ENDOGENOUS PASS-THROUGH AND OPTIMAL MONETARY POLICY: A MODEL OF SELF-VALIDATING EXCHANGE RATE REGIMES*

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Abstract

A currency area can be a self-validating optimal policy regime, even when irrevocably fixed exchange rates do not foster real economic integration and intra-industry trade. In our model, firms choose the optimal degree of exchange rate pass-through to export prices while accounting for expected monetary policies, and monetary authorities choose optimal policy rules while taking firms' pass-through as given. We show that there exist two equilibria, each of which defines a self-validating currency regime. In the first, firms preset prices in domestic currency and let prices in foreign currency be determined by the law of one price. Optimal policy rules then target the domestic output gap, and floating exchange rates support the flex-price allocation. In the second equilibrium, firms preset prices in consumer currency, and a common monetary policy is the optimal policy choice for all countries. Although with fixed exchange rates business cycles become more synchronized across countries, flexible exchange rates deliver a superior welfare outcome.

JEL classification: E5, F4

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I Introduction

The conventional wisdom about the choice of exchange rate regime is that asymmetric, country-specific real shocks weaken the case for fixed exchange rates or the adoption of a single currency. Under these regimes, domestic monetary authorities would lose their ability to use differentiated policy responses to the disturbances hitting the economy. Consistently, it is often argued that business cycle synchronization and macroeconomic convergence are pre-conditions to the implementation of single currency areas, as they crucially reduce the costs of giving up national monetary policy.

In this paper we suggest that this view may not provide reliable guidance in choosing among alternative exchange rate regimes. In fact, a move toward symmetric monetary policy can increase business cycle synchronization and convergence even if there is no change in the magnitude and sign of fundamental shocks. Formally, in this paper we show that, independently 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. Namely, endogenous changes in private agents' expectations and behavior can eliminate all incentives for monetary authorities to pursue independent strategies of national output stabilization in response to asymmetric shocks.

To illustrate our case for self-validating optimal exchange rate regimes, we build a stylized two-country general-equilibrium model focused on the endogenous pricing behavior of firms in both domestic and foreign markets. In our model, the private sector responds to a credible change in monetary regime by choosing pricing strategies that are optimal in the absence of exchange rate flexibility. But conditional on such pricing behavior, a fixed exchange rate turns out to be the optimal monetary regime from the vantage point of the national policymakers as well. As a result, national outputs become more correlated for any given stochastic pattern of the shocks to fundamentals, so to rule out the need for differentiated national monetary policies. Despite the absence of structural changes, economies that adopt a fixed exchange rate regime may satisfy the criteria for an Optimum Currency Area (OCA), according to the theory spelled out by the classic contributions by Mundell [1961], McKinnon [1963], Kenen [1969] and Ingram [1973].[1]

[1] Modern applications and revisions include, among others, Eichengreen [1990, 1992], Dowd

Essential elements of our approach are imperfect competition in production, nominal rigidities in the goods markets, and forward-looking price-setting behavior by firms.[2] Drawing on Corsetti and Pesenti [2004], our setup allows for imperfect pass-through of exchange rate onto export prices. In this paper 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 rule of limited price flexibility contingent on exchange rate movements. Taking firms' pricing and pass-through strategies as given, monetary authorities choose optimal state-contingent policy rules. In a world equilibrium, both the degree of pass-through and monetary policy are jointly determined by optimizing agents.

We show that there are 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.[3] 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.

But there is another equilibrium in which firms preset prices in the consumers' currency, so that there is no response of prices to the exchange rate. With zero pass-through in the world economy, monetary policies are perfectly symmetric across countries, that is, they both respond to the same average of

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.

[2] Related contributions in the recent literature include Obstfeld and Rogoff [2000, 2002], Devereux and Engel [2003], Corsetti and Pesenti [2001, 2004], Benigno [2004], Clarida, Gali and Gertler [2001], Canzoneri, Cumby and Diba [2004]. On the welfare effects of a currency area when political factors influence monetary policy see Neumeyer [1998].

[3] 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.

national shocks. This equilibrium is consistent with 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.

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 the two equilibria in welfare terms. The result is that an OCA is Pareto-inferior to the Friedman-style optimal float in the first equilibrium. Although the private and the 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 via changes of 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.

In the vast literature on optimum currency areas, early arguments for an *endogenous* OCA emphasize that the change in monetary regime could act as a catalyst of business cycle synchronization via trade integration. For instance, Frankel and Rose [1998] stress that the reduction of foreign exchange transaction costs associated to 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 become more synchronized, since sectoral demand shocks and productivity innovations affect all countries at the same time. 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]

[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.

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

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 instead focuses on optimal monetary policies given firms' pricing strategies. The previous two pieces of analysis are brought together in sections 5 and 6, which characterize the equilibrium of the economy. A final section discusses our main results.

II The model

A 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.

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

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

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.

$C_t(j)$ and its Foreign analog are Cobb-Douglas baskets of the Home and

Foreign goods:

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

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

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

where $C_t(h,j)$ and $C_t(f,j)$ are, respectively, consumption of Home variety h and Foreign variety f 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, $C_{\mathrm{H},t}^*(j^*)$ and $C_{\mathrm{F},t}^*(j^*)$, 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.[5] In particular, the utility-based CPIs are:

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

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:

$$\begin{aligned} &B_t(j) + \mathcal{E}_t B_t^*(j) \leq (1+i_{t-1})B_{t-1}(j) + (1+i_{t-1}^*)\mathcal{E}_t B_{t-1}^*(j) + W_t \ell_t(j) \\ (5)\qquad &+ \int_0^1 \Pi_t(h) dh - \int_0^1 p_t(h) C_t(h,j) dh - \int_0^1 p_t(f) C_t(f,j) df \end{aligned}$$

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

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:

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

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

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

The intertemporal allocation is determined according to the Euler equation:

$$(8) \qquad 1 = (1 + i_t)\, E_t Q_{t,t+1}(j)$$

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

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

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

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

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

B 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, $\ell(h)$:

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

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:

$$MC_t(h) = MC_t = W_t/Z_t \tag{12}$$

and Home firms' nominal profits Π_t are defined as:

$$\Pi_t(h) = (p_t(h) - MC_t)\int_0^1 C_t(h,j)dj + (\mathcal{E}_t p_t^*(h) - MC_t)\int_0^1 C_t^*(h,j^*)dj^* \tag{13}$$

where $\mathcal{E}$ 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:

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

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

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

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

$$p_t(h) = P_{\mathrm{H},t} = \frac{\theta}{\theta-1}E_{t-1}MC_t = \frac{E_{t-1}\left(P_tC_t/Z_t\right)}{\Phi} \tag{16}$$

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. Different from most models in the literature, we do not impose *a priori* the restriction that export prices are set in Home currency, implying that all unexpected fluctuations in the exchange rate are 'passed through' one-to-one onto export prices in Foreign currency (in the literature this scenario is referred to as 'Producer Currency Pricing' or PCP). At the same time, 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). We consider instead 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. 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 $\eta_t^* \equiv \partial \ln p_t^*(h)/\partial \ln (1/\mathcal{E}_t)$, Foreign-currency prices of Home varieties are:

$$p_t^*(h) \equiv \frac{\tilde{p}_t(h)}{\mathcal{E}_t^{\eta_t^*}} \qquad 0 \leq \eta_t^* \leq 1 \tag{17}$$

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.[6] At time $t-1$, 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.[7]

In equilibrium we obtain:

$$p_t^*(h) = \frac{\theta}{\theta-1}\frac{1}{\mathcal{E}_t^{\eta^*}}\frac{E_{t-1}\left(MC_t\ Q_{t-1,t}\ p_t^*(h)^{-\theta} P_{\mathrm{H},t}^{*\theta}\ C_{\mathrm{H},t}^*\right)}{E_{t-1}\left(Q_{t-1,t}\ p_t^*(h)^{-\theta} P_{\mathrm{H},t}^{*\theta}\ C_{\mathrm{H},t}^*\ \mathcal{E}_t^{1-\eta^*}\right)} \tag{18}$$

Using (7) and (9), and letting $\Theta_t \equiv \gamma/(1-\gamma)\left(P_t^* C_t^* \mathcal{E}_t / P_t C_t\right)$, we can also write:

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

[6] 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.

[7] 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 $\mathcal{E}$ but close to one for large exchange rate fluctuations). The key results of our analysis would remain unchanged.

Analogous expressions can be derived for the prices set by Foreign firms in the Foreign and the Home market. In the case of Foreign exports the notation is:

$$p_t(f) = \tilde{p}_t^*(f)\mathcal{E}_t^{\eta_t}, \qquad 0 \leq \eta_t \leq 1 \tag{20}$$

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 such that:

$$P_{\mathrm{F},t}^* = \frac{\theta^*}{\theta^*-1}E_{t-1}\left(MC_t^*\right), \quad P_{\mathrm{F},t} = \frac{\theta^*}{\theta^*-1}\mathcal{E}_t^{\eta_t}\frac{E_{t-1}\left(MC_t^* \ \mathcal{E}_t^{1-\eta_t}/\Theta_t\right)}{E_{t-1}\left(1/\Theta_t\right)} \tag{21}$$

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

$$P_{\mathrm{H},t} \geq MC_t, \quad P_{\mathrm{H},t}^* \geq \frac{MC_t}{\mathcal{E}_t} \tag{22}$$

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.

C 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 such that:

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

or, integrating forward:

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

Monetary policy is assumed to make the variable μ_t/μ_{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 $P_t C_t$ (and μ_t^* is equal to $P_t^* C_t^*$): a monetary expansion delivers increased nominal spending.[8] A *monetary union* in our framework is defined as a regime in which $i_t = i_t^*$ for all t. If both countries adopt the same *numeraire*, this implies $\mu_t = \mu_t^*$.

D 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:

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

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

$$\int_0^1 B_t(j) dj + \int_0^1 B_t(j^*) dj^* = \int_0^1 B_t^*(j) dj + \int_0^1 B_t^*(j^*) dj^* = 0. \tag{27}$$

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, 2004], in equilibrium both net wealth and the current account are endogenously zero at *any* subsequent point in time: Home imports from Foreign 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 consume precisely their aggregate sales revenue:

$$\Theta_t = 1, \qquad (1 - \gamma) P_t C_t - \gamma \mathcal{E}_t P_t^* C_t^* = 0. \tag{28}$$

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^*).[9]

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

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

Table 1: The closed-form solution of the model

(29)	$\mathcal{E}_t = \frac{1-\gamma}{\gamma}\frac{\mu_t}{\mu_t^*}$
(30)	$MC_t = \kappa\mu_t/Z_t$
(31)	$MC_t^* = \kappa^*\mu_t^*/Z_t^*$
(32)	$P_{\mathrm{H},t} = \frac{\theta}{\theta-1}E_{t-1}\left(MC_t\right)$
(33)	$P_{\mathrm{F},t} = \frac{\theta^*}{\theta^*-1}\mathcal{E}_t^{\eta_t}E_{t-1}\left[MC_t^*\mathcal{E}_t^{1-\eta_t}\right]$
(34)	$P_{\mathrm{H},t}^* = \frac{\theta}{\theta-1}\frac{E_{t-1}\left[MC_t/\mathcal{E}_t^{1-\eta_t^*}\right]}{\mathcal{E}_t^{\eta_t^*}}$
(35)	$P_{\mathrm{F},t}^* = \frac{\theta^*}{\theta^*-1}E_{t-1}\left(MC_t^*\right)$
(36)	$C_t = \frac{\gamma_W\left(\frac{\theta-1}{\theta}\right)^{\gamma}\left(\frac{\theta^*-1}{\theta^*}\right)^{1-\gamma}\mu_t\mathcal{E}_t^{-\eta_t(1-\gamma)}}{\left[E_{t-1}\left(MC_t\right)\right]^{\gamma}\left[E_{t-1}\left(MC_t^*\mathcal{E}_t^{1-\eta_t}\right)\right]^{1-\gamma}}$
(37)	$C_t^* = \frac{\gamma_W\left(\frac{\theta-1}{\theta}\right)^{\gamma}\left(\frac{\theta^*-1}{\theta^*}\right)^{1-\gamma}\mu_t^*\mathcal{E}_t^{\eta_t^*\gamma}}{\left[E_{t-1}\left(MC_t/\mathcal{E}_t^{1-\eta_t^*}\right)\right]^{\gamma}\left[E_{t-1}\left(MC_t^*\right)\right]^{1-\gamma}}$
(38)	$\ell_t = \left(\frac{\theta-1}{\theta\kappa}\right)\left[\gamma\frac{MC_t}{E_{t-1}\left(MC_t\right)} + (1-\gamma)\frac{MC_t/\mathcal{E}_t^{1-\eta_t^*}}{E_{t-1}\left[MC_t/\mathcal{E}_t^{1-\eta_t^*}\right]}\right]$
(39)	$\ell_t^* = \left(\frac{\theta^*-1}{\theta^*\kappa^*}\right)\left[(1-\gamma)\frac{MC_t^*}{E_{t-1}\left(MC_t^*\right)} + \gamma\frac{MC_t^*\mathcal{E}_t^{1-\eta_t}}{E_{t-1}\left[MC_t^*\mathcal{E}_t^{1-\eta_t}\right]}\right]$

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 $\mathcal{E}_t$ in (29) is proportional to $P_t C_t / P_t^* C_t^*$, that is, a function of the relative monetary stance. The 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).

III Optimal exchange rate pass-through for *given* monetary policy

What is the optimal degree of exchange rate pass-through onto export prices of Home goods in the Foreign market? Taking monetary stances and policy rules as given, Home firms choose η_t^* as to maximize expected discounted profits. In a symmetric environment with $p_t^*(h) = P_{\mathrm{H},t}^*$ the first order condition is:[10]

$$(40) \qquad 1 = \frac{\theta \kappa}{\theta - 1} \frac{E_{t-1}\left[\ln \mathcal{E}_t \ \left(P_t^* C_t^* / Z_t\right) / P_{\mathrm{H},t}^*\right]}{E_{t-1}\left(\ln \mathcal{E}_t\right)} \frac{\gamma}{1-\gamma}$$

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

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

that is:

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

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

$$E_{t-1}[Q_{t-1,t}\left(\tilde{p}_t(h)/P_{\mathrm{H},t}^*\right)^{-\theta} C_{\mathrm{H},t}^* \{\tilde{p}_t(h)\mathcal{E}_t^{1-\eta_t^*+\theta\eta_t^*} - MC_t \mathcal{E}_t^{\theta\eta_t^*}\}]$$

The first order condition yields:

$$0 = E_{t-1}[Q_{t-1,t}\left(\tilde{p}_t(h)/\left(\mathcal{E}_t^{\eta_t^*} P_{\mathrm{H},t}^*\right)\right)^{-\theta} C_{\mathrm{H},t}^* \ln \mathcal{E}_t\{(\theta-1)\,\tilde{p}_t(h)\mathcal{E}_t^{1-\eta_t^*} - \theta MC_t\}]$$

and accounting for the equilibrium expressions for Q, P_{H}^*, C_{H}^* and MC, as well as (28), it is possible to rewrite the first order condition above as in (40).

This is a critical condition. At an optimum, the (reciprocal of the) markup in the export market must be uncorrelated with the (log of the) exchange rate. Trivially, if $\mathcal{E}_t$ is constant or fully anticipated, *any* degree of pass-through is consistent with the previous expression. But if $\mathcal{E}_t$ 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:

$$Cov_{t-1}\left(MC_t^{*}\mathcal{E}_t^{1-\eta_t}, \ln\left(1/\mathcal{E}_t\right)\right) = 0. \tag{43}$$

To build intuition, observe that in equilibrium, Home *ex-post* real profits in the Foreign market[11] are proportional to $\tilde{p}_t(h) - MC_t/\mathcal{E}_t^{1-\eta_t^*}$, that is, they are a concave function of $\mathcal{E}_t$ for $\eta_t^* < 1$.[12] 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.

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:

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

which is solved by $\eta_t^* = 0$. Home monetary shocks affect symmetrically Home marginal costs MC_t and the Home discount rate Q_t, leaving their product unchanged. They also affect the exchange rate: $\mathcal{E}_t$ 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

[11] *Ex-post* real profits from selling in the Foreign market are $Q_{t-1,t}\left(\mathcal{E}_t\tilde{p}_t(h)\mathcal{E}_t^{-\eta^*} - MC_t\right)C_{\mathrm{H},t}^{*}$. Using the equilibrium expression for C_{H}^{*}, $\mathcal{E}$ and Q, the previous expression can be written as:

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

Recall that $\mathcal{E}$ 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 $C_{\mathrm{H},t}^{*}$ is proportional to $\mu_t^*\mathcal{E}_t^{\eta_t^*}$.

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

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:

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

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].[13]

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 $MC_t^*\mathcal{E}_t^{1-\eta_t}$ to be uncorrelated with the exchange rate. This would be the case, for instance, if $\mu_t^* = (Z_t^*)^5/Z_t^4$ and $\eta_t = 0.6$.

IV 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, taking the pass-through coefficients as given.[14] The Home monetary authority seeks

[13] 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].

[14] For an analysis of optimal monetary behavior under discretion see Corsetti and Pesenti [2004].

Table 2: Monetary authorities' optimal reaction functions

$$
\begin{aligned}
\gamma + (1-\gamma)(1-\eta_t) &= \frac{\gamma MC_t}{E_{t-1}(MC_t)} + \frac{(1-\gamma)(1-\eta_t)\, MC_t^* \mathcal{E}_t^{1-\eta_t}}{E_{t-1}\left(MC_t^* \mathcal{E}_t^{1-\eta_t}\right)} \\
&= \frac{\gamma \dfrac{\theta\kappa}{\theta-1}\ell_t}{\gamma + (1-\gamma)\dfrac{P_{\mathrm{H},t}}{\mathcal{E}_t P_{\mathrm{H},t}^*}} + \frac{(1-\gamma)(1-\eta_t)\dfrac{\theta^*\kappa^*}{\theta^*-1}\ell_t^*}{\gamma + (1-\gamma)\dfrac{P_{\mathrm{F},t}}{\mathcal{E}_t P_{\mathrm{F},t}^*}} \qquad (46)
\end{aligned}
$$

$$
\begin{aligned}
1-\gamma+\gamma(1-\eta_t^*) &= \frac{(1-\gamma)\, MC_t^*}{E_{t-1}(MC_t^*)} + \frac{\gamma(1-\eta_t^*)\, MC_t/\mathcal{E}_t^{1-\eta_t^*}}{E_{t-1}\left(MC_t/\mathcal{E}_t^{1-\eta_t^*}\right)} \\
&= \frac{(1-\gamma)\dfrac{\theta^*\kappa^*}{\theta^*-1}\ell_t^*}{1-\gamma+\gamma\dfrac{\mathcal{E}_t P_{\mathrm{F},t}^*}{P_{\mathrm{F},t}}} + \frac{\gamma(1-\eta_t^*)\dfrac{\theta\kappa}{\theta-1}\ell_t}{1-\gamma+\gamma\dfrac{\mathcal{E}_t P_{\mathrm{H},t}^*}{P_{\mathrm{H},t}}} \qquad (47)
\end{aligned}
$$

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 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). Absent 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).

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 onto 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:

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

The optimal policy consists in a commitment to provide a nominal anchor for the economy,[15] and deviate from such stance only when productivity shocks in

[15] As well known (see e.g. Woodford [2003]), rules such as (48) define the monetary stances

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 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 makes exchange rate and price movements perfect substitutes.

The Nash equilibrium will however *not* coincide with a flex-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:

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

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

expressions which imply $\mu_t = \mu_t^*$.[16]

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.[17] In fact, if the exposure of firms' profits to exchange

up to the scale of nominal variables. In fact, the equations (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

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

[16] 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 $\alpha_t = \alpha_t^*$.

[17] This result has been stressed by Devereux and Engel [2003].

rate fluctuations is limited, inward-looking policymakers 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 *optimal monetary union* (or *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).

V Optimal exchange rate pass-through *and* monetary policy in equilibrium

To recapitulate: 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:

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

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:

$$(52) \qquad 1 = \gamma \frac{MC_t}{E_{t-1}(MC_t)} + (1-\gamma)\frac{MC_t^*}{E_{t-1}(MC_t^*)}, \quad \mathcal{E}_t = const, \quad \eta_t = \eta_t^* = 0$$

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, thus 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 as a choice as any other level of η_t and η_t^*. Such weak preference implies that the monetary union is an equilibrium.

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 conjecture that, once cooperative policies are allowed for, the equilibrium allocation becomes unique.

Interestingly, it turns out that the possibility of cooperation does not modify at all the conclusions of our analysis. 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.[18] Also, as shown in Corsetti and Pesenti [2004], optimal policy rules conditional on $\eta_t = \eta_t^* = 0$ are identical with and without cooperation: since exchange rate fluctuations are the only source of international spillover, there cannot be gains from cooperation when non-cooperative monetary rules already imply stable exchange rates.[19] 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.

[18] This result is stressed by Obstfeld and Rogoff [2000, 2002].

[19] 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), *ex ante* the expected disutility from labor is the same as under flexible prices.

VI Endogenous OCAs: Macroeconomics and welfare analysis

Can a monetary union or a regime of irrevocably fixed exchange rate be a self-validating OCA? Our model suggests yes. Policy commitment to monetary union — i.e., the adoption of the 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:

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

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

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

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 $Y_t^{*OCA} = Z_t^* \ell_t^{*OCA}$ are perfectly correlated:

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

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

It is 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:

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

$$(56) \qquad + (1-\gamma) E_{t-1} \ln\left[E_{t-1}\left(\frac{(\mu_t^*)^{\eta_t}\mu_t^{1-\eta_t}}{Z_t^*}\right) / \left(\frac{(\mu_t^*)^{\eta_t}\mu_t^{1-\eta_t}}{Z_t^*}\right)\right]\}$$

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. At best, what monetary policy rules can do is to bridge the gap between the two.

Observe that under the OF equilibrium (51) the term in square bracket 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.

VII Conclusion

In this paper we have shown the existence of two equilibria in a standard open-economy model where the alternative between pricing-to-market and law of one price depends on endogenous choices by firms. 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 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.

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