

GLOBAL IMPLICATIONS OF SELF-ORIENTED NATIONAL MONETARY RULES*

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It is well-known that if international linkages are relatively small, the potential gains to international monetary policy coordination are typically quite limited. But when goods and financial markets are tightly linked, is it problematic if countries unilaterally design their monetary policy rules? Are the stabilization gains from having separate currencies largely squandered in the absence of effective international monetary coordination? We argue that under plausible assumptions the answer is no. Unless risk aversion is very high, lack of coordination in rule setting is a second-order problem compared with the overall gains from macroeconomic stabilization.

I. INTRODUCTION

To what extent might the stabilization gains from having multiple major currencies be squandered through a lack of international cooperation in monetary reform? Over the past ten to fifteen years, individual OECD governments appear to have made enormous progress in mitigating the “commitment” problem in monetary policy. Is it harmful, though, if the major currency areas design their rule-based domestic monetary institutions unilaterally, neglecting international spillover effects? Will such a system produce, say, excessive attention to inflation stabilization and inadequate attention to output stabilization when viewed from a global perspective?

We are not the first to address this question. Persson and Tabellini [1995, 2000] have shown how, in principle, international cooperation in designing *domestic* monetary policy institutions can lead to improved global outcomes, even absent binding international agreements. They themselves, however, cautioned that a deeper understanding of the problem awaited the development of rigorous welfare foundations for open-economy macroeconomics. Fortunately, over the past few years economists have taken large strides in providing such foundations (see the discussion of “new open economy macroeconomics” in Corsetti and Pesenti [2001a], as well as Gali and Monacelli [2000]). In this

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paper we provide a first application of these new models to the design of monetary policy rules in a strategic international setting.

The importance of international cooperation in setting monetary rules turns out to hinge critically on how nominal rigidities interact with other distortions in the economy, e.g., distortions due to monopoly and imperfect capital markets. The smaller the cross effects of the monetary policy rule on “real” distortions, the less the need for cooperation. In special cases where there are no cross effects, cooperation in rule setting can be self-enforcing. One such example in our model is where all shocks are global, so that world risk sharing is efficient under any symmetric monetary policy rules. In more general cases where the distortions do interact, gauging the benefits to cooperation becomes an empirical question. Our attempts to parameterize our model suggest that even when cooperation is beneficial in theory, it may be relatively unimportant empirically. This result bears a family resemblance to others based on the theory of the second best. The closer an optimal cooperative policy comes to eliminating the effects of nominal rigidities—the more monetary policy targets eliminating the distortion through which it directly operates—the lower the temptation for individual countries to defect.

Sections II and III develop a generalization of the new open economy macroeconomic models of Obstfeld and Rogoff [1998, 2000a], extended to incorporate the case of incomplete risk sharing. In Sections IV and V we explore the relationship between the cooperative and noncooperative rule-setting games, and consider how different the outcomes are likely to be empirically. Section VI discusses the relationship of our work to the previous literature, and Section VII concludes.

II. A TWO-COUNTRY STICKY-WAGE MODEL

We first adapt the two-country model of Obstfeld and Rogoff [2000a] to encompass incomplete international asset markets, an extension that turns out to affect fundamentally the scope for international policy coordination. The model itself is not our main focus, and its various building blocks are all relatively familiar, so we outline only the essential features.¹

1. For more details on the underlying model, see Obstfeld and Rogoff [2000a, 2000b].

The world consists of two equally sized and identical countries, Home and Foreign. Firms produce differentiated goods out of differentiated labor inputs indexed by $[0,1]$. Home produces differentiated tradable goods on the interval $[0,1]$, while Foreign's tradables are indexed by $(1,2]$. In addition, each country produces an array of differentiated nontraded goods indexed by $[0,1]$.

Let $Y(i)$ denote output of differentiated good i and $L(i,j)$ the demand for labor input j by producer i . Home traded goods production is given by

$$(1) \quad Y_H(i) = \left[\int_0^1 L_H(i,j)^{(\phi-1)/\phi} dj \right]^{\phi/(\phi-1)}.$$

The Home nontraded-goods production function is identical (with L_N replacing L_H), as are the Foreign production functions. There is only a single contracting period, so we omit time subscripts throughout.

Let $W(j)$ be the nominal wage of worker j and W the exact production-based index of wages.² As usual, firm i 's demand for labor of type j is

$$(2) \quad L(i,j) = \left[\frac{W(j)}{W} \right]^{-\phi} Y(i).$$

A Home individual of type i has the utility function,

$$(3) \quad U^i = \frac{(C^i)^{1-\rho}}{1-\rho} + \chi \log \frac{M^i}{P} - KL^i,$$

where $\rho > 0$ is the (constant) coefficient of relative risk aversion and L^i is total individual labor supply to both sectors. In (3), K is a random shift in the marginal disutility of effort that can be interpreted as a (negative) countrywide Home productivity shock. The Foreign productivity shock, K^* , is distributed symmetrically, though not necessarily independently. Aggregate money supplies, M and M^* , are the other exogenous random variables.

For any person i the overall real consumption index C is Cobb-Douglas with exponent γ on tradables C_T and $1 - \gamma$ on nontradables C_N . The preferences over Home and Foreign traded goods underlying the subindex C_T are likewise Cobb-Douglas, with equal exponents on C_H and C_F . Foreign preferences are

2. The form of the index is $W = [\int_0^1 W(j)^{1-\phi} dj]^{1/(1-\phi)}$.

identical. The consumption subindexes for C_H , C_F , and C_N are constant-elasticity aggregates (analogous to (1)), all with the same substitution elasticity θ . Domestic-currency price indexes for C_H , C_F , and C_N are isomorphic to the wage index given in footnote 2, with the elasticity θ in place of ϕ . The domestic-currency price index for total real consumption C is $P = P_T^\gamma P_N^{1-\gamma}$. The price index for tradable consumption C_T is $P_T = P_H^{1/2} P_F^{1/2}$.

Isomorphic to the labor demand equation (2) are the Home and Foreign consumer demands for individual goods, which depend on relative price with a constant elasticity θ ; e.g., Home demand for a typical Home tradable h is $C_T(h) = [P_T(h)/P_H]^{-\theta} C_H$. Given the assumed unit elasticity of substitution between Home and Foreign goods, and between traded and nontraded goods, we have $C_H = 1/2(P_H/P_T)^{-1} C_T$ (with a parallel formula for C_F) and $C_T = \gamma(P_T/P)^{-1} C$ (with a parallel formula for C_N). The first-order condition governing money demand is

$$(4) \quad M^i/P = \chi(C^i)^\rho.$$

There is no international trade in equities (or in other contingent securities); domestic firms are entirely domestically owned. In the case $\rho = 1$, however, our economy will turn out to mimic one with complete asset markets.

III. WAGE AND PRICE SETTING AND A CLOSED-FORM SOLUTION

A. *Equilibrium*

We assume that workers set nominal wages a period in advance and, ex post, supply the amount of labor that firms demand at the posted nominal wage. The first-order condition for the optimal preset nominal wage is

$$(5) \quad W(i) = \left(\frac{\phi}{\phi - 1} \right) \frac{E\{KL^i\}}{E\{L^i(C^i)^{-\rho}/P\}}.$$

Absent uncertainty, equation (5) would simply give the marginal utility of the real wage as a fixed markup over the marginal disutility of labor.

In contrast to wages, prices are flexible, and moreover, monopolistic firms can price discriminate across the Home and Foreign markets. However, with constant and identical elasticities of demand, prices turn out to be the same constant markup over

wages in both countries, so that, for example, if \mathcal{E} is the domestic-currency price of foreign currency (the nominal exchange rate),

$$(6) \quad P_H = [\theta/(\theta - 1)]W = \mathcal{E}P_H^*.$$

The law of one price holds for any given tradable good, but of course the terms of trade can still vary with the exchange rate:³

$$(7) \quad \text{terms of trade} \equiv \frac{\mathcal{E}P_F^*}{P_H} = \frac{\mathcal{E}W^*}{W}.$$

Because of unit demand elasticities and the constraint that tradable consumption equal tradable output in value, one can easily show that, in all states of nature,

$$C_T = C_T^*.$$

Only the traded-goods component of consumption has to be equal across countries; the overall consumption indexes C and C^* need not move together. However, if we measure Home spending *in units of tradables* as

$$Z \equiv C_T + (P_N/P_T)C_N,$$

then, because $P_N/P_T = (1 - \gamma)C_T/\gamma C_N$,

$$(8) \quad Z = C_T/\gamma = C_T^*/\gamma = Z^*.$$

Equality of the tradables-denominated spending levels Z and Z^* will be convenient for solving the model.

For the subsequent analysis, it is important to observe that for the log consumption case ($\rho = 1$), utility is separable in tradables and nontradables. Thus, when $C_T = C_T^*$ ex post, we will have perfect international sharing of consumption risks in tradable goods. When $\rho \neq 1$, however, the marginal utility of *tradables* consumption depends on consumption of nontradables. In that case, therefore, $C_T = C_T^*$ no longer guarantees international equality of the marginal utility of tradables, as efficient risk sharing would require here. This will be important for policy coordination, as we explain later.

We next solve the model by assuming that the exogenous shocks $\{m, m^*, \kappa, \kappa^*\}$ are jointly normally distributed, where low-

3. The price of the Foreign CPI in terms of the Home CPI, the real exchange rate, also can vary. Note that

$$\text{real exchange rate} \equiv \frac{\mathcal{E}P^*}{P} = \frac{\mathcal{E}P_T^*P_N^{*(1-\gamma)}}{P_T^*P_N^{(1-\gamma)}} = \left(\frac{\mathcal{E}W^*}{W}\right)^{1-\gamma}.$$

ercase letters denote (natural) logs, so that, e.g., $m \equiv \log M$. To simplify, we assume that the Home and Foreign log productivity shocks have *identical* means and variances: $E\kappa = E\kappa^*$ and $\sigma_\kappa^2 = \sigma_{\kappa^*}^2$. One can conveniently define the “world” and “difference” productivity shocks as

$$\kappa_w \equiv \frac{\kappa + \kappa^*}{2}, \quad \kappa_d \equiv \frac{\kappa - \kappa^*}{2}.$$

Note that because κ and κ^* have identical variances, $\text{cov}(\kappa_w, \kappa_d) = 0$ and $\sigma_\kappa^2 = \sigma_{\kappa_w}^2 + \sigma_{\kappa_d}^2$. Decomposing shocks into global and relative components will turn out to be very helpful when we contrast the coordination problems that these two types of shock raise.

B. The Impact of Uncertainty on the Terms of Trade and Spending

We are now prepared to illustrate what is perhaps the most fundamental difference between our model and the models used in earlier analyses of international policy coordination.

We first express the wage-setting equation (5) and its Foreign analog in terms of logs and covariances of logs of the endogenous variables, after simplifying it through use of budget constraints and labor-market equilibrium conditions. The *expected* terms of trade are

$$(9) \quad E\tau \equiv Ee + w^* - w = f(\overset{(?)}{\sigma_{ze}}, \overset{(-)}{\sigma_{\kappa_w e}}, \overset{(-)}{\sigma_{\kappa_d z}}) = \frac{-1}{1 - (1 - \gamma)(1 - \rho)} \\ \times \{ [1 - (1 - \gamma)(1 - \rho)^2] \sigma_{ze} + \sigma_{\kappa_w e} + 2\sigma_{\kappa_d z} \},$$

where τ denotes the natural log of the terms of trade $\mathcal{E}P_F^*/P_H$ —making the log real exchange rate $(1 - \gamma)\tau$. We similarly solve for the expected log of consumption spending measured in tradables,

$$(10) \quad Ez = g(\overset{(?)}{\sigma_z^2}, \overset{(?)}{\sigma_e^2}, \overset{(-)}{\sigma_{\kappa_w z}}, \overset{(-)}{\sigma_{\kappa_d e}}) \\ = \frac{1}{\rho} \left\{ \omega + \lambda - \frac{1}{2\rho} \sigma_\kappa^2 - \frac{1}{2} [1 - (1 - \rho)^2] \sigma_z^2 \right. \\ \left. - \frac{1}{8} [1 - (1 - \gamma)^2(1 - \rho)^2] \sigma_e^2 - \sigma_{\kappa_w z} - \frac{1}{2} \sigma_{\kappa_d e} \right\},$$

where ω and λ are constants that depend on the moments of κ and κ^* .⁴ From equation (8) we see that $Ez = Ez^*$.

In contrast to the ad hoc linear-quadratic formulations used in standard monetary coordination models of the 1980s and 1990s (see Canzoneri and Henderson [1991]), changes in the monetary policy rule affect mean wages and prices here, not only their variances. For example, equation (9) implies that a higher covariance $\sigma_{\kappa_w e}$ between the world disutility of labor shock κ_w and the exchange rate e (a covariance that can be influenced by monetary rules) discourages planned Home labor effort (relative to Foreign's) because Home's relative marginal utility of real consumption will turn out to be unexpectedly low precisely when the world marginal disutility of effort and home labor supply are unexpectedly high. As a consequence, Home's workers will raise their preset wages (compared with Foreign's).

These covariance effects are simply absent in the earlier certainty-equivalent models of monetary policy coordination, which instead impose an arbitrary assumed cost of unexpected inflation to create ex post policy trade-offs. Here, instead, the potential incentive is for countries to manipulate their monetary rules to raise domestic expected welfare at foreigners' expense. For example, through the effects of its monetary rule on wages, a country can try to manipulate selfishly the (average values of the) real exchange rate and terms of trade.⁵

In order to express the variances of the endogenous variables in terms of the exogenous shocks, we need to solve the sticky wage model for the ex post terms of trade innovation (equal to the ex

4. Specifically,

$$\omega \equiv \left\{ \log \left[\frac{(\phi - 1)(\theta - 1)}{\phi\theta} \right] - E\kappa + \frac{(1 - \rho)}{2\rho} \sigma_{\kappa}^2 - \lambda \right\},$$

where

$$\lambda \equiv \frac{(1 - \rho)\gamma[\gamma/2 + \rho(1 - \gamma)]}{\rho[1 - (1 - \gamma)(1 - \rho)]^2} \sigma_{\kappa^*}^2.$$

Again, the reader may refer to our working paper [Obstfeld and Rogoff 2000b] for details.

5. Some of the effects in equations (9) and (10) are of indefinite sign and depend on the size of ρ , the coefficient of risk aversion. (See also Obstfeld and Rogoff [1998, 2000b].) When $\rho = 1$, a ceteris paribus rise in the variance of log consumption measured in tradables, σ_z^2 , will cause workers throughout the world to set higher wages, thereby feeding back into a lower value for Ez . This is also the case for $\rho < 1$, but if ρ is sufficiently above 1, the effect may be reversed. The depressing effect of σ_z^2 on Ez is declining in ρ . Indeed, it undergoes a sign change at $\rho = 2$.

post nominal exchange rate innovation) and the ex post innovation in spending,

$$(11) \quad \hat{e} = \frac{\hat{m} - \hat{m}^*}{1 - (1 - \gamma)(1 - \rho)},$$

$$(12) \quad \hat{z} = \frac{1}{2\rho} (\hat{m} + \hat{m}^*),$$

where carets over variables denote surprise components; e.g., $\hat{m} \equiv m - Em$.⁶ Once we specify monetary rules for m and m^* , we will be able to present an exact reduced-form solution to the model. Before doing so, however, we show how expected utilities depend on equilibrium covariances.

C. Solving Explicitly for Expected Utility

In studying policy rules, we will look at their welfare implications in the limiting case as $\chi \rightarrow 0$ in equation (3). The justification is that expenditure on money services is small relative to that on other goods. Note, though, that if $\rho = 1$, the solution we present below is exact, for any positive χ . When $\rho = 1$, equation (4) implies that, in equilibrium, $\chi C = M/P$. Thus, we can replace the term $\log C + \chi \log M/P$ by $(1 + \chi) \log C$ in evaluating individual utility.⁷

When $\rho = 1$, the utility derived from consumption is simply $\log(C)$, and a Home resident's expected utility (as $\chi \rightarrow 0$) takes the form,

$$(13) \quad EU = Ez + \left(\frac{1 - \gamma}{2}\right)E\tau - \psi,$$

where

$$\psi \equiv \frac{(\phi - 1)(\theta - 1)}{\phi\theta}.$$

6. To solve for z , take logs of the money Euler equation (4) and its Foreign counterpart, assuming that $\chi = \chi^*$. Then average the two, applying the definitions of the price indexes, the markup equations for prices, and the equality $C = P_T Z/P$. The exchange rate equation is derived by a similar calculation in differences.

7. By calculating welfare in the limit as $\chi \rightarrow 0$, we do not literally intend to imagine that money demand is zero. Indeed, we must continue to assume that there is a positive demand for money in order for the model to make sense. Notice, though, how equation (12) shows that the effect of a log monetary innovation on log global spending is the same regardless of how small we make χ . Thus, there is no problem in thinking of our welfare results as becoming an arbitrarily good approximation as $\chi \rightarrow 0$.

Foreign expected utility is given by

$$(14) \quad EU^* = EU - (1 - \gamma)E\tau.$$

Equations (13) and (14) show that while expected consumption measured in tradables, Ez , is a common component of Home and Foreign utility, the real exchange rate (proportional to the terms of trade) is a potential source of conflict. Because expenditure measured in tradables is the same in both countries, a country prefers a real depreciation, which lowers relative prices of non-tradables and gives its expenditure a greater real purchasing power.

Notice that the role of $E\tau$ in equations (13) and (14) does not stem from optimal tariff considerations, since in this model, an optimal tariff would result in a real *appreciation*. As we discuss in Section V, the choice of optimal tariff is separable in our model from the choice of a monetary rule.

In the case $\rho \neq 1$, we evaluate expected utility as $\chi \rightarrow 0$ by calculating

$$(15) \quad EU = E\left\{\frac{C^{1-\rho}}{1-\rho} - KL\right\} = \left(\frac{1}{1-\rho} - \psi\right)E\left\{Z^{1-\rho}\left(\frac{\mathcal{C}W^*}{W}\right)^{((1-\rho)(1-\gamma))/2}\right\} \\ = \left(\frac{1}{1-\rho} - \psi\right)h(Ez, E\tau, \sigma_z^2, \sigma_e^2, \sigma_{ze}),$$

where⁸

$$(16) \quad h(Ez, E\tau, \sigma_z^2, \sigma_e^2, \sigma_{ze}) = \exp\left\{(1-\rho)Ez + \frac{(1-\rho)(1-\gamma)}{2}E\tau\right. \\ \left. + \frac{(1-\rho)^2}{2}\sigma_z^2 + \frac{(1-\rho)^2(1-\gamma)^2}{8}\sigma_e^2 + \frac{(1-\gamma)(1-\rho)^2}{2}\sigma_{ze}\right\}.$$

The expression for Foreign expected utility is of the same form, except that the terms $E\tau$ and σ_{ze} enter with opposite sign. As in the $\rho = 1$ case, the expected terms of trade, $E\tau$, provide a potential source of international conflict. An internationally asymmetric welfare distribution might also be induced by the

8. The wage equation (5) and the national budget constraint show that $E\{KL\} = \psi E\{C^{1-\rho}\}$.

Thus,

$$EU = \left(\frac{1}{1-\rho} - \psi\right)E\{C^{1-\rho}\}.$$

covariance σ_{ze} between world demand and the exchange rate, independently of the effect of σ_{ze} on $E\tau$ shown in equation (9).

IV. POLICY COORDINATION: GLOBALLY EFFICIENT PRECOMMITMENT TO MONETARY RULES

Per our discussion in the introduction, we restrict our attention to comparing policy *rules* such that m and m^* are functions of the productivity shocks κ and κ^* . The commitment to such rules precludes the use of inflation surprises to raise employment and output systematically toward their competitive levels. Similarly, national authorities cannot attempt to manipulate the terms of trade *ex post* through monetary surprises.⁹ Nevertheless, because expected spending and the expected terms of trade do depend on covariance terms that the monetary rules can affect, the ability to precommit does not eliminate all strategic issues.

In general, in sticky wage or price models with additional distortions, it need not be the case that optimal monetary policy aims simply to mimic the flexible-price equilibrium. The reason is that the multiple distortions (in the present setup, including wage stickiness, monopoly, and the possible failure of international consumption risk sharing) can interact. It turns out, however, that for the particular stylized structure we have assumed, the optimal solution to the global cooperation problem will indeed replicate the flexible-wage solution in a number of important cases, as we shall now demonstrate. It will turn out further that in precisely these cases, international cooperation in rule setting is not necessary.

If policymakers could cooperate in choosing their domestic monetary policy rules, then with equal weights on national welfares, they would maximize¹⁰

$$(17) \quad EV = \frac{1}{2} EU^* + \frac{1}{2} EU.$$

9. Corsetti and Pesenti [2001a] show that for some parameter configurations, the incentive to use unanticipated inflation to raise employment may be exactly offset by optimal tariff considerations. In those special cases, results such as ours may be extended to the *ex post* game.

10. Unlike earlier cooperation papers, we do not include an *ad hoc ex post* inflation term in the monetary authorities' objective functions. Although it is perhaps only a sleight of hand, we could have done so by assuming overlapping contracts, while taking the initial level of wages as given. Then, of course, any change in the monetary rule will have a surprise element to it (due to the preexisting wage contracts), and therefore the level of inflation has a redistributive effect. Our analysis neglects these transitional issues.

To accomplish this, they would maximize over the coefficients in monetary policy feedback rules of the form,

$$(18) \quad \hat{m} = -\delta_d \hat{\kappa}_d - \delta_w \hat{\kappa}_w,$$

$$(19) \quad \hat{m}^* = \delta_d^* \hat{\kappa}_d - \delta_w^* \hat{\kappa}_w.$$

(Given the loglinear structure of the model, it is plausible to guess that optimal monetary rules will be loglinear too.) Of course, because $E\kappa_w = E\kappa = E\kappa^*$ by assumption, $E\kappa_d = 0$.

A. Expected Utilities under Flexible and Sticky Wages

As a first step in understanding cooperation and conflict in the choice of domestic policy rules, we calculate the flexible- and sticky-wage levels of utility in Home and Foreign.

Under flexible wages, monetary policy is irrelevant, and the level of expected utility, denoted by a tilde, is

$$(20) \quad E\tilde{U} = \log(\psi) - \psi - E\kappa = E\tilde{U}^*$$

when $\rho = 1$, where we have imposed $E\kappa = E\kappa^*$ and $\sigma_\kappa^2 = \sigma_{\kappa^*}^2$. For $\rho \neq 1$,

$$(21) \quad E\tilde{U} = E\tilde{U}^* = \left(\frac{1}{1-\rho} - \psi \right) \exp\left[\frac{(1-\rho)\omega}{\rho} \right],$$

where the constant ω is defined in footnote 4.

Expected Home utility under sticky wages can be decomposed in terms of the flex-wage expected utility levels given above and the economic uncertainties caused by wage rigidity. Using equations (9) and (10) to substitute for $E\tau$ and Ez in equations (13) and (16), one can calculate that for $\rho \neq 1$,

$$(22) \quad EU = (E\tilde{U}) \exp[(1-\rho)\Omega(\rho)],$$

where $\Omega(\rho)$ is defined (for any $\rho > 0$) as the sum of two terms,

$$\Omega(\rho) = \Omega_w(\rho) + \Omega_d(\rho).$$

The term $\Omega_w(\rho)$ depends on the endogenous covariances $\sigma_e^2, \sigma_{\kappa_w z},$ and $\sigma_{\kappa_d e}$,

$$(23) \quad \Omega_w(\rho) = -\frac{1}{2\rho^2} (\sigma_{\kappa_w}^2 + \sigma_{\kappa_d}^2) + \frac{\lambda}{\rho} - \frac{1}{2} \sigma_z^2 - \frac{\frac{1}{8}[1 - (1-\gamma)^2(1-\rho)]\sigma_e^2 + \sigma_{\kappa_w z} + (\frac{1}{2})\sigma_{\kappa_d e}}{\rho},$$

and $\Omega_d(\rho)$ depends on the endogenous covariances σ_{ze} , $\sigma_{\kappa_{ue}}$, and $\sigma_{\kappa_{de}}$,

$$(24) \quad \Omega_d(\rho) = -\frac{(1-\gamma)}{2} \left[\frac{\rho\sigma_{ze} + \sigma_{\kappa_{ue}} + 2\sigma_{\kappa_{dz}}}{1 - (1-\gamma)(1-\rho)} \right].$$

For $\rho = 1$, the expression corresponding to equation (22) is

$$(25) \quad EU = E\tilde{U} + \Omega(1).$$

For Foreign,

$$EU^* = (E\tilde{U}) \exp[(1-\rho)\Omega^*(\rho)]$$

when $\rho \neq 1$, and when $\rho = 1$, $EU = E\tilde{U} + \Omega^*(1)$, where

$$\Omega^*(\rho) = \Omega_w(\rho) - \Omega_d(\rho).$$

Obviously, $\Omega_w(\rho)$ is a symmetric component of world utility that affects Home and Foreign welfare equally. For example, a rise in the variance of world spending (σ_z^2) or in that of the exchange rate (σ_e^2) has symmetrical expected utility effects upon Home and Foreign.

The term $\Omega_d(\rho)$ is an asymmetric utility component that affects Home and Foreign in opposite ways. For example, a rise in $\sigma_{\kappa_{ue}}$ hurts Home because it becomes more likely that demand for Home output will be unexpectedly high when there is an unexpectedly high global aversion to effort. But that same change represents a commensurate benefit to Foreign.¹¹

B. Multiple Distortions and the Efficiency of the Flexible-Wage Equilibrium

Is it efficient (from an ex ante, expected utility standpoint) to have monetary policy rules aim to mimic the flexible-wage equilibrium, as in the 1980s style of linear rational-expectations monetary models? In general, the answer is not trivial, as we have noted, since wage stickiness is not the only distortion here.

First, we note that policy reaction functions (18) and (19) with

$$(26) \quad \delta_d^{flex} = \delta_d^{*flex} = 1,$$

11. Observe that whereas $E\tilde{U} = E\tilde{U}^*$ when $E\kappa = E\kappa^*$ and $\sigma_\kappa^2 = \sigma_\kappa^{*2}$, EU still need not equal EU^* if monetary policies are asymmetric.

and

$$(27) \quad \delta_w^{flex} = \delta_w^*{}^{flex} = 1$$

indeed replicate the flexible-wage equilibrium. Therefore, such a policy is always feasible in this model.¹² (In models with more complex price rigidities, however, such replication may not be feasible.)

Next, we establish a sufficient condition under which replicating the flexible-wage allocation is indeed the goal of efficient cooperative policies.¹³

PROPOSITION 1. Suppose that the flexible-wage allocation is constrained Pareto efficient ex ante (subject to the constraint that labor supplies are at monopolistic levels). Then a global monetary policy rule that gives the same real allocation as under flexible wages is ex ante efficient.

Proof. (Sketch). Note that the parameters θ and ϕ governing the monopoly distortion terms in (22) and (25) affect only the identical additive or multiplicative constant $E\tilde{U}$, but not any of the elements of $\Omega(\rho)$. One can offer fixed subsidies to production and employment that eliminate the monopoly distortions in the goods and labor markets (in both countries) while affecting only $E\tilde{U}$ but not the relevant gap between EU and $E\tilde{U}$. With these optimal subsidies in place, the flexible-wage equilibrium is clearly first-best efficient (in terms of expected utilities) under the assumption in the proposition: all distortions have been eliminated. Since the subsidies affect only $E\tilde{U}$ in (22) and (25), it therefore follows that even in their absence, one cannot Pareto-improve upon replicating the flexible-wage equilibrium ex post. ■

Under the assumptions of Proposition 1, targeting the flexible-wage allocation is also the *optimal* cooperative policy given the assumed 50-50 weights on country utility in the planner objective function (17). The reason is that $E\tilde{U} = E\tilde{U}^*$; see equation (21). Later, however, we will see that Proposition 1 gives a

12. Verification is left to the reader. (See also Appendix 2.) In terms of the national productivity shocks, the monetary rules would be $\hat{m} = -\hat{\kappa}$, $\hat{m}^* = -\hat{\kappa}^*$. More generally, when labor enters as $(K/v) L^v$ in individual utility (3), then $\delta_d^{flex} = \delta_d^*{}^{flex} = (\rho(1 - \gamma) + \gamma)/(v - (1 - \gamma)(1 - \rho))$ and $\delta_w^{flex} = \delta_w^*{}^{flex} = \rho/[v - (1 - \rho)]$. This generalization, however, would have no important effect on our discussion below.

13. Proposition 1 generalizes the log-case ($\rho = 1$) result proved in Obstfeld and Rogoff [2000a].

sufficient condition for optimality *regardless* of the welfare weights in (17).

C. Optimal Cooperation

The proposition just proved allows a quick but partial characterization of optimal policies. When all productivity shocks are world shocks (that is, $\hat{\kappa}_d \equiv 0$), or when $\rho = 1$, the sharing of tradable consumption risks is efficient, and there are no global distortions to the flexible-wage equilibrium other than the ones caused by monopoly (which enter separably). In these latter cases, therefore, we would expect optimal cooperative policies to target the flex-wage allocation. More generally, however, optimal monetary policy will strike a balance between mitigating the risk sharing and sticky-wage distortions. Specifically, it will exploit the rigidity of wages to improve risk sharing. This is precisely the kind of interaction between distortions that we referred to earlier.

To understand the trade-off between distortions in the general case, we now solve explicitly for the optimal policy rules under cooperation. Equations (13), (14), and (17) show that when $\rho = 1$, the objective to be maximized through policy cooperation is simply

$$EV = \frac{1}{2} EU^* + \frac{1}{2} EU = Ez + \text{constant.}$$

When $\rho \neq 1$, the countries' expected utility levels are given by equations (15)–(16) and their Foreign analogs. Differentiating equation (17) with respect to any policy-rule parameter δ , and noting that $E\{C^{1-\rho}\} = E\{C^*{}^{1-\rho}\}$ in a symmetric equilibrium, the planner's first-order conditions can be written as

$$(28) \quad \frac{d\{Ez + ((1-\rho)/2)\sigma_z^2 + ((1-\rho)(1-\gamma)^2/8)\sigma_e^2\}}{d\delta} = 0.$$

By this logic, we see that for *any* value of ρ , one can derive the optimal cooperative monetary policy rules by assuming that policymakers seek

$$(29) \quad \begin{aligned} \max EV &= \max \left\{ Ez + \frac{(1-\rho)}{2} \sigma_z^2 + \frac{(1-\rho)(1-\gamma)^2}{8} \sigma_e^2 \right\} \\ &= \max \left\{ \frac{\omega}{\rho} + \Omega_w(\rho) \right\} \end{aligned}$$

over the parameters in their linear monetary policy feedback rules. (Recall again that ω is the constant defined in footnote 4.)

The two countries place equal but opposite-signed weights on the expected real exchange rate and on the covariance σ_{ze} between world spending and the nominal exchange rate. These two factors therefore disappear at the global level. This need not imply, of course, that optimal cooperation implies fixing the nominal exchange rate, unless the Home and Foreign productivity shocks happen to be perfectly correlated.

To solve for the cooperative rules that maximize (29), we express the ex post values of z and e as functions of the monetary reaction parameters; this in turn allows us to calculate the covariances in $\Omega_w(\rho)$ —recall equation (23). Appendix 1 expresses the covariances in $\Omega_w(\rho)$ in terms of the δ policy parameters.

The next step is to solve the four first-order conditions given by equation (28) for the cooperatively optimal parameters δ_d^{coop} , δ_d^{*coop} , δ_w^{coop} , and δ_w^{*coop} . By symmetry, $\delta_d^{coop} = \delta_d^{*coop}$ and $\delta_w^{coop} = \delta_w^{*coop}$, where (again, see Appendix 1),

$$(30) \quad \delta_d^{coop} = \frac{1 - (1 - \gamma)(1 - \rho)}{1 - (1 - \gamma)^2(1 - \rho)},$$

$$(31) \quad \delta_w^{coop} = 1.$$

Observe that due to the symmetry of the model, purely symmetric shocks can be handled by adjustments in world spending z alone, whereas purely idiosyncratic shocks can be handled by adjustments of the exchange rate e alone. The rule above represents an optimal symmetrical trade-off between stabilization—a more aggressive procyclical response to the productivity shocks raises world utility—and variability in world spending and the exchange rate. Increases in σ_z^2 or σ_e^2 lower world utility; see (23). Both are higher the more procyclical are the (symmetric) monetary policy rules.

Comparing the globally optimal rules in equations (30) and (31) with the ones that achieve the flexible-wage allocation, equations (26) and (27), we see first that when $\rho = 1$, it is always optimal to target the flexible-wage equilibrium (as per Proposition 1). In the special case of symmetric global productivity shocks, Proposition 1 still applies even when $\rho \neq 1$, and therefore $\delta_w^{coop} = \delta_w^{flex}$. However, $\delta_d^{coop} = \delta_d^{flex}$ for $\rho \neq 1$ only when $\gamma = 0$ or $\gamma = 1$. In those extreme cases, either all goods are tradable (in which case international consumption risk sharing is perfect), or there are no tradables (in which case there are no consumption risks that countries can share).

When $\rho \neq 1$ but $0 < \gamma < 1$, though, the cooperative equilibrium reflects the general principle of the second-best, according to which it could be desirable to refrain from eliminating the sticky-wage distortion in order to mitigate the risk-sharing distortion. In such cases, according to equations (26) and (30), $\delta_d^{coop} < \delta_d^{flex}$ when $\rho < 1$ but $\delta_d^{coop} > \delta_d^{flex}$ when $\rho > 1$. Thus, for $\rho < 1$, exchange-rate fluctuations are dampened relative to a flexible-wage rule, but they are relatively accentuated when $\rho > 1$.

D. Understanding the Trade-off

What explains the way that optimal policies deviate from targeting the flex-wage allocation? Such situations have received scant analytic attention in the monetary policy literature, so we digress to give the intuition. Continuity is not sacrificed, however, by skipping directly to Section V.

To understand the difference between δ_d^{coop} and δ_d^{flex} when risk sharing in tradables is imperfect, note first that by equation (15), one can write countries' ex post marginal utilities of tradables as

$$\text{Home marginal utility of tradables} = Z^{-\rho} \left(\frac{\mathcal{E}W^*}{W} \right)^{((1-\rho)(1-\gamma))/2},$$

$$\text{Foreign marginal utility of tradables} = Z^{-\rho} \left(\frac{\mathcal{E}W^*}{W} \right)^{-(1-\rho)(1-\gamma)/2}.$$

Thus, ex post international marginal utility gaps result exclusively from exchange rate movements (which affect national outputs of nontradables differentially). When there is a positive shock to κ_d , a fall in \mathcal{E} (a Home currency appreciation and a Foreign depreciation) is required to replicate the flexible-wage equilibrium. In the case $\rho < 1$, Home's marginal utility of tradables is consequently below Foreign's at the flexible-wage allocation, as the preceding equations show. In a world of complete asset markets, Home would make a payment of tradables to Foreign in such states of nature. That is impossible here. However, a *reduction* in the extent to which \mathcal{E} falls works very much like a transfer of tradables because, as a result, Home residents work harder, Foreign residents work less, and more Home goods are shipped to Foreign in exchange for fewer Foreign goods.

The logic is symmetric for $\rho > 1$. In that case if asset markets were complete, a positive κ_d would call for a transfer of tradables from Foreign to Home at the flex-wage allocation. Instead, the

cooperative equilibrium calls for a sharper fall in \mathcal{E} than does the flex-wage equilibrium. This induces Home residents to produce fewer of their exports and Foreign residents more of theirs than under flexible wages.

V. NONCOOPERATIVE CHOICE OF POLICY RULES

In designing their monetary rules and institutions, countries seldom ask what impact domestic institutional changes will have on welfare abroad. As we have seen, however, monetary rules can affect the expected real exchange rate, which in turn creates a wedge between home and foreign welfare. Thus, the question naturally arises: is an environment in which nations cooperate in setting rules always strictly superior? Or are there cases in which the optimal cooperative rules can be implemented without a binding global monetary compact?

We show in this section that when the optimal cooperative policy rules target the flexible-wage equilibrium ex post, those rules are also Nash equilibrium rules. When the best cooperative rules do not mimic the flexible-wage equilibrium, however, they are not Nash. A corollary is that countries' responses to global, internationally symmetric, shocks do not raise problems of coordination; only asymmetric shocks may be problematic. This result stands in contrast to earlier literature on international policy cooperation, where trade-offs are caused by assumed ad hoc inflation objectives and where global shocks play a starring role. We will return to this comparison in Section VI.

A. Nash Equilibrium in Policy Rules

Differentiation of equation (16) for EU shows that in the Nash case, the first-order conditions for Home's problem are the same as those for the problem,

$$(32) \quad \max_{\delta_d, \delta_w} \underbrace{\frac{\omega}{\rho} + \Omega_w(\rho)}_{\text{global component}} + \underbrace{\Omega_d(\rho)}_{\text{country-specific component}}$$

given δ_d^* and δ_w^* . Foreign's effective objective function is simply the global component less the country-specific component above.

Starting at the cooperative equilibrium, a small movement of δ_d away from δ_d^{coop} , say, has no first-order impact on the global component of Home expected utility because that term is maxi-

mized by a global planner; recall equation (28). Yet, given the Foreign policy rule, Home might still wish to change its own rule, reaping a net *domestic* gain by shifting the utility-relevant terms $E\tau$ and σ_{ze} in its favor while lowering the global component of welfare by less. In that case, of course, Foreign would lose more than Home gains, and (starting at the cooperative equilibrium) Foreign would face a symmetrical incentive to engage in “beggarthy-neighbor” rule manipulation. The Nash equilibrium, like the cooperative one, is symmetric, so $\delta_d^{Nash} = \delta_d^{*Nash}$, and $\delta_w^{Nash} = \delta_w^{*Nash}$.

Our next result tells us, however, that there is no individual incentive for countries to defect from the cooperative equilibrium when that equilibrium mimics the flexible-wage equilibrium *ex post*.

PROPOSITION 2. In the Nash monetary policy rule setting equilibrium, $\delta_d^{Nash} = \delta_d^{coop} = \delta_d^{flex}$ when $\rho = 1$, and, for any $\rho > 0$, $\delta_w^{Nash} = \delta_w^{coop} = \delta_w^{flex}$.

Proof. See Appendix 1, where it is shown by direct calculation that

$$(33) \quad \delta_d^{Nash} = [1 - (1 - \gamma)(1 - \rho)] \left\{ \frac{2 - \gamma}{[1 - (1 - \gamma)^2(1 - \rho)] + \rho(1 - \gamma)} \right\},$$

$$(34) \quad \delta_w^{Nash} = 1.$$

Setting $\rho = 1$ in equation (33) and comparing the result with equations (30) and (26) for $\rho = 1$ proves the first part of the proposition, while comparison of equation (34) with equations (31) and (27) establishes the second part. ■

Proposition 2 shows that when the flexible-wage equilibrium is *ex ante* constrained-efficient (with respect to the monopoly distortions), Home does not gain by unilaterally moving its policy rule away from cooperation. Constrained efficiency always holds when $\rho = 1$, and it holds for any $\rho > 0$ when all shocks are global. Thus, the cooperative equilibrium—when it mimics the flexible-wage equilibrium—is also the Nash equilibrium of the rule-setting game. But notice that our result actually is stronger than this. In fact, the proposition states that Home never gains from changing its response to global shocks even when idiosyncratic shocks can occur and $\rho \neq 1$. This “separability” property follows from the basic linear-qu-

dratic nature of our model, coupled with the orthogonality of the “world” and “difference” shocks.

Regarding the Nash response to idiosyncratic shocks, we have

PROPOSITION 3. In the Nash monetary policy rule-setting equilibrium, $\delta_d^{flex} > \delta_d^{Nash} > \delta_d^{coop}$ when $\rho < 1$ and $\delta_d^{flex} < \delta_d^{Nash} < \delta_d^{coop}$ when $\rho > 1$.

Proof. Left to the reader. ■

The proof of Proposition 2 in Appendix 1 confirms our earlier claim that under the assumptions of Proposition 1, it is optimal for a global planner to target the flexible-wage equilibrium regardless of the country welfare weights in the objective function (17). Thus, we have

COROLLARY 4. If the flexible-wage allocation is constrained Pareto efficient ex ante, a global monetary policy that gives the same real allocation as under flexible wages is optimal even for a supranational planner who favors one country over the other. ■

B. Discussion of Propositions 2 and 3

Proposition 2’s conclusion that the Nash and cooperative equilibria of the rule-setting game can coincide contrasts sharply with the earlier policy cooperation literature, much of which, as we have noted, dealt with the consequences of noncooperative (ex post) responses to *common* (i.e., symmetric) shocks. Here, the response to such common shocks resulting from cooperative choice of rules is always the same as that resulting from noncooperative choice (and the responses to any shocks are the same when $\rho = 1$). Why?

The basic reason for Proposition 2 is that these are cases in which the policy rule is designed to mimic the constrained-efficient flexible-wage equilibrium, thus setting to zero the Home and Foreign sticky-wage distortions measured by¹⁴

$$\Omega(\rho) = \Omega_w(\rho) + \Omega_d(\rho)$$

14. Of course these terms are not generally set to zero when $\rho \neq 1$ and asymmetric shocks can occur. Indeed, it can be shown (after much algebra) that under the cooperative regime,

$$\Omega(\rho) = \frac{\gamma^2(1 - \gamma)^2(1 - \rho)^2\sigma_{\kappa_d}^2}{2\rho[1 - (1 - \gamma)(1 - \rho)]^2[1 - (1 - \gamma)^2(1 - \rho)]} > 0.$$

and

$$\Omega^*(\rho) = \Omega_w(\rho) - \Omega_d(\rho).$$

But if the sticky-wage distortion has been eliminated, a small increase in the distortion through a change in the policy rule has no first-order welfare effect on Home or Foreign.¹⁵ That is, when the policy parameter δ that solves

$$\frac{d\Omega_w(\rho)}{d\delta} = 0$$

leads to the flexible-wage equilibrium ex post, it must also be true that

$$\frac{d\Omega(\rho)}{d\delta} = \frac{d\Omega^*(\rho)}{d\delta} = \frac{d\Omega_d(\rho)}{d\delta} = 0.$$

Thus, neither country will be tempted to deviate from any policy rule parameter which, taken individually, is tailored to eliminate the effects of sticky wages on the economy's allocation.¹⁶

Implicit in the preceding discussion is the presumption that the sticky wage lowers welfare because wage setters would always prefer to have the option of resetting their wages after uncertainty is realized: when there are no asymmetric shocks (or when $\rho = 1$), $\Omega(\rho)$ is maximized at a value of 0.

Equation (33) reports the Nash response to asymmetric shocks, and Proposition 3 brackets it between the cooperative and flexible-wage response coefficients. When $\rho < 1$, countries respond more aggressively to idiosyncratic shocks than is globally efficient—and as a result, exchange rate variability is excessive relative to the benchmark of optimal cooperation. When $\rho > 1$, however (more likely the relevant case empirically), the Nash equilibrium actually produces more stable exchange rates than does cooperation.

Why? The covariance σ_{ze} is bigger the more activist is Home's monetary policy. As equation (24) shows, this effect (other things

However, δ_w and δ_d enter $\Omega(\rho)$ separably, so we can analyze the problem of choosing δ_w as if asymmetric shocks were absent altogether.

15. It is critical to this argument that the monopoly distortions have effects that are completely separable from those of the sticky-wage distortion, as we have shown above.

16. In the logarithmic case ($\rho = 1$), we can infer that a small shift in the policy rule does not induce any change in the nominal wages that workers choose ex ante. When $\rho \neq 1$, however, wages do change.

equal) has a negative impact on Home. High σ_{ze} implies that world demand is high precisely when the exchange rate is shifting demand toward Home workers. At relatively high values of ρ , the domestically beneficial reduction in σ_{ze} due to reduced monetary activism dominates the domestic harm due to the concomitant rise in $\sigma_{\kappa, \mathcal{E}}$, implying that, left to its own devices, Home would choose a monetary rule that stabilizes the exchange rate more than under cooperation.

By changing its rule to reduce σ_{ze} , Home inflicts a direct beggar-thy-neighbor loss on Foreign, of course. But at the same time $\Omega_w(\rho)$ (a shared, global component of welfare) declines because $\sigma_{\kappa, \mathcal{E}}$ rises; see equation (23). This last effect hurts both countries, which have a common interest in seeing the Home currency relatively appreciated (and the Foreign currency, therefore, relatively depreciated) when Home productivity is relatively low (and, therefore, Foreign productivity relatively high).

Our discussion of Proposition 2 rests on the negative effect of sticky wages on *individual* welfare, but we have not yet considered optimal tariff effects, which pertain to *national* welfare. As a general matter, the decisions of individual wage setters need not completely internalize a country's monopoly power over its exports; see Obstfeld and Rogoff [1998, appendix D.2], Lombardo [1999], and Tille [2000]. Indeed, in this model individual producers overestimate the global elasticity of demand for their products, so that either country could raise its own welfare at foreigners' expense by imposing an optimal import tariff. Might not a monetary policy rule be designed likewise to exploit a country's monopoly power in trade, thereby perhaps raising $\Omega(\rho)$ above zero even in the absence of a risk-sharing distortion?

The answer is no, essentially for the same reason that the sticky-wage distortion does not interact with the micro-level monopoly distortion. To see this, imagine that Home imposes an optimal import tariff to exploit its national monopoly power in trade. Appendix 2 shows that in the flex-wage equilibrium with an ad valorem tariff of t , Home utility $\tilde{U}(t)$ has the form

$$\tilde{U}(t) = \Gamma(t)\tilde{U}(0) = \Gamma(t)\tilde{U},$$

where $\Gamma(t)$ is a function of t and model parameters only, implying that the optimal tariff is state-independent. The optimal tariff under sticky wages and uncertainty maximizes

TABLE I
GAINS FROM STABILIZATION AND COORDINATION (PERCENT OF OUTPUT)

Measure	$\rho = 0.5$	$\rho = 1$	$\rho = 2$	$\rho = 4$	$\rho = 8$
(i) Stabilization gain	3.11	1.01	0.33	0.11	0.03
(ii) Coordination gain	0.02	0	6.3×10^{-3}	9.0×10^{-3}	5.8×10^{-3}
(iii) Ratio (ii)/(i)	7.9×10^{-3}	0	1.9×10^{-2}	0.08	0.18

$$EU(t) = E\{\tilde{U}(t)\} \exp[(1 - \rho)\Omega(\rho)] = \Gamma(t)E\{\tilde{U}(0)\} \exp[(1 - \rho)\Omega(\rho)] \\ = \Gamma(t)EU(0).$$

But then, the first-order condition for the nationalistically optimal tariff [$\Gamma'(t) = 0$] is independent of the conditions for optimal nationalistic monetary policy [$d\Omega(\rho)/d\delta = 0$]. Thus, Home's ex ante welfare is maximized when the allocational effects of sticky wages are nullified ex post by monetary policy, irrespective of whether the optimal Home tariff is actually in place. Choosing optimal tariffs and monetary rules are separable problems in this model, although in general, of course, they might not be.

Finally, if one introduces complete nominal asset markets here, it must effectively be possible to index contracts to any possible shift in monetary rules. As we argued in Obstfeld and Rogoff [1995], the hypothesis of rigid nominal prices then becomes harder to maintain.¹⁷

C. How Can One Plausibly Generate Big Coordination Gains?

One way to assess the quantitative importance of the gain from coordination when $\rho \neq 1$ and $\sigma_{\kappa_{cl}}^2 > 0$ is to simulate our model numerically. To that end, we assume that $\sigma_{\kappa_{cl}}^2 = \sigma_{\kappa_{co}}^2 = 0.01$ and that $\gamma = 0.6$. (Chari, Kehoe, and McGrattan [1998] assume that $\nu = 1.5$ when $(K/\nu)L^\nu$ is the disutility of labor, which would make coordination gains smaller than in our case of $\nu = 1$.) For different values of ρ , Table I calculates three numbers: (i) the gain from monetary policies that target the flexible-wage equilibrium, compared with policies that hold money supplies constant; (ii) the gain from moving from flex-wage policies to the coopera-

17. For an example of a complete nominal contract model, see Chari, Kehoe, and McGrattan [1998]. With complete international asset markets, the model is no longer log linear for $\rho \neq 1$. Nonetheless, it is still true that very simple linear monetary rules can replicate the flex-wage allocation.

tive equilibrium; and (iii) the ratio of (ii) to (i). The gains (i) and (ii) are expressed as *percentages* of the mean flex-wage output level. Notice that because the Nash equilibrium policy responses lie between the flex-wage and cooperative responses, the ratio (iii) is an upper bound on the gains to cooperative versus Nash behavior in rule setting.

The gain to stabilization falls sharply with ρ because the higher is ρ , the less the necessary adjustment of wages to productivity shocks in the flexible-wage equilibrium (see Appendix 2). However, the net gain to cooperation versus simply targeting the flex-wage allocation is uniformly tiny in these calculations. Only at relatively high values of ρ , at which the gain to stabilization is very small, does the gain from coordination climb to over a tenth of the gain from stabilization. It takes implausibly high values of ρ (approaching 100) to raise the coordination gain above 40 percent of the (by then, microscopic) gain from stabilization. In these simulations, deviations from the flexible-wage equilibrium are small, but that might not be the case in more general models.

Our results here are consistent with a much broader literature finding that at the aggregate national level, the potential utility gains from increased international risk sharing are not necessarily large (see Obstfeld and Rogoff [1996, Chapter 5]), especially in a setting such as the present one where price effects already provide a significant measure of risk sharing.

An important caveat is that our model is structured so that global monetary policy can always replicate the flexible-wage equilibrium exactly, if the authorities so choose. In a model with a greater complexity or variety of nominal rigidities, this may not always be so.¹⁸ In such cases, our results here do not imply that the cooperative and Nash equilibria necessarily coincide, even for global shocks. Whether this discrepancy can generate large deviations is an empirical question that deserves further research.

VI. COMPARISONS WITH EARLIER LITERATURE

In a classic paper Oudiz and Sachs [1984] argued that the gains from monetary cooperation across the major economic regions are not likely to be large because Europe, the United States, and Japan are relatively closed economies. They based their results on an old-fashioned Keynesian trade multiplier setup

18. See, for example, Devereux and Engel [2000].

with parameters drawn from then-existing large-scale macroeconomic models. Our results here are quite different, and not only because we are looking at a rule-setting game rather than *ex post* responses to a one-time shock.¹⁹ In our new open economy macroeconomic model, it is likewise the case that the benefit to cooperative international rule setting is small when trade is small. But here, the cooperative and Nash equilibria also converge as goods markets become perfectly integrated. The potential benefits turn out to be greatest in the intermediate cases where both goods and capital markets are imperfectly integrated.²⁰ There are other fundamental differences as well. As indeed was done in all the previous literature, Oudiz and Sachs employed a certainty-equivalence framework in which monetary policy cannot systematically raise the expected value of output or employment. But here, the monetary rule does affect the expected trajectory of the economy via agents' responses to risk. Last (but not least), we show that in our framework, the globally shared shocks (e.g., oil-price shocks) that inspired the older cooperation literature are a nonissue. Only asymmetric shocks lead to coordination failures.

This contrast between our results and the earlier literature with respect to global shocks is not as stark as it seems. The older models typically assumed that the monetary authorities cared about inflation as well as output stabilization, so that the cooperative response to a global shock would not, in general, call for achieving the flexible wage (price) output level. Thus, the standard result of the older literature that Nash responses differ from cooperative ones [Obstfeld and Rogoff 1996, Chapter 9] is perfectly consistent with our Propositions 2 and 3, even though we consider rule-setting games here. We do not include an *ad hoc* *ex post* inflation term in utility, but instead the trade-offs in the monetary rule game are driven by the covariance structure of the model.

Our analysis assumed that liquidity services are a negligible factor in utility. If that were not the case, then in a general setting, an additional distortion would be present that could

19. See also Canzoneri and Edison [1990], who entertain alternative definitions of policy coordination under which gains might be amplified beyond the levels that Oudiz and Sachs reported.

20. Corsetti and Pesenti [2001b] have shown that the same kind of result can arise when there is local-currency pricing of imports. They find that gains to cooperation are largest in the intermediate case of partial exchange-rate pass-through.

discourage policy rules from replicating the flexible price equilibrium.²¹ Our judgment is that this effect is not empirically important and is heavily dependent on the exact specification of money demand. In any event, we proved that when $\rho = 1$ in our model, our results go through exactly even when the utility from real balances is fully incorporated.

This paper does not actually explore the institutional mechanisms by which a rule-based regime might be implemented. Persson and Tabellini [1995] have extended the optimal monetary contracting approach of Walsh [1995] to an open economy setting. They argue that, if properly designed, domestically enforced monetary contracts can sometimes simultaneously mitigate the credibility problems of national monetary authorities vis-à-vis wage setters, and vis-à-vis other national monetary authorities.²² They also informally consider whether the globally optimal cooperative contracting scheme might be the outcome of a game in which countries set contracts unilaterally. While it is true that the contracts Persson and Tabellini propose appear to be rather fragile and complex, more recent work by Jensen [2000] suggests that the problem of complexity, at least, may be remedied.

Finally, Corsetti and Pesenti [2001a] derive the first-order conditions for a Nash equilibrium in policy actions at given wages in a new open economy macroeconomic model. However, they offer their analysis as suggestive and do not attempt to solve fully for Nash equilibrium, nor is their nonstochastic model suited to exploring rule-setting games.

VII. CONCLUSIONS

As the major currency countries adopt institutions more conducive to rule-based monetary policy, one might be concerned at their inward-looking decision-making processes. Modern models of monetary policy transmission suggest a number of channels that might lead countries to choose monetary rules that are optimal from a national perspective but not from a global perspective. While in principle this problem perhaps can be ad-

21. This possibility presupposes that the monetary authority cannot set the rate of trend monetary growth implicit in its rule so as to attain the optimum quantity of money. Under commitment to rules, of course, there would be no scope for policy to engineer unanticipated increases in real money holdings.

22. The importance of considering how international cooperation in monetary policy can simultaneously affect anti-inflation credibility was first highlighted in Rogoff [1985].

dressed with properly designed domestic monetary institutions, in practice, external spillover effects appear to receive only minimal consideration.

We have shown that, surprisingly, this lack of coordination may not always be a big problem, even in a world with significant economic integration. As domestic monetary rules improve, and as international asset markets become more complete, there are plausible circumstances in which the outcome of a Nash monetary rule-setting game begins to approximate the outcome of a cooperative system. In our model, the convergence occurs when globally optimal monetary policy rules seek fully to offset nominal rigidities, and are not forced also to carry the burden of counteracting capital-market imperfections or other extra distortions. This answer falls remarkably neatly out of an explicit welfare analysis in the mode of the “new open economy macroeconomics.” Indeed, one simply cannot properly pose the question we have addressed within the older Mundell-Fleming-Dornbusch style of model that, until now, has served as the workhorse of the cooperation literature.

Our quantitative results suggest that, empirically, the possibility of coordination problems under floating exchange rates is unlikely to contribute much weight to a case for fixed exchange rates. We hardly regard the analysis here as a decisive blow against having a world money, since our framework omits many potentially important elements such as excess volatility, protectionism, and the costs of making and keeping track of payments in multiple currencies. The analysis does cast some doubt, however, on halfway measures to coordinate world monetary policy such as McKinnon’s [1984] “world money supply” targeting or Williamson’s [1985] exchange-rate target zones. Continued improvements of monetary policy institutions at the domestic level, coupled with the further broadening of world capital markets, may render such schemes superfluous or even counterproductive.

APPENDIX 1: COOPERATIVE AND NASH EQUILIBRIA

This appendix shows how to calculate the cooperative and Nash equilibria when monetary rules respond to productivity shocks.

Cooperative Equilibrium

The paper's text showed that cooperative policymakers will seek to maximize (29) over policy rules of the form given in equations (18) and (19). Equations (10), for Ez , and (29) show that to calculate the cooperative equilibrium, we must express the moments $\sigma_z^2, \sigma_e^2, \sigma_{\kappa_w z}$, and $\sigma_{\kappa_d e}$, all of which affect Home and Foreign symmetrically, in terms of the policy parameters of the reaction functions (18) and (19). Expressions (12) and (11) show that rules having the form of (18) and (19) imply

$$\hat{z} = -\frac{1}{2\rho} [(\delta_d - \delta_d^*)\hat{\kappa}_d + (\delta_w + \delta_w^*)\hat{\kappa}_w],$$

$$\hat{e} = -\frac{1}{1 - (1 - \gamma)(1 - \rho)} [(\delta_d + \delta_d^*)\hat{\kappa}_d + (\delta_w - \delta_w^*)\hat{\kappa}_w].$$

Thus, we can write

$$\sigma_z^2 = \frac{(\delta_d - \delta_d^*)^2}{4\rho^2} \sigma_{\kappa_d}^2 + \frac{(\delta_w + \delta_w^*)^2}{4\rho^2} \sigma_{\kappa_w}^2,$$

$$\sigma_e^2 = \left[\frac{\delta_d + \delta_d^*}{1 - (1 - \gamma)(1 - \rho)} \right]^2 \sigma_{\kappa_d}^2 + \left[\frac{\delta_w - \delta_w^*}{1 - (1 - \gamma)(1 - \rho)} \right]^2 \sigma_{\kappa_w}^2,$$

$$\sigma_{\kappa_w z} = -\frac{\delta_w + \delta_w^*}{2\rho} \sigma_{\kappa_w}^2,$$

$$\sigma_{\kappa_d e} = -\frac{\delta_d + \delta_d^*}{1 - (1 - \gamma)(1 - \rho)} \sigma_{\kappa_d}^2.$$

Since the cooperative maximand simplifies to

$$EV = -\frac{1}{2} \sigma_z^2 - \frac{\{1/8[1 - (1 - \gamma)^2(1 - \rho)]\sigma_e^2 + \sigma_{\kappa_w z} + (1/2)\sigma_{\kappa_d e}\}}{\rho} + \text{constant}$$

once we write Ez and $E\tau$ in terms of the relevant variances and covariances of endogenous variables—recall equation (23)—the first-order conditions for the reaction function parameter δ_d is

$$\frac{dEV}{d\delta_d} = \frac{d\Omega_w(\rho)}{d\delta_d} = 0 = -\frac{(\delta_d - \delta_d^*)}{4\rho^2} \sigma_{\kappa_d}^2 - \frac{[1 - (1 - \gamma)^2(1 - \rho)]/2[1 - (1 - \gamma)(1 - \rho)](\delta_d + \delta_d^*)\sigma_{\kappa_d}^2 - \sigma_{\kappa_d}^2}{2\rho[1 - (1 - \gamma)(1 - \rho)]}.$$

(We do not write out a verification of second-order conditions, but that detail is easily filled in given the simple structure of the model.) Observe that, thanks to the model's linearity and the orthogonality of the relative and global shocks κ_d and κ_w , the first-order conditions for the optimal Home and Foreign cooperative response elasticities to κ_d do not depend on the response elasticities to κ_w . A further simplification results from noting that, due to the model's symmetry, we must have $\delta_d^* = \delta_d$ at the optimum. Thus, the preceding first-order condition implies that $\delta_d^{coop} = \delta_d^{*coop} = [1 - (1 - \gamma)(1 - \rho)] / [1 - (1 - \gamma)^2(1 - \rho)]$, which gives us equation (30). As we have observed, this solution differs in general from the flexible-wage solution, equation (26).

To find the cooperative response elasticities δ_w^{coop} and δ_w^{*coop} , we calculate

$$\frac{dEV}{d\delta_w} = \frac{d\Omega_w(\rho)}{d\delta_w} = 0 = -\frac{(\delta_w + \delta_w^*)}{4\rho^2} \sigma_{\kappa_w}^2 - \left(\frac{[1 - (1 - \gamma)^2(1 - \rho)]}{4\rho[1 - (1 - \gamma)(1 - \rho)]^2} \right) (\delta_w - \delta_w^*) \sigma_{\kappa_w}^2 - \frac{1}{2\rho^2} \sigma_{\kappa_w}^2.$$

Again invoking the symmetry of the solution, we find that $\delta_w^{coop} = \delta_w^{*coop} = 1$, which is equation (31). δ_w^{coop} also matches the flexible-wage response in equation (27).

Nash Equilibrium

In a Nash equilibrium Home's problem is to find $\max_{\delta_d, \delta_w} EU$ given δ_d^* and δ_w^* . As equation (32) shows, Home will wish to alter its cooperative policy rule if it can bring about a first-order increase in the country-specific welfare component $\Omega_d(\rho) = ((1 - \gamma)/2)E\tau + ((1 - \gamma)(1 - \rho)/2)\sigma_{ze}$. Since the benefit to Home from any first-order increase in $\Omega_d(\rho)$ corresponds to an equal loss for Foreign, Foreign (of course) would lose more than Home's overall gain if Home were to defect from the cooperative equilibrium.

The first-order condition with respect to δ_w takes the form $dEU/d\delta_w = d\Omega_w(\rho)/d\delta_w + d\Omega_d(\rho)/d\delta_w = 0$. The last subsection gives the derivative $d\Omega_w(\rho)/d\delta_w$. To calculate $d\Omega_d(\rho)/d\delta_w$, recall from equation (24) that

$$\Omega_d(\rho) = -\frac{(1 - \gamma)}{2} \left[\frac{\rho\sigma_{ze} + \sigma_{\kappa_w e} + 2\sigma_{\kappa_d z}}{1 - (1 - \gamma)(1 - \rho)} \right],$$

where the relevant covariances, all of which have opposite effects on Home and Foreign expected utility, are

$$\begin{aligned} \sigma_{ze} &= \frac{(\delta_d^2 - \delta_d^{*2})\sigma_{\kappa_d}^2 + (\delta_w^2 - \delta_w^{*2})\sigma_{\kappa_w}^2}{2\rho[1 - (1 - \gamma)(1 - \rho)]}, \\ \sigma_{\kappa_w e} &= -\frac{\delta_w - \delta_w^*}{1 - (1 - \gamma)(1 - \rho)}\sigma_{\kappa_w}^2, \\ \sigma_{\kappa_d z} &= -\frac{(\delta_d - \delta_d^*)}{2\rho}\sigma_{\kappa_d}^2. \end{aligned}$$

To find the Nash equilibrium of the rule-setting game, we note first that

$$\frac{d\Omega_d(\rho)}{d\delta_w} = -\delta_w + 1.$$

Since the value $\delta_w = 1$ sets the preceding derivative to zero while simultaneously satisfying $d\Omega_w(\rho)/d\delta_w = 0$ (recall the last subsection), we have (by symmetry) that $\delta_w^{Nash} = \delta_w^{*Nash} = 1$. Of course, these Nash responses to the symmetric world shock also are cooperative responses and act to mimic the flexible-wage equilibrium ex post.

On the other hand, the cooperative response coefficient $\delta_d^{coop} \equiv (1 - (1 - \gamma)(1 - \rho))/(1 - (1 - \gamma)^2(1 - \rho))$ does *not* set to zero the derivative

$$\frac{d\Omega_d(\rho)}{d\delta_d} = -\frac{(1 - \gamma)}{2\rho} \left[\frac{\rho\delta_d/(1 - (1 - \gamma)(1 - \rho)) - 1}{1 - (1 - \gamma)(1 - \rho)} \right] \sigma_{\kappa_d}^2.$$

To find the Nash value δ_d^{Nash} , we therefore must solve

$$\begin{aligned} \frac{dEU}{d\delta_d} &= \frac{d\Omega_w(\rho)}{d\delta_d} + \frac{d\Omega_d(\rho)}{d\delta_d} = 0 = -\frac{(\delta_d - \delta_d^*)}{4\rho^2}\sigma_{\kappa_d}^2 \\ &- \frac{\{(1 - (1 - \gamma)^2(1 - \rho))/2[1 - (1 - \gamma)(1 - \rho)]\}(\delta_d + \delta_d^*)\sigma_{\kappa_d}^2 - \sigma_{\kappa_d}^2}{2\rho[1 - (1 - \gamma)(1 - \rho)]} \\ &- \frac{(1 - \gamma)}{2\rho} \left[\frac{\rho\delta_d/(1 - (1 - \gamma)(1 - \rho)) - 1}{1 - (1 - \gamma)(1 - \rho)} \right] \sigma_{\kappa_d}^2. \end{aligned}$$

The Nash equilibrium is symmetric with $\delta_d^{Nash} = \delta_d^{*Nash}$, so the preceding equation has the solution given earlier in equation (33).

APPENDIX 2: FLEXIBLE-WAGE EQUILIBRIUM AND TARIFFS

This appendix shows the effect of a Home tariffs on imports in a flexible-wage version of the model. The discussion has the dual purpose of illustrating how tariffs interact with other distortions, and of showing how to solve the flexible-wage model in general.

Tariffs and the Distribution of World Spending

If the ad valorem tariff rate is t and tariff revenues are rebated to the Home public in lump-sum fashion, then the Home consumer's budget constraint is no longer $P_T C_T = P_H Y_H$; instead, it becomes

$$\begin{aligned} P_T C_T &= P_H Y_H + t \mathcal{E} P_F^* C_F = P_H Y_H + \frac{t \mathcal{E} P_F^*}{2} \left[\frac{\mathcal{E} P_F^* (1+t)}{P_T} \right]^{-1} C_T \\ &= P_H Y_H + \frac{1}{2} \left(\frac{t}{1+t} \right) P_T C_T, \end{aligned}$$

where $P_T = [\mathcal{E} P_F^* (1+t)]^{1/2} P_H^{1/2}$ is the domestic-currency price index for tradables inclusive of the tariff's effect on import prices.

In a world equilibrium, nominal global consumer spending on Home exportables equals the receipts of Home producers, so

$$P_H Y_H = \left[1 - \frac{1}{2} \left(\frac{t}{1+t} \right) \right] P_T C_T = \frac{1}{2} P_T C_T + \frac{1}{2} (\mathcal{E} P_F^*)^{1/2} P_H^{1/2} C_T^*.$$

Solving, we find that $C_T = (1+t)^{1/2} C_T^*$, so that instead of equation (8), we have the following relationship between the overall Home and Foreign expenditure levels, measured in tradables at domestic prices: $Z = (1+t)^{1/2} Z^*$.

Solving for World Spending and the Terms of Trade

Using the deterministic version of the Foreign wage first-order condition corresponding to equation (5), writing out P^* in terms of its components, and using the markup condition (6) for product prices, we derive

$$(35) \quad \left(\frac{\mathcal{E} W^*}{W} \right)^{(1-\rho)\gamma/2} = \frac{1}{\psi} K^* L^{*\rho}.$$

Doing the same for Home, but taking account of the tariff's effect on Home import prices and the Home consumer's budget constraint, we find that

$$(36) \quad \left(\frac{W}{\mathcal{E}W^*} \right)^{(1-\rho)\gamma/2} = \frac{(1+t)^{(1-\rho)\gamma/2}}{\psi[1 - (\gamma t/2(1+t))]^\rho} KL^\rho.$$

To complete the model's solution, we furnish the relationships between L and Z and between L^* and $Z = (1+t)^{1/2}Z^*$. From the Foreign budget constraint, $P_T^*Z^* = (\theta/(\theta - 1))W^*L^*$, and the definition of P_T^* , we conclude that

$$(37) \quad L^* = \left[\frac{W}{\mathcal{E}W^*(1+t)} \right]^{1/2} Z.$$

Since $L = Y_H + Y_N$, the equality of demand for and supply of total Home output leads to

$$(38) \quad L = \left[\left(1 - \frac{\gamma}{2} \right) (1+t)^{1/2} + \frac{\gamma}{2} (1+t)^{-1/2} \right] \left(\frac{\mathcal{E}W^*}{W} \right)^{1/2} Z.$$

Using equations (37) and (38) to eliminate L^* and L , respectively, from equations (35) and (36), we obtain two independent relationships that can be solved for Z and $\mathcal{E}W^*/W$ (as we shall do explicitly later in the $t = 0$ case).

Solving for Utility

Combining the Home wage first-order condition and budget constraint, taking account of the tariff rebate, we find that

$$KL = \psi \left[1 - \frac{\gamma t}{2(1+t)} \right] C^{1-\rho}.$$

By equation (3), we may therefore write overall flex-wage utility (as $\chi \rightarrow 0$) as proportional to $C^{1-\rho}/(1 - \rho)$:

$$(39) \quad \tilde{U}(t) = \left\{ \frac{1}{1-\rho} - \psi \left[1 - \frac{\gamma t}{2(1+t)} \right] \right\} C^{1-\rho}.$$

Noting that

$$C = \left[\frac{\mathcal{E}W^*(1+t)}{W} \right]^{(1-\gamma)/2} Z,$$

we see from the purely multiplicative role of terms involving t in equations (35)–(39) that we may write flex-wage utility in the presence of a nonzero tariff t , $\tilde{U}(t)$, as $\tilde{U}(t) = \Gamma(t)\tilde{U}(0)$, where $\tilde{U}(0) = \tilde{U}$, in terms of our earlier notation, and $\Gamma(t)$ is a complicated function of the tariff rate.

The Flexible-Wage Zero-Tariff Solution

With zero tariffs, the symmetry of the equilibrium leads to a quick solution. Equations (35)–(38) imply that in equilibrium,

$$\frac{\mathcal{E}W^*}{W} = \left(\frac{K^*}{K}\right)^{1/(1-(1-\gamma)(1-\rho))}, \quad Z = \left[\frac{\psi}{(KK^*)^{1/2}}\right]^{1/\rho}.$$

These equations are easily combined with the equations for the ex post sticky-wage values of z and e , equations (12) and (11), to calculate the monetary response elasticities replicating the flexible-wage equilibrium, equations (26) and (27).

We may also calculate

$$\tilde{U} = \left(\frac{1}{1-\rho} - \psi\right) C^{1-\rho},$$

where

$$\begin{aligned} C^{1-\rho} &= \left(\frac{\mathcal{E}W^*}{W}\right)^{(1-\gamma)(1-\rho)/2} Z^{1-\rho} \\ &= \left(\frac{K^*}{K}\right)^{((1-\gamma)(1-\rho))/(2[1-(1-\gamma)(1-\rho)])} \left[\frac{\psi}{(KK^*)^{1/2}}\right]^{(1-\rho)/\rho}. \end{aligned}$$

Using the last equations, we find *expected* utility under wage flexibility:

$$\begin{aligned} E\tilde{U} &= \left(\frac{1}{1-\rho} - \psi\right) \psi^{(1-\rho)/\rho} \cdot \exp\left\{-\frac{(1-\rho)}{\rho} E\kappa + \frac{(1-\rho)^2}{2\rho^2} \sigma_{\kappa}^2\right. \\ &\quad \left.- \frac{(1-\rho)^2 \gamma [(1-\gamma/2) - (1-\gamma)(1-\rho)]}{\rho^2 [1 - (1-\gamma)(1-\rho)]^2} \sigma_{\kappa d}^2\right\} \\ &= \left(\frac{1}{1-\rho} - \psi\right) \psi^{(1-\rho)/\rho} \cdot \exp\left\{-\frac{(1-\rho)}{\rho} E\kappa\right. \\ &\quad \left.+ \frac{(1-\rho)^2}{2\rho^2} \sigma_{\kappa}^2 - \frac{(1-\rho)\lambda}{\rho}\right\}. \end{aligned}$$

This formula corresponds to equation (21) in the text.

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