking: they implement stabilization rules that close national output gaps completely in every period. This equilibrium is inconsistent with fixed exchange rates and implies low correlation among output levels —depending on the cross-country correlation of fundamental shocks. The exchange rate plays the role stressed by Friedman (1953): it brings about the required relative price adjustments that are hindered by the presence of nominal price rigidities.

However, there is another equilibrium in which firms are believed to preset prices in the consumers' currency to avoid price response to the exchange rate. With zero pass-through in the world economy, optimal monetary policies are perfectly symmetric across countries, that is, they both respond to the same average of national shocks. This equilibrium is thus consistent with the OCA: there is no cost in giving up monetary sovereignty because, even if national monetary authorities remained independent, they would still choose to implement the same policy rules, moving interest rates in tandem and responding symmetrically to world-wide shocks. National outputs are perfectly correlated even when shocks are asymmetric. Most interestingly, in our model, the same result would follow assuming that the two national policymakers cooperate with each other.

The two equilibria are, however, not equivalent in terms of welfare: OCA is Pareto-inferior to the Friedman-style optimal float in the first equilibrium. In the OCA equilibrium, the private and public sectors act rationally —in terms of policy and pricing strategies— once the equilibrium without exchange-rate flexibility is selected, conditional on beliefs about export pricing. Yet, there is still room for welfare improvement by creating conditions for relative price adjustment through changes in the

[19] Related literature focuses on the choice of pricing strategies where monetary authorities are assumed to implement non-optimizing, noisy policies (as in the work by Bacchetta and van Wincoop, 2004 and Devereux, Engel and Stoorgard, 2004) rather than optimal rules.

exchange rate. A move toward more volatile rates and less synchronized business cycles would bring about the appropriate change in firms' pricing and pass-through strategies, which in turn would validate the floating regime as optimal.

4.1 Optimal Exchange Rate Pass-Through and Monetary Policy in Equilibrium

To recapitulate our main analytical findings: Home and foreign firms choose the levels of pass-through η_t^* and η_t on the basis of their information at time $t-1$ regarding marginal costs and exchange rates at time t, by solving (42) and (43). Home and foreign monetary authorities take the levels of pass-through η_t^* and η_t as given and determine their optimal monetary stances by solving the conditions (46) and (47). We now consider the joint determination of μ_t, μ_t^*, η_t and η_t^* satisfying the four equations above in the non-trivial case in which the shocks Z_t and Z_t^* are asymmetric.

The following allocation is an equilibrium:

$$MC_t = E_{t-1}(MC_t), \qquad MC_t^* = E_{t-1}(MC_t^*)\,, \quad \eta_t = \eta_t^* = 1 \qquad (51)$$

Purchasing-power parity holds, and there is full pass-through of exchange-rate changes into prices. Monetary policies fully stabilize the national economies by closing output and employment gaps. Exchange rates are highly volatile, their conditional variance being proportional to the volatility of Z_t/Z_t^*. We will refer to this equilibrium as an optimal float (OF).

The logic underlying the OF case can be understood as follows: Suppose foreign firms selling in the home market choose $\eta_t = 1$ and let home-currency prices of foreign goods move one-to-one with the exchange rate, stabilizing their markups. Then the home monetary authority chooses as a rule to stabilize home output fully, no matter the consequences for the exchange rate (the volatility of which does not affect foreign exporters' profits and therefore does not affect, on average, the price of foreign goods paid by home consumers). Note that when $\eta_t = 1$, home output stabilization implies that MC_t is constant and, therefore, uncorrelated with the exchange rate. Home firms, then, will optimally set their pass-through abroad and choose $\eta_t^* = 1$ in order to stabilize their export markup. Since home firms are now fully insulated from exchange-rate fluctuations, the foreign monetary authority optimally chooses to stabilize foreign output with benign neglect of the exchange rate so that MC_t^* is a constant. But in this case foreign firms optimally choose $\eta_t = 1$ as we had assumed initially. The OF case is an equilibrium.

Consider now the following allocation:

$$1 = \gamma \frac{MC_t}{E_{t-1}(MC_t)} + (1-\gamma) \frac{MC_t^*}{E_{t-1}(MC_t^*)}, \quad \varepsilon_t = const, \quad \eta_t = \eta_t^* = 0 \tag{52}$$

This is the LCP scenario brought to its extreme consequences. There is no pass-through of exchange-rate changes into prices, but this hardly matters since the exchange rate is fixed! Optimal national monetary policies are fully symmetric and, thus, they cannot insulate the national economies from asymmetric shocks; it is only on average that they stabilize the national economies by closing output and employment gaps —the most apparent case of an optimal currency area.

To see why the above is an equilibrium, note that if home and foreign firms choose $\eta_t = \eta_t^* = 0$, home and foreign authorities are concerned with the price-distortions of exchange-rate volatility. They will optimize over the trade-off between employment stability and consumers' purchasing power. While they choose their rules independently of each other, the rules they adopt are fully symmetric, thus leading to exchange-rate stability. But if the exchange rate is constant during the period, the choice of the pass-through is no longer a concern for home and foreign firms: zero pass-through is as good a choice as any other level of η_t and η_t^*. Such weak preference implies that the monetary union is an equilibrium.

4.2 Nash versus Coordination

Would the two allocations above still be equilibria if national authorities could commit to coordinated policies, maximizing some weighted average of expected utility of the two national representative consumers? This is an important question as one may argue that policymakers in a monetary union would set their rules together (taking private agents' pricing and pass-through strategies as given), rather than independently. By the same token, if there were large gains from cooperation in a floating exchange-rate regime, there would also be an incentive for policymakers to design the optimal float in a coordinated way. One may speculate that, once cooperative policies are allowed for, the equilibrium allocation becomes unique.

Interestingly, it turns out that the possibility of cooperation does not modify the conclusions of our analysis at all. It can be easily shown that optimal policy rules conditional on $\eta_t = \eta_t^* = 1$ are exactly the same in a Nash equilibrium and under coordination: there are no gains from cooperation in the PCP scenario which replicates the flex-price allocation.[20] Also, as shown in Corsetti and Pesenti (2004), optimal policy rules conditional on $\eta_t = \eta_t^* = 0$ are exactly the same in a Nash equilibrium and under coordination: there are no gains from cooperation, since exchange-rate fluctuations are the only source of international spillover, there cannot be gains from cooperation when non-cooperative

[20] This result is stressed by Obstfeld and Rogoff (2000; 2002).

monetary rules already imply stable exchange rates.[21] While there are policy spillovers for any intermediate degree of pass-through ($0 > \eta, \eta^* > 1$), they disappear in equilibrium under the two extreme pass-through scenarios. In the only two cases relevant for our equilibrium analysis, optimal monetary policy rules are exactly the same whether or not the two national policymakers cooperate.

Macroeconomics and Welfare Analysis

Can a monetary union or a regime of an irrevocably fixed exchange rate be a self-validating OCA? Our model suggests so. Policy commitment to monetary union —i.e., the adoption of rules (49-50)— leads profit-maximizing producers to modify their pricing strategies, lowering their pass-through elasticities. Such behavioral change makes a currency area optimal, even if macroeconomic fundamentals and the pattern of shocks (Z_t and Z_t^* in our framework) remain unchanged across regimes.

A crucial result is that, under an OCA, output correlation is higher than under the alternative OF equilibrium. In fact, under OF, monetary policies are such that employment in both countries is always stabilized (both ex-ante and ex-post) at the constant levels $\ell = \Phi$ and $\ell^* = \Phi^*$. This implies that output correlation under OF depends on the degree of asymmetry of the fundamental shocks:

(53) $$Corr_t(Y_t^{OF}, Y_t^{*OF}) = Corr_t(Z_t \ell_t^{OF}, Z_t^* \ell_t^{*OF}) = Corr_t(Z_t, Z_t^*)$$

Instead, in a monetary union, employment levels are functions of relative shocks:

(54) $$\frac{\theta\kappa}{\theta - 1}\ell_t^{OCA} = \frac{\mu_t^{OCA}/Z_t}{E_{t-1}(\mu_t^{OCA}/Z_t)}, \qquad \frac{\theta^*\kappa^*}{\theta^* - 1}\ell_t^{*OCA} = \frac{\mu_t^{OCA}/Z_t^*}{E_{t-1}(\mu_t^{OCA}/Z_t^*)}$$

where μ^{OCA} is the solution of the system(49)-(50). This implies that output levels $Y_t^{OCA} = Z_t \ell_t^{OCA}$ and $Y_t^{*OCA} = Z_t^{*OCA} \ell_t^{*OCA}$ are perfectly correlated:

(55) $$Corr(Y_t^{OCA}, Y_t^{*OCA}) = Corr_t(\mu_t^{OCA}, \mu_t^{OCA}) = 1$$

[21] With LCP, expected utility at home is identical to expected utility in the foreign country up to a constant that does not depend on monetary policy. For any given shock, consumption increases by the same percentage everywhere in the world economy. Even if ex-post labor moves asymmetrically (so that ex-post welfare is not identical in the two countries, as is the case under PCP), the ex ante expected disutility from labor is the same as under flexible prices.

so that $Corr_t(Y_t^{OCA}, Y_t^{*OCA}) \geq Corr(Y^{OF}, Y^{*OF})$, consistent with the traditional characterization of OCAs.

It is nonetheless possible to rank the OF and the OCA regimes in welfare terms. Focusing on the home country, expected utility $\mathcal{W}$ in (1) can be written as:

$$\mathcal{W}_{t-1} = \mathcal{W}_{t-1}^{FLEX} - \{\gamma E_{t-1} \ln\left[E_{t-1}\left(\frac{\mu_t}{Z_t}\right) / \frac{\mu_t}{Z_t}\right] + (1-\gamma) E_{t-1} \ln\left[E_{t-1}\left(\frac{(\mu_t^*)^{\eta_t}\mu_t^{1-\eta_t}}{Z_t^*}\right) / \left(\frac{(\mu_t^*)^{\eta_t}\mu_t^{1-\eta_t}}{Z_t^*}\right)\right]\} \tag{56}$$

where $\mathcal{W}^{FLEX}$ is defined as the utility that consumers could expect to achieve if prices were fully flexible, thus, independent of monetary regime. By Jensen's inequality, the term in curly brackets is always non-negative: expected utility with price rigidities is never above expected utility with flexible prices. The best that monetary policy rules can do is bridge the gap between the two.

Observe that under the OF equilibrium (51) the term in square brackets becomes zero and $\mathcal{W}^{OF} = \mathcal{W}^{FLEX}$. But this implies that $\mathcal{W}^{OF} \geq \mathcal{W}^{OCA}$, an inequality that holds with strong sign when shocks are asymmetric. It follows that an optimal currency area is always Pareto-inferior *vis-à-vis* a Friedman style optimal flexible exchange-rate arrangement.

Indeed, it is easy to show that the optimal float allocation is the solution to a Nash equilibrium in which monetary authorities take firms' prices, rather than pass-through coefficients, as given. In this case, the monetary reaction function is no longer constrained by specific beliefs about firms' pricing strategies. Rather, central banks in either country focus on actual export pricing, which, as we have explained above, is quite sensitive to stabilization rules.

5. CONCLUSION

One of the main contributions of the recent open-economy monetary literature consists in assessing the international dimensions of optimal monetary policy and the potential welfare gains from following rules that are not strictly inward looking, that is, those that deviate from canonical closed-economy prescriptions. One aspect that has received a great deal of attention concerns firms' export pricing decisions as a key determinant of optimal stabilization policy. In this paper, we take it a step further and recognize that export pricing strategies themselves, and in particular, the choice of currency denomination of exports, are a function of stabilization policy. First we analytically characterize the optimal choice by firms within a stylized framework. While to a large extent specific to the model, this analytical characterization allows us to shed light on a general principle: the degree of exchange-rate pass-through affects the exposure of firms' profits to supply and demand shocks in both domestic and destination markets. To the extent that the firm can choose its pass-through, it will do so optimally, accounting for the covariance between exchange rates and markups.

In general equilibrium, the interaction between export pricing and monetary policy gives rise to the possibility of self-validating currency and monetary regimes. In particular, we have provided an example of a global economy with standard features where there can be two equilibria, as the choice between pricing-to-market and law of one price depends on optimal choices by firms in response to policy decisions. This result suggests that credible policy commitment to monetary union may lead to a change in pricing strategies, making a monetary union the optimal monetary arrangement in a self-validating way.

It is worth emphasizing that, conditional on the central bank's beliefs about firms' pricing, a common monetary policy is optimal because, for given producers' pricing strategies, the use of the exchange rate for stabilization purposes would entail excessive welfare costs in the form of higher import prices and lower purchasing power across countries. Once a monetary union takes off and firms adapt their pricing strategies to the new environment, the best course of action for the monetary authorities is to avoid any asymmetric policy response to asymmetric shocks. As a result, even in the absence of structural effects brought about by monetary integration, the correlation of national outputs increases.

But our model also suggests that the argument for self-validating optimal currency areas could be used in the opposite direction as an argument for self-validating optimal floating regimes. For a given pattern of macroeconomic disturbances, in fact, policy commitment to a floating regime may be the right choice despite the observed high synchronization of the business cycle across the countries participating in a monetary union: in equilibrium there will be an endogenous change in pricing strategies (with higher pass-through levels in all countries) which support floating rates as the optimal monetary option. In fact, the two institutional corner solutions for exchange-rate regimes can be Pareto ranked in welfare terms, leaving the optimal float the unambiguous winner.

Two observations are in order regarding the fact that the model we adopt in this paper assumes a high degree of risk sharing. As a future direction for research, and in light of the evidence against efficient integration of financial markets, it would be appropriate to revisit the same topic in a model with financial frictions and imperfections (a point stressed by Corsetti, Dedola and Leduc, 2010). While this perspective may make it harder to derive a clean case of self-validating regimes, the main message of our contributions would remain valid. An ex-post increase in business cycle synchronization is, at best, a very imperfect criterion to assess the success of monetary integration.

Second, once we move away from the strong conditions ensuring risk sharing, it would be appropriate to reconsider it in a model where firms can hedge (if only imperfectly) exchange-rate risk. In a more general model (say, allowing for non-traded goods), monetary policy and exchange-rate movements will generally not be able to stabilize sectoral outputs and domestic and international relative prices. Efficient markets for hedging instruments may then be a precondition for reaping the benefits of floating exchange rates. Incidentally, this is an argument that has been repeatedly emphasized by Vittorio Corbo, to whom this book is dedicated. We indeed find it appropriate to end this article with a quotation of Vittorio's work on exchange rate regimes, taken from one of his papers addressing the issue "Is it time for a common currency for the Americas?" (Corbo 2001, 2002):

> "While few countries are willing to follow the path of dollarization, a larger number is moving toward more flexible systems. However, more flexible systems must be accompanied by the development of forward and future exchange rate markets to enable market participants to hedge against exchange rate volatility. Otherwise, the costs of real exchange-rate variability could be high. As countries move toward the use of more flexible exchange-rate arrangements, they will need to make the selection of the monetary anchor more explicit. Here, much progress has been made in the region in implementing quite successful full-fledged ITFs. Thus, for a country that has built strong macro fundamentals and has a safe and sound financial system, the alternative of keeping its own currency, combining a floating exchange rate system with inflation targeting, may be a better choice"(Corbo, 2002).[22]

[22] See page 109 of Corbo, 2002.

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