ARE VALUATION EFFECTS DESIRABLE FROM A GLOBAL PERSPECTIVE?

Pierpaolo Benigno
LUISS "Guido Carli"

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Abstract

Recent studies have emphasized the role of valuation effects due to exchange rate movements in easing the process of adjustment of the external balance of a country. This paper asks to what extent valuation effects are desirable from a global perspective as a mean to achieve an efficient allocation of resources. In a frictionless world, it is desirable to have large movements in prices and exchange rates. But once a small concern for price stability is introduced not only should prices be stabilized but also the response of the exchange rate should be muted. There is a minor role for valuation effects that depends both on the size and composition of assets and liabilities.

The analysis of the external imbalances of a country has recently become a compelling subject of research for the historically high current account deficits recorded in the US economy together with the increasing worsening of its net foreign asset position.[1]

The current paradigm to think about the external balance of a country is the so-called "intertemporal approach to the current account". According to this theory, the external adjustment of a country occurs through movements in the trade balance, as a consequence of changes in the allocation of real quantities and equilibrium relative prices.[2]

This approach misses an important channel of adjustment, a financial one, since it assumes that the portfolio return is not varying over time and neglects the heterogenous composition of the financial instruments that are part of the portfolio of a country. Even if there are no changes in the borrowing decisions of a country, the net foreign asset position can change because the market value of the stock of assets and liabilities varies. Movements in the nominal exchange rate are an important source of these valuation effects.

This paper analyzes the extent to which the valuation channel due to the exchange rate is desirable from a global welfare perspective. The main finding is that whereas in a frictionless world valuation effects are of important magnitude once a small concern for price stability is introduced they are less desirable and play a minor role. The prescription for adopting inflation-targeting regimes that results from current monetary models is strong enough to dominate other objectives like the world distribution of wealth through valuation effects.

The issue of desirability has been neglected by the current literature. Studies as Gourinchas and Rey (2005, 2006), Lane and Milesi-Ferretti (2005, 2006) and Tille (2003, 2004), have documented that in the recent experi-

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[1] See Clarida (2006) for a collection of works on the subject and Backus et al. (2005).
[2] This is the approach taken by Obstfeld and Rogoff (2005).

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ence of the US economy valuation effects have accounted for a large fraction of the changes in the international investment position of the country and have concluded that a depreciation of the US dollar can ease the real adjustment needed to reduce the external imbalances.[3] As pointed out by Obstfeld (2004), a theory in which financial adjustments and in particular exchange rate movements are important in determining the frontier of the feasible allocation of quantities and relative prices can raise the tempting argument that exchange rates adjust to sustain any real allocation achieved. They can even balance any current imbalance with the risk of being at the end destabilizing for the economy.

Desirability puts discipline on the allocation of consumption and relative prices that should be of interest by focusing on which movements in exchange rates are compatible with that real allocation.

To address this issue, we propose a two-country model in which each country is specialized in the production of a bundle of goods. In the benchmark case, there are no frictions except for the ex-ante incompleteness of financial markets. In particular it is assumed that each country can only borrow in a risk-free nominal bond denominated in its currency and lend in a risk-free nominal bond denominated in the other country's currency.

In a frictionless world, exchange rate and assets movements are desirable for achieving the efficient allocation of resources across countries. In a rough quantitative experiment we find that they should be of important magnitude compared with that of the shocks. For a 1% permanent increase in productivity, the exchange rate should appreciate by 5.5% and the net foreign asset position worsen in the amount of 3% of gross domestic product for the country that experiences the increase in productivity. However, once a small degree of price friction is introduced that implies an average duration of price contracts just above the unit interval (3 months), producer prices should be stabilized even following permanent shocks. Moreover the short and long-run responses of the exchange rate are substantially dampened and reduced

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[3]See also Blanchard et al. (2005) and Cavallo and Tille (2006).

to one tenth of the magnitude we observe in the frictionless-case economy. Valuation effects are less desirable.

This paper further contributes to the current literature by revisiting the implications of the theory of the "intertemporal approach to the current account" on the mechanism of adjustment following permanent or transitory shocks with the twist of valuation effects.

Following a *permanent* productivity shock in one country, the intertemporal approach to the current account would suggest that the consumption of the country that experiences the favorable shock should increase proportionally without any changes in the net-foreign asset position.[4] Instead, global efficiency would require a transfer of real wealth to the other country. In a frictionless world valuation effects work in this direction: an appreciation of the nominal exchange rate acts as a negative financial shock that reduces the portfolio return of the country with the high productivity. This channel is strong enough to worsen in a permanent way its net foreign asset position and results in a permanent transfer of wealth to the other economy. Through this mechanism consumption can also increase abroad.

Following a *temporary* shock, the classic theory would suggest that the country affected by the shock accumulates net foreign assets that allow to spread across time the temporary increase in wealth and achieve higher profile of consumption in future periods. Instead, a global optimum requires on one side that there is no intertemporal propagation of the shock and on the other side that consumption should temporarily increase abroad. This is possible if the country with the high productivity experiences also a negative financial shock that distributes the additional real wealth to the other country. Again an appreciation of the nominal exchange rate would work for this end. In contrast with the permanent-shock case, the net foreign asset position improves in the short run and returns immediately back to the initial value.[5]

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[4]This example considers a model with fixed capital stock.

[5]In the main text, we discuss also the dynamics following shocks that influence consumption preferences.

There has been a recent interest on the analysis of valuation effects from the view of micro-founded models. Tille (2005) presents a richer structure of financial markets, but in which the only focus is on monetary shocks and on how valuation effects affect their transmission mechanisms. Kollman (2003) studies the welfare effects of alternative, but sub-optimal, monetary policy regimes in a quantitative business cycle model of a two-country world. Ghironi et al. (2005) analyzes the impact of valuation effects on the cross-holdings of equity. Devereux and Saito (2005) presents a tractable portfolio model that emphasizes the interaction between monetary policy and the current account for hedging purpose from a positive point of view.

The structure of this work is the following. Section 1 presents the model economy, studies the efficient allocation and its implementation with decentralized markets. Section 2 discusses the response of prices, exchange rates, and assets following permanent productivity or preference shocks. Section 3 extends the benchmark model adding price rigidities, while Section 4 analyzes the constrained efficient allocation. Section 5 studies the robustness of previous results when there are significant frictions in the price mechanism. Section 6 concludes.

1   Model

The world economy consists of two countries, which are labelled H and F or domestic and foreign, with population size n and $1 - n$ respectively and $0 < n < 1$. The structure of the model is similar to most of the current open-macro models.[6] Each country is specialized in the production of a bundle of goods of size n and $1 - n$ for country H and F, respectively. All goods are traded without frictions and households within a country are identical and have preferences of the form

$$U_{t_0} = E_{t_0} \sum_{t=t_0}^{\infty} \beta^{t-t_0} \left[\frac{C_t^{1-\rho} g_t^{\rho}}{1-\rho} - \frac{1}{n} \int_0^n \frac{l_t(h)^{1+\eta}}{1+\eta} dh \right] \tag{1}$$

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[6] See Obstfeld and Rogoff (2001) among others.

for country H and

$$U_{t_0}^* = E_{t_0} \sum_{t=t_0}^{\infty} \beta^{t-t_0} \left[\frac{C_t^{*1-\rho} g_t^{*\rho}}{1-\rho} - \frac{1}{1-n} \int_n^1 \frac{l_t^*(f)^{1+\eta}}{1+\eta} df \right] \tag{2}$$

for country F where E_t denotes the expectation conditional on the information set at a generic time t and β is the intertemporal discount factor with $0 < \beta < 1$. The momentary utility at a generic time t depends on consumption indexes C and C^*, for households in country H and F respectively, where $\rho > 0$ is the inverse of the intertemporal elasticity of substitution in consumption and g and g^* are country-specific shocks to the preferences toward consumption. The index C is defined as

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

where θ, with $\theta > 0$, is the intratemporal elasticity of substitution between the bundles of goods C_H and C_F. In particular C_H includes the consumption of all the goods produced in country H and is defined as

$$C_H \equiv \left[\left(\frac{1}{n} \right)^{\frac{1}{\sigma}} \int_o^n c(h)^{\frac{\sigma-1}{\sigma}} dh \right]^{\frac{\sigma}{\sigma-1}},$$

where σ is the intratemporal elasticity of substitution across the goods produced within country H, with $\sigma > 1$, and $c(h)$ indeed denotes consumption of a variety h of these goods; C_F includes instead the consumption of the goods produced in country F with elasticity of substitution among them equal to σ

$$C_F \equiv \left[\left(\frac{1}{1-n} \right)^{\frac{1}{\sigma}} \int_n^1 c(f)^{\frac{\sigma-1}{\sigma}} df \right]^{\frac{\sigma}{\sigma-1}}$$

where $c(f)$ is consumption of one of these goods. The index C^* is defined in a similar way. It follows that n denotes at the same time the population size of country H, the size of goods produced in country H and the weight in the general consumption indexes C and C^* given to the goods produced in country H. Another implication of the above structure of consumption

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preferences is that there is no home bias in consumption – preferences are similar across countries. Given prices $p(h)$ and $p^*(h)$ for a generic good h, in the currency of country H and F respectively, and given prices $p(f)$ and $p^*(f)$ for a generic good f, we assume that the law-of-one-price holds for all goods, i.e. $p(h) = Sp^*(h)$ and $p(f) = Sp^*(f)$ where S is the nominal exchange rate, i.e. the price of the currency of country F relative to that of H.

Given the above consumption indexes, it is possible to define in an appropriate way the consumption-based price indexes P, P_H and P_F in currency of country H and P^*, P_H^* and P_F^* in currency of country F. Since the law-of-one-price holds and the consumption bundles are identical across countries, purchasing power parity holds at the level of all the consumption-based price indexes. Moreover, the aggregate demands of generic goods h and f, produced respectively in country H and F, are given by

$$y(h) = \left(\frac{p(h)}{P_H}\right)^{-\sigma} \left(\frac{P_H}{P}\right)^{-\theta} (nC + (1-n)C^*), \tag{3}$$

and

$$y^*(f) = \left(\frac{p(f)}{P_F}\right)^{-\sigma} \left(\frac{P_F}{P}\right)^{-\theta} (nC + (1-n)C^*), \tag{4}$$

where P_H/P and P_F/P obey the following restriction[7]

$$n \left(\frac{P_H}{P}\right)^{1-\theta} + (1-n) \left(\frac{P_F}{P}\right)^{1-\theta} = 1. \tag{5}$$

As it is shown in (1) and (2), the momentary utility of each household includes the disutility of supplying labor to the production of each of the goods produced in its country. Disutility is separable across the varieties of labor offered. Technology to produce a generic domestic good is given by $y(h) = z \cdot L(h)$ where $L(h)$ is an average of the labor of variety h supplied by the households of country H and z is a country-specific shock to labor productivity. In particular, all households being alike, the equilibrium is symmetric

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[7]It is indifferent whether we denominate relative prices in the domestic or foreign currency since the law-of-one-price holds.

and $L(h) = l(h)$. Similarly in country F, there is a production technology of the form $y^*(f) = z^* \cdot L^*(f)$ for a generic good f with $L^*(f) = l^*(f)$ and z^* is a country-specific shock to labor productivity in country F. After substituting $l(h) = y(h)/z$ and $l^*(f) = y^*(f)/z^*$ in (1) and (2) and using the aggregate demands (3) and (4), we can write

$$U_{t_0} = E_{t_0} \sum_{t=t_0}^{\infty} \beta^{t-t_0} \left[\frac{C_t^{1-\rho} g_t^{\rho}}{1-\rho} - \frac{Y_t^{1+\eta} z_t^{-(1+\eta)}}{1+\eta} \Delta_t \right] \tag{6}$$

and

$$U_{t_0}^* = E_{t_0} \sum_{t=t_0}^{\infty} \beta^{t-t_0} \left[\frac{C_t^{*1-\rho} g_t^{*\rho}}{1-\rho} - \frac{Y_t^{*1+\eta} z_t^{*-(1+\eta)}}{1+\eta} \Delta_t^* \right] \tag{7}$$

where we have defined appropriate output aggregators of the form

$$Y \equiv \left(\frac{P_H}{P} \right)^{-\theta} (nC + (1-n)C^*), \tag{8}$$

$$Y^* \equiv \left(\frac{P_F}{P} \right)^{-\theta} (nC + (1-n)C^*), \tag{9}$$

and indexes of price dispersion

$$\Delta = \frac{1}{n} \int_0^n \left(\frac{p(h)}{P_H} \right)^{-\sigma} dh \geq 1, \tag{10}$$

$$\Delta^* = \frac{1}{1-n} \int_n^1 \left(\frac{p(f)}{P_F} \right)^{-\sigma} df \geq 1. \tag{11}$$

1.1   Efficient allocation

To answer the question of whether valuation effects are desirable, we need to specify an allocation of real quantities and relative prices. We choose it as the solution of the following Pareto problem in which the objective

$$W_{t_0} = nU_{t_0} + (1-n)U_{t_0}^* \tag{12}$$

is maximized by choosing the sequences $\{C_t, C_t^*, Y_t, Y_t^*, P_{H,t}/P_t, P_{F,t}/P_t, \Delta_t, \Delta_t^*\}_{t=t_0}^{\infty}$ under the sequences of constraints (5), (8), (9), (10) and (11).

There are two direct implications of the above maximization problem: (i) there is no intertemporal dimension, (ii) it is efficient not to create any price dispersion in both countries, i.e. $\Delta_t = \Delta_t^* = 1$ for each t. The remaining set of first-order conditions (which are necessary and sufficient) can be written as

$$\frac{C_t}{C_t^*} = \frac{g_t}{g_t^*}, \tag{13}$$

$$C_t^{-\rho} g_t^{\rho} \frac{P_{H,t}}{P_t} = Y_t^{\eta} z_t^{-(1+\eta)}, \tag{14}$$

$$C_t^{*-\rho} g_t^{*\rho} \frac{P_{F,t}}{P_t} = Y_t^{*\eta} z_t^{*-(1+\eta)}. \tag{15}$$

Condition (13) shows that an increase in g at time t—other things being equal– increases the ratio of consumption between country H and F in a proportional way. Combining appropriately the above first-order conditions we obtain that terms of trade, labelled T , depend on the ratio of the productivity shocks as

$$T_t \equiv \frac{P_{F,t}}{P_{H,t}} = \left(\frac{z_t}{z_t^*}\right)^{\frac{(1+\eta)}{1+\theta\eta}}. \tag{16}$$

A similar observation applies to the ratio of output

$$\left(\frac{Y_t}{Y_t^*}\right) = \left(\frac{z_t}{z_t^*}\right)^{\frac{(1+\eta)\theta}{1+\theta\eta}}. \tag{17}$$

In particular an increase at time t in the productivity of labor of country H increases aggregate output in country H relative to country F, decreases the price of goods produced in country H relative to that of country F worsening the terms of trade of country H.

1.2 Implementation of the efficient allocation in a frictionless economy

Up to this point, we have analyzed the efficient allocation for real quantities and relative prices. In our framework, the question of whether valuation effects –exchange rate movements– are beneficial is parallel to the issue of

determining which movements, if any, in prices and exchange rates are compatible with the efficient allocation when markets for goods, labor and assets are decentralized.

Starting from the labor market, we assume that households supply labor in a competitive market and at the margin they equate their marginal rate of substitution between labor and consumption to the real wage for each of the varieties h of labor offered. This optimality condition reads as

$$\frac{w_t(h)}{P_t} = \frac{1}{n}\frac{l_t(h)^\eta}{C_t^{-\rho}g_t^\rho} \tag{18}$$

for households in country H and

$$\frac{w_t^*(f)}{P_t^*} = \frac{1}{1-n}\frac{l_t^*(f)^\eta}{C_t^{*-\rho}g_t^{*\rho}} \tag{19}$$

for those in country F where $w_t(h)$ and $w_t^*(f)$ are nominal wages for varieties of labor h and f denominated in the currency of country H and F, respectively.

Firms act instead in a monopolistically-competitive market and maximize their profits. Demand is aggregated across the two markets, as in (3) and (4), and each firm can freely choose its price in its own currency. Profits of a generic firm producing good h in country H are given by

$$\pi_t(h) = (1-\tau)p_t(h)y_t(h) - nw_t(h)l_t(h)$$

where τ is a tax rate on firm's revenue. We assume that firms are monopolistically-competitive. This is notably one reason for why the efficient allocation cannot be decentralized. To avoid this problem, we assume that τ is set as a subsidy in a way to offset the monopolistic distortions.[8] In this case, optimality conditions on the side of the firms imply that

$$p_t(h) = \frac{nw_t(h)}{z_t} \tag{20}$$

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[8]The subsidy is financed through lump-sum taxes that adjust to balance the budget of the government in any possible allocation.

for a generic firm h in country H and

$$p_t^*(f) = \frac{(1-n)w_t^*(f)}{z_t^*} \tag{21}$$

for a generic firm f in country F. Combining (20) into (18) and (21) into (19) we obtain

$$p_t(h) = P_t \frac{y_t(h)^\eta}{C_t^{-\rho} g_t^\rho z_t^{1+\eta}}, \tag{22}$$

and

$$p_t^*(f) = P_t^* \frac{y_t^*(f)^\eta}{C_t^{*-\rho} g_t^{*\rho} z_t^{*1+\eta}}. \tag{23}$$

In particular equations (22) and (23) imply a symmetric equilibrium in which all firms within a country set the same price – i.e. $p_t(h) = P_{H,t}$ and $p_t(f) = P_{F,t}$. Given the specified goods and labor markets, it follows that (22) and (23) are consistent with (14) and (15), respectively.

To complete the implementation of the efficient allocation we need to specify the structure of the asset markets. This is needed to enforce the first-order condition (13) under decentralized markets. It is known that complete asset markets would be appropriate for this purpose.[9] We mean frictionless trade within and across countries in a set of one-period real (denominated in the common general consumption index) contingent securities that span all the possible states of nature at the maturity period together with a suitable assumption on the initial state-contingent allocations of bonds at the starting period t_0. With complete markets, there is no role for valuation effects since all the implementation of the desired equilibrium falls on the state-contingent return of the securities. Movements in prices and exchange rates are redundant. They are not even determined.

This observation points toward a possible role for valuation effects when asset markets are incomplete. To illustrate the mechanism, we start from a simple form of incomplete markets in which the only asset traded across countries is a non-state contingent nominal bond with one-period maturity denominated in the currency of country H. To keep the analysis simple, we

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[9]See Ljungqvist and Sargent (2004, ch. 8).

assume that markets are complete within each country. In this case each household within a country has a unique intertemporal budget constraint. Summing all these constraints among households living in a country together with the balance-budget constraint of the government we obtain the overall resource constraint of each country. In particular for country H we obtain

$$B_{t-1} = E_t \sum_{\tau=t}^{\infty} Q_{t,\tau}[P_{H,\tau}Y_\tau - P_\tau C_\tau]$$

where B_{t-1} denotes risk-free nominal debt (in per-capita terms) denominated in currency of country H issued at time $t-1$ and maturing at date t. The above resource constraint of country H requires that debt maturing at time t should be equal to an appropriate expected present discounted value of nominal trade surplus. In particular the discount factor $Q_{t,\tau}$ is given by the ratio of marginal utilities of nominal income across periods

$$Q_{t,\tau} = \beta^{T-t}\frac{C_\tau^{-\rho}g_\tau^\rho}{C_t^{-\rho}g_t^\rho}\frac{P_t}{P_\tau} \tag{24}$$

from which it follows that

$$\frac{B_{t-1}}{P_t} = E_t\left\{\sum_{\tau=t}^{\infty}\beta^{\tau-t}\frac{C_\tau^{-\rho}g_\tau^\rho}{C_t^{-\rho}g_t^\rho}\left[\frac{P_{H,\tau}}{P_\tau}Y_\tau - C_\tau\right]\right\}. \tag{25}$$

In the efficient allocation the RHS of (25) is a given number; moreover B_{t-1} is also given. It follows that (25) can determine whether there exists a positive price level P at time t that is compatible with the efficient allocation.[10] In the efficient allocation (14) and (15) determine $P_{H,t}/P_t$ and $P_{F,t}/P_t$. When P_t is determined then also $P_{H,t}$ and $P_{F,t}$ are determined but not necessarily S_t. To complete the decentralization of the allocation, we need to add Euler equations because of the intertemporal trading in the risk-free bond denominated in the currency of country H. These are given by

$$\frac{C_t^{-\rho}g_t^\rho}{P_t} = \beta(1+i_t)E_t\left\{\frac{C_{t+1}^{-\rho}g_{t+1}^\rho}{P_{t+1}}\right\} \tag{26}$$

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[10]In this example, it might be possible that there is no such price. This is the case if the sign of B_{t-1} is different from the sign of the RHS of (25).

for country H and

$$\frac{C_t^{*-\rho} g_t^{*\rho}}{P_t} = \beta(1 + i_t)E_t \left\{ \frac{C_{t+1}^{*-\rho} g_{t+1}^{*\rho}}{P_{t+1}} \right\} \tag{27}$$

for country F, where i_t is the risk-free nominal interest rate.

We assume that there are no frictions in holding money as in the cashless-limiting economy of Woodford (2003). In this case the optimal path of nominal interest rates is not determined in the Pareto problem. It follows that in (26) even if P_t is determined, the time t expectation of the marginal utility of nominal income at time $t + 1$, i.e. $E_t\{C_{t+1}^{-\rho} g_{t+1}^{\rho}/P_{t+1}\}$, is not determined. This has implications for the determinacy of prices and bond holdings in the following periods. Indeed lead equation (25) one period and take the time t expectation to obtain

$$B_{t+1}E_t \left\{ \frac{C_{t+1}^{-\rho} g_{t+1}^{\rho}}{P_{t+1}} \right\} = E_t \left\{ \sum_{\tau=t+1}^{\infty} \beta^{\tau-t-1} C_\tau^{-\rho} g_\tau^{\rho} \left[\frac{P_{H,\tau}}{P_\tau} Y_\tau - C_\tau \right] \right\}.$$

It follows that since $E_t\{C_{t+1}^{-\rho} g_{t+1}^{\rho}/P_{t+1}\}$ is not determined, B_{t+1} is not determined and so P_{t+1}. In general, except for the initial price level, there are many paths of prices, asset position and exchange rate which are all compatible with the efficient allocation.

Our interest in this paper is to model an economy in which it is possible to trade internationally two risk-free bonds, one denominated in country H's currency and the other in country F's currency. The purpose is to investigate the role of exchange-rate valuation effects that are due to the different currency compositions of the country portfolio. In this case (25) becomes

$$\frac{B_{t-1}}{P_t} - \frac{S_t A_{t-1}^*}{P_t} = E_t \left\{ \sum_{\tau=t}^{\infty} \beta^{\tau-t} \frac{C_\tau^{-\rho} g_\tau^{\rho}}{C_t^{-\rho} g_t^{\rho}} \left[\frac{P_{H,\tau}}{P_\tau} Y_\tau - C_\tau \right] \right\}. \tag{28}$$

where A_{t-1}^* denotes country H's per-capita holdings of nominal assets denominated in the currency of country F. We assume that B and A are positive.[11]

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[11] This is going to capture the fact that the US economy is overall a net lender in securities denominated in foreign currency and borrower in dollar-denominated securities.

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Since an additional bond is traded, on the side of the households, two other Euler equations should be satisfied of the form

$$\frac{C_t^{-\rho}g_t^{\rho}}{P_t^*} = \beta(1+i_t^*)E_t\left\{\frac{C_{t+1}^{-\rho}g_{t+1}^{\rho}}{P_{t+1}^*}\right\} \tag{29}$$

in country H and

$$\frac{C_t^{*-\rho}g_t^{*\rho}}{P_t^*} = \beta(1+i_t^*)E_t\left\{\frac{C_{t+1}^{*-\rho}g_{t+1}^{*\rho}}{P_{t+1}^*}\right\} \tag{30}$$

in country F where i^* is the risk-free nominal interest rate in currency of country F. In this case, equation (28) shows that given B_{t-1} and A_{t-1}^* and the value of the RHS of (28) it is not even possible to determine in a distinct way P_t or S_t. But, contrary to the previous example, it is always possible to find some positive P_t and S_t that are compatible with the efficient allocation for the fact that both B_{t-1} and A_{t-1} are assumed to be positive. The argument for indeterminacy of subsequent prices, exchange rates and asset positions still applies to this case.

2   Two textbook experiments

The results of the previous section point towards the desirability of valuation effects since these are the mechanisms through which incomplete markets can be completed and the efficient allocation reached. In particular, exchange rate movements can have an important role in distributing wealth across countries. To get some further insights on the frictionless economy, we restrict the degrees of indeterminacy by making additional assumptions on the path of prices in future periods.[12] The restrictions that we are imposing are not arbitrarily but indeed consistent with those that a model with small frictions in the price mechanism would impose.[13] In this limiting case,

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[12] In this way the expected marginal utility of nominal income is determined. This solves the determinacy problem of future prices, exchange rate and asset position analyzed in the previous section.

[13] Later we discuss the model in details.

the efficient allocation is approximated closely while prices, exchange rate and asset positions are determined.

We analyze two experiments. Let us assume that the equilibrium of the economy is at a stationary solution in which $z_t = z_t^* = \bar{z}$, $g_t = \bar{g}$ and $g_t = \bar{g}^*$. Moreover in this stationary solution prices and exchange rate are also constant.

In particular (28) implies that

$$\bar{C} = \bar{p}_H \bar{Y} + (1 - \beta)\bar{a}^* - (1 - \beta)\bar{b} \tag{31}$$

and as a consequence of the equilibrium in goods and assets market that

$$\bar{C}^* = \bar{p}_F \bar{Y}^* - (1 - \beta)\bar{a}^* + (1 - \beta)\bar{b}, \tag{32}$$

where upper-bars denote steady-state values and we have defined $\bar{p}_H = \bar{P}_H/\bar{P}$, $\bar{p}_F = \bar{P}_F/\bar{P}$, $\bar{a}^* = \bar{A}^*/\bar{P}^*$ and $\bar{b} = \bar{B}/\bar{P}$. Moreover we assume that $\bar{C}, \bar{C}^*, \bar{Y}, \bar{Y}^*, \bar{p}_H, \bar{p}_F$ are consistent with the efficient allocation, i.e. besides satisfying (31) and (32) they also satisfy (13)–(15). In particular given a value of $\bar{a}^*$ and $\bar{b}$ we assume that steady-state values of $\bar{g}$ and $\bar{g}^*$ are such that (13) is necessarily satisfied.[14] In this economy, we analyze the effect of either a permanent increase in g or a permanent increase in z along the efficient allocation to study which movements in prices and exchange rate are compatible with that allocation.

2.1 An increase in productivity of country H

2.1.1 A permanent shock

First we focus on a permanent productivity shock in country H. In this case, looking at the system (13)–(15) we know that real quantities and relative

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[14] As in Devereux and Sutherland (2006), the steady-state values of $\bar{a}^*$ and $\bar{b}$ are determined by the second-order approximations of the portfolio conditions and then by the variances and covariances of the stochastic disturbances. Since there are only two assets and four shocks, markets are incomplete. We can in particular choose the variances and covariances of the stochastic disturbances in a way to calibrate $\bar{a}^*$ and $\bar{b}$ to the desired values.

prices jump directly to the new equilibrium value and stay there forever. In particular condition (13) implies that consumption in the two countries should increase or decrease in the same proportion.[15] Equation (16) shows that the terms of trade of country H should worsen in a permanent way, i.e. P_F/P_H should increase while equation (17) shows that output in country H should increase relative to that of country F. Most important, a combination of (16) and (17) determine the ratio of real human wealth across countries as

$$\frac{\frac{P_{H,t}Y_t}{P_t}}{\frac{P_{F,t}Y_t^*}{P_t}} = \left(\frac{z_t}{z_t^*}\right)^{\frac{(1+\eta)(\theta-1)}{1+\theta\eta}}. \tag{33}$$

Following a positive productivity shock in the domestic economy, real human wealth in country H increases relative to that of country F provided θ, the intratemporal elasticity of substitution between domestic and foreign traded goods, is greater than the unitary value. Indeed in this case terms-of-trade movements do not offset output increases. In particular $\theta = 1$ corresponds to the case discussed in Cole and Obstfeld (1991) and Corsetti and Pesenti (2001) in which real human wealth is perfectly risk-shared across countries even when there are asymmetric shocks. On the opposite $\theta < 1$ corresponds to a case of 'immiserizing growth' in which a country is poorer when its productivity increases. In what follows we assume that θ is larger than the unitary value so that following a permanent productivity shock in country H there is a permanent increase in real human wealth of country H relative to country F.

In the standard theory of the intertemporal approach to the current account a permanent increase in human wealth of a country would correspond to a parallel increase in its consumption without any accumulation of assets or liabilities since there is no need of smoothing wealth across time.[16] Here instead the efficient allocation would require that consumption increases in

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[15]It can be shown that following a positive productivity shock in one country consumption should increase in both countries under the efficient allocation.

[16]With standard theory we mean a model in which only one real bond is traded across countries.

both countries and in a proportional way. How is it possible? This can happen if country H, at the time the shock hits, experiences also a negative shock to its financial wealth in a way that is forced to accumulate liabilities in future periods whose financial payments balance the permanent increase in human wealth. In this way wealth is transferred to the other country. In particular, the nominal exchange rate should appreciate.

We show that this is indeed a possible equilibrium. A log-linear approximation to the intertemporal budget constraint of country H, equation (28), implies that

$$\beta \cdot (\hat{a}_t^* - \hat{b}_t) = (\hat{a}_{t-1}^* - \hat{b}_{t-1}) - \frac{\bar{b}}{\bar{Y}}(\beta \hat{\imath}_t - \pi_t) + \frac{\bar{a}^*}{\bar{Y}}(\beta \hat{\imath}_t^* - \pi_t^*) + \hat{p}_{H,t} + \hat{Y}_t - \frac{s}{n}\hat{C}_t \quad (34)$$

where a hat variable denotes log deviation of the respective variable in reference to the original steady state with the exception of $\hat{b}_t = (b_t - \bar{b})/\bar{Y}$, $\hat{a}_t^* = (a_t^* - \bar{a}^*)/\bar{Y}$, $\pi_t = \ln P_t/P_{t-1}$ and $\pi_t^* = \ln P_t^*/P_{t-1}^*$. Moreover $s = n[1 + (1 - \beta)(\bar{a}^*/\bar{Y} - \bar{b}/\bar{Y})]$. Let us assume that the shock hits the economy at time t_0. Since we are analyzing a permanent shock, consumption jumps immediately to its new permanent level. According to (34), this is given by

$$\hat{C} = \frac{n}{s}\left[\hat{p}_H + \hat{Y} + (1 - \beta)(\hat{a}^* - \hat{b})\right]$$

in the domestic economy and

$$\hat{C}^* = \frac{1 - n}{1 - s}\left[\hat{p}_F + \hat{Y}^* - (1 - \beta)(\hat{a}^* - \hat{b})\right],$$

in the foreign economy where we have eliminated the time-subscript to denote permanent deviations with respect to the original steady state. Taking the difference between the above two equations we obtain that

$$2(1 - \beta)(\hat{a}^* - \hat{b}) = (\hat{p}_F + \hat{Y}^* - \hat{p}_H - \hat{Y}) + \frac{s}{n}(\hat{C} - \hat{C}^*) - \frac{n - s}{n(1 - n)}\hat{C}^*. \quad (35)$$

Since the first-term on the right-hand side is negative because of (33), the second term is zero because of (13) and the third term is likely to be small in magnitude for reasonable calibration, it follows that $\hat{a}^* - \hat{b}$ should be negative meaning that the domestic economy is permanently worsening its net foreign

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asset position. To restrict the degrees of indeterminacy, we assume that prices jump at the new equilibrium value at the time of the shock and remain stable afterward.[17] In this case equations (26), (27), (29) and (30) imply that the interest rates are not going to move away from the initial steady state, so that even $\hat{i}_{t_0}$ and $\hat{i}_{t_0}^*$ are zero. We can then write (34) at time t_0 as

$$\beta(\hat{a}^* - \hat{b}) = \frac{\bar{b}}{\bar{Y}}\pi_{t_0} - \frac{\bar{a}^*}{\bar{Y}}\pi_{t_0}^* + \hat{p}_H + \hat{Y} - \frac{s}{n}\hat{C}$$

and in a specular way

$$-\beta(\hat{a}^* - \hat{b}) = -\frac{\bar{b}}{\bar{Y}}\pi_{t_0} + \frac{\bar{a}^*}{\bar{Y}}\pi_{t_0}^* + \hat{p}_F + \hat{Y}^* - \frac{1-s}{1-n}\hat{C}$$

whose difference imply

$$2\beta(\hat{a}^* - \hat{b}) = 2\frac{\bar{b}}{\bar{Y}}\pi_{t_0} - 2\frac{\bar{a}^*}{\bar{Y}}\pi_{t_0}^* - (\hat{p}_F + \hat{Y}^* - \hat{p}_H - \hat{Y}) - \frac{s}{n}(\hat{C} - \hat{C}^*) + \frac{n-s}{n(1-n)}\hat{C}^*.$$
(36)

A comparison between equations (35) and (36) shows that

$$\frac{\bar{b}}{\bar{Y}}\pi_{t_0} - \frac{\bar{a}^*}{\bar{Y}}\pi_{t_0}^* = (\hat{a}^* - \hat{b}) < 0.$$

In particular in this equilibrium it is still not possible to determine π_{t_0} or $\pi_{t_0}^*$. Since P and P^* are both functions of P_H, P_F^* and S, the above condition imposes only one restriction on the triplet P_H, P_F^* and S. Another restriction is given by the determination of T from equation (16), but this is not enough to determine all prices.[18] However, we can infer that at least one of the following inequalities should be true: i) $\pi_{t_0}^* > 0$; ii) $\pi_{t_0} < 0$. In general country H should experience a negative financial shock either through an increase in the real value of liabilities or a decrease in the real value of assets. Since $\Delta s_{t_0} = \ln S_{t_0} - \ln S_{t_0-1} = \pi_{t_0} - \pi_{t_0}^*$ an exchange rate appreciation would help in this direction.

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[17]This assumption is compatible with the way we have constructed the new permanent levels of consumption.

[18]Our limiting flexible-price economy is going instead to determine all prices.

2.1.2 A temporary shock

We move to the analysis of the adjustment following a temporary productivity shock. The standard theory of the intertemporal approach to the current account would say that the country that experiences the favorable temporary increase in human wealth should increase assets to smooth wealth and consumption across future periods. In our context, to accord with the efficient allocation, consumption should instead move up and proportionally in both countries in the period of the shock and return back to the original steady state thereafter. This is compatible with a path that requires net foreign assets to return back to the initial level in the period subsequent to the occurrence of the shock. To restrict the degrees of indeterminacy, we assume that P_H and P_F^* jump at the time of the shock and remain stable after that. Since in the efficient allocation the terms of trade should worsen on impact and return back to the initial value in the following periods, the assumption that P_H and P_F^* just move on impact and remain stable afterward implies that the second movement in the terms of trade is entirely brought about by an appreciation of the nominal exchange rate. We have then pinned down the exchange rate movement from period t_0 to period $t_0 + 1$. Considering the flow resource constraint of country H at time $t_0 + 1$ we can write

$$
\beta \cdot (\hat{a}_{t_0+1}^* - \hat{b}_{t_0+1}) = (\hat{a}_{t_0}^* - \hat{b}_{t_0}) - \frac{\bar{b}}{\overline{Y}}(\beta \hat{\imath}_{t_0+1} - \pi_{t_0+1}) + \frac{\bar{a}^*}{\overline{Y}}(\beta \hat{\imath}_{t_0+1}^* - \pi_{t_0+1}^*)
$$
$$
+ \hat{p}_{H,t_0+1} + \hat{Y}_{t_0+1} - \frac{s}{n}\hat{C}_{t_0+1}
$$

in which we know that in the efficient allocation $\hat{p}_{H,t_0+1} = \hat{Y}_{t_0+1} = 0$. We further guess that $\hat{a}_{t_0+1}^* = \hat{b}_{t_0+1} = \hat{\imath}_{t_0+1} = \hat{\imath}_{t_0+1}^* = 0$ and $\pi_{t_0+1} = n\Delta s_{t_0+1}$, $\pi_{t_0+1}^* = -(1-n)\Delta s_{t_0+1}$ to obtain

$$
(\hat{a}_{t_0}^* - \hat{b}_{t_0}) = -\Delta s_{t_0+1}\left(n\frac{\bar{b}}{\overline{Y}} + (1-n)\frac{\bar{a}^*}{\overline{Y}}\right) > 0. \tag{37}
$$

In equation (37), having determined the movements of the exchange rate from period t_0 to period $t_0 + 1$, we can determine the overall net foreign asset position at the time of the shock and infer that it should improve in

country H. This is in contrast with the permanent-shock case. The reason for why country H should improve its foreign asset position at time t_0 is because the terms of trade should improve at time $t_0 + 1$ and the exchange rate appreciate. This acts as a negative financial shock reducing the overall portfolio real return. It follows that to compensate for this shock the domestic country should accumulate foreign assets above liabilities in the period of the shock in order to maintain the initial level of consumption in period $t_0 + 1$ and afterward.

We show in the appendix that in the period in which the shock hits

$$2\frac{\bar{b}}{\bar{Y}}\pi_{t_0} - 2\frac{\bar{a}^*}{\bar{Y}}\pi_{t_0}^* = (\hat{p}_{F,t_0} + \hat{Y}_{t_0}^* - \hat{p}_{H,t_0} - \hat{Y}_{t_0}) - (1-\beta+2\rho\beta)\left(\frac{\bar{b}}{\bar{Y}} - \frac{\bar{a}^*}{\bar{Y}}\right)\hat{C}_{t_0}. \quad (38)$$

Since the first-term on the RHS of (38) is negative because of (33) and assuming that country H starts with a negative net foreign asset position over output, it follows that the LHS should be also negative. As in the previous case, we cannot determine π_{t_0} and $\pi_{t_0}^*$, but we can infer that at least one of the following inequalities should be true: i) $\pi_{t_0}^* > 0$; ii) $\pi_{t_0} < 0$. In general country H should experience a negative financial shock at the time the favorable temporary productivity shock hits. An appreciation of the nominal exchange rate can help for this purpose.

The story is the following. When a temporary productivity shock hits country H, a wealth transfer should immediately occur to sustain consumption in the other economy. This happens through a financial shock that distributes wealth across country. Part of the increase in human wealth in country H is then absorbed by a fall in financial wealth. The remaining parts are consumed in the efficient proportion and used to improve the net foreign asset position. This improvement is needed to cushion against the negative future financial shock driven by the appreciation of the nominal exchange rate that works to improve the terms of trade. Even though price and exchange rate implications are similar whether the shock is temporary or permanent, the dynamic of the net foreign asset position is different. With a temporary shock country H should accumulate foreign assets in the short

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run that should return back to the initial steady state thereafter. With a permanent shock, country H should accumulate foreign liabilities and worsen its net foreign asset position forever.

2.2 An increase in the preference shock of country H

First we focus on a permanent shock. As an important difference with respect to the previous case, neither the terms of trade nor relative output nor relative real human wealth across countries should change in the efficient allocation. However, equation (13) shows that the ratio of consumption between countries should move proportionally to match the increase in g. In the standard intertemporal approach to the current account, there is no increase in human wealth. However consumption in the domestic economy rises through a permanent worsening of the terms of trade without any accumulation of assets. Here, it is instead possible to achieve the efficient allocation without any movement in the terms of trade provided country H receives a positive shock to financial wealth sufficient to increase the current level of consumption and to increase net foreign asset holdings in a way to sustain consumption at higher level even in the future. Indeed since (35) still holds under this experiment, we observe that now the RHS of (35) is likely to be positive so that

$$(\hat{a}^* - \hat{b}) > 0$$

and country H should indeed improve its net foreign asset position. Following previous steps we obtain

$$\frac{\bar{b}}{\bar{Y}}\pi_{t_0} - \frac{\bar{a}^*}{\bar{Y}}\pi_{t_0}^* = (\hat{a}^* - \hat{b}) > 0,$$

from which it follows that at the time of the shock country H should be affected by a favorable financial shock that either inflates the value of liabilities or appreciates the asset holdings. An exchange rate depreciation can help for this purpose.

The case of a temporary shock is even simpler. Since in the efficient allocation there should not be any movement in the terms of trade there

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is no need to increase or decrease the net foreign asset position to cushion against financial shocks in future periods. The net foreign asset position of each country remains stable at the initial steady state. However, at the time the shock hits, consumption in country H can increase because appropriate movements in prices and exchange rate temporarily improve its financial wealth.

2.3   Some numerical computations

As a rough idea on the magnitude of the movements in prices and exchange rates needed to achieve the efficient allocation we perform some computations in a 'limiting' flexible price economy. The model considered is similar to the one presented in the previous section, but with some frictions in the price-setting mechanisms. Details are in the following section. The limit is taken with respect to those frictions making them very small in a way to approximate the flexible-price allocation and still determining the path of prices and exchange rate. Moreover, the results are in line with the discussion of sections 2.1 and 2.2.

In this section, we introduce the calibration of the parameters of the model. First, we assume that the countries are of equal size, $n = 0.5$. We consider a quarterly model with a steady-state real interest rate equal to 1% on a quarterly basis, implying a value of β equal to 0.99. We assume $\sigma = 7.66$ implying a potential mark-up of 15% and set $\theta = 2$ as in Obstfeld and Rogoff (2006). Micro-data suggests Frisch elasticity to be in the range of $0.05 - 0.3$. We set $\eta = 5$ which corresponds to a Frisch elasticity of 0.20. For the risk-aversion coefficient we choose $\rho = 2$, consistent with the work of Eichenbaum et al. (1988) that found a range of $0.5 - 3$.

Studies as Gourinchas and Rey (2006), Higgins et al. (2006), Lane and Milesi-Ferretti (2004, 2006), Tille (2003, 2005) have documented that the composition of foreign assets and liabilities of the US economy is quite diversified ranging from bonds, equities to FDI. Moreover an important characteristic of the current composition is that the assets are mostly denominated

in foreign currency while liabilities are mostly denominated in US dollars. In particular, as discussed in Tille (2005), the US economy is an overall net lender in securities denominated in foreign currency and borrower in dollar-denominated securities. In our exercise, we assume that all these positions are made by bonds and in particular that the assets coincide with holdings of bonds denominated in foreign currency while the liabilities coincide with issuing bonds denominated in domestic currency. To calibrate the steady state of the model, we refer to Tille (2005) for the US portfolio positions in the year 2004. In particular, the US net foreign asset position in that year is negative and equal to -22% of the GDP. In particular the net leverage position in foreign currency corresponds to assets equal to the amount of 50% of GDP while net dollar liabilities are 72% of GDP. In our simple two-bond economy, this maps in assuming that $\bar{a}^*/\bar{Y}$ is equal to $0.50*4/n$ (since assets are in per-capita terms and output is on a quarterly basis), while $\bar{b}/\bar{Y}$ is equal to $0.72*4/n$.[19]

Following a 1% permanent increase in country H productivity, we find that the nominal exchange rate should appreciate by 5.54%, the GDP price level in country H, P_H, should decrease by 3.6%, while that of country F, P_F^*, should increase by 2.5%. The CPI price level in country H, P, should fall by 3.32% and the foreign CPI price level, P^*, should increase in the amount of 2.22%. An important role in the adjustment is taken up by the accumulation of liabilities towards the rest of the world. Indeed the overall net asset position goes from -22% to -25.25% in percentage of GDP.

Following a 1% permanent increase in the shock to the consumption preferences in country H, the nominal exchange rate should depreciate by the amount of 9.86%, P_H should increase by 5.82%, while P_F^* should decrease by 4.04%, P should increase by 5.82% and P^* should fall in the amount of 4.04%. However, part of the adjustment is taken up by the accumulation of foreign assets in country H with respect to the rest of the world, the overall

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[19]As discussed in the previous section, we are implicitly calibrating the variances and covariances of the shocks in a way to obtain the desired values for the steady-state portfolio positions.

net foreign asset position goes from -22% to -15.76%.

In general following permanent shocks, even of small dimension, there are large movements of prices and assets which are compatible with the efficient allocation.[20]

There is no long-run asset accumulation when shocks are temporary. Following a 1% temporary increase in productivity in the domestic economy, the net foreign asset position moves to -21.45% in the period of the shock and reverts back to the initial value in the following period. No change occurs when the economies are perturbed by a temporary shock to the preference. The adjustment is mostly done by exchange rates and prices. Following again a 1% temporary increase in productivity of country H, the nominal exchange rate should appreciate by 0.3% in the period of the shock and by 0.5% in the following period, the GDP price level in country H should decrease by 0.5%, while in country F should increase by 0.3% in the period of the shock and remain stable afterwards. Following a temporary 1% increase in the preference shock of country H, the nominal exchange rate should depreciate by 0.34% in the period of the shock, the GDP price level in country H should increase by 0.20%, while in country F should decrease by 0.13% in the period of the shock and remain stable afterward.

3   Adding price rigidities

The result that in a frictionless economy prices and exchange rates adjust in accordance with the current account to sustain the efficient allocation is reminiscent of the role of prices in optimal taxation problem that relieve taxes from the role of maintaining the intertemporal resource of the government in balance.[21]

In this section we study how a concern for a low volatility of prices,

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[20]Corsetti and Konstantinou (2005) find that permanent shocks explain a large fraction of the variance of the current account, especially at long-horizon.

[21]Recent works in the area are Benigno and Woodford (2006), Schmitt-Grohe and Uribe (2005) and Sims (2002).

in line with the recent literature on inflation targeting (see among others Woodford, 2003), affects this result. We explore the role of price rigidities modelled following Calvo (1983) and Yun (1996). In particular, a generic firm producing good h in country H faces each period a constant probability of adjusting its price. In this event the price chosen at a generic time t might last until period T with probability α^{T-t} where $0 \le \alpha < 1$ and $1-\alpha$ is indeed the probability that a generic firm changes its price in a certain period. The problem of a generic firm producing good h in country H that is chosen to set its price in period t is that of maximizing the following expected stream of profits

$$E_t \sum_{T=t}^{\infty} \alpha^{T-t} Q_{t,T} \left[(1-\tau)p_t(h)\tilde{y}_T(h) - n\frac{w_T(h)}{z_T}\tilde{y}_T(h) \right]$$

where

$$\tilde{y}_T(h) = \left(\frac{p_t(h)}{P_{H,t}}\right)^{-\sigma} \left(\frac{P_{H,t}}{P_t}\right)^{-\theta} (nC_t + (1-n)C_t^*).$$

As in Benigno and Woodford (2005), the first-order condition of this problem can be combined with the expression for $w_T(h)$ and $Q_{t,T}$ given by (18) and (24) to yield an aggregate supply equation of the form

$$\frac{1 - \alpha\Pi_{H,t}^{\sigma-1}}{1-\alpha} = \left(\frac{F_t}{K_t}\right)^{\frac{\sigma-1}{1+\sigma\eta}} \tag{39}$$

having used the law of motion of the general price index P_H implied by the Calvo's model. In particular, we have defined

$$K_t \equiv E_t \sum_{T=t}^{\infty} (\alpha\beta)^{T-t} z_T^{-(1+\eta)} Y_T^{1+\eta} \left(\frac{P_{H,T}}{P_{H,t}}\right)^{\sigma(1+\eta)}, \tag{40}$$

$$F_t \equiv E_t \sum_{T=t}^{\infty} (\alpha\beta)^{T-t} C_T^{-\rho} g_T^{\rho} Y_T \left(\frac{P_{H,T}}{P_T}\right) \left(\frac{P_{H,T}}{P_{H,t}}\right)^{\sigma-1}, \tag{41}$$

and $\Pi_{H,t} \equiv P_{H,t}/P_{H,t-1}$. In a similar way we obtain an aggregate supply equation for country F

$$\frac{1 - \alpha^*(\Pi_{F,t}^*)^{\sigma-1}}{1-\alpha^*} = \left(\frac{F_t^*}{K_t^*}\right)^{\frac{\sigma-1}{1+\sigma\eta}}, \tag{42}$$

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where we have defined $\Pi_{F,t}^* \equiv P_{F,t}^*/P_{F,t-1}^*$,

$$K_t^* \equiv E_t \sum_{T=t}^{\infty} (\alpha^*\beta)^{T-t}(z_T^*)^{-(1+\eta)}(Y_T^*)^{1+\eta}\left(\frac{P_{F,T}^*}{P_{F,t}^*}\right)^{\sigma(1+\eta)}, \qquad (43)$$

$$F_t^* \equiv E_t \sum_{T=t}^{\infty} (\alpha^*\beta)^{T-t}(\mu_T^*)^{-1}C_T^{*-\rho}g_T^{*\rho}Y_T^*\left(\frac{P_{F,T}}{P_T}\right)\left(\frac{P_{F,T}^*}{P_{F,t}^*}\right)^{\sigma-1}, \qquad (44)$$

where $1 - \alpha^*$ with $0 \le \alpha^* < 1$ denotes the probability that a firm of country F is chosen to adjust its price in a certain period. Moreover, the price-setting mechanism assumed implies that the indexes of price dispersions (10) and (11) follow the laws of motion

$$\Delta_t = \alpha\Delta_{t-1}\Pi_{H,t}^{\sigma(1+\eta)} + (1-\alpha)\left(\frac{1-\alpha\Pi_{H,t}^{\sigma-1}}{1-\alpha}\right)^{-\frac{\sigma(1+\eta)}{1-\sigma}}, \qquad (45)$$

$$\Delta_t^* = \alpha^*\Delta_{t-1}^*(\Pi_{F,t}^*)^{\sigma(1+\eta)} + (1-\alpha^*)\left(\frac{1-\alpha^*(\Pi_{F,t}^*)^{\sigma-1}}{1-\alpha^*}\right)^{-\frac{\sigma(1+\eta)}{1-\sigma}}. \qquad (46)$$

An important implication of the assumption of price rigidities is that it is no longer possible to implement the efficient allocation when markets are incomplete. This can be seen by noting that indeed setting $\Pi_{H,t} = \Pi_{F,t}^* = 1$ in each period t assures that $F_t = K_t$ and $F_t^* = K_t^*$ so that conditions (14) and (15) are necessarily satisfied. Efficiency requires certain movements in relative prices $P_{H,t}/P_t$ and $S_t P_{F,t}^*/P_t$. But the requirement that $\Pi_{H,t} = \Pi_{F,t}^* = 1$ restricts necessarily the paths of P_t and S_t in a way that (28) is not satisfied in general when its RHS is evaluated at the efficient allocation.

4   Constrained-efficient allocation

Since the efficient allocation is not feasible, we investigate which allocation is optimal in this second-best environment. To do this, we analyze the solution using approximation methods. First, we require that the constrained efficient policy and the efficient policy coincides in a steady-state in which $z_t = z_t^* = \bar{z}$ and $g_t = \bar{g}$ and $g_t = \bar{g}^*$. We know that if $\Pi_{H,t} = \Pi_{F,t}^* = 1$ conditions (14)

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and (15) are necessarily satisfied and so they will be in a stationary solution with zero producer inflation at all times. However in the steady-state, (28) implies that

$$\bar{C} = (1 - \beta)\bar{a}^* - (1 - \beta)\bar{b} + \bar{p}_H\bar{Y}$$

$$\bar{C}^* = -(1 - \beta)\bar{a}^* + (1 - \beta)\bar{b} + \bar{p}_F\bar{Y}^*.$$

As in the previous section, for given initial conditions $\bar{b}$ and $\bar{a}^*$, we choose $\bar{g}$ and $\bar{g}^*$ in a way that (13) is also satisfied. This implies that in the stationary solution the incomplete-market allocation under producer-price stability is efficient.

Our objective is to characterize the departure of the constrained-efficient allocation from the efficient allocation when there are small movements of the stochastic disturbances from the above-defined stationary solution. In particular, we are interested in characterizing a log-linear approximation to the constrained-efficient allocation. This can be obtained as a solution of a linear-quadratic problem. Since the steady-state in the constrained problem is efficient, the quadratic objective function can be obtained by just taking a second-order expansion of the objective function of the Pareto problem (12), using the method of Rotemberg and Woodford (1998).

As shown in Benigno (2001), the objective function can be written as[22]

$$W_{t_0} = -\frac{U_C \overline{C}^W}{2} \mathrm{E}_{t_0} \left\{ \sum_{t=t_0}^{\infty} \beta^{t-t_0} L_t \right\}, \tag{47}$$

with

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

where, for a generic variable X, we denote with $\hat{X}$ the log-deviation of the variable X from the steady state, with $\tilde{X}$ the log-deviation of the variable

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[22]To compute the constrained-efficient policy there is no need to use a LQ solution, this is convenient to obtain an objective function. See also Pescatori (2005) for an alternative derivation in a closed-economy heterogenous-agent model.

X from the steady state in the efficient allocation; X^W denotes the weighted average with weights s and $1 - s$ of the variables X and X^* for country H and F respectively, X^R is the relative difference between X and X^*; $\pi_{H,t} = \ln P_{H,t}/P_{H,t-1}$ and $\pi^*_{F,t} = \ln P^*_{F,t}/P^*_{F,t-1}$. In particular $k \equiv (1-\alpha)(1-\alpha\beta)(\rho+\eta)/[\alpha(1+\sigma\eta)]$ and $k^* \equiv (1-\alpha^*)(1-\alpha^*\beta)(\rho+\eta)/[\alpha^*(1+\sigma\eta)]$; t.i.p. denotes terms independent of policy while $\mathcal{O}(\|\xi\|^3)$ denotes terms of order higher than the third. $\tilde{C}^W_t$, $\tilde{C}^R_t$ and $\tilde{T}_t$ can be obtained from a log-linear approximation of constraints (13), (14) and (15). They are all linear combinations of the shocks of the model as detailed in the appendix.

This loss function indeed shows that it would be optimal to achieve the efficient allocation for both quantities and relative prices. Indeed consumption and terms of trade movements are penalized for fluctuating around the efficient allocation. At the same time it is optimal to set producer (or GDP) inflation rate in each country to zero since, when prices are staggered as in the Calvo's model, inflation creates inefficient variation among prices of goods which are produced according to the same technology. We have already discussed that the efficient allocation cannot be achieved when markets are incomplete and prices sticky. There are three conflicting objectives: (i) the objective of efficient risk sharing; (ii) the desire for producer price stability; (iii) the desire for an efficient adjustment in international relative prices. The constrained-efficient policy should then balance the losses in the above criterion taking into account the structural constraints. In particular, a log-linear approximation to the constraints (8), (9), (26) to (30), (39) to (46) suffices for analyzing the constrained problem. The solution is detailed in the appendix.

5 Are valuation effects desirable when prices are sticky?

We have seen that in the incomplete-market model without other frictions, prices and exchange rate adjust substantially in accordance with the efficient

allocation of quantities and relative prices. In this section, we study the desirability of these movements when there are instead frictions in the price mechanism. We assume that the degrees of price rigidity are equal across countries, i.e. $\alpha = \alpha^*$, and let α varying from small numbers close to zero –which approximate the flexible-price allocation discussed in section 2.2– to higher numbers indicating a substantial amount of price rigidities.

The focus is on unexpected permanent or transitory shocks. In this case, the returns of assets and liabilities will be equalized in the periods after the shock and the valuation channel due to exchange-rate movements is effective only at the time the shock hits the economies. Figure 1 shows the percentage changes in the log deviations with respect to the steady state of producer prices, domestic and foreign, and exchange rate at the time the shock hits following a permanent increase of 1% in the productivity of country H. In particular we study how these movements vary when α moves from zero to higher numbers. The result is striking. It is sufficient a small amount of price rigidities to substantially dampen the response of prices and exchange rates. A value of α close to 0.1 meaning a price duration of 3 month and a half would already be sufficient. In particular when α is equal to 0.2– implying a price duration of approximately 4 months– domestic and foreign GDP price levels should be stabilized. In particular the reaction of the exchange rate is substantially reduced compared to the flexible-price case minimizing the desirability of valuation effects.

Figure 2 analyzes the ratio between the long-run net foreign asset position of country H and the long-run value of output to study what is the long-run impact of the shock on the financial position of the countries. The initial value for this ratio is the calibrated one -22%. In a similar way to Figure 1, a small amount of price rigidity is sufficient to dampen the response of assets. When there are sufficient frictions in the price adjustment, the net foreign asset position of country H is close to the initial value in contrast to the large worsening when prices are flexible.

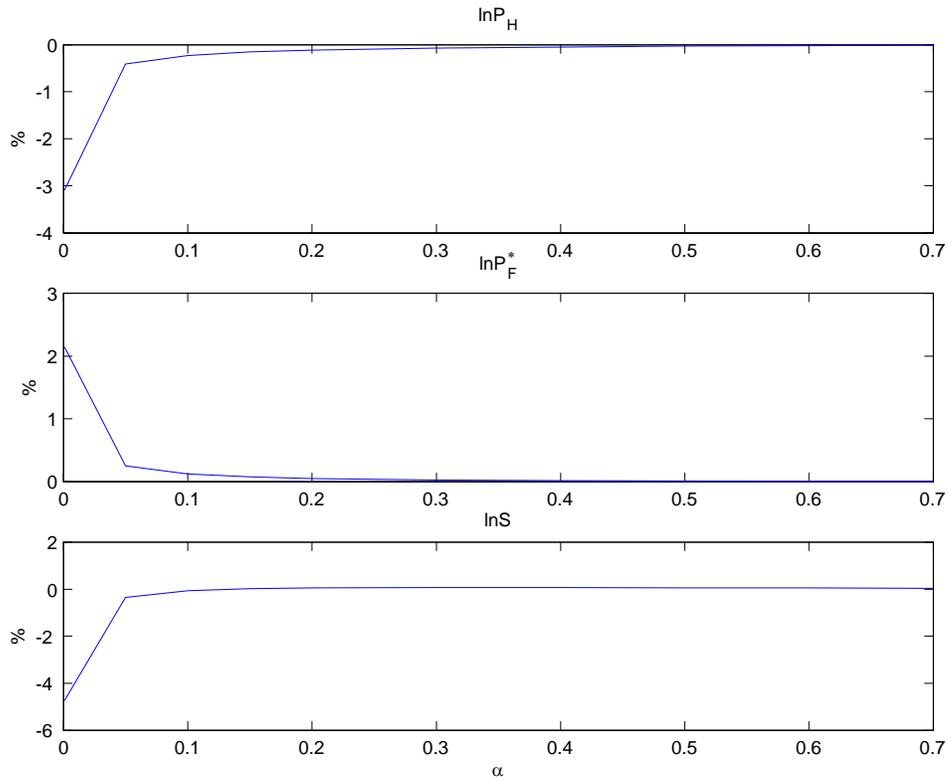Figures 3 and 4 repeat the experiment when the economies are subject to

Figure 1: Short-run percentage changes of prices ($\ln P_H$ and $\ln P_F^*$) and exchange rate ($\ln S$) with respect to the initial steady state for different degrees of nominal rigidities (α) following a 1% permanent increase in productivity in country H.
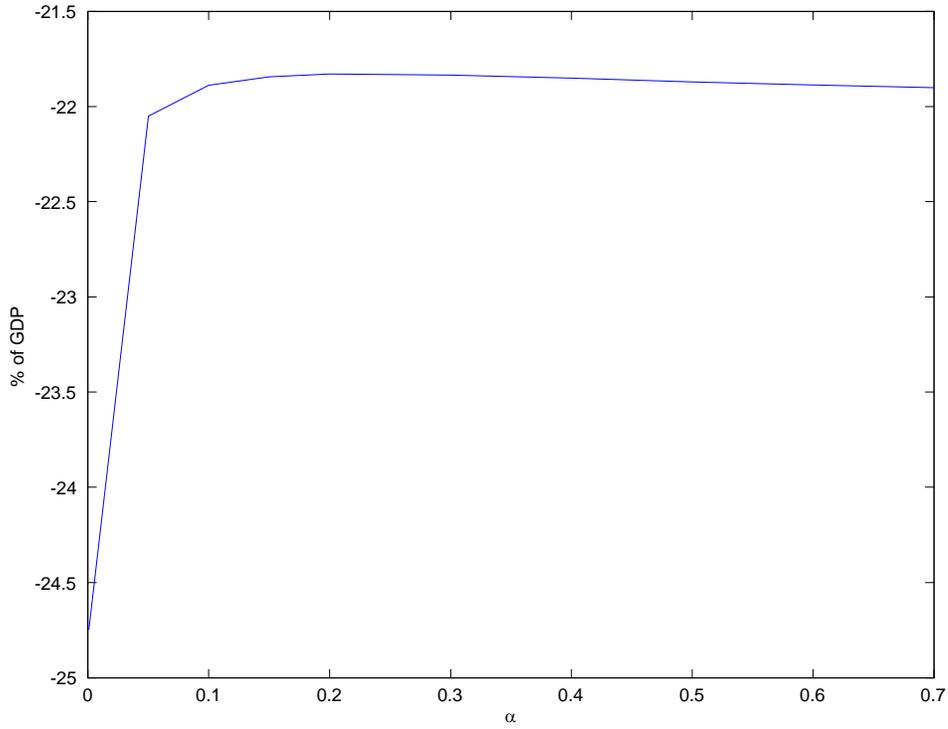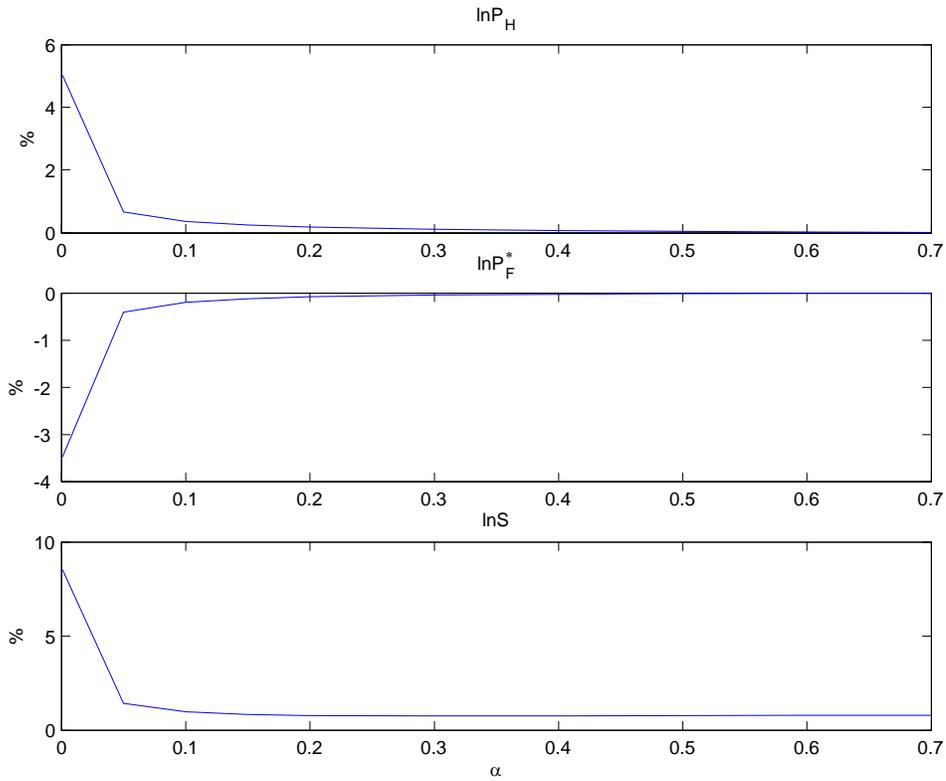
Figure 2: Ratio between the long-run value of the net foreign assets and GDP in country H for different degrees of nominal rigidities (α) following a 1% permanent increase in productivity in country H. (Initial steady state is -22% of GDP)

Figure 3: Short-run percentage changes of prices ($\ln P_H$ and $\ln P_F^*$) and exchange rate ($\ln S$) with respect to the initial steady state for different degrees of nominal rigidities (α) following a 1% permanent increase in the preference shock in country H.
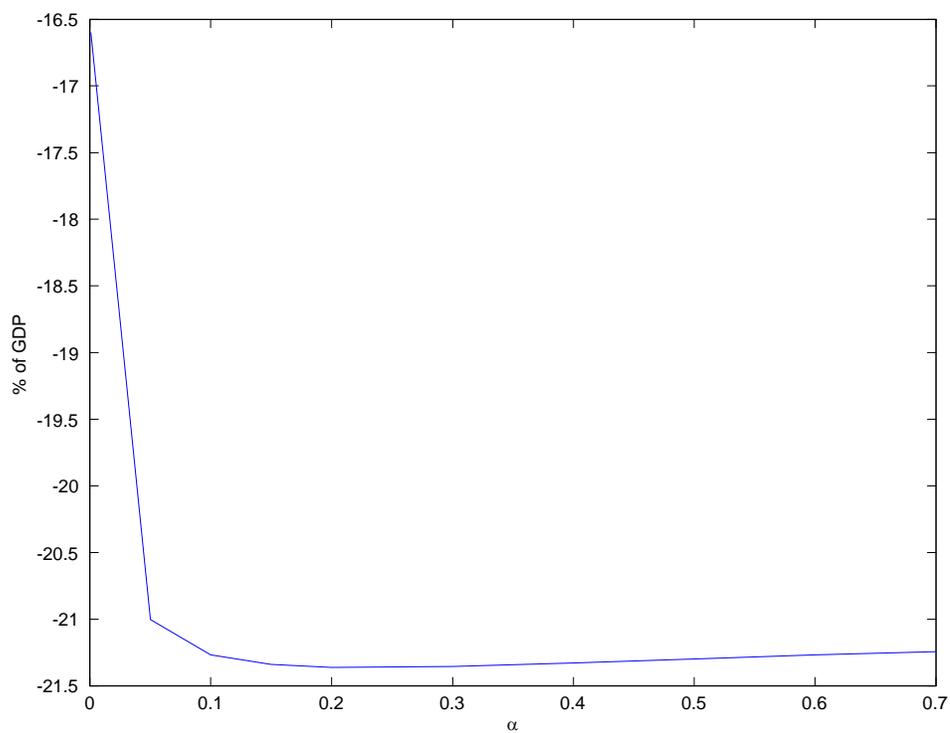
Figure 4: Ratio between the long-run value of the net foreign assets and GDP in country H for different degrees of nominal rigidities (α) following a 1% permanent increase in the preference shock in country H. (Initial steady state is -22% of GDP)

a permanent shock to consumption preferences in country H. The conclusion does not change. It is sufficient a small amount of price rigidity to dampen the overall response of prices, exchange rate and assets.

To substantiate the parallel with the optimal taxation literature, even there a small concern for price stability is sufficient to move the trade-off between using distorting taxes or prices to balance the intertemporal constraint of the government towards the use of taxes .[23]

We now investigate the features of the constrained-efficient allocation when prices are sticky. We do this under the calibration of section 2.3 but here we assume that prices are sticky for three quarters in country H ($\alpha = 0.66$) and for four quarters in country F ($\alpha^* = 0.75$). We investigate the responses of the main variables of interest to permanent shocks as in previous analyses. Since there is no interesting dynamic in the response of the variables except for what can be learnt from the first and final periods, we just focus on the short-run and long-run responses. With short-run response, we mean the impulse response at the time the shock occurs; with long-run response we mean the impulse response in a sufficient distant period of time. Table 1 presents the results for both shocks with 1% magnitude. In particular we have defined tb_t as the ratio of the log deviations of the trade balance with respect to the original steady state over initial steady-state output. The variable nfa_t denotes the changes in the net foreign asset position with respect to the initial value as a percentage of GDP.

Producer prices do not vary much both in the short and long run. Indeed, the concern for price stability built into the loss function (47) is strong enough to keep these prices stable. If producer prices do not move much, most of the stabilizing role is taken up by the nominal exchange rate. Focusing first on the permanent productivity shock, a striking feature of the results reported in Table 1 (second and third columns) is that short and long-run behaviors are quite different. In particular, the exchange rate does not react much in the short run and depreciates in the long run. To understand

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[23]See Benigno and Woodford (2006) and Schmitt-Grohe and Uribe (2005).

	Productivity Shock		Preference Shock	
	Short Run	Long Run	Short Run	Long Run
$\hat{C}$	0.43	0.66	0.63	0.27
$\hat{C} - \tilde{C}$	0.00	0.23	-0.01	-0.37
$\hat{C}^*$	-0.02	0.20	0.39	0.02
$\hat{C}^* - \tilde{C}^*$	-0.45	-0.22	0.74	0.37
$\hat{T}$	0.05	0.46	0.79	0.13
$\hat{T} - \tilde{T}$	-0.48	-0.08	0.79	0.13
$\ln P_H$	-0.01	0.00	0.02	0.00
$\ln P_F^*$	0.00	0.00	0.00	0.00
$\ln S$	0.04	0.46	0.81	0.13
$\hat{Y}$	0.25	0.89	1.30	0.28
$\hat{Y}^*$	0.14	-0.03	-0.27	0.01
tb_t	-0.14	0.45	1.06	0.08
nfa_t	-0.34	0.11	1.44	0.75

Table 1: Short and long-run responses following a 1% permanent increase in either productivity or preference shock. Benchmark calibration.

this, let us move back to the frictionless world where consumption in both countries should rise, but in the same magnitude, and the terms of trade should worsen to make goods which are produced more efficiently cheaper. There are two objectives: risk sharing and the terms of trade adjustment. Our results would point to say that the terms of trade objective is dominating in the long run and indeed the exchange rate permanently depreciate to meet this objective. In the long run the domestic country enjoys higher real human wealth and output together with a worsening of the terms of trade that pushes up consumption. Instead, in the short run the exchange rate works for the risk-sharing objective. In particular the exchange rate does not react much, terms of trade improve, production in country H does not increase as it should and consumption in country H does not rise much. The overall combination of these effects produce a negative financial shock so that liabilities are accumulated in the short run while they are replenished in the long-run.

Similar balance between the two objectives can be observed when the economies are hit by a permanent shock to the consumption preferences in country H. Indeed the risk-sharing objective would require that consumption in country H increases relative to that of country F while the terms of trade should not move. Even in this case, the behavior of the exchange rate is different comparing the short and long run. In the short run, the exchange rate substantially depreciates while in the long run it goes closely to the initial value. As in the previous case, the terms of trade objective dominates in the long run while in the short run the exchange rate works in favour of the risk-sharing objective. Indeed the initial depreciation of the exchange rate acts as a positive financial shock for country H and increases the return of holding foreign assets improving its net-foreign assets position. This is the channel through which it is possible to sustain a higher level of consumption in the long-run relative to the foreign country.

We study the robustness of previous results by investigating how a different composition of the net foreign asset position affects the outcome. We

	$\frac{\bar{a}^*}{Y} = 0\%$		$\frac{\bar{a}^*}{Y} = 50\%$		$\frac{\bar{a}^*}{Y} = 100\%$	
	SR	LR	SR	LR	SR	LR
$\hat{C}$	0.43	0.66	0.43	0.66	0.44	0.64
$\hat{C} - \tilde{C}$	0.00	0.24	-0.01	0.23	0.01	0.21
$\hat{C}^*$	-0.04	0.20	-0.03	0.20	0.02	0.22
$\hat{C}^* - \tilde{C}^*$	-0.47	-0.23	-0.46	-0.23	-0.41	-0.20
$\hat{T}$	0.41	0.46	0.06	0.46	-0.22	0.47
$\hat{T} - \tilde{T}$	-0.13	-0.08	-0.49	-0.08	-0.77	-0.07
$\ln P_H$	-0.01	0.00	-0.01	0.00	-0.02	0.00
$\ln P_F^*$	-0.00	0.00	0.00	-0.00	0.00	0.00
$\ln S$	0.41	0.47	0.05	0.47	-0.24	0.47
$\hat{Y}$	0.60	0.89	0.26	0.89	0.06	0.90
$\hat{Y}^*$	-0.13	-0.03	0.14	-0.03	0.45	-0.04
tb_t	0.38	0.45	-0.15	0.46	-0.55	0.49
nfa_t	0.05	0.14	-0.33	0.10	-1.25	-0.19

Table 2: Short (SR) and long-run (LR) responses (%) following a 1% permanent increase in productivity in country H. Alternative assumptions on the composition of net foreign assets.

assume three alternative scenarios. In all cases, the overall net foreign asset position is calibrated to -22% of GDP. However, in the first scenario there are no assets denominated in foreign currency, all the net foreign asset position is made by liabilities denominated in domestic currency amounting to a total of 22% of GDP. In the second scenario, assets are 50% of GDP while liabilities 72%, in the third case assets are 100% of GDP while liabilities amount to 122%. Table 2 presents the results for the case in which the economies are affected by a permanent productivity shock in country H, while Table 3 analyzes the case of a permanent shock to consumption preferences.

	$\frac{\bar{a}^*}{Y} = 0\%$		$\frac{\bar{a}^*}{Y} = 50\%$		$\frac{\bar{a}^*}{Y} = 100\%$	
	SR	LR	SR	LR	SR	LR
$\hat{C}$	0.65	0.24	0.64	0.27	0.63	0.33
$\hat{C} - \tilde{C}$	0.00	-0.41	-0.01	-0.38	-0.02	-0.32
$\hat{C}^*$	0.47	0.05	0.44	0.02	0.27	-0.04
$\hat{C}^* - \tilde{C}^*$	0.82	0.40	0.39	0.37	0.62	0.31
$\hat{T}$	0.23	0.15	0.74	0.14	1.16	0.12
$\hat{T} - \tilde{T}$	0.23	0.15	0.79	0.14	1.16	0.12
$\ln P_H$	0.01	-0.01	0.02	0.00	0.03	0.00
$\ln P_F^*$	0.01	0.01	0.00	0.01	-0.01	0.00
$\ln S$	0.23	0.13	0.81	0.13	1.20	0.11
$\hat{Y}$	0.79	0.29	1.30	0.28	1.61	0.26
$\hat{Y}^*$	0.33	-0.01	-0.28	0.01	-0.72	0.03
tb_t	0.25	0.13	1.06	0.08	1.56	-0.01
nfa_t	0.41	0.27	1.43	0.75	3.12	1.56

Table 3: Short (SR) and long-run (LR) responses (%) following 1% permanent increase in the preference shock of country H. Alternative assumptions on the composition of net foreign assets.

In the first case, when all liabilities are in the amount of 22% of GDP,

the exchange rate depreciates even in the short run. Moreover the domestic country experiences a short and long-run improvement in the trade balance. The terms of trade objective is dominating even in the short run. Instead with a more diversified composition of the net foreign assets, the exchange rate works to improve risk sharing. This is seen by inspecting the table and observing that the consumption gaps get smaller as the financial position becomes more diversified.

However, the gains are really of small order. This points more towards substantiating the overall argument that the concern for price stability intrinsic in models with price rigidity is sufficient to dampen the desirability of valuation effects.

6 Extensions and conclusion

In this paper we have analyzed to what extent the exchange-rate valuation channel is desirable. We have indeed focused on the constrained-efficient or, whether applicable, efficient allocation from the point of view of a global planner and asked which movements in prices and exchange rate are compatible with those allocations. In a pure frictionless world, large movements in prices, exchange rates and assets are needed to distribute financial wealth in an efficient way across countries. However, as soon as small frictions in the price mechanism are added, a strong argument for price stability emerges and valuation effects are muted. We have also discussed how the standard theory of the "intertemporal approach to the current account" should be modified to account for prices and exchange rate movements when permanent or transitory shocks perturb the economy.

We have chosen a very stylized model that presents several limitations. Here, we discuss to what extent our results are robust to relaxing some of the assumptions made. We have analyzed only bond economies, although with bonds denominated in different currencies. An important extension should consider also trade in equities. There are two potential roles for

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valuation effects when equities are considered: i) changes in equity prices are an important source of movements in the market value of wealth; ii) if equities are denominated in different currencies then exchange-rate movements can be an important source of valuation effects. Concerning the first channel, this is less relevant from an empirical perspective. Among others, Tille (2005) has documented that for the US external position valuation effects due to changes in the price of equities overall cancel out when both sides of assets and liabilities are considered together. The second channel is instead already taken into account in our analysis. What matters for the exchange-rate valuation channel in a log-linear approximation is the steady-state portion of wealth denominated in foreign currency and not its composition. Our results will not change if part of that share is made up by equities.

By increasing the number of financial instruments traded there can be more scope for risk sharing. This is actually going to reinforce our results. Indeed, when markets are complete the exchange rate is completely relieved from the role of distributing wealth across countries. In the second-best world with price frictions, price stability can be implemented and the exchange rate moves the terms of trade in the desired way.

There is one dimension along which the results might change. This is when large shocks are considered. In the optimal taxation literature, Siu (2001) has shown that optimal inflation variability is low when shocks are small but becomes more desirable when shocks are of large magnitude. It might be the case that with large shocks the objective of risk-sharing dominates that of price stability requiring then large unexpected movements in the exchange rate. Perhaps the magnitude of the shocks required for this effect to prevail is not the one which is mainly relevant in driving the external dynamics of developed economies. A complete analysis of this issue goes beyond the scope of the approximation methods used in this work.

Finally, we have focused on the welfare-maximizing allocation from the point of view of a central planner. There are other possible allocations in our economy that can be supported by alternative paths of prices and exchange

rate. In particular, each country has an incentive to use monetary policy to redirect valuation effects in its favor. Issue of cooperation might arise and countries might have incentive to maximize their own welfare. It is however likely that even in this case a small concern for price stability can reduce these incentives or at the least dampen the extent to which valuation effects can be really used to increase in a strategic manner the welfare of each country.

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A   Appendix

Derivation of equation (38)

A log-linear approximation of the Euler equations (26), (27), (29) and (30) at time t_0 implies that

$$\hat{i}_{t_0} = \pi_{t_0+1} + \rho(\hat{C}_{t_0+1} - \hat{C}_{t_0}),$$

$$\hat{i}^*_{t_0} = \pi^*_{t_0+1} + \rho(\hat{C}^*_{t_0+1} - \hat{C}^*_{t_0}).$$

Since $\hat{C}_{t_0+1} = \hat{C}^*_{t_0+1} = 0$ in the efficient allocation and we have furthermore guessed that $\pi_{t_0+1} = n\Delta s_{t_0+1}$ and $\pi^*_{t_0+1} = -(1-n)\Delta s_{t_0+1}$ we obtain

$$\hat{i}_{t_0} = n\Delta s_{t_0+1} - \rho\hat{C}_{t_0} \tag{A.1}$$

$$\hat{i}^*_{t_0} = -(1-n)\Delta s_{t_0+1} - \rho\hat{C}^*_{t_0}. \tag{A.2}$$

In particular, the resource constraint at time t_0 requires that

$$\beta\cdot(\hat{a}^*_{t_0} - \hat{b}_{t_0}) = (\hat{a}^*_{t_0-1} - \hat{b}_{t_0-1}) - \frac{\bar{b}}{\bar{Y}}(\beta\hat{i}_{t_0} - \pi_{t_0}) + \frac{\bar{a}^*}{\bar{Y}}(\beta\hat{i}^*_{t_0} - \pi^*_{t_0}) + \hat{p}_{H,t_0} + \hat{Y}_{t_0} - \frac{s}{n}\hat{C}_{t_0}$$

in which we can substitute (37), (A.1) and (A.2) to obtain

$$\frac{\bar{b}}{\bar{Y}}\pi_{t_0} + \rho\beta\frac{\bar{b}}{\bar{Y}}\hat{C}_{t_0} - \rho\beta\frac{\bar{a}^*}{\bar{Y}}\hat{C}^*_{t_0} - \frac{\bar{a}^*}{\bar{Y}}\pi^*_{t_0} + \hat{p}_{H,t_0} + \hat{Y}_{t_0} - \frac{s}{n}\hat{C}_{t_0} = 0.$$

In a similar way we obtain for country F that

$$-\frac{\bar{b}}{\bar{Y}}\pi_{t_0} - \rho\beta\frac{\bar{b}}{\bar{Y}}\hat{C}_{t_0} + \rho\beta\frac{\bar{a}^*}{\bar{Y}}\hat{C}^*_{t_0} + \frac{\bar{a}^*}{\bar{Y}}\pi^*_{t_0} + \hat{p}_{F,t_0} + \hat{Y}^*_{t_0} - \frac{(1-s)}{(1-n)}\hat{C}^*_{t_0} = 0.$$

Taking the difference between the above two equations, we obtain

$$2\frac{\bar{b}}{\bar{Y}}\pi_{t_0} + 2\rho\beta\frac{\bar{b}}{\bar{Y}}\hat{C}_{t_0} - 2\rho\beta\frac{\bar{a}^*}{\bar{Y}}\hat{C}^*_{t_0} - 2\frac{\bar{a}^*}{\bar{Y}}\pi^*_{t_0} + \hat{p}_{H,t_0} + \hat{Y}_{t_0} - \hat{p}_{F,t_0} - \hat{Y}^*_{t_0} - \frac{s}{n}\hat{C}_{t_0} + \frac{(1-s)}{(1-n)}\hat{C}^*_{t_0} = 0.$$

We use the fact that equation (13) in a log-linear form implies $\hat{C}_{t_0} = \hat{C}^*_{t_0}$ and substitute it in the above equation to get equation (38) in the main text

$$2\frac{\bar{b}}{\bar{Y}}\pi_{t_0} - 2\frac{\bar{a}^*}{\bar{Y}}\pi^*_{t_0} = (\hat{p}_{F,t_0} + \hat{Y}^*_{t_0} - \hat{p}_{H,t_0} - \hat{Y}_{t_0}) - (1 - \beta + 2\rho\beta)\left(\frac{\bar{b}}{\bar{Y}} - \frac{\bar{a}^*}{\bar{Y}}\right)\hat{C}_{t_0}$$

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where we have also used the definition of s.

Constrained-efficient allocation

In this section we show how to obtain a log-linear approximation to the constrained-efficient policy. First, we note that in a first-order approximation to the first-order conditions (13), (14) and (15) we obtain the log-linear approximation to the efficient allocation for the following variables

$$\tilde{C}_t^W = \frac{\eta}{\eta + \rho}[n\hat{z}_t + (1-n)\hat{z}_t^*] + \frac{\rho}{\eta + \rho}[s\hat{g}_t + (1-s)\hat{g}_t^*],$$

$$\tilde{T}_t = \frac{\eta}{1 + \eta\theta}(\hat{z}_t - \hat{z}_t^*),$$

$$\tilde{C}_t^R = \hat{g}_t - \hat{g}_t^*,$$

where

$$\tilde{C}_t^W = s\tilde{C}_t + (1-s)\tilde{C}_t^*,$$

and

$$\tilde{C}_t^R = \tilde{C}_t - \tilde{C}_t^*.$$

The constrained efficient allocation is obtained by minimizing

$$E_{t_0} \sum_{t=t_0}^{\infty} \beta^{t-t_0}\{(\rho + \eta) \cdot [\hat{C}_t^W - \tilde{C}_t^W]^2 + s(1-s)\rho[\hat{C}_t^R - \tilde{C}_t^R]^2$$

$$+ n(1-n)(1+\eta\theta)\theta \cdot [\hat{T}_t - \tilde{T}_t]^2 + n\frac{\sigma}{k}(\pi_{H,t})^2 + (1-n)\frac{\sigma}{k^*}(\pi_{F,t}^*)^2\}$$

under the following sequence of constraints. A first-order approximation to (26)

$$\rho(\hat{C}_t - \hat{g}_t) = \rho E_t(\hat{C}_{t+1} - \hat{g}_{t+1}) - (\hat{\imath}_t - E_t\pi_{t+1}); \tag{A.3}$$

a first-order approximation to (30)

$$\rho(\hat{C}_t^* - \hat{g}_t^*) = \rho E_t(\hat{C}_{t+1}^* - \hat{g}_{t+1}^*) - (\hat{\imath}_t^* - E_t(\pi_{t+1} - \Delta s_{t+1})); \tag{A.4}$$

a first-order approximation to (27) that together with (30) implies

$$\hat{\imath}_t = \hat{\imath}_t^* + E_t\Delta s_{t+1}; \tag{A.5}$$

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a first-order approximation to (39), (40) and (41) that together with (8) imply

$$\pi_{H,t} = k[\eta \hat{C}_t^W + (1+\eta\theta)(1-n)\hat{T}_t + \rho\hat{C}_t - (1+\eta)\hat{z}_t - \rho g_t] + \beta E_t \pi_{H,t+1}; \quad (A.6)$$

a first-order approximation to (42), (43) and (44) that together with (9) imply

$$\pi_{F,t}^* = k^*[\eta \hat{C}_t^W - n(1+\eta\theta)\hat{T}_t + \rho\hat{C}_t^* - (1+\eta)\hat{z}_t^* - \rho g_t^*] + \beta E_t \pi_{F,t+1}^*; \quad (A.7)$$

a first-order approximation to the terms of trade identity $T_t = S_t P_{F,t}^*/P_{H,t}$

$$\hat{T}_t = \hat{T}_{t-1} + \Delta s_t + \pi_{F,t}^* - \pi_{H,t}; \quad (A.8)$$

the relation between CPI inflation and GDP inflation rates given in a log-linear form by

$$\pi_t = n\pi_{H,t} + (1-n)(\pi_{F,t}^* + \Delta s_t); \quad (A.9)$$

the definition

$$\hat{C}_t^W = s\hat{C}_t + (1-s)\hat{C}_t^*; \quad (A.10)$$

and the law of motion of the net-foreign asset position of country H given in a log-linear form by

$$\beta \cdot (\hat{a}_t^* - \hat{b}_t) = (\hat{a}_{t-1}^* - \hat{b}_{t-1}) - \frac{\bar{b}}{\bar{Y}}(\beta \hat{i}_t - \pi_t) + \frac{\bar{a}^*}{\bar{Y}}(\beta \hat{i}_t^* - \pi_t^*) + (\theta-1)(1-n)\hat{T}_t + \hat{C}_t^W - \frac{s}{n}\hat{C}_t. \quad (A.11)$$

The minimization problem is solved by forming the Lagrangian in which multipliers $\phi_{1,t}$ to $\phi_{9,t}$ are attached to the constraints (A.3) to (A.11), respectively. The first-order conditions of this minimization problem together with the constraints (A.3)-(A.11) and the process of the stochastic disturbances form a system of stochastic difference equations which is solved using standard rational-expectation solution algorithms.