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Price Stability with Imperfect Financial Integration

This paper studies whether the international monetary system can be affected by asymmetries in the cross-country positions in the international financial markets, i.e., the fact that some countries are large debtors while others are creditors. An important channel that is explored is the interaction between international risk sharing and the stabilization role of monetary policy in each country. The main finding is that the welfare costs of incomplete markets and the gains of deviating from a policy of price stability are increasing with the cross-country asymmetries in the initial net international positions and in particular they become nonnegligible when the persistence of the shocks increases (1% of a permanent shift in steady-state consumption, for the welfare costs of incomplete markets, and 0.2%, for the gains of deviating from a policy of price stability). When global imbalances become larger, optimal monetary policy requires an increase in the volatilities of the real returns on assets and in particular of the nominal interest rates, which should happen to be more correlated across countries.

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THE LAST 15 years have recorded sizable and unprecedented current account deficits run by the United States accompanied by a gradual deterioration of the U.S. net international investment position that reached −22% of GDP in the year 2005 and has improved to −17% in 2007. Almost three-quarters of the world's surpluses are absorbed by the U.S. deficit. As documented by Lane and Milesi-Ferretti (2002), these developments have been paralleled by an increase in international financial diversification through instruments of different risk and liquidity characteristics. For the United States both assets and liabilities have increased up to 128% and 145% of GDP. These developments are usually welcomed for the gains that arise because of more integrated financial markets. Still, net negative positions in the international markets matter and global imbalances might have important negative macroeconomic consequences.

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This paper studies whether the international monetary system can be affected by the presence of large asymmetries in the positions in international financial markets, i.e., the fact that some countries are large debtors while others are creditors. An important channel that will be explored is the interaction between international risk sharing and the stabilization role of monetary policy. In an important paper Obstfeld and Rogoff (2002) have shown that in a distorted economy with lack of full international risk-sharing self-oriented policies that achieve price stability in each country can replicate the cooperative outcome. The spillovers that monetary policymakers have on the risk-sharing margin are of second-order importance. This paper readdresses this issue in a two-country dynamic model that solves for the optimal cooperative monetary policy when countries have nonzero, but specular, positions in the international financial markets.

The understanding of whether there should be deviations from a policy of price stability at the international level goes parallel with the analysis of the costs of market incompleteness. The main finding is that the welfare costs of incomplete markets are increasing with the cross-country asymmetries in the initial net international positions and in particular they become nonnegligible when the persistence of the shocks increases. In the baseline scenario they are smaller than 0.20% of a permanent increase in steady-state consumption and they increase up to 1% with the persistence of the shocks. In these cases there are also important gains of deviating from a policy of price stability, above 0.2%.

Whereas optimal monetary policy requires a modest increase in the volatility of the producer-price inflation rates, the important adjustment should come through an increase in the volatility of real returns on assets traded. This is mostly reflected in an increase in the volatility of the nominal interest rates in both countries. Indeed, appropriate movements in the asset returns and so valuation effects can correct asymmetries in the business cycle synchronization improving risk sharing. Moreover, optimal monetary policy—in the calibrated example—requires more synchronization of the cross-country nominal interest rates when global imbalances increase. Instead, a policy of price stability commands a mildly positive correlation which is independent of the size of the global imbalances.

The welfare costs of incomplete markets and the optimal monetary policy regime are analyzed using a linear-quadratic solution method in a two-country model in which two bonds, issued in different currencies, are traded. Benigno and Woodford (2006) have shown that linear-quadratic solution methods are appropriate, as a first-order approximation of the optimal solution, for a general class of models. One important exception is the case in which the zero-order approximation is indeterminate, which turns out to be the relevant case for portfolio shares when portfolio choices are considered. In this paper, this problem is resolved by assuming the existence of transaction frictions in trading the two bonds as in Ghironi, Lee, and Rebucci (2006). However, Ghironi, Lee, and Rebucci focus on the case in which only equities are traded and do not consider optimal policies. Without trading frictions, a zero-order approximation will not determine portfolio shares which are instead going to be function of the ratio of second-order moments, as discussed in Devereux and Sutherland (2006). However, in this case, a linear-quadratic solution method, as an approximation of the optimal policy, would not be feasible.[1]

The detailed structure of the work is as follows. Section 1 presents the model. Section 2 discusses the steady state of the model and Section 3 shows the log-linear approximation of the equilbrium conditions. Section 4 presents the welfare criterion while Section 5 computes the welfare costs of incomplete markets under a policy of price stability and the gains obtained by pursuing the optimal cooperative policy, assuming zero initial foreign asset holdings. Finally, Section 6 concludes.

1. THE MODEL

The model belongs to the class of dynamic stochastic general equilibrium models that have been used for the evaluation of monetary policy both in the closed and open-economy literature. The important novelty is the treatment of an incomplete-market asset structure that can be directly compared to the complete-market one used in the literature (see among others Benigno and Benigno 2003, 2006, Corsetti and Pesenti 2006, Devereux and Engel 2003, Kollmann 2002, Obstfeld and Rogoff 2002). Our utility-based welfare criterion can also allow for a direct evaluation of the welfare costs of imperfect risk sharing, with particular emphasis on the different assumptions on the structural parameters of the model, the nature of the shocks—whether supply or demand—and the role of monetary policy.[2]

We consider a world with two countries, home (H) and foreign (F). The population on the segment $[0, n]$ belongs to country H while the population on the segment $(n, 1]$ belongs to country F. In each country, a continuum of differentiated goods is produced with measure equal to the population size. The utility of a generic consumer j belonging to country H is

$$U^j = \mathrm{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{j\,1-\rho} g_t}{1-\rho} - \frac{1}{n} \int_0^n \frac{y_t^j(h)^{1+\eta} z_t^{-(1+\eta)}}{1+\eta} dh \right] \right\},$$

where E_0 denotes the expectation conditional on the information set at date 0, while β is the intertemporal discount factor, with $0 < \beta < 1$.

Households enjoy utility from goods consumption, while they receive disutility from producing goods. The utility function is separable in these two factors. Moreover, in each country, a generic household contributes to the production of all the goods with

1. Benigno (Forthcoming) performs an analysis of valuation effects from a welfare perspective in a model without transaction costs and with multiple assets traded but in a perfect foresight, so that the steady-state portfolio allocation can be taken as given. In a stochastic model, within specific class of policy rules, it is possible to make comparisons of the equilibrium allocation across alternative policies as in Devereux and Sutherland (2007).

2. A nonexhaustive list of studies has analyzed the welfare costs of imperfect risk sharing in nonmonetary models as Cole and Obstfeld (1991), Kim et al. (2003), Lewis (1996), Mendoza (1995), Obstfeld (1994), and van Wincoop (1994, 1999).

a separable disutility.[3] g is a preference shock, whereas z is a productivity shock. These shocks are country specific. With starred variables we denote country's F variables.

The consumption index C^j is defined as follows:

$$C^j \equiv \left[n^{\frac{1}{\theta}} \left(C_H^j\right)^{\frac{\theta-1}{\theta}} + (1-n)^{\frac{1}{\theta}} \left(C_F^j\right)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}, \tag{1}$$

where C_H^j and C_F^j are consumption indexes of the continuum of differentiated goods produced, respectively, in countries H and F,

$$C_H^j \equiv \left[\left(\frac{1}{n}\right)^{\frac{1}{\sigma}} \int_o^n c^j(h)^{\frac{\sigma-1}{\sigma}} dh \right]^{\frac{\sigma}{\sigma-1}}, \quad C_F^j \equiv \left[\left(\frac{1}{1-n}\right)^{\frac{1}{\sigma}} \int_n^1 c^j(f)^{\frac{\sigma-1}{\sigma}} df \right]^{\frac{\sigma}{\sigma-1}}. \tag{2}$$

The elasticity of substitution across goods produced within a country is denoted by σ, which is assumed greater than one, while the elasticity of substitution between the bundles C_H and C_F is θ.

We assume that all the goods are traded and that the law-of-one-price holds. We further assume that the same composition of the consumption bundle C applies to country F. Given these assumptions, it follows that purchasing power parity holds, i.e., $P = SP^*$, $P_H = SP_H^*$ and $P_F = SP_F^*$, where S is the nominal exchange rate. Here we define the relative price T, the terms of trade, as $T \equiv P_F/P_H$.

The household j's demands of a generic good h, produced in country H, and of the generic good f, produced in country F, are

$$c^j(h) = \left(\frac{p(h)}{P_H}\right)^{-\sigma} \left(\frac{P_H}{P}\right)^{-\theta} C^j, \qquad c^j(f) = \left(\frac{p(f)}{P_F}\right)^{-\sigma} \left(\frac{P_F}{P}\right)^{-\theta} C^j. \tag{3}$$

Aggregating across all households in the world economy, we can write total demands of good h and f as

$$y^d(h) = \left(\frac{p(h)}{P_H}\right)^{-\sigma} \left(\frac{P_H}{P}\right)^{-\theta} C^W, \qquad y^d(f) = \left(\frac{p(f)}{P_F}\right)^{-\sigma} \left(\frac{P_F}{P}\right)^{-\theta} C^W, \tag{4}$$

where world consumption C^W is defined as

$$C^W \equiv \int_0^1 C^j dj.$$

We assume that there are two bonds traded internationally: one is denominated in the currency of country H and the other in the currency of country F. Both bonds

3. This form of utility function can be seen as the outcome of a decentralized labor market in which households get disutility from supplying hours across all the firms within a country. This disutility is separable in the various efforts provided. On the other side, firms employ work, which is perfectly substitutable in production, from all the households belonging to their country.

are risk-free with one-period maturity. Thus, the budget constraint of household j in country H (expressed in real terms with respect to the consumption-based price index) is

$$\frac{S_t A_t^j}{P_t(1+i_t^*)} - \frac{B_t^j}{P_t(1+i_t)} \leq \frac{S_t A_{t-1}^j - B_{t-1}^j}{P_t} + (1-\tau)\frac{1}{P_t}\frac{1}{n}\int_0^n p_t(h) y_t(h)\, dh$$
$$- C_t^j + - \frac{\chi}{2(1+i_t^*)}\left(\frac{S_t A_t^j}{P_t} - \bar{a}\right)^2 + TR_t^j,$$

at each date t. A_t^j is household j's holding of the risk-free one-period nominal bond, denominated in units of currency F. The nominal interest rate on this bond is i_t^*. B_t^j is household j's debt issued in units of the risk-free one-period nominal bond denominated in currency H. The nominal interest rate on this bond is i_t. We are assuming that households of country H hold assets denominated in foreign currency and issue debt in domestic currency, which reflects the current net international position of the U.S. economy.[4] Most important, we are assuming that there is a quadratic cost in changing the real asset position when trading in the foreign bond market with respect to a constant real value, denoted by $\bar{a}$; χ is a nonnegative parameter that measures this cost in terms of units of the consumption index, which is rescaled by the factor $1/(1+i_t^*)$ just for analytical convenience and without losing generality. The cost of moving the holdings of foreign assets serves for the purpose of determining the steady-state value of the foreign-asset position in a zero-order approximation without the need of taking second-order approximations as in Devereux and Sutherland (2007). In particular, we adapt the method of Ghironi, Lee, and Rebucci (2006) to bonds trading.[5] As it will be clear later, the steady-state debt position is instead determined by a specular cost faced by the households of country F in holding assets denominated in the currency of country H.

In characterizing the budget constraint, we also assume that all the households belonging to a country share the revenues from running the firms in equal proportion. Finally, τ denotes a country-specific proportional tax on nominal income, while TR_t^j denotes transfers to household j, which include government transfers and the revenues obtained from the transaction costs in trading bonds faced by the households of country F. In particular we assume that

$$TR_t^j = \frac{1}{n}\left[\tau\int_0^n \frac{p_t(h)}{P_t} y_t(h) dh + \frac{\chi^*}{2(1+i_t)}\int_n^1 \left(\frac{A_t^{*i}}{S_t P_t^*} - \bar{a}^*\right)^2 di\right].$$

4. The model can be easily adapted to deal with the opposite case.

5. A previous version of this work, Benigno (2001), was analyzing a model with just one asset traded internationally and using a debt-elastic interest rate to pin down a unique steady state. That framework can be also generalized to two-asset trading.

Indeed, the flow budget constraint of a representative household i of country F is given by

$$\frac{A_t^{*i}}{S_t P_t^*(1+i_t)} - \frac{B_t^{*i}}{P_t^*\left(1+i_t^*\right)} \leq \frac{A_{t-1}^{*i}}{S_t P_t^*} - \frac{B_{t-1}^{*i}}{P_t^*} + (1-\tau^*)\frac{1}{1-n}\frac{1}{P_t^*}\int_n^1 p_t^*(f) y_t^*(f)\, df + - C_t^{*i} - \frac{\chi^*}{2(1+i_t)}\left(\frac{A_t^{*i}}{S_t P_t^*} - \bar{a}^*\right)^2 + TR_t^{*i},$$

where now χ^* parameterizes the costs of changing the asset holdings, in country F, which are now denominated in the currency of country H. In a specular way to the portfolio positions of households in country H, households in country F invest in assets denominated in the currency of the other country, where they face a transaction cost, and borrow in domestic currency.[6] We further assume that the initial level of wealth is the same across all the households belonging to the same country. This assumption, combined with the fact that all the households within a country work for all the firms sharing the profits in equal proportions, implies that within a country all the households face the same budget constraint. In their consumption decisions, they will choose the same consumption path. We can then drop the index j or i and consider a representative household for each country. However, consumption will not be necessarily risk shared at an international level.

Optimal consumption and portfolio choices imply the following Euler equations in country H : i)

$$E_t\{M_{t+1}(1+i_t)\} = 1, \tag{5}$$

which reflects trading in the bond denominated in domestic currency and ii)

$$E_t\left\{M_{t+1}\left(1+i_t^*\right)\frac{S_{t+1}}{S_t}\right\} = 1 + \chi\left(\frac{S_t A_t}{P_t} - \bar{a}\right), \tag{6}$$

which reflects trading in the bond denominated in foreign currency, where the nominal stochastic discount factor M_{t+1} is defined by

$$M_{t+1} = \beta\frac{C_{t+1}^{-\rho} g_{t+1}}{C_t^{-\rho} g_t}\frac{P_t}{P_{t+1}}.$$

6. Standard borrowing constraints apply to the optimization problem of home and foreign households.

Equations (5) and (6) imply deviations from uncovered interest parity that reflect the cost of trading in the bond denominated in foreign currency. We obtain

$$E_t\left\{M_{t+1}\left[\left(1+i_t^*\right)\frac{S_{t+1}}{S_t}-(1+i_t)\right]\right\}=\chi\left(\frac{S_t A_t}{P_t}-\bar{a}\right).$$

In country F, the following Euler equations hold: *i*)

$$E_t\left\{M_{t+1}^*\left(1+i_t^*\right)\right\}=1, \tag{7}$$

which reflects trading in the bond denominated in the currency of country F and *ii*)

$$E_t\left\{M_{t+1}^*(1+i_t)\frac{S_t}{S_{t+1}}\right\}=1+\chi^*\left(\frac{A_t^*}{S_t P_t^*}-\bar{a}^*\right), \tag{8}$$

which reflects trading in the bond denominated in the currency of country H, where the nominal stochastic discount factor M_{t+1}^* is given by

$$M_{t+1}^*=\beta\frac{C_{t+1}^{*-\rho}g_{t+1}^*}{C_t^{*-\rho}g_t^*}\frac{P_t^*}{P_{t+1}^*}.$$

A further implication of the arbitrage conditions (5), (6), (7), and (8) is that an increase in the real asset holdings of country H should be compensated by a decrease in country F, i.e.,

$$\chi\left(\frac{S_t A_t}{P_t}-\bar{a}\right)=-\chi^*\left(\frac{A_t^*}{S_t P_t^*}-\bar{a}^*\right).$$

Note that equilibrium in the asset markets requires that

$$nA_t=(1-n)B_t^*$$

and

$$nB_t=(1-n)A_t^*.$$

We can obtain the aggregate budget constraint of country H by integrating the budget constraints of the households living in country H together with the government's budget constraint to get, in per capita terms,

$$\frac{S_t A_t}{P_t\left(1+i_t^*\right)} - \frac{B_t}{P_t(1+i_t)}$$
$$= \frac{S_t A_{t-1} - B_{t-1}}{P_t} + \left(\frac{P_{H,t}}{P_t}\right)^{1-\theta} C_t^W - C_t - \frac{\chi}{2\left(1+i_t^*\right)}\left(\frac{S_t A_t^j}{P_t} - \bar{a}\right)^2$$
$$+ \frac{1-n}{n}\frac{\chi^*}{2(1+i_t)}\left(\frac{A_t^*}{S_t P_t^*} - \bar{a}^*\right)^2. \tag{9}$$

1.1 Price-Setting Decisions

In this model suppliers behave as monopolists in selling their products. They can affect the quantity demanded through their pricing decisions as shown in equation (4). However, they are small with respect to the overall market and take as given the indexes P, P_H, P_F, and C, C^*. Prices are subject to changes at random intervals as in the Calvo–Yun model (see Calvo 1983, Yun 1996). In each period, a seller faces a fixed probability $1-\alpha$ of adjusting the price, irrespective on how long it has been since the last change had occurred. In this event the price is chosen to maximize the expected discounted profits under the circumstance that the decision on the price is still maintained; in fact, the seller also assumes that the price chosen at a certain date t will apply in the future at date $t+k$ with probability α^k. It is important to note that all the sellers that belong to the same country and can modify their price at a certain time will face the same discounted future demands and marginal costs under the hypothesis that the new price is maintained. Hence, they will set the same price. We denote with $\tilde{p}_t(h)$ the price of the good h, in country h, chosen at date t and with $\tilde{y}_{t,T}(h)$ the total demand of good h at time $T \geq t$ under the circumstances that the price $\tilde{p}_t(h)$ still applies. From (4), $\tilde{y}_{t,T}(h)$ is

$$\tilde{y}_{t,T}(h) = \left(\frac{\tilde{p}_t(h)}{P_{H,T}}\right)^{-\sigma}\left(\frac{P_{H,T}}{P_t}\right)^{-\theta} C_T^W.$$

The optimal choice $\tilde{p}_t(h)$ is:

$$\tilde{p}_t(h) = \frac{\sigma}{(\sigma-1)(1-\tau)} \frac{\mathrm{E}_t \sum_{T=t}^{\infty} (\alpha\beta)^{T-t} \tilde{y}_{t,T}^{\eta}(h) z_T^{-(1+\eta)} \tilde{y}_{t,T}(h)}{\mathrm{E}_t \sum_{T=t}^{\infty} (\alpha\beta)^{T-t} \lambda_T \tilde{y}_{t,T}(h)}, \tag{10}$$

where λ_T is the marginal utility of nominal income which is common across all agents within a country. To simplify the analysis, we assume that the distorting taxes are set in a way to offset the monopolistic distortions, i.e., $(1-\tau) = \sigma/(\sigma-1)$. Under the

Calvo-style price-setting behavior, a fraction $(1-\alpha)$ of sellers, that can choose to adjust the price, sets the same price. Thus, we obtain the following state equation for $P_{H,t}$

$$P_{H,t}^{1-\sigma} = \alpha P_{H,t-1}^{1-\sigma} + (1-\alpha)\tilde{p}_t(h)^{1-\sigma}. \tag{11}$$

Similar optimal price-setting decisions hold in country F, with the appropriate modifications.

1.2 Complete Markets

When international markets are complete, both domestic and foreign households can trade in a set of state-contingent securities that deliver one unit of the home and/or foreign currency in each state of nature. Under this market structure, the marginal utilities of consumption will be proportional and can be equated at all dates and states of nature by an appropriate choice of the initial asset allocation

$$C_t^{-\rho} g_t = C_t^{*-\rho} g_t^*. \tag{12}$$

In characterizing the allocation of consumption, under complete markets, there is no need to outline the path of the current account.

2. STEADY STATE

In a steady state without inflation, $M_{t+1} = M_{t+1}^* = \beta$ for each t.[7] From equations (5) and (7) we obtain that $1 + \bar{\imath} = 1 + \bar{\imath}^* = \beta^{-1}$, which imply in equations (6) and (8) that $a_t = A_t/P_t^* = \bar{a}$ and $a_t^* = A_t^*/P_t = \bar{a}^*$, which then determine the steady state of real assets holdings for country H and F, respectively. From the equilibrium conditions in the asset markets it follows that $b_t = B_t/P_t = \bar{b} = \bar{a}^* \cdot (1-n)/n$ and $b_t^* = B_t^*/P_t^* = \bar{b}^* = \bar{a} \cdot n/(1-n)$. The flow budget constraint of the home country implies

$$\bar{C} = (1-\beta)(\bar{a} - \bar{b}) + \left(\frac{\bar{P}_H}{\bar{P}}\right)^{1-\theta} \bar{C}^W, \tag{13}$$

whereas that of the foreign country implies

$$\bar{C}^* = (1-\beta)(\bar{a}^* - \bar{b}^*) + \left(\frac{\bar{P}_F}{\bar{P}}\right)^{1-\theta} \bar{C}^W.$$

7. Note that zero CPI inflation rate in both countries implies zero exchange rate depreciation, since PPP always holds in our model.

Relative prices are linked by the following condition

$$n\left(\frac{\bar{P}_H}{\bar{P}}\right)^{1-\theta} + (1-n)\left(\frac{\bar{P}_F}{\bar{P}}\right)^{1-\theta} = 1. \tag{14}$$

Moreover, the price-setting conditions imply

$$\bar{C}^{-\rho}\bar{g}\frac{\bar{P}_H}{\bar{P}} = \left(\frac{\bar{P}_H}{\bar{P}}\right)^{-\theta\eta}(\bar{C}^W)^{\eta}\bar{z}^{-(1+\eta)}, \tag{15}$$

$$\bar{C}^{*-\rho}\bar{g}^*\frac{\bar{P}_F}{\bar{P}} = \left(\frac{\bar{P}_F}{\bar{P}}\right)^{-\theta\eta}(\bar{C}^W)^{\eta}\bar{z}^{*-(1+\eta)}. \tag{16}$$

Given the already determined $\bar{a}$ and $\bar{b}$, equilibrium conditions (13)–(16) determine $\bar{C},\ \bar{C}^*, \bar{P}_H/\bar{P}$ and $\bar{P}_F/\bar{P}$ for given $\bar{g},\ \bar{g}^*,\ \bar{z}$, and $\bar{z}^*$ since $\bar{C}^W = n\bar{C} + (1-n)\bar{C}^*$. In particular we choose $\bar{g}$ and $\bar{g}^*$ such that in the steady state $\bar{C}^{-\rho}\bar{g} = \bar{C}^{*-\rho}\bar{g}^*$.

3. LOG-LINEAR APPROXIMATION OF THE EQUILIBRIUM CONDITIONS

We limit our analysis to the fluctuations around the above defined steady state through a log-linear approximation of the equilibrium conditions. In particular a log-linear approximation of the no-arbitrage conditions (5) and (6) implies

$$\rho E_t\hat{C}_{t+1} - E_t\hat{g}_{t+1} = \rho\hat{C}_t - \hat{g}_t + \hat{\imath}_t - E_t\pi_{t+1},$$
$$\rho E_t\hat{C}_{t+1} - E_t\hat{g}_{t+1} = \rho\hat{C}_t - \hat{g}_t + \hat{\imath}_t^* - E_t\pi_{t+1}^* - \chi\bar{a}\hat{a}_t,$$

where hats denote log-deviations of a variable with respect to the steady state and $\pi_{t+1} \equiv \ln P_{t+1}/P_t, \pi_{t+1}^* \equiv \ln P_{t+1}^*/P_t^*$. As already discussed in the previous section, the above equations imply deviations from uncovered interest parity even in a log-linear approximation. Indeed,

$$\hat{\imath}_t^* - \hat{\imath}_t + E_t\Delta s_{t+1} = \chi\bar{a}\hat{a}_t, \tag{17}$$

since $\pi_t = \pi_t^* + \Delta s_t$, where $\Delta s_t = \ln S_t/S_{t-1}$. Assuming $\bar{a} > 0$ it follows that the excess return in investing in the bonds denominated in currency of country F with respect to those denominated in currency of country H should be positive, when the asset holdings of country H increase above the steady state.

Similarly, we can take a log-linear approximation of the no-arbitrage conditions (7) and (8) to obtain

$$\rho E_t\hat{C}_{t+1}^* - E_t\hat{g}_{t+1}^* = \rho\hat{C}_t^* - \hat{g}_t^* + \hat{\imath}_t - E_t\pi_{t+1} - \chi^*\bar{a}^*\hat{a}_t^*,$$
$$\rho E_t\hat{C}_{t+1}^* - E_t\hat{g}_{t+1}^* = \rho\hat{C}_t^* - \hat{g}_t^* + \hat{\imath}_t^* - E_t\pi_{t+1}^*.$$

As discussed in the previous section, a further implication of the above four Euler equations is the following restriction on the movements in cross-country asset holdings

$$\chi \bar{a} \hat{a}_t = -\chi^* \bar{a}^* \hat{a}_t^*.$$

The price-setting decisions in the domestic country, equations (10) and (11), together with (4), imply the following AS equation

$$\pi_{H,t} = k\big[\eta \hat{C}_t^W + (1-n)(1+\eta\theta)\hat{T}_t + \rho \hat{C}_t - (1+\eta)\hat{z}_t - \rho \hat{g}_t\big] + \beta E_t \pi_{H,t+1}, \tag{18}$$

where $\pi_{H,t} \equiv \ln P_{H,t}/P_{H,t-1}$ and $k \equiv (1-\alpha)(1-\alpha\beta)(\rho+\eta)/[\alpha\,(1+\sigma\eta)]$. Note that a log-linear approximation to aggregate consumption delivers

$$\hat{C}_t^W = \phi \hat{C}_t + (1-\phi)\hat{C}_t^*, \tag{19}$$

where ϕ is the steady-state share of home consumption over world consumption defined as $\phi \equiv n \cdot [1 + (1-\beta)(\bar{a}/\bar{Y} - \bar{b}/\bar{Y})]$.

Similarly, in the foreign country, we get

$$\pi_{F,t}^* = k^*\big[\eta \hat{C}_t^W - n(1+\eta\theta)\hat{T}_t + \rho \hat{C}_t^* - (1+\eta)\hat{z}_t^* - \rho \hat{g}_t^*\big] + \beta E_t \pi_{F,t+1}^*, \tag{20}$$

where $\pi_{F,t}^* \equiv \ln P_{F,t}^*/P_{F,t-1}^*$ and $k^* \equiv (1-\alpha^*)(1-\alpha^*\,\beta)(\rho+\eta)/[\alpha^*\,(1+\sigma\,\eta)]$. The terms of trade are defined as $T_t = S_t P_{F,t}^*/P_{H,t}$, which implies

$$\hat{T}_t = \hat{T}_{t-1} + \Delta s_t + \pi_{F,t}^* - \pi_{H,t}. \tag{21}$$

The relationship between CPI and GDP inflation rates, in a log-linear form, implies that

$$\pi_t = n\pi_{H,t} + (1-n)\big(\pi_{F,t}^* + \Delta s_t\big). \tag{22}$$

Finally, a log-linear approximation to the budget constraint (9) implies

$$\beta \cdot \left(\frac{\bar{a}}{\bar{Y}}\hat{a}_t - \frac{\bar{b}}{\bar{Y}}\hat{b}_t\right) = \left(\frac{\bar{a}}{\bar{Y}}\hat{a}_{t-1} - \frac{\bar{b}}{\bar{Y}}\hat{b}_{t-1}\right) - \frac{\bar{b}}{\bar{Y}}(\beta\hat{\imath}_t - \pi_t) + \frac{\bar{a}}{\bar{Y}}\big(\beta\hat{\imath}_t^* - \pi_t^*\big) + (\theta-1)(1-n)\hat{T}_t + \hat{C}_t^W - \frac{\phi}{n}\hat{C}_t - \chi\beta\frac{\bar{a}}{\bar{Y}}\hat{a}_t + \chi^*\beta\frac{\bar{b}}{\bar{Y}}\hat{b}_t, \tag{23}$$

which shows the important role of valuation effects, ex-post movements in the real return of assets and liabilities, in driving the dynamic of the net foreign asset position of a country when indeed steady-state asset and liability positions are different from zero. In particular, valuation effects are captured by the π_t and π_t^* terms on the right-hand-side of equation (23), which are the variables that affect the ex-post real returns of the two bonds. Exchange rate movements are indirectly included since $\pi_t^* = \pi_t - \Delta s_t$. Note that the debate in the literature has mainly identified valuation effects with the ex-post changes in the real returns due to the direct effect of exchange-rate movements while in general the ex-post variability of real returns depends on many factors.

4. WELFARE CRITERION

A natural criterion that serves at the same time for the purposes of evaluating the costs of market incompleteness and comparing alternative monetary policy regimes is the sum of the utilities of the consumers

$$W \equiv \mathrm{E}_0\left\{\sum_{t=0}^{\infty} \beta^t w_t\right\},$$

where

$$w_t \equiv n\frac{C_t^{1-\rho} g_t}{1-\rho} + (1-n)\frac{C_t^{*1-\rho} g_t^*}{1-\rho} - \int_0^n \frac{y_t(h)^{1+\eta} z_t^{-(1+\eta)}}{1+\eta} dh - \int_n^1 \frac{y_t^*(f)^{1+\eta} z_t^{*-(1+\eta)}}{1+\eta} df.$$

The Appendix shows that a second-order approximation of W, around a steady state in which a taxation subsidy completely offsets the monopolistic distortions in both countries, delivers the following welfare criterion

$$W = -\frac{\bar{C}^{-\rho}\bar{g}\overline{C}^W}{2}\mathrm{E}_0\left\{\sum_{t=0}^{\infty} \beta^t L_t\right\}, \tag{24}$$

with

$$L_t = (\rho+\eta)\cdot\left(\hat{C}_t^W - \tilde{C}_t^W\right)^2 + \phi(1-\phi)\rho\cdot\left(\hat{C}_t^R - \tilde{C}_t^R\right)^2 + n(1-n)(1+\eta\theta) \times \theta\cdot(\hat{T}_t - \tilde{T}_t)^2 + n\frac{\sigma}{k}\cdot(\pi_{H,t})^2 + (1-n)\frac{\sigma}{k^*}\cdot\left(\pi_{F,t}^*\right)^2 + \text{t.i.p.} + \mathcal{O}(\|\xi\|^3),$$

where $\hat{C}_t^R \equiv \hat{C}_t - \hat{C}_t^*$ and $\tilde{C}_t^W,\ \tilde{C}_t^R,\ \tilde{T}_t$ are the flexible-price levels of the respective variables that are functions of the shocks of the model; t.i.p. denotes elements that are independent of policy while $\mathcal{O}(\|\xi\|^3)$ measures residuals of third order in the maximum amplitude of the shocks.

Using equation (24), one can evaluate the deadweight losses implied by the distortions existing in the model. Once the monopolistic distortions are offset by appropriate taxation subsidies, the flexible-price, complete-market allocation is the efficient allocation for the whole economy. Any departure from this allocation produces losses for society. Price stickiness is a source of distortions when, combined with staggered prices, creates dispersion of demand across goods that are produced according to the same technology. The squares of the producer inflation rates in each country capture these distortionary costs. On the other side, relative prices should move when there are asymmetric productivity shocks. In fact, the terms of trade should offset asymmetric supply shocks. In the welfare function, this is captured by the square of the terms of trade with respect to their efficient level. Finally, the world and relative consumption gaps should be completely stabilized. In particular, a departure from the complete risk sharing of the marginal utilities of nominal incomes creates welfare costs. And the microfounded welfare criterion delivers appropriate weights for each of these costs.

It is important to note that when markets are complete and prices are sticky, a policy of zero producer inflation rates in both countries achieves the optimum for society and closes all the gaps in the above loss function.

5. THE WELFARE COSTS OF IMPERFECT RISK SHARING AND THE ROLE OF INTERNATIONAL MONETARY POLICY COOPERATION

There are many angles through which the welfare costs of incomplete markets can be studied in this work since there are many possible monetary regimes that depend on the monetary policy rules followed by each country. A natural candidate is the allocation that corresponds to a policy of zero producer inflation rates in both countries, i.e., $\pi_{H,t} = \pi^*_{F,t} = 0$ at all dates t–a "price stability" policy. First of all, as discussed in the previous section, this combination of policies achieves the first best when markets are complete. Moreover, it implements the flexible-price allocation independently of the asset structure. In fact, the literature on the costs of incomplete markets has mainly focused on real fluctuations. Finally, many studies in the optimal monetary policy literature in closed economy have analyzed the conditions under which strict price stability is an optimal policy. See Woodford (2003) for an overview. A policy of zero producer inflation rate is the natural open-economy counterpart of those analyses.[8]

After having evaluated the welfare costs of incomplete markets under price stability, we will analyze the conditions under which a departure from price stability can substantially reduce these costs.

Our strategy is to fix the calibration of some parameters and to vary others that are instead more controversial and critical for driving the magnitude of the welfare costs. We set $\beta = 0.99$, which implies that the steady-state real interest rate is around 4% (in a quarterly model). We assume that country H is United States while country F is the rest of the world. We assume that countries are of equal size, $n = 0.5$. Following recent empirical works on the estimation of forward-looking aggregate supply equations, we

8. See Benigno and Benigno (2003, 2006) and Sutherland (2001) for a general analysis of the conditions under which this definition of price stability is optimal even from a noncooperative perspective.

assume that α and α^* are both equal to 0.66, which implies that the duration of the price contracts is three quarters. The degree of monopolistic competition is taken from Rotemberg and Woodford (1998), where they set $\sigma = 7.66$, which implies an average markup of 15%. Microdata suggests Frisch elasticity to be in the range of 0.05 – 0.3. Thus, we assume that $\eta = 5$ which corresponds to a Frisch elasticity of 0.28. As in Ghironi, Lee, and Rebucci (2007), we assume that the costs of adjusting the bond holdings with respect to the steady state are such that $\chi = \chi^* = 0.01$.[9]

We make two alternative assumptions on the risk-aversion coefficient. In one scenario, we choose $\rho = 1$, consistently with the work of Eichenbaum et al. (1988) that found a range of 0.5–3. Barsky et al. (1987) have instead suggested values greater than 5. We then analyze another scenario in which $\rho = 6$. As outlined in Obstfeld and Rogoff (2000) the intratemporal elasticity of substitution is a critical parameter in this class of open-macro models. According to some recent studies, such as Harrigan (1993) and Trefler and Lai (1999), a sensible assumption for this parameter is 6. The RBC literature instead assumes values in the range of 1–2. We produce a robustness analysis for values between 0.8 and 6.

Finally, following Baxter (1995), we assume the following process for the productivity disturbances

$$\begin{pmatrix} \hat{z}_t \\ \hat{z}_t^* \end{pmatrix} = \begin{bmatrix} 0.995 & 0 \\ 0 & 0.995 \end{bmatrix} \begin{pmatrix} \hat{z}_{t-1} \\ \hat{z}_{t-1}^* \end{pmatrix} + \begin{pmatrix} u_{1,t} \\ u_{1,t} \end{pmatrix},$$

where u_1 and u_2 are white-noise processes with standard deviations σ_{u_1}=0.0073 and σ_{u_2}=0.0073 and correlation equal to 0.19. Since the empirical literature is silent on the estimation of the demand shocks, we assume, as it is usually done in the RBC literature (Stockman and Tesar 1995), that they are distributed in the same way as the productivity shocks.[10]

A recent empirical literature (see Lane and Milesi-Ferretti 2002, 2005, Tille 2005) has documented an increased diversification of countries' portfolio. In particular, Lane and Milesi-Ferretti (2002) have shown that the net international positions over GDP vary across countries and are in general different from zero. They further argue that the level and the composition of net international position is a key state variable and a critical determinant of the benefits of international financial integration. In our context, the assumptions on steady-state assets and liabilities are relevant for capturing this empirical evidence.

We make several alternative assumptions: (i) $\bar{a}/\bar{Y} = \bar{b}/\bar{Y} = 0$ capturing the unrealistic case (though frequently used in the previous RBC literature) of a zero steady

9. Kollman (2003) has used Lane and Milesi-Ferretti (2002) estimates on the relationship between real interest rate differentials and net foreign asset position. He assumes a value of 0.0019 in a case in which the net foreign asset position is normalized by exports. In our case, since the net foreign asset position is normalized by quarterly GDP, with an export/GDP ratio of 15%, a value of 0.0019 implies a value for χ equal to 0.012, which is consistent the calibration that we use.

10. Between demand and productivity shocks, the white-noise disturbances are statistically independent.

TABLE 1

Welfare Costs of Incomplete Markets under Producer-Price Stability (% of a permanent shift in steady-state consumption)

	(1) $\bar{a}/\bar{Y}=0$ $\bar{b}/\bar{Y}=0$ $\rho=1$	(2) $\bar{a}/\bar{Y}=-0.5$ $\bar{b}/\bar{Y}=0$ $\rho=1$	(3) $\bar{a}/\bar{Y}=0.53$ $\bar{b}/\bar{Y}=0.74$ $\rho=1$	(4) $\bar{a}/\bar{Y}=0.7$ $\bar{b}/\bar{Y}=1.1$ $\rho=1$	(5) $\bar{a}/\bar{Y}=0.53$ $\bar{b}/\bar{Y}=0.74$ $\rho=6$
			Productivity shock		
$\theta=0.8$	0.0075	0.0133	0.0066	0.0187	0.0208
$\theta=1$	0.0000	0.0013	0.0096	0.0242	0.0577
$\theta=2$	0.0307	0.0276	0.0480	0.0616	0.2420
$\theta=3$	0.0549	0.0516	0.0709	0.0822	0.3120
$\theta=5$	0.0795	0.0763	0.0931	0.1019	0.3683
$\theta=6$	0.0864	0.0832	0.0992	0.1073	0.3821
			All shocks		
$\theta=0.8$	0.1379	0.1422	0.1363	0.1460	0.0624
$\theta=1$	0.1210	0.1206	0.1314	0.1446	0.0860
$\theta=2$	0.1341	0.1289	0.1547	0.1687	0.2569
$\theta=3$	0.1527	0.1471	0.1728	0.1851	0.3243
$\theta=5$	0.1729	0.1674	0.1911	0.2014	0.3790
$\theta=6$	0.1787	0.1733	0.1963	0.2059	0.3927

Notes: θ is the intratemporal elasticity of substitution, ρ is the risk-aversion coefficient; $\bar{a}/\bar{Y}$ is the steady-state asset position in foreign currency of country H over GDP; $\bar{b}/\bar{Y}$ is the steady-state liability position in domestic currency of country H over GDP.

state of both assets and liabilities; (ii) $\bar{a}/\bar{Y}=-0.5*4/n$ and $\bar{b}/\bar{Y}=0$ describing the case of a country borrower in the international markets in foreign-currency debt for the amount of 50% of GDP;[11] (iii) $\bar{a}/\bar{Y}=0.53\cdot 4/n$ and $\bar{b}/\bar{Y}=0.74\cdot 4/n$ capturing the U.S. net international position in the year 2005: indeed, as discussed in Lane and Milesi-Ferretti (2007) the net international position was negative and equal to −21,5% of the GDP, in particular the net leverage position in foreign currency corresponded to assets equal to 53.4% of GDP while net dollar liabilities were 74.8% of GDP; and (iv) $\bar{a}/\bar{Y}=0.7*4/n$ and $\bar{b}/\bar{Y}=1.10*4/n$ capturing a pessimistic scenario for the U.S. economy in which the net international position reaches −40% of GDP, with net assets in foreign currency increasing to 70% and net liabilities in domestic currency to 110% of GDP.

Table 1 shows the welfare costs of incomplete markets under producer-price stability. The top part of the table presents the case in which there are only productivity shocks, while the bottom part considers the case of both productivity and demand shocks. Focusing on the first column and the only-productivity-shock case, it is interesting to note the special case ($\theta=1$) in which there are no welfare costs. Indeed, it is a well-established result that, with Cobb-Douglas preferences, the terms of trade provide a risk-sharing role. Indeed, this finding has been well emphasized by Cole and Obstfeld (1991) and Corsetti and Pesenti (2001). However, this is true only when there are productivity shocks and the steady-state international position is zero along all dimensions. In the case of demand shocks, complete risk sharing requires relative

11. The variables $\bar{a}/\bar{Y}$ and $\bar{b}/\bar{Y}$ are in per capita terms and $\bar{Y}$ is quarterly GDP so that $\bar{a}/\bar{Y}$ and $\bar{b}/\bar{Y}$ should be corrected by the factor $n/4$ to get numbers comparable with those used in data analyses.

consumption to move in the same direction as demand shocks, so that real income should move asymmetrically across countries. In the $\theta = 1$ case, instead, real income moves proportionally. The terms of trade can still be a vehicle of wealth distribution, when $\theta = 1$, but this contrasts with its primal role of allocating production efficiently across countries. Similarly, when the steady-state portfolio positions are different from zero, consumption moves also for valuation effects and so real income should move asymmetrically across countries.

As θ departs from 1, the costs increase in a convex manner. They become higher the higher is the intertemporal elasticity of consumption. With only productivity shocks, they are in the range between 0.05% and 0.10% depending on the various assumptions on the steady-state portfolio allocations. In the last column, when the risk-aversion coefficient is increased up to 6, the costs become quite important and reach 0.23%–0.40% for reasonable assumptions on the intertemporal elasticity of substitution.[12] They can be even higher if we include the costs of eliminating all the business-cycle volatility that still remains under the complete market allocation.

Moreover, when we include demand shocks, the costs of incomplete markets are in the range between 0.10% and 0.20% even in the low-risk-aversion scenario. Another interesting feature of our results is that the costs increase when the net international position becomes larger, even when more assets are traded. Whereas it is true that increasing the number of assets traded internationally should improve welfare—because it reduces the degree of market incompleteness—in our model the steady-state portfolio positions are exogenously fixed by the convex cost of changing the portfolio allocation and so they do not necessarily serve for the purpose of enhancing risk sharing. Indeed, steady-state portfolio allocations are endogenous in a model without transaction frictions, as in Devereux and Sutherland (2007). However, endogenous portfolio allocation would rarely coincide with the empirical ones and can be hardly manipulated in that direction.

Are there welfare gains of conducting a policy that deviates from price stability? Table 2 investigates this issue. The gains are in general small of an order lower then 0.01% except under the parameterizations of the last two columns, i.e., when the net international position worsens and when the risk-aversion coefficient increases. Indeed, when the steady-state net international position worsens to -40% of GDP (increasing both assets and liabilities), the gains of conducting an optimal monetary policy can reach even 0.06% of a permanent shift in steady-state consumption. A producer-price stability policy is a symmetric policy in an asymmetric world. When the asymmetries in the initial holdings of foreign assets are important, it cannot succeed in approximating well the first best. Wealth effects induced by asymmetries in the holdings of foreign assets imply additional welfare costs that can be reduced by appropriate coordination of monetary policies. With an increase in the risk-aversion coefficient, they become even larger reaching 0.15% of GDP.

12. The results of the literature are controversial. Some of the papers report very small gains from international risk-sharing (less than 0.1% of units of steady-state consumption) while others report much higher values (sometimes of the order of 20%). A nonexhaustive list is Cole and Obstfeld (1991), Lewis (1996), Mendoza (1995), Obstfeld (1994), and van Wincoop (1994, 1996).

TABLE 2

Welfare Gains by Using the Optimal Monetary Policy (% of a permanent shift in steady-state consumption)

	(1) $\bar{a}/\bar{Y}=0$ $\bar{b}/\bar{Y}=0$ $\rho=1$	(2) $\bar{a}/\bar{Y}=-0.5$ $\bar{b}/\bar{Y}=0$ $\rho=1$	(3) $\bar{a}/\bar{Y}=0.53$ $\bar{b}/\bar{Y}=0.74$ $\rho=1$	(4) $\bar{a}/\bar{Y}=0.7$ $\bar{b}/\bar{Y}=1.1$ $\rho=1$	(5) $\bar{a}/\bar{Y}=0.53$ $\bar{b}/\bar{Y}=0.74$ $\rho=6$
			Productivity shock		
$\theta=0.8$	0.00004	0.0014	0.0014	0.0105	0.0057
$\theta=1$	0.00000	0.0001	0.0036	0.0149	0.0500
$\theta=2$	0.00004	0.0006	0.0052	0.0169	0.1371
$\theta=3$	0.00005	0.0011	0.0039	0.0136	0.1478
$\theta=5$	0.00004	0.0014	0.0022	0.0099	0.1508
$\theta=6$	0.00004	0.0015	0.0023	0.0090	0.1509
			All shocks		
$\theta=0.8$	0.0008	0.0010	0.0364	0.0622	0.0379
$\theta=1$	0.0005	0.0067	0.0283	0.0583	0.0688
$\theta=2$	0.0002	0.0036	0.0145	0.0390	0.1449
$\theta=3$	0.0001	0.0033	0.0090	0.0277	0.1533
$\theta=5$	0.0001	0.0032	0.0052	0.0186	0.1550
$\theta=6$	0.0001	0.0033	0.0045	0.0166	0.1557

Notes: θ is the intratemporal elasticity of substitution, ρ is the risk-aversion coefficient; $\bar{a}/\bar{Y}$ is the steady-state asset position in foreign currency of country H over GDP; $\bar{b}/\bar{Y}$ is the steady-state liability position in domestic currency of country H over GDP.

An important determinant of the welfare costs of incomplete markets in standard international real business-cycle models is the persistence of the shocks (Baxter 1995, Baxter and Crucini 1995). We have already used quite persistence productivity and demand shocks. We now experiment with even higher values, by moving the roots of the autoregressive components from 0.995 to 1. Figure 1, under the assumptions $\theta = 1.5$, $\bar{a}/\bar{Y} = 0.53 \cdot 4/n$ and $\bar{b}/\bar{Y} = 0.74 \cdot 4/n$, studies the welfare costs of incomplete markets (the continuous line) and the welfare costs under the optimal monetary policy regime (the dashed line) by varying the degree of persistence of the shocks. In particular the analysis is done by considering only productivity shocks. The top part of the chart considers the interval [0.995,1), while the second part of the chart zooms on the interval [0.995,0.999]. Not surprisingly, the welfare costs are increasing with the persistence parameter starting from 0.03%, when persistence is 0.995, reaching 0.12%, when persistence is 0.999, and surpassing 1%, with persistence close to the unit root. The gains increase from 0.005% to 0.03%, up to values larger than 0.1%.

These results are quite striking if we consider that we have focused only on productivity shock, on a low-risk-aversion coefficient and a relatively low intratemporal elasticity of substitution. With alternative assumptions, like those of the last column of Tables 1 and 2, welfare costs and welfare gains would reach even higher numbers.

But, how does the volatility of macroeconomic variables change when the net international position worsens substantially? Figures 2 and 3 compare the standard deviations of relevant macroeconomic variables between the price stability and the optimal policy when net international debt position of country H varies from 0%

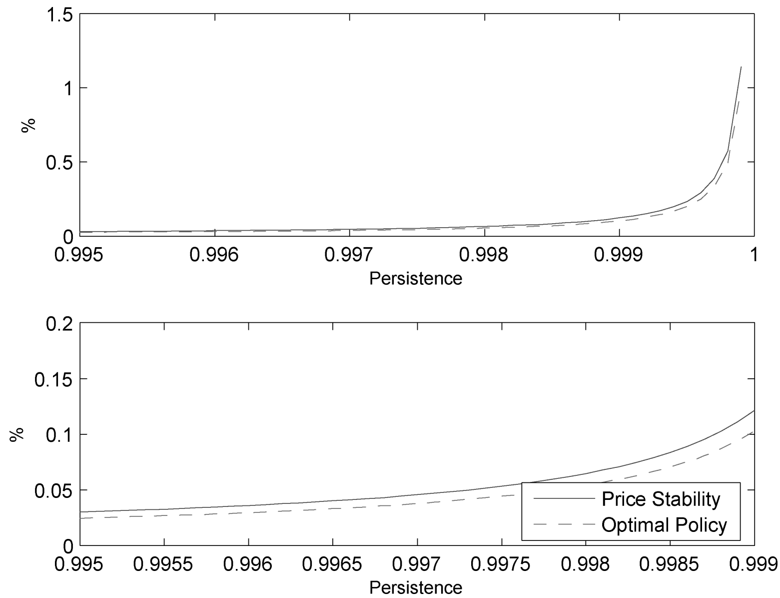

FIG. 1. Welfare Costs (% of a Permanent Shift in Steady-State Consumption) of the Price-Stability (continuous line) and Optimal Policy (dashed line) When the Persistence of the Productivity Shocks Increases.

NOTES: In the top chart the x-axis refers to the root of the autoregressive process of productivity in the interval [0.995, 1), bottom chart considers the interval [0.995, 0.999].

to 100% of GDP.[13] The volatility of producer-price inflation in the home country increases as the liability position worsens. This increase is significant for values of the debt above 20% of GDP. However, the standard deviation remains contained toward low numbers, below 0.1% at an annual rate. The volatility of home and foreign CPI inflation rates and of the nominal exchange rate decreases as the net international position worsens both under the optimal and the price stability policy. The decrease is more pronounced under the price stability policy. The most interesting fact is that whereas the volatilities of the domestic and foreign nominal interest rates are stable under the price stability policy, they increase substantially under the optimal policy and again become important in magnitude when net debt increases above 20% of GDP.

However, we have shown in equation (23), that important determinants of the net international position are the real returns of the two assets. Indeed, Figure 3 shows that the volatilities of the real returns increase in a substantial way under the optimal policy while they remain constant under a price-stability policy.

13. In Figures 2 and 3, the following calibration is used: $\rho = 1, \theta = 1.5, \eta = 0.47, \beta = 0.99, \chi = 0.01, \alpha = \alpha^* = 0.66$, and only productivity shocks are considered, distributed as in the benchmark case. In this experiment, liabilities are set to be three times the absolute value of the net international position, while assets are set to be twice that value.

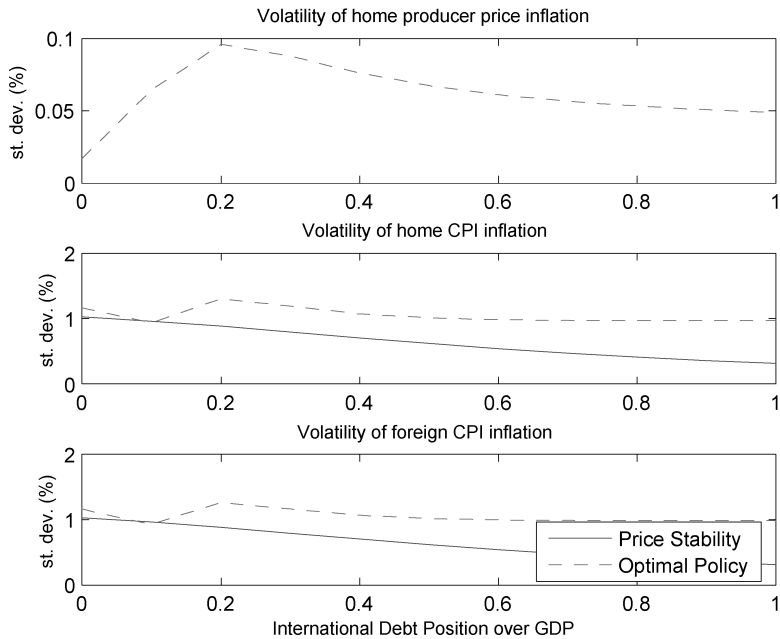

FIG. 2. Comparisons between Selected Moments under the Price-Stability (continuous line) and Optimal Policy (dashed line) When the International Net Debt Position of Country H Increases.

NOTES: Top chart: Volatility (standard deviation in %) of home producer price inflation. Middle chart: Volatility (standard deviation in %) of home CPI inflation. Bottom chart: Volatility (standard deviation in %) of foreign CPI inflation. On the x-axis the international net debt position of country H over GDP ranging in the interval [0, 1].

The intuition for this result depends on the importance of the risk-sharing objective embedded into the welfare function (24). When there are large asymmetries in the initial distribution of wealth, variations in the asset returns can have a large repercussion on the countries' consumption profiles. If a country receives a positive productivity shock, on a first impact, this affects real income and then consumption. As a consequence, the cross-country consumption differential increases. If on top of that the country is a debtor in the international markets, the impact of the shock on the cost of debt can increase or decrease the amount of financial liabilities of the country and work in the direction of magnifying or reducing the cross-country consumption differentials. In particular, an increase in the financial cost of the outstanding debt worsens the financial position of the country reducing its consumption and enhancing risk sharing. Since an important component of the real return is the nominal interest rate, more volatile nominal interest rate are needed to generate such valuation effects that produce volatile real asset returns. Interestingly, Figure 4 shows that the excess real return between the two assets is less volatile under the optimal policy than under the price stability policy. Indeed, the excess real return captures the deviations from uncovered interest parity and is directly related to the changes

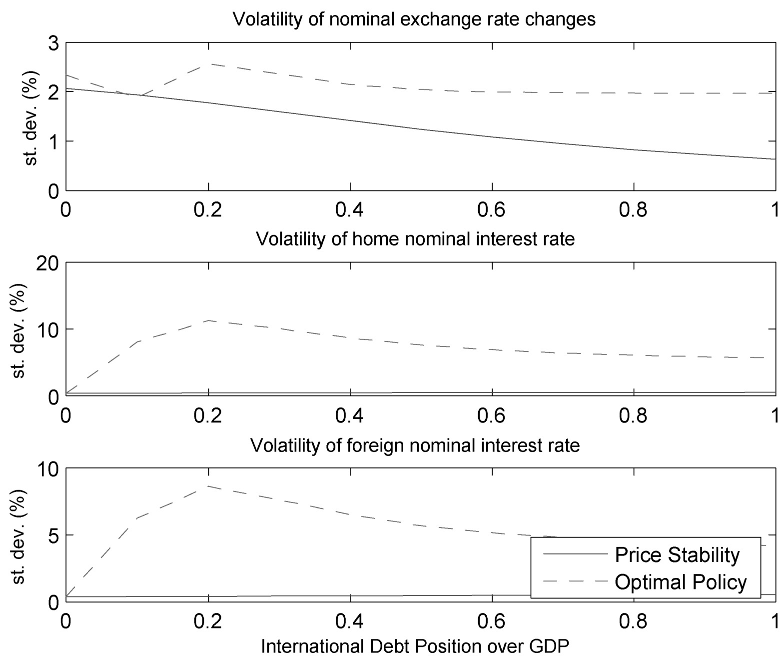

FIG. 3. Comparisons between Selected Moments under the Price-Stability (continuous line) and Optimal Policy (dashed line) When the International Net Debt Position of Country H Increases.

NOTES: Top chart: Volatility (standard deviation in %) of the nominal exchange rate. Middle chart: Volatility (standard deviation in %) of home nominal interest rate. Bottom chart: Volatility (standard deviation in %) of foreign nominal interest rate. On the x-axis the international net debt position of country H over GDP ranging in the interval [0, 1].

in foreign asset holdings, as shown in equation (17). Enhanced risk sharing requires reduced volatility of the net foreign asset position since most of the risk-sharing action occurs through contingent movements in the return of the assets and not necessarily through variations in the financial positions which instead can adjust more slowly.

But, is it the case that an increased dispersion in the external financial position of countries requires much more integrated and coordinated monetary policies? Figure 5 answers to this question by showing the correlation of the producer-price inflation rates and nominal interest rates under the optimal and the price-stability policy. Under optimal policy, the correlation of producer-price inflation rates starts on the negative side when the net international steady-state position is zero and increases and becomes positive as the international position worsens. Obviously, under a price stability policy, the correlation of the producer inflation rates is zero. Instead, the correlation between the nominal interest rates increases under the optimal policy while decreases under the price stability policy. On top of this, the last graph shows that the optimal policy requires much more correlated real returns.

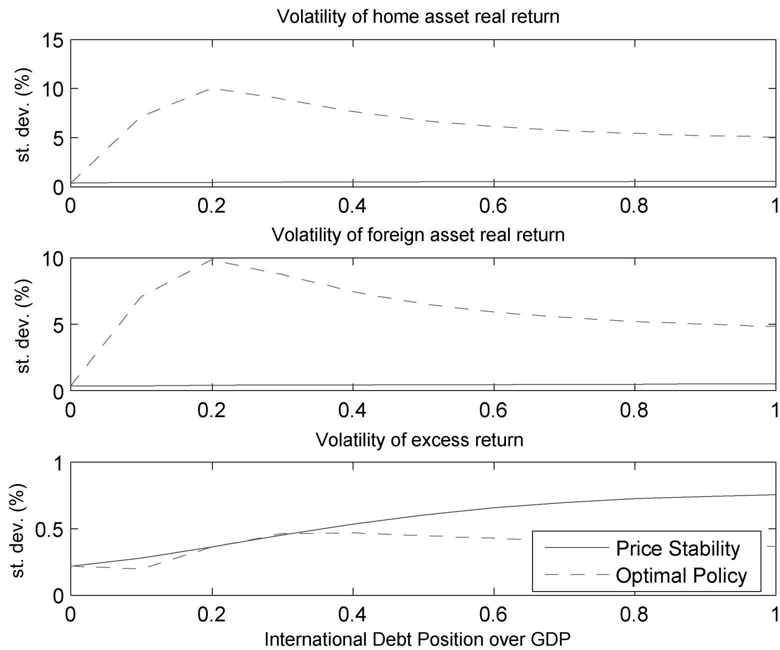

FIG. 4. Comparisons between Selected Moments under the Price-Stability (continuous line) and Optimal Policy (dashed line) When the International Net Debt Position of Country H Increases.

NOTES: Top chart: Volatility (standard deviation in %) of the real return in the home asset. Middle chart: Volatility (standard deviation in %) of the real return of the foreign asset. Bottom chart: Volatility (standard deviation in %) of the excess return between two assets. On the x-axis the international net debt position of country H over GDP ranging in the interval [0, 1].

6. CONCLUSION

This paper has shown that the deepness of financial markets associated with large exposures of some countries in the international financial markets is not innocuous for the designing of the international monetary system. This issue becomes more relevant when the asymmetries in the countries' exposures increase together with the persistence of the shocks. These results have been obtained in a simple model of incomplete markets in which only two bonds are traded and where there are transaction costs in trading in the international markets. However, the increase in financial integration that we observe in the data is accompanied by the proliferation of several financial instruments of different characteristics in terms of risk, liquidity and maturity. Increased global diversification that improves international risk sharing is able to automatically correct for asynchronized international business cycles, without the need of monetary policy coordination. But, as Obstfeld (2005) suggests, "the amount of real diversification is surely lower" than what one would expect from a first look at

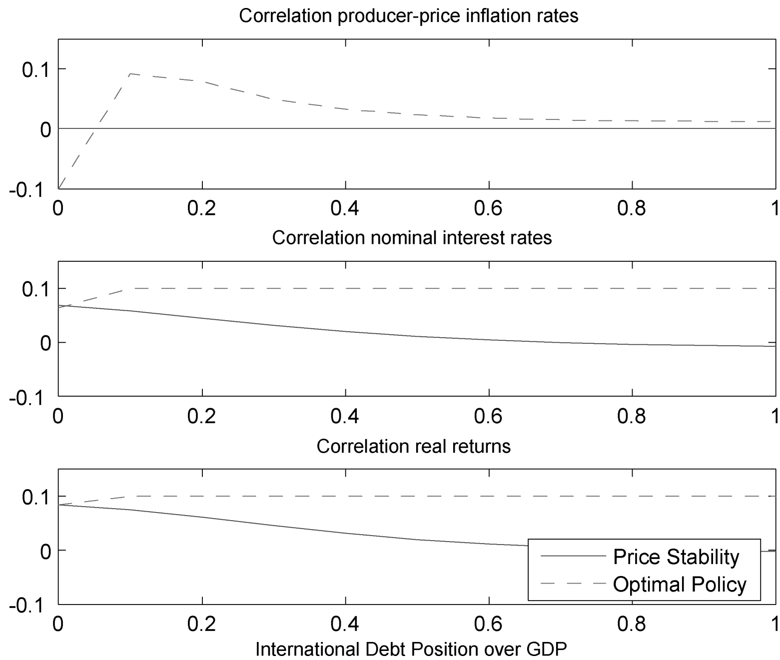

FIG. 5. Comparisons between Selected Moments under the Price-Stability (continuous line) and Optimal Policy (dashed line) When the International Net Debt Position of Country H Increases.

NOTES: Top chart: Correlation between the producer-price inflation rates of the two countries. Middle chart: Correlation between the nominal interest rates of the two countries. Bottom chart: Correlation between the real returns of the two bonds. On the x-axis the international net debt position of country H over GDP ranging in the interval [0, 1].

the data because of the many intermediaries through which the financial instruments pass. Under these circumstances, our simplifying assumption can represent a first step toward a more complex analysis. Ghironi, Lee, and Rebucci (2006) consider a similar framework in which equities are the only assets traded. An interesting extension would be the inclusion of equity trading together with bond trading. In particular it would be interesting to study whether the optimal allocation would require more variation in the real returns on equity rather than bonds or viceversa. This would most likely depend on the portfolio allocations among the different instruments. In the same vein, it would be interesting to allow for endogenous portfolio choices as in Devereux and Sutherland (2007) and to solve for the optimal allocation. A linear-quadratic solution would not be appropriate for this context.

The market structure assumed in this paper—of incomplete markets combined with transaction costs—has been successfully used to analyze the interaction between supply-side behavior, market structure and the real exchange rate in Benigno and Thoenissen (2003). For a UK-euro area calibration, they show that when TFP increases in the traded-good sector, a depreciation of the terms of trade offsets the appreciation of the relative price of nontraded goods, contrasting with the

Balassa–Samuelson proposition. Moreover, Benigno and Thoenissen (2007) have shown that this very simple form of market structures is sufficient in generating the observed cross-correlation between relative consumption and real exchange rate, so as to explain the Backus–Smith anomaly. In an empirical analysis, Selaive and Tuesta (2003) find that consumption growth and real exchange rates may be consistent with a significant role for the net foreign asset position as it would be implied by the model of this paper. In this vein, our model should also be extended to include departures from PPP due to the existence of nontraded goods or to deviations from the law of one price. In this case, the welfare criterion would also display an objective for real exchange rate stabilization as in Devereux and Engel (2007).

The model of this paper does not consider capital accumulation. This is left to future research. It is likely that the inclusion of fixed investment can reduce the *ex ante* volatility of the real returns, but not the *ex post* volatility which is needed for the insurance mechanism discussed in this paper.

An important question that is left to future research is to explain what would happen when each country is just interested in maximizing the welfare of its residents. Indeed, to maximize the consumption of its own residents, each policymaker has an incentive to reduce the financial costs of its liabilities or to increase the return of its assets independently of the business cycle synchronization. This interest contrasts with that of the other policymaker.

APPENDIX

In this appendix we derive equation (24) in the text. The welfare criterion is

$$W = \mathrm{E}_0\left\{\sum_{t=0}^{\infty}\beta^t w_t\right\},$$

where the utility flow is defined as a weighted average of the utility of both countries

$$\begin{aligned} w_t \equiv\ & n\frac{C_t^{1-\rho}g_t}{1-\rho} + (1-n)\frac{C_t^{*1-\rho}g_t^*}{1-\rho} - \int_0^n \frac{y_t(h)^{1+\eta}z_t^{-(1+\eta)}}{1+\eta}dh \\ & - \int_n^1 \frac{y_t^*(f)^{1+\eta}z_t^{*-(1+\eta)}}{1+\eta}df. \end{aligned} \tag{A1}$$

First, we take a second-order expansion of the term

$$n\frac{C_t^{1-\rho}g_t}{1-\rho} + (1-n)\frac{C_t^{*1-\rho}g_t^*}{1-\rho}$$

under the assumption that in the steady state the marginal utilities of consumption are equated across countries, i.e.,

$$\bar{C}^{-\rho}\bar{g} = \bar{C}^{*-\rho}\bar{g}^*.$$

We take a second-order expansion of the term

$$n\frac{C_t^{1-\rho}g_t}{1-\rho}+(1-n)\frac{C_t^{*1-\rho}g_t^*}{1-\rho}$$

obtaining

$$\begin{aligned}n\frac{C_t^{1-\rho}g_t}{1-\rho}+(1-n)\frac{C_t^{*1-\rho}g_t^*}{1-\rho} &= n\bar{C}^{-\rho}(C_t-\bar{C})+(1-n)\bar{C}^{*-\rho}\left(C_t^*-\bar{C}\right)\\ &+\frac{n}{2}\bar{C}^{-\rho-1}(C_t-\bar{C})^2+\frac{1-n}{2}\bar{C}^{*-\rho-1}\left(C_t^*-\bar{C}\right)^2+n\bar{C}^{-\rho}(C_t-\bar{C})(g_t-\bar{g})\\ &+(1-n)\bar{C}^{*-\rho}\left(C_t^*-\bar{C}\right)\left(g_t^*-\bar{g}^*\right)+\text{t.i.p.}+\mathcal{O}(\|\xi\|^3), \qquad \text{(A2)}\end{aligned}$$

where $O(\| \xi \|^3)$ represents all the terms that are of third order or higher in the deviations of the various variables from their steady-state values and in t.i.p. we include all the terms that are independent of monetary policy. After some steps we get

$$\begin{aligned}n\frac{C_t^{1-\rho}g_t}{1-\rho}+(1-n)\frac{C_t^{*1-\rho}g_t^*}{1-\rho} &= \bar{C}^{-\rho}\bar{g}\bar{C}^W\Bigg[\hat{C}_t^W+\frac{1}{2}\left(\hat{C}_t^W\right)^2-\frac{\rho}{2}\left(\hat{C}_t^W\right)^2\\ &-\phi(1-\phi)\frac{\rho}{2}\left(\hat{C}_t^R-\rho^{-1}\hat{g}_t^R\right)^2+\rho\hat{C}_t^W\left(\phi\hat{g}_t+(1-\phi)\hat{g}_t^*\right)\Bigg]\\ &+\text{t.i.p.}+\mathcal{O}(\|\xi\|^3), \qquad \text{(A3)}\end{aligned}$$

where $\hat{C}_t=\ln(C_t/\bar{C})$, $\hat{C}_t^*=\ln(C_t^*/\bar{C}^*)$ and $\hat{C}_t^W=\ln(C_t^W/\bar{C}^W)$.

Similarly, we take a second-order Taylor expansion of $\frac{y_t(h)^{1+\eta}z_t^{-(1+\eta)}}{1+\eta}$ around a steady state where $y_t(h)=\bar{Y}=\bar{C}^W$ for each h, at each date t, and where $z_t=1$ at each date t, obtaining

$$\begin{aligned}\frac{y_t(h)^{1+\eta}z_t^{-(1+\eta)}}{1+\eta} &= \bar{Y}^\eta(y_t(h)-\bar{Y})+\frac{1}{2}\bar{Y}^{\eta-1}(y_t(h)-\bar{Y})^2\\ &+\bar{Y}^\eta(1+\eta)(y_t(h)-\bar{Y})(z_t-1)+\text{t.i.p.}+\mathcal{O}(\|\xi\|^3). \qquad \text{(A4)}\end{aligned}$$

In the same way, we can take an expansion of $\frac{y_t^*(f)^{1+\eta}z_t^{*-(1+\eta)}}{1+\eta}$ obtaining

$$\begin{aligned}\frac{y_t^*(f)^{1+\eta}z_t^{*-(1+\eta)}}{1+\eta} &= \bar{Y}^\eta(y_t^*(f)-\bar{Y})+\frac{1}{2}\bar{Y}^{\eta-1}\left(y_t^*(f)-\bar{Y}\right)^2+\bar{Y}^\eta(1+\eta)\\ &\times\left(y_t^*(f)-\bar{Y}\right)\left(z_t^*-1\right)+\text{t.i.p.}+\mathcal{O}(\|\xi\|^3). \qquad \text{(A5)}\end{aligned}$$

Combining (A4) and (A5), we obtain after some algebra that

$$\int_0^n \frac{y_t(h)^{1+\eta} z_t^{-(1+\eta)}}{1+\eta} dh + \int_n^1 \frac{y_t^*(f)^{1+\eta} z_t^{*-(1+\eta)}}{1+\eta} df = \bar{Y}^{1+\eta} \cdot \Big[\hat{C}_t^W + \frac{1}{2}\big(\hat{C}_t^W\big)^2$$
$$+ n\mathrm{E}_h[\hat{y}_t(h)] + (1-n)\mathrm{E}_f[\hat{y}_t(f)] + n(1-n)\theta(\hat{T}_t)^2 + \frac{n}{2}\mathrm{E}_h[\hat{y}_t(h)]^2$$
$$+ \frac{1-n}{2}\mathrm{E}_f[\hat{y}_t(f)]^2 + n\frac{\eta}{2} \cdot \mathrm{E}_h[\hat{y}_t(h)]^2 + (1-n)\frac{\eta}{2} \cdot \mathrm{E}_f[\hat{y}_t(f)]^2$$
$$- n(1+\eta) \cdot \hat{z}_t \mathrm{E}_h \widehat{y}_t(h) - (1-n)(1+\eta) \cdot \hat{z}_t^* \mathrm{E}_f \hat{y}_t(f) \Big] + \text{t.i.p.} + \mathcal{O}(\|\xi\|^3). \tag{A6}$$

Note that

$$\mathrm{E}_h[\hat{y}_t(h)]^2 = \mathrm{var}_h \hat{y}_t(h) + [E_h \hat{y}_t(h)]^2, \tag{A7}$$

$$\mathrm{E}_h[\hat{y}_t(f)]^2 = \mathrm{var}_h \hat{y}_t(f) + [E_h \hat{y}_t(f)]^2. \tag{A8}$$

We can define the aggregators

$$Y_{H,t} = \left[\left(\frac{1}{n}\right) \int_o^n y(h)^{\frac{\sigma-1}{\sigma}} dh \right]^{\frac{\sigma}{\sigma-1}} = \left(\frac{P_{H,t}}{P_t}\right)^{-\theta} C_t^W,$$
$$Y_{F,t} = \left[\left(\frac{1}{1-n}\right) \int_n^1 y(f)^{\frac{\sigma-1}{\sigma}} df \right]^{\frac{\sigma}{\sigma-1}} = \left(\frac{P_{F,t}}{P_t}\right)^{-\theta} C_t^W,$$

and take a second-order approximation of them obtaining

$$\hat{Y}_{H,t} = E_h \hat{y}_t(h) + \frac{1}{2}\left(\frac{\sigma-1}{\sigma}\right) \mathrm{var}_h \hat{y}_t(h) + \mathcal{O}(\|\xi\|^3), \tag{A9}$$
$$\hat{Y}_{F,t} = E_f \hat{y}_t(f) + \frac{1}{2}\left(\frac{\sigma-1}{\sigma}\right) \mathrm{var}_f \hat{y}_t(f) + \mathcal{O}(\|\xi\|^3). \tag{A10}$$

Finally, substituting (A7), (A8), (A9), and (A10) into (A6) we obtain,

$$\int_0^n \frac{y_t(h)^{1+\eta} z_t^{-(1+\eta)}}{1+\eta} dh + \int_n^1 \frac{y_t^*(f)^{1+\eta} z_t^{*-(1+\eta)}}{1+\eta} df = \bar{Y}^{1+\eta} \cdot \Big\{ \hat{C}_t^W + \frac{1}{2}\big(\hat{C}_t^W\big)^2$$
$$+ n(1-n)\theta \hat{T}_t{}^2 + \frac{1}{2}\eta \cdot \big[n\hat{Y}_{H,t}^2 + (1-n)\hat{Y}_{F,t}^2\big] - (1+\eta) \cdot \big[n\hat{Y}_{H,t}\hat{z}_t$$
$$+ (1-n)\hat{Y}_{F,t}^* \hat{z}_t^*\big] + \frac{1}{2}(\sigma^{-1}+\eta)[n\mathrm{var}_h \hat{y}_t(h) + (1-n)\,\mathrm{var}_f \hat{y}_t(f)] \Big\}$$
$$+ \text{t.i.p.} + \mathcal{O}(\|\xi\|^3). \tag{A11}$$

Combining (A3), (A11), and (A1) and substituting the expressions for $\hat{Y}_{H,t},\ \hat{Y}_{F,t}$ after some algebra we get

$$\begin{aligned} w_t = & -\bar{C}^W \bar{C}^{-\rho} \bar{g} \left\{ \frac{1}{2}(\rho+\eta)\big[\hat{C}_t^W - \tilde{C}_t^W\big]^2 + \frac{1}{2}\phi(1-\phi)\rho\big[\hat{C}_t^R - \tilde{C}_t^R\big]^2 \right. \\ & + \frac{1}{2} n(1-n)(1+\eta\theta)\theta[\hat{T}_t - \tilde{T}_t]^2 \\ & \left. + \frac{1}{2}(\sigma^{-1}+\eta)\cdot[n\mathrm{var}_h \hat{y}_t(h) + (1-n)\,\mathrm{var}_f \hat{y}_t(f)] \right\} \\ & + \mathrm{t.i.p.} + \mathcal{O}(\|\xi\|^3) \end{aligned}$$

after having used the definitions of $\tilde{C}_t^W,\ \tilde{C}_t^R$, and $\tilde{T}_t$. given by

$$\begin{aligned} \hat{C}_t^R &= \frac{1}{\rho}\hat{g}_t^R, \\ \tilde{C}_t^W &= \frac{1}{\rho+\eta}\big[\hat{g}_t^W + (\phi-n)\hat{g}_t^R\big] + \frac{\eta}{\rho+\eta}\hat{z}_t^W, \\ \tilde{T}_t &= \frac{\eta}{1+\theta\eta}\hat{z}_t^R. \end{aligned}$$

Following Woodford (2003), we derive $\mathrm{var}_h \widehat{y}_t(h)$ and $\mathrm{var}_f \widehat{y}_t(f)$ to get

$$\begin{aligned} \sum_{t=0}^{\infty} \beta^t \mathrm{var}_h\{\log y_t(h)\} &= \frac{\alpha}{(1-\alpha)(1-\alpha\beta)}\sigma^2 \sum_{t=0}^{\infty} \beta^t (\pi_{H,t})^2 + \mathrm{t.i.p.} + \mathcal{O}(\|\xi\|^3), \\ \sum_{t=0}^{\infty} \beta^t \mathrm{var}_f\{\log y_t(f)\} &= \frac{\alpha^*}{(1-\alpha^*)(1-\alpha^*\beta)}\sigma^2 \sum_{t=0}^{\infty} \beta^t (\pi_{F,t}^*)^2 + \mathrm{t.i.p.} + \mathcal{O}(\|\xi\|^3). \end{aligned}$$

We finally obtain we can get

$$W = -\frac{\bar{C}^{-\rho}\bar{g}\overline{C}^W}{2}\mathrm{E}_0\left\{ \sum_{t=0}^{\infty} \beta^t L_t \right\}, \tag{A12}$$

with

$$\begin{aligned} L_t = & (\rho+\eta)\cdot\left(\hat{C}_t^W - \tilde{C}_t^W\right)^2 + \phi(1-\phi)\rho\cdot\left(\hat{C}_t^R - \tilde{C}_t^R\right)^2 \\ & + n(1-n)(1+\eta\theta)\theta\cdot(\hat{T}_t - \tilde{T}_t)^2 + n\frac{\sigma}{k}\cdot(\pi_{H,t})^2 + (1-n)\frac{\sigma}{k^*}\cdot\left(\pi_{F,t}^*\right)^2 \\ & + \mathrm{t.i.p.} + \mathcal{O}(\|\xi\|^3), \end{aligned}$$

which corresponds to equation (24) in the text.

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