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Monetary Policy Rules in a Two-Country World

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Abstract
This paper computes welfare-maximizing Taylor-style interest rate rules, in a business cycle model of a two-country world. The model assumes staggered price setting, violations of the Law of One Price, due to pricing-to-market, and productivity shocks, as well as shocks to the uncovered interest rate parity (UIP) condition--these shocks can be interpreted as reflecting biased exchange rate forecasts by "noise traders". Optimized policy rules closely replicate the equilibrium under price flexibility. Monetary policy coordination (joint maximization of world welfare) yields very limited welfare gains, compared to the Nash outcome. UIP shocks have a non-negligible negative effect on welfare, especially when these shocks are highly persistent, and when trade linkages between the two countries are strong. The adoption of an exchange rate peg may thus be welfare improving, if the adoption of the peg reduces the variance of the UIP shocks. The model explains thus the propensity of very open economies to peg their exchange rate vis-à-vis their main trading partners.

JEL classification: E4, F3, F4
Keywords: Monetary Policy rules; Open economy; Business cycles

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1. Introduction

This paper studies the effects of monetary policy rules on welfare and business cycles, using a model of a two-country world. The model assumes staggered price setting, departures from the Law of One Price (due to pricing-to-market), physical capital, and incomplete international financial markets (bonds-only) . There are productivity shocks, as well as a shock to the uncovered interest parity (UIP) condition (that can be interpreted as reflecting biased exchange rate forecasts by "noise traders").

Monetary policy in each country is described by a rule according to which the interest rate is set as a function of a GDP and of price inflation. The model is solved using Sims' (2000) new solution technique that is based on a second-order expansion of the equilibrium conditions. Existing normative studies on monetary policy regimes in open economies mostly use highly stylized models for which exact closed form solutions can be derived (e.g., Corsetti and Pesenti (2001), Devereux and Engel (2000), Obstfeld and Rogoff (2001)); the simplifying assumptions made in these models include, in particular: full international risk sharing, and the absence of physical capital. The technique used here allows to dispense with these restrictive assumptions.

In the economy considered here, optimized policy rules closely replicate the equilibrium under price flexibility. Monetary policy coordination (joint maximization of world welfare) yields very limited welfare gains, compared to the Nash outcome—this is the case even when trade linkages between the two countries are strong. Exchange rate volatility induced by UIP shocks may be highly detrimental to welfare, especially under strong trade linkages. An exchange rate peg may be welfare improving, if the peg reduces the variance of the UIP shocks.

Section 2 of this paper presents the model and discusses the solution method, Section 3 presents the results and Section 4 concludes.

2. The model

A two-country world is considered. In each country there are firms, a representative household and a central bank (the structure of preferences and technologies follows Kollmann, 2002, 2001a). Each country produces a single non-tradable final good and a continuum of tradable intermediate goods indexed by $s\in[0,1]$. The final good sector is perfectly competitive. Each country's final good is produced from domestic and imported intermediate goods; the final good is consumed and used for investment. There is monopolistic competition in intermediate goods markets. Intermediate goods producers use domestic capital and labor as inputs (capital and labor are immobile internationally). In each country, the household owns all domestic producers and the capital stock, which it rents to producers. It also supplies labor. The markets for rental capital and for labor are competitive.

Preferences and technologies are symmetric across the countries. Foreign variables are denoted by an asterisk. The following description focuses on the Home country.

2.1. Final good production

The Home final good is produced using the aggregate technology

$$Z_t=\{(\alpha^d)^{1/\vartheta}(Q_t^d)^{(\vartheta-1)/\vartheta}+(\alpha^m)^{1/\vartheta}(Q_t^m)^{(\vartheta-1)/\vartheta}\}^{\vartheta/(\vartheta-1)}\ , \qquad (1)$$

with α^d, $\alpha^m>0$, $\alpha^d+\alpha^m=1$, $\vartheta>0$. Z_t is final good output at date *t*; Q_t^d, Q_t^m are quantity indices of domestic and imported intermediate goods, respectively:

$Q_t^{\mathbf{i}} = \{\int_0^1 q_t^i(s)^{(\nu-1)/\nu} ds\}^{\nu/(\nu-1)}$ with $\nu > 1$, for **i**=d,m, where $q_t^d(s)$ and $q_t^m(s)$ are quantities of the domestic and imported type s intermediate goods. Let $p_t^d(s)$ and $p_t^m(s)$ be the prices of these goods in Home currency. Cost minimization in Home final good production implies:

$$q_t^{\mathbf{i}}(s) = (p_t^{\mathbf{i}}(s)/P_t^{\mathbf{i}})^{-\nu} Q_t^{\mathbf{i}}, \quad Q_t^{\mathbf{i}} = \alpha^{\mathbf{i}} (P_t^{\mathbf{i}}/P_t)^{-\vartheta} Z_t \quad \text{for } \mathbf{i}\text{=d,m}, \tag{2}$$

$$\text{with } P_t^{\mathbf{i}} = \{\int_0^1 p_t^{\mathbf{i}}(s)^{1-\nu} ds\}^{1/(1-\nu)}, \quad P_t = \{\alpha^d (P_t^d)^{1-\vartheta} + \alpha^m (P_t^m)^{1-\vartheta}\}^{1/(1-\vartheta)} . \tag{3}$$

P_t^d [P_t^m] is a price index for domestic [imported] intermediate goods that are sold in the Home market. Perfect competition implies that the price of the Home final good is P_t (its marginal cost is $\{\alpha^d (P_t^d)^{1-\vartheta} + \alpha^m (P_t^m)^{1-\vartheta}\}^{1/(1-\vartheta)}$).

2.2. Intermediate goods firms

The technology of the firm that produces intermediate good s in the Home country is:

$$y_t(s) = \theta_t K_t(s)^{\psi} L_t(s)^{1-\psi}, \quad 0 < \psi < 1. \tag{4}$$

$y_t(s)$ is the firm's output at date *t*; θ_t is an exogenous productivity parameter that is identical for all Home intermediate goods producers; $K_t(s)$ and $L_t(s)$ are the amounts of capital and labor used by the firm.

Let R_t and W_t be the rental rate of capital and the wage rate. Cost minimization implies: $L_t(s)/K_t(s) = \psi^{-1}(1-\psi)R_t/W_t$. The firm's marginal cost is: $MC_t = (1/\theta_t) R_t^{\psi} W_t^{1-\psi} \psi^{-\psi} (1-\psi)^{1-\psi}$.

The firm's good is sold in the domestic market and exported: $y_t = q_t^d(s) + q_t^{m*}(s)$, where $q_t^d(s)$ [$q_t^{m*}(s)$] is domestic [export] demand. The firm faces the following export demand function: $q_t^{m*}(s) = (p_t^{m*}(s)/P_t^{m*})^{-\nu} Q_t^{m*}$, where p_t^{m*} is the firm's export price, in terms of foreign currency.

The profit of a domestic intermediate good producer, π_t^{dx} is:

$$\pi_t(p_t^d(s), p_t^{m*}(s)) = (p_t^d(s) - MC_t)/(p_t^d(s)/P_t^d)^{-\nu} Q_t^d + (e_t p_t^{m*}(s) - MC_t)/(p_t^{m*}(s)/P_t^{m*})^{-\nu} Q_t^{m*}, \tag{7}$$

where e_t is the nominal exchange rate, expressed as the Home currency price of foreign currency.

Motivated by the empirical failure of the Law of One Price, and in particular by widespread pricing-to-market behavior (e.g., Knetter, 1993), it is assumed that intermediate goods producers can price discriminate between the domestic market and the export market ($p_t^d(s) \neq e_t p_t^{m*}(s)$ is possible), and that they set prices in the currencies of their customers.

There is staggered price setting, à la Calvo (1983): intermediate goods firms cannot change prices, in buyer currency, unless they receive a random "price-change signal." The probability of receiving this signal in any particular period is 1-*d*, a constant. Thus, the mean price-change-interval is 1/(1-*d*). Following Yun (1996) and Erceg et al. (2000) it is assumed that when a firm does not receive a "price-change signal," its price is automatically increased at the steady state growth factor of the price level (in the buyer's country). (Throughout this paper, the term "steady state" refers to the deterministic steady state.) Firms are assumed to meet all demand at posted prices.

Consider a Home country intermediate good producer that, at time *t*, sets a new price in the domestic market, $p_{t,t}^d$. If no "price-change signal" is received between t and $t+\tau$, the price is $p_{t,t}^d \Pi^{\tau}$ at $t+\tau$, where Π is the steady state growth factor of the domestic price level.

The firm sets $p^d_{t,t} = Arg\ \underset{\mathbf{p}}{Max} \sum_{\tau=0}^{\tau=\infty} d^\tau E_t\{\rho_{t,t+\tau}\, \pi_{t+\tau}(\mathbf{p}\Pi^\tau, p^x_{t+\tau}(s))/P_{t+\tau}\}$, where $\rho_{t,t+\tau}$ is a pricing kernel (for valuing date $t+\tau$ pay-offs) that equals the household's marginal rate of substitution between consumption at t and at $t+\tau$ (see discussion below). Let $\Xi^d_{t,t+\tau} = \rho_{t,t+\tau}(P_t/P_{t+\tau})Q^d_{t+\tau}(P^d_{t+\tau})^\nu$. The solution of the maximization problem regarding $p^d_{t,t}$ is:

$$p^d_{t,t} = (\nu/(\nu-1))\left\{\sum_{\tau=0}^{\infty}(d\Pi^{-\nu})^\tau E_t \Xi^d_{t,t+\tau} MC_{t+\tau}\right\} \Big/ \left\{\sum_{\tau=0}^{\infty}(d\Pi^{1-\nu})^\tau E_t \Xi^d_{t,t+\tau}\right\}. \quad (8)$$

Analogously, a Home intermediate good producer that gets to choose a new export price at date *t* sets that price at:

$$p^{m*}_{t,t} = (\nu/(\nu-1))\left\{\sum_{\tau=0}^{\infty}(d(\Pi^*)^{-\nu})^\tau E_t \Xi^{m*}_{t,t+\tau} MC_{t+\tau}/e_{t+\tau}\right\} \Big/ \left\{\sum_{\tau=0}^{\infty}(d(\Pi^*)^{1-\nu})^\tau E_t \Xi^{m*}_{t,t+\tau}\right\}, \quad (9)$$

where $\Xi^{m*}_{t,t+\tau} = \rho_{t,t+\tau}(P_t/P_{t+\tau})(e_{t+\tau}/e_t)Q^{m*}_{t+\tau}(P^{m*}_{t+\tau})^\nu$, while Π^* is the steady state growth factor of the Foreign price level.

The price indices P^d_t, P^{m*}_t (see (3), (6)) evolve according to:

$$(P^d_t)^{1-\nu} = d(P^d_{t-1}\Pi)^{1-\nu} + (1-d)(p^d_{t,t})^{1-\nu}; \quad (P^{m*}_t)^{1-\nu} = d(P^{m*}_{t-1}\Pi^*)^{1-\nu} + (1-d)(p^{m*}_{t,t})^{1-\nu}. \quad (11)$$

2.3. The representative household

The preferences of the Home household are described by:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, L_t). \quad (12)$$

E_t denotes the mathematical expectation conditional upon complete information pertaining to period *t* and earlier. C_t and L_t are period *t* consumption and labor effort. $0<\beta<1$ is the subjective discount factor. U is a utility function given by:

$$U(C_t, L_t) = \ln(C_t) - L_t. \quad (13)$$

As indicated earlier, the household owns all domestic producers and accumulates physical capital. The law of motion of the capital stock is:

$$K_{t+1} + \phi(K_{t+1}, K_t) = K_t(1-\delta) + I_t, \quad (14)$$

where I_t is gross investment, $0<\delta<1$ is the depreciation rate of capital, and ϕ is an adjustment cost function: $\phi(K_{t+1},K_t) = \frac{1}{2}\Phi\{K_{t+1}-K_t\}^2/K_t$, $\Phi>0$.

The Home household also holds nominal one-period denominated in Home and in Foreign currency. In order to ensure stationarity of the dynamic equilibrium (which allows to solve the model using the Sims (2000) method), it is assumed that the Household bears financial transaction/intermediation costs that are quadratic functions of the stocks of Home and Foreign currency bonds, respectively. (Without these costs, the model is a version of the permanent income theory of consumption, and net assets and consumption are non-stationary.) The period *t* budget constraint of the Home household is:

$$A_{t+1} + e_t B_{t+1} + \varphi^A_t(A_{t+1}) + \varphi^B_t(B_{t+1}) + P_t(C_t + I_t) = A_t(1+i_{t-1}) + e_t B_t(1+i^*_{t-1}) + R_t K_t + \int_0^1 \pi_t(s)\,ds + W_t L_t. \quad (15)$$

A_t and B_t are net stocks of Home and Foreign currency bonds that mature in period *t*, while i_{t-1} and i^*_{t-1} are the interest rates on these bonds. $\varphi^A_t(A_{t+1}) = P^d_t \frac{1}{2}\phi^A \cdot (A_{t+1}/P^d_t)^2$ and $\varphi^B_t(B_{t+1}) = P^d_t \frac{1}{2}\phi^B \cdot (B_{t+1}e_t/P^d_t)^2$ (where $\phi^A, \phi^B \geq 0$), are the period t financial transaction costs.

The household chooses a strategy $\{A_{t+1}, B_{t+1}, K_{t+1}, C_t, L_t\}_{t=0}^{t=\infty}$ to maximize its expected lifetime utility (12), subject to constraints (14) and (15) and to initial values A_0, B_0, K_0. Ruling out Ponzi schemes, the following equations are first-order conditions of this decision problem:

$$1 = \frac{1+i_t}{1+\phi^A \cdot (A_{t+1}/P_t^d)} E_t\{\rho_{t,t+1}(P_t / P_{t+1})\}, \tag{16}$$

$$1 = \frac{1+i_t^*}{1+\phi^B \cdot (B_{t+1}e_t)/P_t^d} E_t\{\rho_{t,t+1}(P_t / P_{t+1})(e_{t+1}/e_t)\}, \tag{17}$$

$$1 = E_t\{\rho_{t,t+1}(R_{t+1}/P_{t+1} + 1 - \delta - \phi_{2,t+1})/(1+\phi_{1,t})\}, \tag{18}$$

$$W_t / P_t = C_t, \tag{19}$$

where $\rho_{t,t+1} = \beta C_t / C_{t+1}$, $\phi_{1,t} = \partial\phi(K_{t+1}, K_t)/\partial K_{t+1}$, $\phi_{2,t+1} = \partial\phi(K_{t+2}, K_{t+1})/\partial K_{t+1}$. (16)-(18) are Euler conditions, and (19) says that the household equates its marginal rate of substitution between consumption and leisure to the real wage rate.

2.4. Uncovered interest parity

Taking a (log-)linear approximation (around $A_{t+1} = B_{t+1} = 0$) (16) and (17) yields:

$$E_t \ln(e_{t+1}/e_t) \cong i_t - i_t^* - \phi^A (A_{t+1}/P_t^d) + \phi^B (B_{t+1}e_t/P_t^d).$$

Because of transaction costs in bond markets (and because of the second order terms that have been suppressed in this (log-) linear approximation), uncovered interest parity (UIP) (i.e. the condition $E_t \ln(e_{t+1}/e_t) = i_t - i_t^*$) does **not** hold in the model here. However, departures from UIP that are caused by transaction costs (and by second order terms) turn out to be very small, in the model simulations discussed below (i.a. because the values of the adjustment cost parameters ϕ^A, ϕ^B used below are close to zero). Given the well-documented strong and persistent empirical departures from UIP during the post-Bretton Woods era (e.g., Lewis, 1995), variants of the model are explored in which the Home Euler condition for Foreign currency bonds (17) is disturbed by a stationary exogenous stochastic random variable, φ_t ("UIP shock," henceforth):

$$1 = \frac{1+i_t^*}{1+\phi^B \cdot (B_{t+1}e_t)/P_t^d} \varphi_t \; E_t\{\rho_{t,t+1}(P_t / P_{t+1})(e_{t+1}/e_t)\}. \tag{20}$$

Up to a (log-)linear approximation (around $A_{t+1} = B_{t+1} = 0$, $\varphi_t = 1$) (16) and (20) imply

$$E_t \ln(e_{t+1}/e_t) \cong i_t - i_t^* - \phi^A \cdot (A_{t+1}/P_t^d) + \phi^B \cdot (B_{t+1}e_t/P_t^d) - \ln(\varphi_t). \tag{21}$$

As discussed in the Appendix, φ_t can be interpreted as reflecting a bias in the Home household's date *t* forecast of the date *t*+1 exchange rate, e_{t+1}. It is assumed that Home and Foreign households make identical exchange rate forecasts—and, thus that these forecasts exhibit the same biases.

The counterparts to (16), (20) and (21), for the Foreign household are:

$$1 = \frac{1+i_t^*}{1+\phi^{B*} \cdot (B_{t+1}^*/P_t^{d*})} E_t\{\rho_{t,t+1}^*(P_t^*/P_{t+1}^*)\}, \quad 1 = \frac{1+i_t}{1+\phi^{A*} \cdot A_{t+1}^*/(e_t P_t^{d*})} \frac{1}{\varphi_t} E_t\{\rho_{t,t+1}^*(P_t^*/P_{t+1}^*)(e_t/e_{t+1})\}, \tag{22}$$

$$E_t \ln(e_{t+1}/e_t) \cong i_t - i_t^* - \phi^{A*} \cdot A_{t+1}^*/(e_t P_t^{d*}) + \phi^{B*} \cdot (B_{t+1}^*/P_t^{d*}) - \ln(\varphi_t) \tag{23}$$

where A_t^* and B_t^* are the (net) stocks of Home- and Foreign-currency bonds held by the Foreign representative household.

(Frankel and Froot, 1989, document biases in exchange rate forecasts; structural models with UIP shocks have, i.a., been studied by Mark and Wu, 1998; Jeanne and Rose, 2002; McCallum and Nelson, 1999, 2000; Taylor, 1993b.)

2.5. Market clearing conditions

Supply equals demand in intermediate goods markets because intermediate goods firms meet all demand at posted prices. In the Home country, market clearing for the final good, labor, and rental capital requires:

$$Z_t = C_t + I_t, \quad L_t = \int_0^1 L_t(s)ds, \quad K_t = \int_0^1 K_t(s)ds, \tag{24}$$

Z_t, L_t and K_t are the supplies of the Home final good, of Home labor, and of Home rental capital, respectively, while $\int_0^1 L_t(s)ds$ and $\int_0^1 K_t(s)ds$ represent total demand for Home labor and capital (by Home intermediate goods producers).

Market clearing for bonds requires:

$$A_t + A_t^* = 0, \quad B_t + B_t^* = 0. \tag{25}$$

2.6. Monetary policy rules

Much recent research on monetary policy regimes has focused on rules that stipulate a response of the interest rate to inflation and to real GDP (e.g., Taylor, 1993a, 1999). The following baseline rules for Home and Foreign monetary policy are considered here:

$$i_t = i + \Gamma_\pi \widehat{\Pi}_t^d + \Gamma_y \widehat{Y}_t \quad \text{and} \quad i_t^* = i^* + \Gamma_\pi^* \widehat{\Pi}_t^{d*} + \Gamma_y^* \widehat{Y}_t^* \tag{26}$$

with $\widehat{\Pi}_t^d = (\Pi_t^d - \Pi)/\Pi$, $\widehat{Y}_t = (Y_t - Y)/Y$, where $\Pi_t^d = P_t^d / P_{t-1}^d$ is the growth factor of the Home price index of domestic intermediate goods that are sold in the Home market--(gross) Home domestic PPI inflation. Y_t is Home real GDP. i and Y are the steady state Home nominal interest rate and steady state Home GDP, respectively. Throughout the paper, variables without time subscripts denote steady state values, and $\hat{x}_t = (x_t - x)/x$ is the relative deviation of a variable x_t from its steady state value, x. Γ_π, Γ_y, Γ_π^* and Γ_y^* in (25) are parameters. Each central bank commits to setting the parameters of its policy rules at time-invariant values.

A Central Bank that seeks to maximize household welfare would, in general, adopt a feedback rule that stipulates a response of the interest rate to all current and lagged state variables (e.g., Clarida et al., 1999, and Rotemberg and Woodford, 1997). I focus on "simple" rules such as those shown in (26) because: (i) simple rules appear to capture quite well actual central bank behavior (e.g., Taylor, 1993a, 1999); (ii) the use simple rules facilitates commitment as the public can easily monitor whether central banks sticks to such rules; (iii) computationally, it does not seem feasible to determine the unrestricted welfare maximizing rule for the complex model considered here.

The following policy arrangements will be considered:

(i) A regime of international monetary **cooperation**, in which the policy parameters of both central banks are set at the values that maximize 'world' welfare, defined as the sum of the unconditional expected values of Home and Foreign utility $E(U(C_t, L_t)) + E(U(C_t^*, L_t^*))$.

(ii) A **Nash** game in which each central bank selects the policy parameters that maximize the unconditional utility of 'its' household, taking as given the policy parameters of the other central bank.

(iii) An **exchange rate peg**. A unilateral peg and a bilateral peg will be considered. Under the unilateral peg, the central bank of one of the countries follows an interest rate rule of the type indicated in (25), and it maximizes the welfare of 'its' household, while the central bank of the other country pegs the nominal exchange rate. In the bilateral peg, the mean world interest rate is set as a function of world PPI inflation and world output:

$$(i_t + i_t^*)/2 = i + \Gamma_\pi^{peg}(\widehat{\Pi}_t^d + \widehat{\Pi}_t^{d*})/2 + \Gamma_y^{peg}(\widehat{Y}_t + \widehat{Y}_t^*)/2,$$

and the policy parameters Γ_π^{peg} and Γ_y^{peg} are set to maximize world welfare ($E(U(C_t, L_t)) + E(U(C_t^*, L_t^*))$).

2.7. Solution method, welfare measures

The model is solved using Sims' (2000) second-order accurate method, and the objective functions of the central banks are maximized numerically with respect to the policy parameters (attention is restricted to parameter values for which a unique stationary equilibrium exists).

A second-order Taylor expansion of the utility function around the steady state gives: $E(U(C_t, L_t)) \cong U(C, L) + E(\widehat{C}_t) - LE(\widehat{L}_t) - Var(\widehat{C}_t)$, where $Var(\widehat{C}_t)$ is the variance of $\widehat{C}_t$. (For the parameter values used below, L=0.74.)

In what follows, welfare is expressed as the permanent relative change in consumption (compared to the steady state), ζ, that yields expected utility $E(U(C_t, L_t))$: $U((1+\zeta)C, L) = U(C, L) + E(\widehat{C}_t) - LE(\widehat{L}_t) - Var(\widehat{C}_t)$. ζ can be decomposed into components, denoted ζ^m and ζ^v, that reflect the means of consumption and hours worked, and the variance of consumption, respectively:

$$U((1+\zeta^m)C, L) = U(C, L) + E(\widehat{C}_t) - LE(\widehat{L}_t), \quad U((1+\zeta^v)C, L) = U(C, L) - Var(\widehat{C}_t).$$

(13) implies $\ln(1+\zeta) = E(\widehat{C}_t) - LE(\widehat{L}_t) - Var(\widehat{C}_t)$, $\ln(1+\zeta^m) = E(\widehat{C}_t) - LE(\widehat{L}_t)$, $\ln(1+\zeta^v) = -Var(\widehat{C}_t)$ and thus $(1+\zeta) = (1+\zeta^m)(1+\zeta^v)$.

2.8. Parameters (non-policy)

The steady state Home and Foreign *real* interest rates are assumed to be identical, $r \equiv (1+i)/\Pi - 1 = (1+i^*)/\Pi^* - 1$. r is set at $r = 0.01$, a value that corresponds roughly to the long-run average return on capital. The subjective discount factor is, hence, set at 1/(1.01), since $\beta(1+r) = 1$ holds in steady state.

φ, the elasticity of substitution between (aggregate) Home and Foreign intermediate goods, in final good production, equals the price elasticity of (aggregate) exports and imports (see (2), (5)). φ is set at φ=1, a value in the range of estimates of prices elasticities of aggregate imports and exports reported by Hooper and Marquez (1995). α^m (see (1)) is set so that the steady state imports GDP ratio is 10%, which corresponds roughly to the imports/GDP ratios of the U.S. (A sensitivity analysis is conducted with respect to α^m.)

The steady state price-marginal cost markup factor for intermediate goods is set at $\nu/(\nu-1) = 1.2$, consistent with the findings of Martins et al. (1996) for G7 countries. The technology parameter ψ (see (4)) is set at $\psi = 0.24$, which entails a 60% steady state labor income/GDP ratio, consistent with data for these countries. Aggregate data suggest a quarterly capital depreciation rate of about 2.5%; thus, δ=0.025 is used. The capital adjustment cost parameter Φ is set at Φ=8 in order to match the fact that the standard deviation of HP filtered log investment is three to four times larger than that of GDP in the sample countries.

The transaction cost parameters for bonds are assumed to be identical across countries: $\phi^A = \phi^{B*}$, $\phi^B = \phi^{A*}$. The modified interest rate parity conditions (21), (23) and the market clearing condition for bonds (25) imply that, up to a (log-)linear approximation (around $A_{t+1} = B_{t+1} = 0$, $\varphi_t = 1$), the stocks of Home currency bonds and of Foreign currency bonds held by a given country each account for half that country's net asset position: e.g., $A_{t+1}/P_t^d \cong \frac{1}{2} \cdot NFA_{t+1}/P_t^d$ and $e_t B_{t+1}/P_t^d \cong \frac{1}{2} \cdot NFA_{t+1}/P_t^d$, where $NFA_{t+1} = A_{t+1} + e_t B_{t+1}$ is the Home net foreign asset position at the end of period t (expressed in Home currency). Substituting these expression into (21) shows that the cross-country interest rate differential depends on the net foreign asset position:

$$i_t - i_t^* \cong E_t \ln(e_{t+1}/e_t) + \tfrac{1}{2}(\phi^A - \phi^B) NFA_t/P_t^d + \ln(\varphi_t). \quad (27)$$

Panel regressions (for 21 OECD countries) presented by Lane and Milesi-Ferretti (2001) [LMF] show that cross-country's interest rate differential are *negatively* related to net foreign assets. In terms of the model here, this suggests that $\phi^A < \phi^B$, i.e. that (loosely speaking) trading in own-currency bonds is less costly than trading in foreign-currency bonds. The LMF estimates imply that $\frac{1}{2}(\phi^A - \phi^B) = -0.0019/Q^{m*}$, where is Q^{m*} is steady state Home exports (see discussion in Appendix). Unfortunately, the LMF study does not allow to separately identify ϕ^A and ϕ^B. I set ϕ^A and ϕ^B at the lowest possible (non-negative) values that are consistent with the LMF estimate for $(\phi^A - \phi^B)$: ϕ^A=0, $\phi^B = 0.0038/Q^{m*}$.

Recent estimates of Calvo-style price setting equations suggest that in G7 economies the average price-change interval is about 4 quarters (e.g., Lopez-Salido (2000)). Hence, *d* is set at *d*=0.75. The steady state growth factors of the domestic and world price levels are set at $\Pi = \Pi^* = 1$. Π and Π^* have no effect on real variables, because of indexing.

Home and Foreign productivity follow this process:

$$\begin{bmatrix} \ln(\theta_t) \\ \ln(\theta_t^*) \end{bmatrix} = \begin{bmatrix} 0.906 & 0.088 \\ 0.088 & 0.906 \end{bmatrix} \begin{bmatrix} \ln(\theta_{t-1}) \\ \ln(\theta_{t-1}^*) \end{bmatrix} + \begin{bmatrix} \varepsilon_t^\theta \\ \varepsilon_t^{\theta*} \end{bmatrix}, \quad (28)$$

where ε_t^θ and $\varepsilon_t^{\theta*}$ are normal white noises with standard deviation 0.0085. The correlation between ε_t^θ and $\varepsilon_t^{\theta*}$ is 0.258. Backus et al. (1995) argue that (27) captures the time series behavior of total factor productivity in the U.S. and in an aggregate of European countries.

Kollmann (2002b) constructs quarterly estimates of departures from UIP between the U.S: dollar and an aggregate of European currencies (Germany, France, Italy), for the period 1973-94. [1] Previous structural models with UIP shocks have assumed that these shocks follow an AR(1) process (Taylor (1993), McCallum and Nelson (1999)). Fitting an AR(1) model to the estimated $\ln(\varphi_t)$ series yields:

$$\ln(\varphi_t) = 0.55 \ln(\varphi_{t-1}) + \varepsilon_t^\varphi, \quad (29)$$

[1] Let $\upsilon_{t+1} \equiv i_t - i_t^* - \ln(e_{t+1}/e_t)$. (21) and ϕ^A=0 imply: $E_t \upsilon_{t+1} = \ln(\varphi_t) - \phi^B \cdot (B_{t+1} e_t / P_t^d)$. If the term $\phi^B \cdot (B_{t+1} e_t / P_t^d)$ is small, then $E_t \upsilon_{t+1} \approx \ln(\varphi_t)$, and an estimate of $\ln(\varphi_t)$ can be obtained by projecting υ_{t+1} on variables in the date t information set. Kollmann (2002) constructs an estimated $\ln(\varphi_t)$ series by regressing υ_{t+1} on lagged values of υ_{t+1}, and on current values and lags 1-4 of Home and Foreign interest rates and GDP (i.e. on $\{\upsilon_{t-s}, i_{t-s}, i_{t-s}^*, Y_{t-s}, Y_{t-s}^*\}_{s=0,..,4}$).

where ε_t^{φ} is a normal white noise with standard deviation 0.0259. One set of simulations discussed below uses this estimated AR(1) process. (Taylor and McCallum-Nelson use similar AR(1) parameters).[2] Hence UIP shocks are rather volatile (standard deviation: 3.10%), and their first-order autocorrelation (0.55) is positive.

However, it appears that this AR(1) process understates the persistence of UIP shocks. The following Table reports autocorrelations of order $\tau = 1,..,8$ of the estimated $\ln(\varphi_t)$ series (standard errors in parentheses):

τ-th order Autocorrelations of quarterly UIP shocks (US-Europe, 1973-94)

τ	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
	0.53	0.31	0.39	0.34	0.28	0.23	0.16	0.19	0.28	0.08	0.08	0.10	0.10	0.15	0.11	0.04
	(0.10)	*(0.09)*	*(0.05)*	*(0.09)*	*(0.12)*	*(0.10)*	*(0.11)*	*(0.13)*	*(0.16)*	*(0.17)*	*(0.13)*	*(0.15)*	*(0.15)*	*(0.13)*	*(0.14)*	*(0.13)*

The historical autocorrelations of order greater than 1 are all larger than the autocorrelations implied by an AR(1) process with a root of 0.55.

The following two-factor model allows to better capture the serial correlation of historical UIP shocks:

$$\ln(\varphi_t) = a_t + u_t, \quad a_t = \lambda a_{t-1} + \varepsilon_t^a, \quad 0 < \lambda < 1 \tag{30}$$

where a_t and ε_t^a are independent white noises with standard deviations σ_a and σ_u, respectively. In (30), the UIP shock is modeled as the sum of a serially correlated random variable and of an i.i.d. random variable. (30) implies that the $\tau - th$ order autocorrelation of $\ln(\varphi_t)$, denoted by $\rho_\varphi(\tau)$ is given by: $\rho_\varphi(\tau) = \lambda^\tau\, \Upsilon$, for $\tau \geq 1$, where $\Upsilon = Var(a_t)/Var(\ln(\varphi_t))$, $Var(a_t) = \sigma_a^2/(1-\lambda^2)$. Fitting (using Non-Linear Least Squares) the equation $\rho_\varphi(\tau) = \lambda^\tau\, \Upsilon$ to the historical autocorrelations shown in the above Table yields these estimates: $\lambda = 0.88$ and $\Upsilon = 0.52$. Under (30), $Var(\ln(\varphi_t)) = Var(a_t) + \sigma_u^2$. Setting $Var(\ln(\varphi_t))$ at its historical value (0.0318), then pins down σ_a and σ_u: $\sigma_a = 0.0120$ and $\sigma_u = 0.0212$.

3. Results

Tables 1-3 show the results. In these Tables, $\Pi_t = P_t/P_{t-1}$ is gross CPI (final good) inflation. $\Delta e = e_t/e_{t-1}$ is the depreciation factor of the nominal exchange rate. $\mu_t^d = P_t^d/MC_t$ and $\mu_t^{m*} = e_t P_t^{m*}/MC_t$ are geometric averages of the markup factors of individual domestic intermediate goods producers in the domestic market and in the export market (e.g., $\mu_t^d = \{\int_0^1 \mu_t^d(s)^{1-\nu} ds\}^{1/(1-\nu)}$, where $\mu_t^d(s) = p_t^d(s)/MC_t$). $RER_t = e_t P_t^*/P_t$ is the Home real exchange rate. NFA_t is the Home net foreign asset position, expressed in units of Home consumption, and normalized by steady state GDP (expressed in units of consumption).

[2] Taylor (1993b) reports estimated standard deviations of UIP innovations of the U.S. vis-à-vis the other G7 countries that range between 0.037 and 0.101. He sets the autocorrelation of the UIP shock at 0.5.

($NFA_t = (A_{t+1}/P_t + e_t B_{t+1}/P_t)/\Upsilon$, where Υ is the steady state value of Y_t^{nom}/P_t, with Y_t^{nom}: Home nominal GDP; see Appendix.) [3]

Predicted standard deviations and mean values of these (and other) variables are shown, as well as impulse responses. The variables are quarterly. The statistics/responses for the domestic interest rate (i_t) and NFA_t refer to differences of these variables from steady state values (i_t is a quarterly rate expressed in fractional units), while statistics/responses for the remaining variables refer to relative deviations from steady state values. All statistics/responses are expressed in percentage terms. Results are presented for simulations in which the economy is subjected to just (Home and Foreign) productivity shocks (see Cols. labeled "Shocks to θ,θ^*," and "Shocks to φ,") and for simulations in which the economy is simultaneously subjected to productivity and UIP shocks (Cols. labeled "Shocks to θ,θ^*,φ").

3.1. Baseline AR(1) specification for UIP shocks

Table 1a shows results for the model with the baseline AR(1) specification forUIP shocks (equation (29)), and a **10% steady state imports/GDP ratio**.

In that version of the model, the optimized response coefficients under cooperation (see Cols. (1)-(3)) are $\Gamma_\pi = 10.61$ and $\Gamma_y = -0.01$. Thus, the optimized rule under cooperation has a strict anti-inflation stance, and the output response coefficient is close to zero. Under the optimized rule, nominal and real exchange rates are highly volatile. The main source of exchange rate movements are UIP shocks. Welfare under the optimized rule (with productivity and UIP shocks) is slightly higher than in the deterministic steady state ($\zeta = 0.008\%$); UIP shocks have a slight negative effect on welfare: $\zeta = -0.006\%$ when the economy is subjected just to UIP shocks.

Cols. (4)-(6) in Table 1a show results for a version of the model with flexible prices ($d = 0$). The behavior of real variables in the sticky-prices economy (under the optimized rule) closely resembles the behavior under flexible prices (the flex-prices variant of the model uses the optimized policy rule derived under sticky prices). (Interestingly welfare is slightly lower under flexible prices: it appears that this is due to the fact that the volatility of asset stocks (A_t, B_t) is somewhat higher under flexible prices—as a result of this, average bond-transaction costs are slightly higher, and mean consumption is slightly lower, in the flex-prices equilibrium).

Col. (7) reports results for the Nash outcome (under sticky prices). In the Nash equilibrium, the policy response coefficients are very similar to those generated under cooperation ($\Gamma_\pi = 8.50$ and $\Gamma_y = -0.01$). As a result, the welfare and business cycle statistics are very similar under the two monetary policy arrangements.

Cols. (8)-(10) report results for a version of the (sticky-prices) model with a (symmetric) peg. When there are UIP shocks, welfare under the peg ($\zeta = -0.14\%$) is markedly lower than under optimized policy, i.a. because UIP shocks induce high volatility of the domestic interest rate, under the peg. However, it seems plausible that a (credible) peg reduces the variance of UIP shocks (see Kollmann (2001)). The subsequent discussion is based on the assumption that the adoption of a peg eliminates the UIP shocks (i.e. drives their

[3] The Foreign real exchange rate is $RER_t^* = P_t/(e_t P_t^*)$, and the Foreign net foreign asset position is $NFA_t^* = (A_{t+1}/(e_t P_t^*) + B_{t+1}/P_t^*)/\Upsilon^*$, where Υ^* is the steady state value of Y_t^{nom*}/P_t^*, with Y_t^{nom*}: Foreign nominal GDP.

variance to zero). Under this assumption, the peg induces just slightly smaller welfare $(\zeta = 0.007)$ than the optimized cooperative rule $(\zeta = 0.008)$.

Table 1b considers a variant of the sticky-prices model (with baseline AR(1) structure for UIP shocks), in which the **steady state imports/GDP ratio is set at 40%**. In that variant, the optimized rules under cooperation has a somewhat less strict anti-inflation stance $(\Gamma_{\pi} = 2.91, \Gamma_{y} = -0.003)$. UIP shocks have a slightly stronger negative effect on welfare, but the welfare effect of these shocks remains small ($\zeta = -0.019\%$, under optimized rule), despite the significant (nominal and real) exchange rate volatility induced by these shocks (under optimized rule). A peg (that eliminates the UIP shocks) now induces higher welfare ($\zeta = 0.006\%$) than the optimized float ($\zeta = -0.016\%$, with joint productivity *and* UIP shocks).

3.2. Two-factor specification of UIP shocks

A shortcoming of the baseline AR(1) specification of the UIP shocks, is that the predicted autocorrelation of the real exchange rate (about 0.5) is markedly lower than that that seen in the data (autocorrelation of linearly detrended log real exchange rate between U.S. and Europe, during post-Bretton Woods era: 0.99).

Tables 2a and 2b consider a version of the model in which UIP shocks are governed by the 2-factor structure (30). In that version, the real exchange rate (under the optimized float) is more volatile (standard deviation: about 15%), and markedly more persistent (autocorrelation: about 0.8). The more persistent UIP shocks in Table 2 have a stronger negative effect on welfare (than the less persistent shocks in Table 1): $\zeta = -0.16\%$, when the steady state imports/GDP ratio is 10%, and $\zeta = -0.30\%$, when the steady state imports/GDP ratio is 40%. Accordingly, a peg (that eliminates the UIP shocks) now induces markedly higher welfare ($\zeta = 0.006$) than the optimized float.

APPENDIX

• UIP shocks and biased exchange rate forecasts

Assume that (Home and Foreign) household *beliefs* at *t* about e_{t+1} are given by a probability density function, f_t^s, that differs from the true pdf, f_t, by a factor $1/\varphi_t$: $f_t^s(e_{t+1},\Omega)=f_t(e_{t+1}/\varphi_t,\Omega)/\varphi_t$, where Ω is any other random variable. The Home [Foreign] Euler equation for foreign currency bonds is then given by (20) [(22)].

• Estimation of λ (see (23))

Up to a (log-)linear approximation, (16), (20), (23) imply $\tilde{r}_t-\tilde{r}_t^*=-\lambda(B_{t+1}/P_t^*)/\chi+E_t\ln(RER_{t+1}/RER_t)+\varphi_t-1$, where $\tilde{r}_t=i_t-E_t\ln(P_{t+1}/P_t)$ and $\tilde{r}_t^*=i_t^*-E_t\ln(P_{t+1}^*/P_t^*)$ are expected domestic and world real interest rates, and $RER_t=e_tP_t^*/P_t$ is the real exchange rate. Lane and Milesi-Ferretti (2001) fit this equation to a panel of 21 OECD economies, using annualized % interest rates and net foreign assets (NFA) normalized by annual exports. Based on instrumental variables (allowing for country fixed-effects), estimates of about 3 are obtained for the coefficient of the normalized NFA (Table 7, Cols. 5-8). In terms of the relation between quarterly fractional interest rate differentials and NFA normalized by quarterly exports, this implies a coefficient $\lambda=3/1600\cong 0.0019$ (the value used in the simulations).

• Price setting in the intermediate goods sector

A domestic firm that gets to choose a new domestic price at date *t* sets that price at (see (8)):

$$p_{t,t}^d=(\nu/(\nu-1))\{\sum_{\tau=0}^{\tau=\infty}\lambda_{t,t+\tau}E_tMC_{t+\tau}/\Pi^\tau\}+(\nu/(\nu-1))\frac{\sum_{\tau=0}^{\tau=\infty}(d\Pi^{1-\nu})^\tau Cov_t(\Xi_{t,t+\tau}^d,MC_{t+\tau}/\Pi^\tau)}{\sum_{\tau=0}^{\tau=\infty}(d\Pi^{1-\nu})^\tau E_t\Xi_{t,t+\tau}^d}$$

$$\text{where } \lambda_{t,t+\tau}=(d\Pi^{1-\nu})^\tau E_t\Xi_{t,t+\tau}^d/\{\sum_{\tau=0}^{\tau=\infty}(d\Pi^{1-\nu})^\tau E_t\Xi_{t,t+\tau}^d\},\quad \text{with } \sum_{\tau=0}^{\tau=\infty}\lambda_{t,t+\tau}=1.$$

($Cov_t(x,y)\equiv E_txy-E_txE_ty$: conditional covariance between x and y.) Hence, $p_{t,t}^d$ equals a weighted average of expected future (detrended) marginal costs (multiplied by the steady state markup factor $\nu/(\nu-1)$), *plus* a weighted sum of (conditional) covariances between future marginal costs and $\Xi_{t,t+\tau}^d=\beta^\tau(C_t/C_{t+\tau})(P_t/P_{t+\tau})Q_{t+\tau}^d(P_{t+\tau}^d)^\nu$. $Cov_t(\Xi_{t,t+\tau}^d,MC_{t+\tau}/\Pi^\tau)$ (and, thus, $p_{t,t}^d$) is higher, the higher the covariance between $MC_{t+\tau}/\Pi^\tau$ and date $t+\tau$ demand for the product sold by the firm (that demand is proportional to $Q_{t+\tau}^d(P_{t+\tau}^d)^\nu$; see (2)).

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Table 1a. Baseline model (AR(1) UIP shocks), 10% imports/GDP ratio

	Cooperation: Sticky prices			Cooperation: Flexible prices			Nash: Sticky prices	Symmetric Peg: Sticky prices		
	Shocks to:			Shocks to:			Shocks to:	Shocks to:		
	θ,θ^*,φ	θ,θ^*	φ	θ,θ^*,φ	θ,θ^*	φ	θ,θ^*,φ	θ,θ^*,φ	θ,θ^*	φ
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*
Standard deviations (in %)										
Y	8.26	8.26	0.12	8.27	8.27	0.31	8.26	8.88	8.21	3.38
C	8.03	8.04	0.21	8.06	8.02	0.75	8.04	8.52	8.00	2.91
I	10.24	10.21	0.74	10.68	10.09	3.48	10.23	16.74	9.83	13.55
Π	0.06	0.02	0.06	0.69	0.10	0.69	0.06	0.32	0.10	0.31
Π^d	0.01	0.01	0.00	0.01	0.01	0.00	0.02	0.40	0.12	0.38
i	0.15	0.15	0.00	0.15	0.15	0.03	0.16	1.90	0.04	1.90
Δe	7.15	1.05	7.07	6.98	1.04	6.90	7.14	0.00	0.00	0.00
RER	6.89	1.80	6.65	5.60	1.59	5.37	6.88	2.05	0.90	1.84
NFA	4.41	0.46	4.39	4.63	0.41	4.61	4.41	5.24	0.22	5.24
A	2.07	0.22	2.05	2.17	0.19	2.16	2.07	2.46	0.10	2.45
B	2.07	0.22	2.05	2.17	0.19	2.16	2.07	2.46	0.10	2.45
μ^d	0.03	0.03	0.00	0.00	0.00	0.00	0.03	3.94	0.71	3.87
μ^m	6.01	1.14	5.89	0.00	0.00	0.00	6.00	3.94	0.71	3.87
Means (in %)										
Y	0.38	0.35	0.03	0.38	0.35	0.03	0.38	0.36	0.34	0.02
C	0.35	0.33	0.01	0.34	0.34	0.01	0.34	0.24	0.32	-0.08
Q^d	0.36	0.35	0.01	0.36	0.35	0.01	0.36	0.26	0.34	-0.08
Q^m	0.43	0.32	0.11	0.61	0.35	0.26	0.44	0.69	0.34	0.35
L	0.03	-0.00	0.03	0.03	-0.00	0.03	0.03	0.04	-0.00	0.04
K	0.45	0.40	0.04	0.45	0.40	0.04	0.45	0.43	0.39	0.04
RER	0.23	0.02	0.22	0.15	0.01	0.14	0.23	0.02	0.00	0.02
NFA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	-0.02
A	-4.42	-0.01	-4.41	-4.29	-0.01	-4.28	-4.42	-0.03	-0.00	-0.03
B	4.42	0.01	4.41	4.29	0.01	4.28	4.42	0.03	0.00	0.03
μ^d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.01	0.26
μ^m	0.11	0.03	0.08	0.00	0.00	0.00	0.11	-0.10	0.01	-0.11
First-order autocorrelations										
Y	0.99	0.99	0.97	0.99	0.99	0.54	0.99	0.90	0.99	0.33
Δe	-0.24	-0.08	-0.25	-0.24	-0.08	-0.25	-0.24	---	---	---
RER	0.47	0.83	0.44	0.50	0.86	0.47	0.47	0.94	0.97	0.94
Welfare (% equivalent variation in consumption)										
ζ	0.008	0.015	-0.006	0.001	0.018	-0.017	0.008	-0.141	0.007	-0.149
ζ^m	0.332	0.338	-0.006	0.326	0.340	-0.014	0.332	0.221	0.328	-0.106
ζ^v	-0.322	-0.322	-0.000	-0.324	-0.321	-0.003	-0.329	-0.362	-0.319	-0.042

Notes: $\boldsymbol{\theta}$: productivity; $\boldsymbol{i^*}$: world interest rate; $\boldsymbol{\varphi}$: UIP shock; $\boldsymbol{P^*}$: world price level; ***Y***: GDP; ***C***: consumption; ***I***: investment; $\boldsymbol{\Pi}$: gross CPI (final good) inflation; $\boldsymbol{\Pi}^d$: gross domestic PPI inflation; ***i***: *d*omestic nominal interest rate; $\Delta \boldsymbol{e}$: depreciation factor of nominal exchange rate; ***RER***: real exchange rate; ***NFA***: net foreign assets (expressed in units of foreign good and normalized by steady state GDP); $\boldsymbol{\mu}^d$, $\boldsymbol{\mu}^x$, $\boldsymbol{\mu}^m$: average markup factors of domestic intermediate goods producers in the domestic market and in the export markets, and of importers; $\boldsymbol{Q}^d$, $\boldsymbol{Q}^x$: domestic intermediate goods sold domestically and exported;: $\boldsymbol{Q}^m$ imports; ***L***: hours worked; ***K***: capital stock; ζ , ζ^m , ζ^v : welfare measures.

Standard deviations and means of i and NFA refer to differences from steady state values; statistics for the remaining variables refer to relative deviations from steady state values. All statistics have been multiplied by 100, i.e. expressed in percentage terms.

Table 1b. Other variants of sticky-prices model (AR(1) UIP shocks)

	40% Imports/GDP ratio			
	Cooperation:		Nash:	Peg
	θ,θ^*,φ	φ	θ,θ^*,φ	θ,θ^*
	(1)	*(2)*	*(3)*	*(4)*
Standard deviations (in %)				
Y	8.24	0.59	8.24	8.20
C	8.06	0.83	8.06	7.99
I	10.49	2.99	10.51	9.76
Π	0.25	0.24	0.25	0.02
Π^d	0.07	0.01	0.07	0.12
i	0.23	0.04	0.23	0.04
Δe	6.99	6.91	6.99	0.00
RER	6.00	5.88	6.00	0.20
NFA	18.80	18.77	18.82	0.22
A	8.82	8.80	8.82	0.10
B	8.82	8.80	8.82	0.10
μ^d	0.17	0.03	0.15	0.71
μ^m	5.88	5.75	5.88	0.71
Means (in %)				
Y	0.48	0.59	0.48	0.34
C	0.38	0.83	0.38	0.32
Q^d	0.39	0.04	0.39	0.33
Q^m	0.48	0.16	0.48	0.33
L	0.12	0.12	0.12	-0.00
K	0.58	0.19	0.58	0.389
RER	0.18	0.17	0.18	0.00
NFA	0.05	0.06	0.06	-0.00
A	-17.08	-17.06	-17.07	-0.00
B	17.08	17.06	17.07	0.00
μ^d	0.00	0.00	0.00	0.01
μ^m	0.09	0.06	0.09	0.01
First-order autocorrelations				
Y	0.99	0.94	0.99	0.99
Δe	-0.25	-0.25	-0.25	-0.99
RER	0.39	0.37	0.39	0.96
Welfare (% equivalent variation in consumption)				
ζ	-0.016	-0.019	-0.016	0.006
ζ^m	0.308	-0.016	0.308	0.326
ζ^v	-0.324	-0.003	-0.324	-0.319

Table 2a. Baseline model; UIP shocks: two-factor structure; 10% imports/GDP ratio

	Cooperation:						Nash:	Symmetric Peg		
	Sticky prices			Flexible prices			Sticky prices	Sticky prices		
	Shocks to:			Shocks to:			Shocks to:	Shocks to:		
	θ,θ^*,φ	θ,θ^*	φ	θ,θ^*,φ	θ,θ^*	φ	θ,θ^*,φ	θ,θ^*,φ	θ,θ^*	φ
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Standard deviations (in %)										
Y	8.29	8.26	0.69	8.32	8.27	0.95	8.29	9.67	8.21	5.11
C	8.12	8.03	1.18	8.25	8.02	1.93	8.12	9.48	8.00	5.08
I	10.86	10.19	3.75	12.26	10.09	6.96	10.86	23.75	9.83	21.61
Π	0.18	0.02	0.18	0.90	0.10	0.89	0.18	0.83	0.10	0.82
Π^d	0.03	0.03	0.00	0.03	0.03	0.01	0.03	1.04	0.12	1.03
i	0.16	0.16	0.02	0.17	0.17	0.04	0.16	1.82	0.04	1.82
Δe	9.26	1.01	9.20	9.01	1.03	8.96	9.26	0.00	0.00	0.00
RER	14.97	1.74	14.86	13.01	1.59	12.91	14.97	8.26	0.90	8.21
NFA	26.54	0.45	26.53	26.97	0.41	26.97	26.54	28.22	0.22	28.21
A	12.44	0.21	12.44	12.65	0.19	12.65	12.44	13.24	0.10	13.23
B	12.44	0.21	12.44	12.65	0.19	12.65	12.44	13.24	0.10	13.23
μ^d	0.06	0.06	0.01	0.00	0.00	0.00	0.06	5.96	0.71	5.92
μ^m	9.65	1.13	9.59	0.00	0.00	0.00	9.65	5.96	0.71	5.92
Means (in %)										
Y	0.58	0.35	0.22	0.58	0.35	0.23	0.58	0.52	0.34	0.17
C	0.31	0.33	-0.02	0.37	0.34	0.03	0.31	-0.10	0.32	-0.43
Q^d	0.42	0.35	0.07	0.44	0.35	0.08	0.42	-0.06	0.34	-0.40
Q^m	0.67	0.32	0.35	1.85	0.35	1.50	0.67	1.86	0.34	1.52
L	0.23	-0.00	0.23	0.21	-0.00	0.21	0.23	0.27	-0.00	0.27
K	0.62	0.40	0.22	0.69	0.40	0.28	0.63	0.47	0.39	0.08
RER	1.12	0.01	1.10	0.84	0.01	0.83	1.12	0.34	0.00	0.33
NFA	-0.26	-0.00	-0.25	-0.31	-0.00	-0.30	-0.26	-0.46	-0.00	-0.46
A	-9.20	-0.01	-9.20	-8.94	-0.01	-8.93	-9.20	-0.52	-0.00	-0.52
B	9.20	0.01	9.20	8.94	0.01	8.93	9.20	0.52	0.00	0.52
μ^d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.01	5.92
μ^m	0.70	0.03	0.67	0.00	0.00	0.00	0.70	-0.27	0.01	5.92
First-order autocorrelations										
Y	0.99	0.99	0.98	0.99	0.99	0.89	0.99	0.88	0.99	0.58
Δe	-0.12	-0.08	-0.12	-0.12	-0.08	-0.12	-0.12	---	---	-0.48
RER	0.81	0.83	0.81	0.84	0.86	0.84	0.81	0.98	0.97	0.98
Welfare (% equivalent variation in consumption)										
ζ	-0.152	0.015	-0.167	-0.102	0.018	-0.120	-0.152	-0.720	0.007	-0.727
ζ^m	0.178	0.338	-0.159	0.238	0.340	-0.101	0.178	-0.273	0.328	-0.599
ζ^v	-0.329	-0.322	-0.007	-0.340	-0.321	-0.018	-0.329	-0.448	-0.319	-0.129

Table 2b. Other variants of sticky-prices model (UIP shocks: two-factor structure)

	40% Imports/GDP ratio			
	Cooperation:		Nash:	Peg
	θ,θ^*,φ	φ	θ,θ^*,φ	θ,θ^*
	(1)	*(2)*	*(3)*	*(4)*
Standard deviations (in %)				
Y	8.53	2.29	8.53	8.20
C	8.67	3.31	8.67	7.99
I	14.89	11.04	14.89	9.76
Π	0.54	0.53	0.54	0.02
Π^d	0.15	0.08	0.15	0.12
i	0.30	0.15	0.30	0.04
Δe	8.23	8.18	8.23	0.00
RER	8.81	8.76	8.81	0.20
NFA	76.62	76.61	76.62	0.22
A	35.93	35.93	35.93	0.10
B	35.93	35.93	35.93	0.10
μ^d	0.35	0.20	0.35	0.71
μ^m	8.40	8.33	8.40	0.71
Means (in %)				
Y	0.96	0.62	0.96	0.34
C	0.43	0.11	0.43	0.32
Q^d	0.59	0.24	0.59	0.33
Q^m	0.80	0.48	0.80	0.33
L	0.59	0.59	0.59	-0.00
K	1.15	0.76	1.15	0.39
RER	0.38	0.38	0.38	0.00
NFA	-0.01	-0.01	-0.01	-0.00
A	-29.37	-29.38	-29.40	-0.00
B	29.37	29.39	29.40	0.00
μ^d	0.01	0.00	0.01	0.01
μ^m	0.31	0.30	0.33	0.01
First-order autocorrelations				
Y	0.99	0.98	0.99	0.99
Δe	-0.14	-0.14	-0.14	---
RER	0.63	0.63	0.63	0.96
Welfare (% equivalent variation in consumption)				
ζ	-0.306	-0.307	-0.306	0.006
ζ^m	0.069	-0.252	0.069	0.326
ζ^v	-0.375	-0.054	-0.375	-0.319

Table 3. Sticky-prices model, more persistent UIP shocks--parameters picked to match post-BW std & autocorr. of RER (AR(1) with 0.99 root; std of innovation: 0.268%); 10% imports/GDP ratio

	Cooperation:		Nash:	Peg
	θ,θ^*,φ	φ	θ,θ^*,φ	θ,θ^*
	(1)	*(2)*	*(3)*	*(4)*
Standard deviations (in %)				
Y	8.33	1.07	8.33	8.21
C	8.23	1.76	8.23	8.00
I	10.58	2.81	10.58	9.83
Π	0.13	0.13	0.13	0.10
Π^d	0.02	0.00	0.03	0.12
i	0.16	0.02	0.16	0.04
Δe	4.56	4.44	4.56	0.00
RER	13.38	13.26	13.38	0.90
NFA	74.68	74.68	74.68	0.22
A	35.02	35.02	35.02	0.10
B	35.02	35.02	35.02	0.10
μ^d	0.04	0.00	0.05	0.71
μ^m	5.19	5.06	5.19	0.71
Means (in %)				
Y	0.84	0.49	0.84	0.34
C	0.34	0.00	0.34	0.32
Q^d	0.72	0.36	0.72	0.34
Q^m	1.26	0.93	1.26	0.34
L	0.49	0.49	0.49	-0.00
K	0.90	0.49	0.90	0.39
RER	0.89	0.88	0.89	0.00
NFA	-2.27	-2.27	-2.27	-0.00
A	-5.03	-5.02	-5.03	-0.00
B	5.03	5.02	5.03	0.00
μ^d	0.05	0.00	0.00	0.01
μ^m	0.26	0.23	0.26	0.01
First-order autocorrelations				
Y	0.99	0.99	0.99	0.99
Δe	-0.02	-0.02	-0.02	---
RER	0.94	0.94	0.94	0.97
Welfare (% equivalent variation in consumption)				
ζ	-0.299	-0.314	-0.299	0.007
ζ^m	0.038	-0.299	0.038	0.328
ζ^v	-0.338	-0.015	-0.338	-0.319