Macroeconomic Implications of a Key Currency*

by

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ABSTRACT

What are the macroeconomic consequences of the dominant role of the dollar in the international monetary system? Here, we present a calibrated two country model in which exports are invoiced in the key currency, and government bonds denominated in the key currency are held internationally to facilitate trade. Domestic government bonds and money are held in each country to facilitate domestic transactions. Our model generates deviations from uncovered interest parity that are as volatile as some empirical estimates, but much too small by others. Our model also speaks to some other empirical anomalies, such as the Backus - Smith puzzle. Shocks affecting asset supplies – such as bond financed tax cuts, and open market operations – have large effects in our model because they generate non-Ricardian changes in household wealth. Generally, shocks emanating from the key currency country do more to destabilize the world economy than equal sized shocks coming from the other country. Similarly, monetary and fiscal policy innovations in the key currency country are more potent than those in the other country. On the other hand, the key currency country is more vulnerable to financial market turbulence, such as a sell off of key currency bonds, which can lower consumption dramatically.

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1. Introduction

The implications of a key currency were hotly debated in the 1950's and 60's, both in academia and in political circles. Valery Giscard d'Estaing, while still a French finance minister, asserted that the U.S. enjoyed an "exorbitant privilege" because of the role of the dollar in the international monetary system.[1] The U.S. could finance a current account deficit by issuing dollar assets at low rates of interest. Why? Because a large fraction of international trade was invoiced in dollars, and dollar assets were desired by importers and exporters to facilitate trade; dollars were also desired by central banks as official reserves.[2]

The dollar continues to play a dominant role in the international monetary system.[3] And the dollar figures prominently in current policy discussions: the U.S. has financed most of its recent current account deficits by issuing dollar denominated debt, and there is much speculation in the press about what might happen if foreign dollar holders decided to diversify into other currencies.

In this paper, we build a model in which international trade is invoiced in the key currency, and bonds denominated in the key currency are held to facilitate international trade (and as official reserves). Since key currency bonds provide liquidity services, they are held at a low rate of interest; this is source of the "exorbitant privilege" accruing to the key currency country. Back of

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[1] This phrase is sometimes attributed to Charles de Gaulle, but is evidently due to Giscard d'Estaing, in 1965. See Gourinchas and Rey (2007), footnote 4, for an account.

[2] Aliber (1964) cites numerous political discussions of the costs and benefits of being the key currency country, and he discusses academic arguments to the effect that the U.S. might be constrained in its ability to lower its payments deficit and in its choice of policies to achieve full employment.

[3] Goldberg and Tille (2008; Table 1) report that large shares of various countries' imports and exports are invoiced in dollars. Lane and Milesi-Ferretti have a series of papers documenting the proclivity of foreigners for dollar assets; see for example Lane and Milesi-Ferretti (2007).

the envelope calculations suggest that this privilege is worth slightly more than a half of a percent of U.S. consumption each year.[4] And, one of our tasks will be to investigate the potential consequences of a sudden reversal of the recent buildup of foreign official holdings of dollars.

The recent academic literature has shied away from these issues, and one reason for this is undoubtedly that currently popular models almost invariably assume that bonds denominated in different currencies are perfect substitutes: portfolio managers do not distinguish between them if their expected returns (when evaluated in a common currency) are equal. Expected returns equalize in these models, resulting in the standard uncovered interest parity (or UIP) condition.[5] These models are not suitable for analyzing the asymmetries implied by a key currency: there is no special role for dollar denominated assets.

While macroeconomic modeling has generally assumed that bonds are perfect substitutes, a lively empirical literature has questioned the validity of the UIP condition. There appear to be large, frequent and persistent deviations from UIP in the data.[6] And, there have been some efforts to introduce deviations from UIP into theoretical models, either because the data required it or the question being analyzed required it.

Deviations from UIP have been introduced in a variety of ways. Blanchard et al (2006)

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[4] At the end of 2007, foreign holdings of U.S. Treasury securities amounted to about 90 percent of quarterly U.S. consumption. We have computed the average liquidity premium on Treasury securities to be about 0.0065 per quarter. These imply a value of the exorbitant privilege of 0.585 percent of consumption.

[5] The literature prior to the mid 1970's generally assumed that bonds were imperfect substitutes; see Branson and Henderson (1985) for a survey. Then, following the popularity of the Dornbusch (1976) model, and empirical work in the late 1970's and early 1980's, modelers gravitated towards the perfect substitutes assumption.

[6] Wickens (2008) provides a brief review of this literature. Lewis (1995) provides a more extensive review of the earlier literature.

follow a much earlier literature that simply assumes bonds denominated in different currencies are imperfect substitutes and posits asset demand functions that depend on relative rates of return and financial wealth. They expand upon a model by Kouri (1976) to discuss the causes and long run consequences of recent U.S. current account deficits. Some versions of the IMF's GEM assume portfolio adjustment costs,[7] and this creates portfolio balance effects in the model's dynamics. Other modelers have simply added an exogenous UIP shock, calibrated to match the volatility of exchange rates and (ex-post) UIP deviations observed in the data.[8] And some take a more structural approach, modeling the deviations from UIP as endogenous, time varying risk premia.[9]

In this paper, we model deviations from UIP as endogenous, time varying liquidity premia. More specifically, we build a fully articulated NOEM model in which government bonds denominated in different currencies provide different kinds of transactions services, making them imperfect substitutes. There are two countries in our model – the key currency country and a country representing the rest of the world. Both countries price their exports in terms of the key currency. Consequently, households in each county use the key currency bond to facilitate their purchases of imported goods; and within each country, households use their own government bond and money to facilitate their purchases of domestic goods.[10] Key currency bonds also serve as

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[7] See Pesenti (2008).

[8] See Kollmann (2002, 2005), and McCallum and Nelson (2000).

[9] Lewis (1995) surveys early contributions to this literature. See Alverez, Atkeson and Kehoe (2007) for a more recent application.

[10] Holmstrom and Tirole (1998) provide a rationale for government provision (and management) of liquidity. They show that with aggregate uncertainty, the private sector cannot adequately supply its liquidity needs. The government can raise welfare by issuing bonds, which will command a liquidity premium over private debt.

official reserves. In this setup, all government liabilities are "liquid" and imperfectly substitutable, in the sense that each provides a distinct kind of transactions service.

Any liquid asset commands an endogenous, time varying liquidity premium; or equivalently, in equilibrium, the liquid asset's pecuniary return is below the return on a safe but illiquid bond (which we will call the CCAPM rate). The liquidity premium will vary with the supply of the asset – an increase in supply reduces the marginal value of transactions services provided by the asset and reduces the spread between the liquid asset's rate and the CCAPM rate.[11] Deviations from UIP reflect the differences in liquidity premia on bonds denominated in the two currencies. In our calibrated model, shocks that change the quantity or value of the two liquid bonds and create non trivial deviations from UIP.

In this paper, we study the macroeconomic implications of a key currency at business cycle frequencies. We do this in three ways. First, we look at the second moments generated by our calibrated model. We show that our model is capable of capturing some features of the U.S. data, and we also find that our model makes headway in explaining some of the empirical anomalies documented in the literature, such as the Backus - Smith puzzle and the high volatility of real and nominal exchange rates; our model is also capable of generating a "liquidity effect" (or fall in the nominal interest rate in response to an increase in the rate of money growth).

Second, we use impulse response functions (IRFs) to study the way in which the key

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[11] This property of our model is consistent with the evidence presented in Krishnamurthy and Vissing-Jorgensen (2008) who show that the spread between AAA-rated corporate debt and government debt is high when the stock of government debt (relative to GDP) is low and is low when the stock of government debt is high. They attribute this sensitivity of the spread to changes in the marginal convenience value of government debt. Greenwood and Vayanos (2008) also find that debt stocks affect yield spreads. They show that the yield curve for government debt depends on the relative quantities of debt by maturity.

currency assumptions – international holdings of the key currency bond, and key currency pricing of traded goods – work in our model. Here, we focus on shocks that change the supplies of various liquid assets: bond financed decreases in taxes, open market operations, and a sell off of foreign official holdings of the key currency bond.

The IRFs show that the way we have introduced imperfect substitutability – through time varying liquidity premia – has far reaching consequences for the importance of financial market developments on real economic activity. An earlier empirical literature on portfolio balance models found only small, and imprecisely measured, effects of changes in bond supplies on relative rates of return. Our model is consistent with this empirical result. Calibrated shocks to asset supplies produce moderate movements in interest rates and UIP deviations, but they can have large effects on consumption in our model. This is because the spread between the liquid bond rate and the CCAPM rate makes our model non-Ricardian, and shocks can produce large changes in household wealth. For example, a bond financed tax cut will generate expectations of future tax liabilities. In a Ricardian world, the tax cut would have no effect on consumption: households would simply save the cut in current taxes to pay future taxes. In our model however, the tax liability accrues at the liquid government bond rate, while households discount future tax liabilities at the higher CCAPM rate; a temporary tax cut generates a positive wealth effect and raises private consumption. Our model implies that moderate financial market developments can have important implications for real economic activity.

And finally, we use our model to investigate the potential consequences of a sudden unwinding of the "exorbitant privilege" enjoyed by the key currency country. In particular, we suppose that foreign central banks suddenly sell off a portion of their key currency reserves; we calibrate the sale to match accumulation of official dollar reserves over the last five years. The results are dramatic: consumption in the key currency country falls by about 2.5 percent in each of the first two years.

Generally speaking, our IRFs indicate that shocks to asset supplies originating in the key currency county have larger effects at home and abroad than shocks emanating from the other country. Partly this is due to portfolio balance effects – changes in supplies and valuations of the liquid assets. But, the key currency pricing of exports also plays an important role. A tax cut, or an increase in the money growth rate, emanating from the key currency country will reduce the relative price of imports in *both* countries. By contrast, a tax cut or an increase in the money growth rate in the other country will raise the relative price of imports in *both* countries. This implication of key currency pricing is bound to be a provocative result in our model.

In any case, our results imply that the key currency country can be a greater source of global instability than other countries. They also imply that the monetary and fiscal policies of the key currency country are more potent, domestically and internationally, than the policies of other countries. And finally, they imply that the key currency country is susceptible to financial market shocks – such as a sell off of key currency bonds – in a way that other countries are not.

The rest of the paper proceeds as follows: In Section II, we outline our model and discuss its calibration. In Section III, we show that the model makes headway in explaining some important anomalies or puzzles that have been documented in the empirical literature. In Section IV, we study the ways in which our key currency assumptions work in our model, illustrating the asymmetric effects of changes in various asset supplies. In Section V, we use our model to study the potential consequences of a sudden sell off of U.S. debt. And in Section VI, we conclude with a discussion of the implications of our results for future work.

II. A Two Country Model with a Key Currency

Our model consists of two countries – Home and Foreign; here we have in mind the United States and the rest of the world. Bonds are imperfect substitutes for money in each country, and this makes Home and Foreign bonds imperfect substitutes internationally.[12] The Home country provides the key currency.[13] Foreign households hold Home bonds to facilitate trade, and the Foreign government holds Home bonds as reserves. In the steady state, the current account is balanced, but international portfolios are not symmetric: Home earnings on Foreign equity are balanced by Foreign earnings on Home bonds. Moreover, Foreign firms price their exports in units of the Home currency. These two asymmetries – Foreign demand for Home bonds and key currency pricing of exports – drive our results.

The rest of the model draws standard features from the NOEM literature. Monopolistically competitive firms produce an aggregate consumption good in each country; household consumption reflects habit formation and a bias for the domestically produced good; labor is the only factor of production (there being no capital or investment); the labor market is competitive and wages are

[12] Banks use government bonds to manage the liquidity of their deposits, and households hold them indirectly through their access to money market mutual funds and other financial institutions. In Canzoneri, Cumby, Diba and Lopez-Salido (2008a), we present a closed economy model with banks, bank deposits and bank loans. Here, due to the complexity of the two country model, we take a less structural approach. In Canzoneri, Cumby, Diba and Lopez-Salido (2008b) we study the dynamic properties of a closed economy version of our present framework. In particular, we show that the familiar Taylor Principle is not a necessary condition for determinacy.

[13] The Euro and the Yen are of course competing for key currency status. Modeling competing currencies is beyond the scope of the current paper.

flexible, but prices are set ala Calvo. First, we present the model and its steady state; then, we discuss its calibration.

II. A. The Model

Home Households –

In the Home country, there is a continuum of households on the unit interval. The utility of household h is

(1) $U_t(h) = E_t\sum_{j=t}^{\infty}\beta^{j-t}[\log(c_j(h)- \xi c_{j-1}) - \kappa(1+\chi)^{-1}n_j(h)^{1+\chi}]$

where $c_t(h)$ is consumption of a composite final good (defined below), $n_t(h)$ is hours of work, c_{t-1} is aggregate consumption, and the parameter ξ is a measure of habit persistence. Households are identical in this model; so, we can dispense with household indices. Moreover, the population has measure one; so in equilibrium, per capita supplies and demands will be equal to aggregate supplies and demands. The household's budget constraint, in units of the Home consumption good, is[14]

(2) $m_t + b_{H,t} + (1+\tau_t)c_t = w_t n_t + (m_{t-1} + R_{t-1}b_{H,t-1})/\Pi_t + tr_t - x_t + div_{H,t} + s(q_t\, div^*_{F,t})$

Home households hold Home money, m_t, and Home bonds, $b_{H,t}$, to finance their purchases ($\tau_t c_t$ is a transactions cost which will be described later); $w_t n_t$ is real wage income; w_t is the competitive market wage; R_{t-1} is the gross nominal interest rate on Home bonds; $\Pi_t = P_t/P_{t-1}$ is the gross rate of inflation of the Home consumption good price; tr_t is a lump sum transfer and x_t is a lump sum tax;

[14] A note on notation: H and F subscripts will be used to denote Home and Foreign assets or products when those bonds or products are used in both countries; Home money, for example, is not held by Foreign entities, and therefore needs no subscript. Supercript *'s will denote Foreign household demands and supplies of assets or products; they will also denote Foreign interest rates, Foreign inflation rates, velocity, relative prices in the Foreign country, and various "foreign" variables and parameters.

$div_{H,t}$ is Home dividends, q_t is the real exchange rate (Home consumption goods per Foreign good), $div^*_{F,t}$ is Foreign dividends, and s is the Home household's (constant) share of those dividends.[15]

Following Schmitt-Grohe and Uribe (2004), we assume that transactions costs are proportional to consumption, and the factor of proportionality is an increasing function of velocity.

$$(3)\quad \tau_t = \begin{cases} (A/v_t)(v_t - \nu)^2 & \text{for } v_t > \nu \\ 0 & \text{for } v_t \leq \nu \end{cases}$$

where ν is the satiation level of velocity and A is a cost parameter. The new element here is in our definition of velocity

$$(4)\quad v_t = c_t/\tilde{m}_t$$

where effective transactions balances – $\tilde{m}_t$ – are a Cobb Douglass aggregate of money and bonds

$$(5)\quad \tilde{m}_t = m_t^{\varsigma} b_{H,t}^{(1-\varsigma)}$$

where $1-\varsigma \in [0, 1]$ measures the importance of bonds in facilitating trade.

The household's first order conditions include:

$$(6)\quad w_t\lambda_t = n_t^{\chi}$$

$$(7)\quad (c_t - \kappa c_{t-1})^{-1} = \lambda_t[1 + 2A(v_t - \nu)]$$

$$(8)\quad 1 - A[v_t^2 - \nu^2]\varsigma(\tilde{m}_t/m_t) = \beta E_t[(\lambda_{t+1}/\lambda_t)/\Pi_{t+1}] \equiv 1/\tilde{R}_t$$

$$(9)\quad 1 - A[v_t^2 - \nu^2](1-\varsigma)(\tilde{m}_t/b_t) = R_t\beta E_t[(\lambda_{t+1}/\lambda_t)/\Pi_{t+1}] = R_t/\tilde{R}_t$$

where λ_t is the marginal value of wealth, and $\tilde{R}_t$ is the CCAPM rate. We will think of $\tilde{R}_t$ as the

[15] We do not model the equities market. We simply assume that each household owns a proportionate share of the steady state Home country portfolio of Home and Foreign equity. The size of this portfolio will be calibrated so that Home earnings on foreign equity balance Foreign earnings on Home bonds in the steady state.

return on a bond that does not provide transactions services;[16] $R_t/\tilde{R}_t$ is less than one, reflecting the non-pecuniary return (or liquidity premium) on Home bonds. (6) is a standard labor supply curve, and (7) defines the marginal value of wealth. When real resources are depleted in the purchase of consumption goods, the marginal value of wealth is less than the marginal utility of consumption. (8) and (9) are the first order conditions for money and bonds.

Foreign Households –

Foreign households are modeled symmetrically, but with one major exception: Foreign households use the Home bond, in addition to their own money and bonds, to finance their purchases. The utility of a representative household is

(10) $U_t^* = E_t\sum_{j=t}^{\infty}\beta^{j-t}[\log(c_j^* - \xi c_{j-1}^*) - \kappa^*(1+\chi)n_j^{*\,1+\chi}],$

where c_{j-1}^* is again aggregate consumption, and the household's budget constraint is

(11) $m_t^* + b_{F,t}^* + b_{H,t}^*/q_t + (1+\tau_t^*)c_t^* = w_t^* n_t^* + (m_{t-1}^* + R_{t-1}^* b_{F,t-1}^* + R_{t-1}b_{H,t-1}^*/q_t)/\Pi_t^* + tr_t^* - x_t^* + (1-s)div_{F,t}^*$.

Transactions costs are again proportional to consumption,

(12) $\tau_t^* = \begin{cases} (A^*/v_t^*)(v_t^* - \nu^*)^2 & \text{for } v_t^* > \nu^* \\ 0 & \text{for } v_t^* \leq \nu^* \end{cases}$

where

(13) $v_t^* = c_t^*/\tilde{m}_t^*.$

However, effective transactions balances – $\tilde{m}_t^*$ – are given by

(14) $\tilde{m}_t^* = m_t^{*\omega1} b_{F,t}^{*\,\omega2}(b_{H,t}^*/q_t)^{(1-\omega1-\omega2)}$

[16] The CCAPM bond would be in zero net supply in equilibrium, so we suppressed it in our equations.

where $0 < \omega_1$, $0 < \omega_2$, and $\omega_1 + \omega_2 < 1$.

The household's first order conditions include:

(15) $w_t^* \lambda_t^* = n_t^{*\chi}$

(16) $(c_t^* - \xi^* c_{t-1}^*)^{-1} = \lambda_t^*[1 + 2A^*(v_t^* - \nu^*)]$

(17) $1 - A^*[v_t^{*2} - (\nu^*)^2]\omega_1(\tilde{m}_t^*/m_t^*) = 1/\tilde{R}_t^*$

(18) $1 - A^*[v_t^{*2} - (\nu^*)^2]\omega_2(\tilde{m}_t^*/b_{F,t}^*) = R_t^*/\tilde{R}_t^*$

(19) $1 - A^*[v_t^{*2} - (\nu^*)^2](1 - \omega_1 - \omega_2)(\tilde{m}_t^* q_t/b_{H,t}^*) = R_t\beta E_t[(\lambda_{t+1}^*/\lambda_t^*)(q_t/q_{t+1})(1/\Pi_{t+1})]$

Equations (15), (16), (17) and (18) are analogous to the first order conditions for the Home household. The Foreign household also holds Home bonds, and (19) is the first order condition for that decision. As we shall see, first order conditions (18) and (19) provide the analogue of the uncovered interest parity (UIP) condition in our model.

Interest rate spreads due to the transactions services of bonds –

Home and Foreign bonds provide transactions services to households. So, bonds are imperfect substitutes for money, and imperfect substitutes for one another. This is reflected in a number of interest rate spreads. First, first order conditions (8) and (9) imply

(20) $$\frac{\tilde{R}_t - R_t}{\tilde{R}_t - 1} = \left(\frac{1-\varsigma}{\varsigma}\right)\left(\frac{m_t}{b_{H,t}}\right)$$

We can think of the Home CCAPM rate, $\tilde{R}_t$, as a the return on a bond that does not provide transactions services. There is a positive spread, $\tilde{R}_t - R_t$, between this rate and the rate on liquid bonds, since the latter provide a non-pecuniary return. This spread depends on the ratio of money to bonds, and as we will see in Section IV.C, this generates a "liquidity effect" for monetary policy.

An expansionary open market operation increases the ratio, lowers R_t, and increases the spread. The Foreign household's first order conditions for money and bonds, (17) and (18), imply an analogous spread between the Foreign CCAPM rate and the Foreign bond rate, $\tilde{R}^*_t$ - R^*_t.

A novel aspect in this paper is that there is a deviation from the usual UIP condition, since Home and Foreign bonds are imperfect substitutes. Home and Foreign bonds provide transactions services to the Foreign household; its first order conditions, (18) and (19), introduce deviations from UIP in our model. Linearizing around the steady state (described below) we obtain,

$$(21) \qquad \hat{R}^*_t - \hat{R}_t + E_t\left(\hat{e}_{t+1} - \hat{e}_t\right) = \frac{\left(1 - \omega_1 - \omega_2\right)}{\omega_2}\left(\frac{\tilde{R}^* - R^*}{R^*}\right)\left(\hat{b}^*_{F,t} + \hat{q}_t - \hat{b}^*_{H,t}\right)$$

where variables without a time subscript are steady state values and a ^ denotes a percentage deviation from the steady state value. The deviation from UIP depends on the ratio of the stocks of Home and Foreign bonds. Intuitively, we can think of (21) as:

(22) $\text{dev(UIP)} \equiv R_t - \{R^*_t + E_t[\Delta\log(e_{t+1})]\} = npr^*_t - npr_t$.

where e is the nominal exchange rate and npr and npr* are the marginal non pecuniary returns (or marginal liquidity value) from holding another unit of the bond in question. The relative marginal non-pecuniary value of the bond depends on the ratio of Home bond and Foreign bonds in the Foreign household's portfolio: $(b^*_{H,t}/q_t)/b^*_{F,t}$, or in nominal terms, $B^*_{H,t}/e_tB^*_{F,t}$. When, for example, the ratio falls, npr rises and npr* falls; so, dev(UIP) falls. This relationship between relative asset supplies and relative returns figures prominently in the discussion that follows.

The empirical literature on portfolio balance effects in financial markets often considered regressions of spreads – e.g. ex-post deviations from uncovered interest parity – on relative asset quantities. Equation (21) shows that in our model the coefficient on the relative asset stocks is proportional to the liquidity premia. In our model a small liquidity premium (2.6% per annum in the steady state) implies non-trivial wealth effects with corresponding macroeconomic consequences. As we show in Section IV below, the difference in the present values of future tax liabilities discounted at the rates on liquid and illiquid debt leads to sizable changes in consumption in response to a temporary tax cut.

Firms, Key Currency Pricing, Intermediate Goods, and Final Goods –

The modeling of monopolistic competition is now standard; our description can be brief, focusing on aspects that are specific to our model. A continuum of monopolistically competitive firms hire labor on a competitive labor market and produce a continuum of intermediate goods using a linear technology with a common productivity shock; the log of the productivity shock follows an AR1 process with autoregressive parameter ρ_z and innovation $\epsilon_{z,t}$. The Home national product, $y_{H,t}$, is a CES aggregate of these intermediate goods, with elasticity of substitution ζ. The Home consumption good (appearing in the utility function (1)) is a CES aggregate of Home consumption of the Home product, $c_{H,t,}$ and Home consumption of the Foreign product, $c_{F,t}$:

(23) $c_t = [\mu_t^{1/\eta} c_{H,t}{}^{(\eta-1)/\eta} + (1-\mu_t)^{1/\eta} c_{F,t}{}^{(\eta-1)/\eta}]^{\eta/(1-\eta)}$

where $\mu_t > ½$ reflects a bias for Home goods. $\log(\mu_t)$follows an AR1 process with mean $\log(\mu)$, autoregressive parameter ρ_μ and innovation $\epsilon_{\mu,t}$. Similarly, the Foreign consumption good is

(24) $c_t^* = [\mu^{1/\eta} c_{F,t}^{*\,(\eta-1)/\eta} + (1-\mu)^{1/\eta} c_{H,t}^{*\,(\eta-1)/\eta}]^{\eta/(1-\eta)}$.

The Home and Foreign household's first order conditions imply

(25) $$\frac{c_{H,t}}{c_{F,t}} = \left(\frac{\mu_t}{1-\mu_t}\right)\left(\frac{p_{F,t}}{p_{H,t}}\right)^{\eta}$$

(26) $$\frac{c^*_{F,t}}{c^*_{H,t,}} = \left(\frac{\mu}{1-\mu}\right)\left(\frac{p^*_{H,t,}}{p^*_{F,t}}\right)^{\eta}$$

Intermediate goods firms in each country set their prices ala Calvo; the Calvo parameter is set so that the average duration of a price "contract" is four quarters in each country. Here again, however, there is an important asymmetry due to our assumption of a key currency. Home firms set prices in terms of the Home currency, and the law of one price holds for Home goods sold domestically and abroad ($P_{H,t} = e_t P^*_{H,t}$, where e_t is the nominal exchange rate). Letting lower case letters denote prices relative to CPIs,

(27) $p_{H,t} = q_t p^*_{H,t}$

By contrast, Foreign firms price their exports in terms Home currency, and the law of one price does not hold.

Monetary and Fiscal Policy –

The Home government's flow budget constraint is

(28) $m_t + d_t = (m_{t-1} + R_{t-1}d_{t-1})/\Pi_t + p_{H,t}g_t + tr_t - x_t$

where d_t is the supply of Home government bond. Home government spending falls entirely on the Home good; $\log(g_t)$ follows an AR1 process with mean $\log(g)$, autoregressive parameter ρ_g and innovation $\epsilon_{g,t}$. $\log(x_t)$ follows an AR1 process, with autoregressive parameter ρ_x and (negative) innovation $\epsilon_{x,t}$. $\epsilon_{x,t}$ is a tax cut shock; it will have interesting effects since bonds provide transactions service, making our model non- Ricardian. We use the lump sum transfers, tr_t, to assure fiscal solvency:[17]

(29) $tr_t = -\phi_d(d_{t-1} - \bar{d})$

The Foreign government holds Home bonds as reserves, $b^{G*}_{H,t}$. The Foreign government's tax and transfer schemes are analogous to (25) and (26), but its flow budget constraint is

(30) $m^*_t + d^*_t = (m^*_{t-1} + R^*_{t-1}d^*_{t-1})/\Pi^*_t + b^{G*}_{H,t}/q_t - R_{t-1}b^{G*}_{H,t-1}/\Pi_t q_t + p^*_{F,t}g^*_t + tr^*_t - x^*_t$.

Once again, g^*_t and x^*_t follow AR1 processes, and tr^*_t responds to the level of the debt.

One of the shocks we will consider is a sale of Home bonds by the Foreign government,

(31) $b^{G*}_{H,t-1} - \bar{b}^{G*}_H = \rho_B(b^{G*}_{H,t-1} - \bar{b}^{G*}_H) - \epsilon_{B,t}$.

For monetary policy, we will consider both interest rate rules and money growth rules. The Home policy rules are standard:

(32a) $\log(R_t/\bar{R}) = \rho_R\log(R_{t-1}/\bar{R}) + (1-\rho_R)\phi_\pi\log(\Pi_t/\bar{\Pi}) + (1-\rho_R)\phi_y[\log(y_{H,t}) - \log(\bar{y}_{H,t})] + \epsilon_{R,t}$

(32b) $\log(M_t/M_{t-1}) = \rho_M\log(M_{t-1}/M_{t-2}) + (1-\rho_M)\log(\bar{\Pi}) + \epsilon_{M,t}$

The Foreign policy rules are defined analogously.

The interest rate rules are of course more realistic, but the impulse response functions generated with interest rate rules conflate the direct effect of shocks with the effects of the endogenous response of monetary policy to the shocks. The fixed money growth rules provide a

[17] The model is non-Ricardian in the sense that the timing of tax payments matter, but fiscal policies are Ricardian in the sense of Woodford's "fiscal theory of the price level".

simpler conceptual framework for our analysis. For example, the shock just defined, $\varepsilon_{B,t}$, would be a sterilized foreign exchange intervention with a fixed money growth rule for the Foreign government, but not with an interest rate rule.

Equilibrium Conditions and the Current Account

Most of the market equilibrium conditions are obvious. Here, we focus on those about which there may be some confusion. For Home bonds,

(33) $d_t = b_{H,t} + b^*_{H,t} + b^{G*}_{H,t}$

Government spending falls on the domestic good in each country, so

(34) $y_{H,t} = (1+\tau_t)c_{H,t} + g_t + (1+\tau^*_t)c^*_{H,t}$

(35) $y^*_{F,t} = (1+\tau^*_t)c^*_{F,t} + g^*_t + (1+\tau_t)c_{F,t}$

Combining the public and private budget constraints and imposing the market clearing conditions, we arrive at the balance of payments identity:

(36) $(1+\tau^*_t)p_{H,t}c^*_{H,t} - (1+\tau_t)p_{F,t}c_{F,t} - (R_{t-1}\Pi_t^{-1}-1)(b^*_{H,t-1}+b^{G*}_{H,t-1}) + s(q_t\, div^*_{F,t})$

$= CA_t = (b^*_{H,t-1} - b^*_{H,t}) + (b^{G*}_{H,t-1} - b^{G*}_{H,t})$

Home's current account surplus is Home's exports (including Foreign's transactions costs) less Home's imports (including transactions costs) less Home's real interest payments to Foreign plus Home's receipts of dividend income from Foreign. The balance of payments identity links the current account to the change in Home's real net foreign assets.

II.B. Calibration of the Model

We do not report the steady state equations but the way we solve for the steady state equilibrium is dictated by our approach to the model's calibration. Some parameters are either estimated or taken from the literature, such as the productivity process which is taken from Backus, Kehoe, and Kydland (1995). But our model has a number of parameters (in our specifications of transactions costs and the transactions technology) that we cannot pin down in a standard way. Moreover, we want our model to match observed ratios of asset stocks to consumption, interest rates, and inflation. Our strategy is to set our parameters to match these variables. We set the ratios reported in the first panel of Table 1 using historical averages and set transactions cost to 0.8 percent of consumption.[18] We then use the ratios in the steady state equations to back out the parameters reported in the second panel of Table 1.

We do not attempt to calibrate the Foreign country to fit "rest of world" data. Instead, we calibrate Home to U.S. data, and then – apart from the key currency features – we calibrate Foreign in a symmetric fashion. In the steady state, net exports are zero and the current account is balanced, but international portfolios are not symmetric: Home residents hold equity claims on Foreign firms and Foreign residents hold Home bonds. Home residents earn the CCAPM rate on their Foreign equity claims while Foreign residents earn the liquid bond rate on their Home bond holdings. And because liquid assets command liquidity premia in the (non stochastic) steady state, and not just in the transition dynamics, Home earns a higher rate of return on its foreign assets than it pays on its foreign liabilities, as is the case in the U.S. data. Home is a net debtor, but Home equity receipts from Foreign firms are balanced by Foreign earnings on Home bonds. The difference in the rates of return is sufficient in the steady state to balance the income receipts and payments.

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[18] The banking sector accounts for about 1.6 percent of employment. We assume that roughly half of this is associated with facilitating transactions.

The existence of a liquid premium on bonds that depends on relative asset supplies even in the steady state implies that permanent changes in monetary and/or fiscal policy that affect the real steady state values of liquid assets will affect the steady state liquidity premia. Monetary and fiscal policies will therefore affect the steady state equilibrium.[19] For example, (20) also holds in the steady state. The steady-state CCAPM rate is given by Π/β and does not depend on the ratio m/b. An open market operation that increases m/b will therefore reduce the steady state interest rate.

III. Fitting the Data and Addressing Puzzles in the Literature

Much can be learned by generating second moments from our calibrated model and comparing these moments with the corresponding statistics in the quarterly data. In performing this exercise, we use our estimated interest rate rules for monetary policy; in the next section, we employ money growth rules to better understand the workings of our model. Our purpose here is to see how well our rather rudimentary model fits some of the standard features in the U.S. data, to see whether our model can address some well known empirical puzzles, and to see which shocks or structural features of the model contribute most in these assessments.

Unconditional moments are reported in Table 2. The second column reports statistics (or targets for the model to fit) from the data; these statistics are described in the Appendix. In the last five columns of Table 2, we report moments generated from five versions of the model, adding shocks or structural features one by one.

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[19] Aspects of this are discussed further in Canzoneri, Cumby, Diba and Lopez-Salido (2008a).

Moments in the third column of Table 2 come from a stripped down version of the model which may be described as an International Real Business Cycle model: prices are flexible; bonds do not provide transactions services (the model is Ricardian); and the Home demand shock is shut down. Moments in the fourth column come from a version of the model which may be described as a standard New Open Economy Model; it starts with the IRBC model and adds producer currency Calvo price setting (exports are priced in the sellers currency). Moments in the fifth column come from a version of the model that adds the demand shock. Moments in the sixth column add key currency pricing of exports. And finally, moments in the last column come from the full blown Key Currency model, obtained by adding liquid bonds and a special role for the key currency bond.

III. 1. Capturing Some Standard Features in the U.S. Data

Our model does fairly well in capturing standard features of the U.S. data. This is perhaps somewhat surprising since we have not modeled investment and we have not calibrated the Foreign country to match any particular country or group of countries. Instead, our model is symmetric apart from the features associated with Home's key currency status.[20]

Looking at the first row of moments in Table 2, we see that Home inflation in the IRBC model is, as might be expected, more volatile than U.S. inflation. The standard NOEM models (columns 4 and 5) bring volatility down, but not enough. Adding key currency pricing (columns 6 and 7) brings the model in line with the data. In the second row of moments, we see that Home consumption is not as volatile in any version the model as it is in the U.S. data; in fact, the IRBC

[20] The departures from symmetry are: (1) Foreign households and the Foreign government hold Home bonds and Home households hold claims on Foreign dividends in return; and (2) both Home and Foreign exporters set prices in Home currency.

model does better on this score than the standard NOEM models (columns 4 and 5). Adding liquid bonds (column 7) raises the volatility to the level of the IRBC. Why? Variance decompositions (not reported here) show that adding this non-Ricardian element allows demand shocks to play a much bigger role, presumably through their effect on household wealth. Much the same story holds for the volatility of the Home interest rate, and the interest rate differential. Volatility is too low in all versions of the model, and the IRBC model does better than the standard NOEM models. The Key Currency model raises the volatility to match the IRBC model.

III. 2. Addressing Puzzles in the Literature

The Key Currency model makes some headway in addressing several anomalies that have been documented in the empirical literature. While the model does not resolve all of these puzzles, it does do significantly better than the IRBC model or the standard NOEM models.

The fifth and sixth rows of moments in Table 2 address *the exchange rate volatility puzzle*: IRBC models and NOEM models have a hard time matching the volatility of the nominal and real exchange rates that has been documented in the data. Columns 5, 6 and 7 show that adding the demand shock, then key currency pricing, and finally liquid bonds, increases these volatilities dramatically. The next row of Table 2 shows that all of the sticky price versions of the model do a good job of matching the correlation between real and nominal exchange rates found in the data; this is not lost in the Key Currency model.

Row 8 in Table 2 speaks to *the Backus and Smith puzzle*. Backus and Smith (1993) argue that the correlation between changes in the real exchange rate and changes in relative consumption is between -0.6 and 0.2 in the data, but much higher in IRBC models. In our model, the correlation falls within the Backus - Smith range, due in large part to our demand shock. As can be seen from the eighth row of moments, the correlation is 0.67 for the IRBC and standard NOEM model without the demand shock. When the shock is added, the correlation in the standard NOEM model comes down to 0.16, which is near the top of the Backus - Smith range. And the correlation in our Key Currency Model fall to -0.43, near the bottom of the Backus - Smith range. These correlations are very sensitive to the asymptotic variance of the demand shock. Our point estimate of the auto-regressive parameter in the shock process is 0.95 (see the Appendix), which implies a very large variance. If we lower this parameter to 0.90, then the correlation in the standard NOEM model rises to 0.52, and the correlation on our Key Currency model rises to -0.18, which is at the center of the Backus - Smith range.

The final line in the top part of Table 2 speaks to a related puzzle. IRBC models generate a correlation between Home and Foreign consumption that is too close to 1.0. As can be seen in Table 2, adding sticky prices, a demand shock, and vehicle currency pricing do relatively little to reduce that correlation. The non-Ricardian features of our model are instrumental in reducing the correlation to the middle of the range reported by Backus, Kehoe, and Kydland.

The next to last row in Table 2 addresses *the uncovered interest parity puzzle*. In models that assume home and foreign bonds are perfect substitutes, UIP holds exactly, but we seem to observe large and persistent deviations from UIP in the data. Some models posit a (largely) unexplained shock to UIP to fill the gap. In our model there is no need for an artificial shock; equilibrium deviations from UIP occur in response to all of the shocks in the model.

Our model generates UIP deviations with a standard deviation of 44 basis points (expressed at an annual rate), or about a third of the standard deviation for interest differentials (as reported in row 4, at a quarterly rate). This value is large enough to be of consequence, but it may or may not be deemed sufficient to be consistent with the data. The empirical literature is split on this issue. One approach uses the volatility of fitted values of regressions of either the change in the exchange rate or of the ex-post deviation from UIP on the interest rate differential. This approach yields extremely large estimates of the volatility. Lewis (1995) characterizes the volatility as between 9 and 11 percent at an annual rate. This corresponds to 3.3 - 4.3 times the volatility of the interest differential in our model. By this measure, our model's standard deviation is too small by a factor of 20 or more. A second approach used in the literature, which is taken by Froot and Frankel (1989), uses survey data to measure expected exchange rate changes. This approach yields considerably smaller estimates of the volatility of UIP deviations – mostly in the 30 - 35 basis point range, although one estimate is nearly 80 basis points. In summary, depending on which set of estimates we believe, the volatility of deviations from UIP generated by our model is either about right, or too small by an order of magnitude.

Finally, although our model generates nontrivial deviations from UIP, it does not resolve *the forward premium puzzle*. As can be seen from the last line in Table 2, the correlation between the lagged interest differential and exchange rate changes is positive for each of the models we consider. Resolving the forward premium puzzle would require that the model generate a negative correlation.

IV. Macroeconomic Implications of a Key Currency in Our Two Country Model

Our key currency assumptions – Home bonds held by Foreign households, and all exports invoiced in Home currency – imply asymmetries that are not found in standard NOEM models. To understand these asymmetries, and to assess their importance, we now ask how various shocks pass through our two country model. Our two countries are symmetric except for the key currency assumptions; so, differences in analogous impulse response functions (IRFs) are attributable to the existence of a key currency.

Our modeling of the key currency entails portfolio balance considerations and pricing considerations. To isolate the portfolio balance effects and to highlight the non-Ricardian features of our model, which arise from the liquidity of bonds, we begin our discussion with a flexible price version of the model. We also assume that monetary policy is characterized by fixed money growth rules (instead of interest rate rules); this allows a cleaner interpretation of the shocks that change the supplies of Home and Foreign currency assets. We consider a number of these shocks: Home and Foreign tax cuts increase the supplies of the Home and Foreign government bonds; and Home and Foreign money growth shocks substitute money for bonds. After we understand these fundamental portfolio balance considerations, we add Calvo price setting and the key currency pricing of exports. As we shall see, sticky and asymmetric pricing has a dramatic effect on the way shocks pass through our model economy, modifying the basic portfolio balance considerations we began with.

It may be helpful to state our three basic results at the outset. First, shocks affecting asset supplies have big effects on consumption, and real economic activity generally, because changes in liquid bonds create large non-Ricardian wealth effects. Second, shocks emanating from the key currency country have a greater effect on consumption, both domestically and abroad, than shocks emanating from the other country. There are two basic reasons for this second result: key currency bonds are held internationally, and key currency pricing implies positive relative price effects (analogous to terms of trade effects) in *both* countries for shocks to assets denominated in the key currency, and negative relative price effects in *both* countries for shocks to assets that are not denominated in the key currency. And finally, shocks to asset supplies imply large valuation effects and sudden jumps in the current account, jumps that dwarf subsequent movements in the trade balance. We should note that these valuation effects are not captured in the conventional balance of payments measure of the current account;[21] our analysis suggests that they are big and very important to our understanding of the international transmission of shocks.

IV. A. A Bond Financed Home Tax Cut

We begin by considering an unexpected, but persistent ($\rho_x = 0.9$), reduction in Home lump sum taxes; the size of the initial shock is one percent of output. This tax cut increases the wealth of Home taxpayers. Why? The government issues bonds to cover the decrease in revenue, and taxpayers know that future tax liabilities have increased. But, households discount future income and tax liabilities at the CCAPM rate, while the government borrows at a lower rate of interest because its bonds provide a non-pecuniary return; so, the temporary tax cut generates a positive wealth effect. (Equivalently, the household could invest its tax cut in CCAPM bonds and have more than enough to pay its future tax liabilities.) In addition, the Home government collects seigniorage on the low interest bonds that it has the power to issue, lowering the tax burden and increasing the wealth effect. Finally, the additional bonds issued by the Home government augment the supply of liquid assets available to Home and Foreign households, generating an expansionary, and inflationary, liquidity effect.

With Flexible Prices (top panel of Figure 1)

The increase in wealth makes Home households want to consume more and work less, decreasing output and raising real wages. The rise in consumption, combined with home bias,

[21] See Kollmann (2006).

requires a real appreciation of the Home currency. This increase in the relative price of Home goods is a decline in the Foreign country's terms of trade. That decline creates a negative wealth effect, which reduces Foreign consumption and raises the Foreign labor supply. Output rises in the Foreign country, and real wages fall. The negative wealth effect arising from the adverse terms of trade movement is reinforced by an increase in seigniorage that Foreign households pay to the Home government, since in equilibrium they end up holding more of the low interest Home government bonds. For Home households, the increased seigniorage revenue from abroad decreases tax liabilities and reinforces the positive wealth effect arising from the tax cut.

The increase in the supply of Home bonds requires an adjustment of portfolios, which is accomplished by a change in relative asset prices, or equivalently, asset returns. Foreign households are the only agents in our model that hold both Home and Foreign bonds, and their portfolio demands play the major role here. The increase in the relative supply of Home bonds causes its relative price – the Home nominal exchange rate – to depreciate. In equilibrium, the ratio of Home to Foreign bonds in the Foreign household's portfolio – $B^*_{H,t}/e_t B^*_{F,t}$ – falls. To make Foreign households want to hold this new portfolio, the relative expected rate of return on Home assets must fall; that is, the initial deviation from UIP must be negative. But as the Home government continues to issue more Home bonds over time, the bond ratio rises, and the deviation from UIP must rise to maintain equilibrium in bond markets.

From Figure 1, the initial fall in the deviation from UIP is about -12 basis points (at an annual rate), while the subsequent rise over the next twenty quarters is about 20 basis points. These rather modest figures seem consistent with an earlier empirical literature that failed to find large and significant effects of changes in asset supplies on relative rates of return.

How is this accomplished in the financial markets? Each of the returns in (22) – R_t, R^*_t, and - $E_t[\Delta\log(e_{t+1})]$ – plays a role. From (20), R_t rises in response to the decrease in the ratio $m_t/b_{H,t}$; and from (9) and (18), R^*_t rises because the fall in $B^*_{H,t}/e_t$ reduces the ratio $\tilde{m}^*_t/b^*_{F,t}$. In equilibrium, $m_t/b_{H,t}$ falls more than $\tilde{m}^*_t/b^*_{F,t}$; so, R_t rises more than R^*_t. A large increase in $E_t[\Delta\log(e_{t+1})]$ (not pictured) is therefore needed for bond market equilibrium.

Home bonds are used by households in both countries to facilitate trade; so, the Home government's issue of new bonds increases world liquidity (and decreases transactions costs in the household budget constraints). This increases consumption demand and raises the price levels in both countries. Not surprisingly, Home inflation exceeds Foreign inflation.

Figure 1 also shows the reaction of the Home current account, which is defined in (36) as the change in real net foreign assets; in our graphs, the current account is measured as a fraction of Home steady state output. The current account deficit that follows the first period makes sense: Home consumption rises and Home production falls, and a trade deficit ensues. What is interesting is the initial positive spike, which results from valuation effects. The jump in prices lowers the real value of Home debt to foreigners; so, the real interest payments to foreigners fall in the initial period.

Adding Calvo Price Setting and Key Currency Pricing of Exports (bottom panel of Figure 1)

As before, a Home tax cut increases the supply of Home bonds, raising Home wealth and increasing the supply of world liquidity. But with sticky prices, the inflationary effect is spread out over 10 quarters; so, the real value of liquid assets is not inflated away as quickly. And since prices do not rise as much, consumption demand is higher, and firms have to meet this demand. Home consumption rises much more than in the flexible price case, and output rises instead of falling.

The key currency pricing of exports has more provocative implications: a Home tax cut initially reduces the relative price of the imported good *for both* Home and Foreign households. This is due to an asymmetry in exchange rate passthrough, which is due in turn to the key currency pricing of exports. As in the case of flexible prices, the expansion of Home consumption (in conjunction with home bias) requires a decline in the relative price of Foreign goods, $p_{F,t}/p_{H,t}$, for Home consumers; the nominal exchange rate plays no direct role in this because Foreign exporters set prices in terms of the Home currency. But Home exporters also set prices in Home currency, and the depreciation of the Home nominal exchange rate reduces the Foreign currency price of Home goods; the relative price of Foreign goods, $p^*_{F,t}/p^*_{H,t}$, rises for Foreign consumers. $p_{F,t}/p_{H,t}$ falls at the same time as $p^*_{F,t}/p^*_{H,t}$ rises. This rise in $p^*_{F,t}/p^*_{H,t}$ is however reversed after a couple of quarters, as firms get to reset their prices.

In any case, these relative price movements are analogous to an improvement in the terms of trade for households in *both* countries, increasing consumption in each. And in contrast with the flexible price case, Foreign consumption actually rises for a few quarters. Developments in financial markets and in the current account are qualitatively similar to those in the flexible price case.

IV. B. A Bond Financed Foreign Tax Cut

Here we consider a Foreign tax cut of equal size; that is, Foreign lump sum taxes are cut by one percent of output, and the tax cut is as persistent as the Home tax cut. Aside from the initial valuation effect on the current account, the effects of a Foreign tax cut are qualitatively similar to those of a Home tax cut. But significant differences in the magnitude of the responses do arise. Foreign bonds are not held by Home households; so, one might expect that the spillover effects of the Foreign tax cut will be smaller than those of a Home tax cut. What is, perhaps, surprising is that the own effects of the Foreign tax cut also differ significantly from those of a Home tax cut.

With Flexible Prices (top panel of Figure 2)

A Foreign tax cut raises Foreign wealth for the same reason as before – the actual tax liability grows at a rate that is lower than the rate at which Foreign households discount their tax liabilities. This wealth effect raises Foreign consumption and reduces Foreign labor supply. Foreign output falls and Foreign real wages rise. And, as with the Home tax cut, a reduction in Foreign taxes generates a wealth transfer. Increased Foreign consumption, combined with home bias, produces an increase in the relative price of foreign goods in both countries ($p_{F,t}/p_{H,t}$ and $p^*_{F,t}/p^*_{H,t}$ both rise). This "terms of trade" effect reinforces the wealth increase for Foreign households and reduces Home wealth.

Seigniorage payments also change as a result of the Foreign tax cut. The expansion in Foreign consumption raises foreign liquidity demand and Foreign households acquire more Home bonds. This will result in a wealth transfer from Foreign to Home equal to the present value of the change in seigniorage revenues, which mitigates the increase in Foreign consumption and the reduction in Foreign labor supply. Because of Home's key currency status, both Home and Foreign tax cuts raise foreign seigniorage payments to Home. This asymmetry implies that a Foreign tax cut has a smaller own effect on consumption, output, hours worked, real wages, and relative prices than does a Home tax cut.

These asymmetries are quite pronounced, as can be seen by comparing Figures 1 and 2. Consider, for example, the implications of Home and Foreign tax cuts for consumption. The own effect on consumption of a Foreign tax cut is almost an order of magnitude smaller than the own effect of a Home tax cut. Similarly, the spillover effect of a Foreign tax cut is almost an order of magnitude smaller.

The adjustment of international portfolios is analogous to the previous case with one major exception: adjustment once again requires a small negative deviation from UIP. Symmetry with the previous case might have suggested a positive deviation. However, in equilibrium, the ratio of Home bonds to Foreign bonds – $B^*_{H,t}/e_tB^*_{F,t}$ – in the Foreign households portfolio falls slightly:[22] the fall in e_t does not quite offset the rise in $B^*_{F,t}$. As the deficit continues, the ratio and the deviation from UIP continue to fall. Over the 20 quarter horizon, the deviation from UIP falls about 30bp.

Finally, it is interesting to note that the initial valuation effect on the Home current account is much the same for Home and Foreign tax cuts. Here, as in the case of the Home tax cut, the rise in the Home price level inflates away the real value of the Foreign debt to Home taxpayers, and initially, the real interest payments fall. This produces a spike in the Home current account that is much larger in absolute value than the trade surpluses that follow.

Adding Calvo Price Setting and Key Currency Pricing of Exports (bottom panel of Figure 2)

The asymmetries due to key currency pricing found in Figure 2 are striking. The relative price of Foreign goods ($p_{F,t}/p_{H,t}$) rises for Home consumers, as was the case with flexible prices. However, the relative price of Foreign goods ($p^*_{F,t}/p^*_{H,t}$) falls for Foreign consumers. These asymmetries are again due the an asymmetry in exchange rate passthrough. The increase in Foreign consumption (in conjunction with home bias) drives up $p_{F,t}/p_{H,t}$, and nominal exchange rate movements play no direct role in this because Foreign exporters price in terms of Home currency. However, Home exporters also price in terms of the Home currency, and the appreciation of the

[22] In other parameterizations, the ratio and dev(UIP) can rise on impact; and then fall as the deficit continues.

Home currency raises the Foreign currency price of Home goods, reducing the relative price, $p^*_{F,t}/p^*_{H,t}$, faced by Foreign consumers. This rather perverse change in $p^*_{F,t}/p^*_{H,t}$ eventually rights itself, but it takes longer to do so than in the case of a Home tax cut.

The interesting thing to note here is that the Foreign tax cut raises the relative prices of imports for households in both countries, while the Home tax cut reduces the relative price of imports for both. Key currency pricing of exports implies an asymmetry in exchange rate passthrough, and in turn, this asymmetry in passthrough implies that the Home tax cut induces a positive wealth effect in both countries, while the Foreign tax cut produces a negative wealth effect in both. So, we now see that both of our key currency assumptions – that Foreign households hold Home bonds, and that Home exporters price in terms of Home currency – work in same direction to make the Foreign tax cut's own effects and spillover effects on consumption weaker than those of the Home country's tax cut. Indeed, this can be seen directly by comparing Figures 1 and 2.

IV. C. Money Growth Shocks

Finally, in Figure 3 we compare the effects of Home and Foreign money growth shocks of equal size. The Home shock is more expansionary, in terms of its own effects and its spillover effects. In fact, the Home shock actually raises Foreign consumption and output. These differences can be explained along the lines of the previous arguments, with asymmetric exchange rate passthrough playing a prominent role. In particular, with the Home shock, both countries experience a decline in the relative price of imports, and with the Foreign shock, both experience an increase. It is also interesting to note that our Key Currency model generates a liquidity effect: an increase in money growth decreases both nominal and real interest rates, and expands output. This "liquidity effect" has been difficult to generate in NNS models; and indeed, the nominal interest rate rises in the NOEM (with producer currency pricing) version of our two country model.

V. A Sudden Unwinding of the Exorbitant Privilege

By of the end of 2007, foreign official holdings of U.S. Treasury securities had increased by nearly 150 percent since the end of 2000 and by more than 90 percent (or $758 billion) since the end of 2002. In other words, the U.S. has financed its recent current account deficits in large part by issuing low interest debt. Some observers think this trend is not sustainable, and they worry about the consequences of a sudden unwinding of the “Exorbitant Privilege”.

Here, we use our Key Currency model to analyze the macroeconomic consequences of a partial unwinding of the recent official reserve accumulation. The size, and permanence, of a potential sell off of U.S. securities is of course a matter of speculation. We choose to consider an unexpected, but persistent, sale of Home bonds by the Foreign central bank equal to the reserve buildup since the end of 2002, and we assume the half life of the shock is about five years. The macroeconomic consequences of this sale depend on what the Foreign government does with the proceeds, and on how the monetary authorities in both countries react. Here, we assume that the Foreign government uses the proceeds of the sale to buy back it own debt. And, we assume that the monetary authorities follow the interest rate rule (32).[23]

The Foreign government’s sale of Home bonds results in a wealth transfer from Home taxpayers to Foreign taxpayers. When the Foreign government holds Home bonds as reserves, it is

[23] If the foreign central bank followed the money growth rule used in the last section, the asset sale we are considering would be equivalent to a sterilized foreign exchange intervention.

paying a seigniorage tax to the Home government.[24] Put another way, Foreign taxpayers are giving Home taxpayers a low interest loan (lower than the Foreign taxpayers could get on a CCAPM bond). When the Foreign government sells Home bonds, it reverses the process, and the resulting wealth transfer unwinds Home's "Exorbitant Privilege."

This wealth transfer has the predictable effects of lowering Home consumption and raising Foreign consumption, and as can be seen in Figure 4, these effects are huge:[25] Home consumption is lower by 2.1 percent in the first year, and 2.8 percent in the second; Foreign consumption higher by 2.3 percent in the first year, and 2.7 percent in the second.[26]

The sale of Home bonds by the Foreign central bank creates an excess supply of Home bonds, which results in an immediate depreciation of the Home currency of approximately 6%. The ratio of Home bond to Foreign bonds – $B^*_{H,t}/e_tB^*_{F,t}$ – in the Foreign household's portfolio rises in equilibrium. Portfolio adjustment requires an increase in the relative return on Home bonds, or a positive deviation from UIP, of just over 4 percent (at an annual rate). Home interest rates rise by about 50 basis points (at an annual rate) initially and by more than one percentage point after a few

[24] The Home government receives two kinds of seigniorage in our model. It receive seigniorage on the cash it issues: $(\tilde{R}_t - 1)M_t$ (where M is nominal); and it receives seigniorage on the bonds it issues: $(\tilde{R}_t - R_t)B_t$ (where B is nominal).

[25] The IRFs are linear in the size of the shock. So, the reader who wants to consider a smaller (or larger) shock can do so by simply re-scaling: a sale of half the size, will have half the effect on consumption. In the same vein, we should also note that the IRFs are computed from a linearization of the model, and they may not be very accurate for large shocks, such as the one we are considering here.

[26] These reactions are not quite symmetric because transactions costs differ in the two countries.

quarters.[27] Foreign interest rates fall by about 2.5 percentage points initially, but that decline diminishes steadily. The rest of the deviation from UIP comes from an expected appreciation of the Home nominal exchange rate.

Finally, the Home current account improves by just under one percent of GDP. The expected increase in net exports is initially reinforced by an inflation induced decline in the real value of the debt to foreigners. After a couple of quarters, the decline in interest income from abroad offsets the effect of inflation on the real value of Home debt held abroad, and real interest income from Foreign bond holdings declines.

In summary, a sudden and persistent sell off of Home bonds, calibrated to undo the accumulation of dollar denominated reserves over the last five years, results in a large depreciation of the Home exchange rate, moderate (though significant) movements in interest rates, and huge effects on Home and Foreign consumption.

VI. Conclusion

Does the United States actually benefit from its key currency status. It enjoys an "exorbitant privilege", which we have estimated to be slightly more than one half of a percent of consumption per year. But there would also appear to be costs. We have presented a calibrated two country model in which the countries are symmetric except for the fact that the Home country has key

[27] This interest rate effect between two estimates in the literature. Krishnamurthy and Vissing-Jorgensen (2008) estimate that if foreign central banks were to sell all of their dollar assets, U.S. Treasury rates would rise by less than 50 basis points. Warnock and Warnock (2006) estimate that eliminating one year (2004) of foreign official purchases would raise (long-term) U.S. interest rates by 90 basis points.

currency status: both countries price their exports in Home currency, and both countries hold Home government bonds to facilitate international transactions. Our results imply that there are important asymmetries due to the existence of a key currency. But do these asymmetries work to the advantage of the U.S.? Our results imply that U.S. monetary and fiscal policy innovations are more potent because of its key currency status.

Our results also suggest that the shocks emanating from the U.S. contribute more to destabilize the world economy than shocks from the rest of the world. In Section IV, we focused on money growth rules, and we did not mention productivity shocks. Figures 5 and 6 were generated using the interest rate rules for monetary policy, and Figure shows the effects of productivity shocks. Shocks coming from the key currency country generally have bigger own effects and spillover effects than equal sized shocks from the other country.

And finally, our results suggest that the United States is much more vulnerable to financial market turbulence – such as a sudden sell off in dollar denominated debt – than other countries. It is not clear that all of this works to the U.S.'s advantage. That question would appear to be a fruitful topic for future work.

Of independent interest, our Key Currency model generates deviations from uncovered interest parity that are as volatile as some (but certainly not all) empirical estimates. Our model also speaks to some other empirical anomalies, such as the Backus - Smith puzzle and exchange rate volatility puzzle, and our model generates a "liquidity effect" in response to an increase in money growth. Liquidity effects have been hard to produce in NNS models

Shocks affecting asset supplies – such as bond financed tax cuts, foreign exchange interventions, and increases in money growth – have large effects in our model because they generate non-Ricardian changes in household wealth. The non-Ricardian nature of our model stems from way we have chosen to make money and bonds imperfect substitutes: we assume both money and bonds provide liquidity services, rather than focusing on, say, risk premia. And this is probably what distinguishes our work most from the rest of the literature.

Appendix: Estimated Model Parameters

1. Fiscal Variables

a. Government purchases

Regress: $\log(g_t)$ on a time trend and save residuals as detrended series $ldt(g_t)$

$$ldt(g_t) = \gamma + \rho_g \, ldt(g_{t-1}) + \epsilon_{g,t}$$

Data: $\log(g_t)$ = log of real government consumption and investment, NIPA Table 1.1.5, deflated to real terms using the price index for GDP

Sample: 1974:1 - 2007:4

Estimates: $\rho_g = 0.98$

$\sigma(\epsilon_g) = 0.0086$

b. Taxes

Regress: $\log(x_t)$ on a time trend and save residuals as detrended series $ldt(x_t)$

$$ldt(x_t) = \gamma + \rho_\tau \, ldt(x_{t-1}) + \epsilon_{x,t}$$

Data: $\log(x_t)$ = log of real current government receipts, NIPA Table 3.1, line 1, deflated by price index for GDP

Sample: 1974:1 - 2007:4

Estimates: $\rho_x = 0.90$

$\sigma(\epsilon_x) = 0.02$

2. Foreign Official Demand for U.S. Treasury Securities

Regress: $\log(b^{G*}_{H,t})$ on a time trend and save residuals as detrended series, $ldt(b^{G*}_{H,t})$

$$ldt(b^{G*}_{H,t}) = \gamma + \rho_B \, ldt(b^{G*}_{H,t-1}) + \epsilon_{B,t}$$

Data: $b^{G*}_{H,t}$ = foreign official holdings U.S. Treasury Securities, Flow of Funds, Table L.107, line 9 converted into real terms by dividing by the price index for personal consumption expenditures.

Sample period: 1974:1 - 2007:4

Estimates: $\rho_B = 0.964$

$\sigma(\epsilon_B) = 0.0434$

3. Elasticity of substitution in home consumption: Taken from Heathcoate and Perri (2002).

The elasticity can also be estimated from the regression:

$$\log(c_{F,t}) = \alpha_0 + \alpha_1 \log(c_t) + \alpha_2 \log(p_{F,t}) + \epsilon_u$$

Data: We use two series for $c_{F,t}$, real imports of consumer goods and services. Both are taken from NIPA table 4.2.5. One is the sum of lines 26, 35, 36, 42, 43 converted into real terms by deflating by price index for non-oil imports. The other is line 38, imports of nondurable consumer goods, deflated by the corresponding price index.

$\log(c_t)$ = log of real personal consumption expenditures

$p_{F,t}$ = price index for non-oil imports/price index for PCE or the price index for imports of nondurable consumer goods/price index for PCE.

Sample period: 1974:1 - 2007:4

Estimates: α_1: The two estimates are 0.97 and 1.30 and neither differs significantly from 1.0, the value implied by equation 25.

α_2: The two estimates are -1.03 and -0.83, which bracket the Heathcoate-Perri value, -0.9.

ρ_u: Both estimates are 0.95.

$\sigma(\epsilon_u)$ = 0.031 at an annual rate or 0.00775 per quarter

4. Monetary Policy Rule

a. Interest Rate Rule, equation (32),

$\log(R_t/\bar{R}) = \rho_R \log(R_{t-1}/\bar{R}) + (1-\rho_R)\phi_\pi \log(\Pi_t/\bar{\Pi}) + (1-\rho_R)\phi_y[\log(y_{H,t}/\bar{y}_{H,t})] + \epsilon_{R,t}$.

Parameter values ($\rho_R = 0.8$, $\phi_\pi = 2.0$, $\phi_y = 0.20$, and $\sigma(\epsilon_R) = 0.009$) are taken from Canzoneri, Cumby, and Diba (2007b) who estimate a rule for the Volker-Greenspan period. We set the steady-state inflation and federal funds rates at their quarterly averages for the same period used to estimate the interest rate rule. These values are 0.7 and 1.1 percent per quarter.

b. Money Supply Rule

$\log(M_t/M_{t-1}) = (1-\rho_M)\log(\bar{\Pi}) + \rho_M \log(M_{t-1}/M_{t-2}) + \epsilon_{M,t}$.

Parameter values ($\rho_M = 0.5$ and $\sigma(\epsilon_M) = 0.009$) are taken from Ohanian, Stockman, and Kilian (1995).

5. Interest Rate Differentials and Effective Exchange Rates

a. Effective Exchange Rates

Data: Nominal and real effective exchange rates from IFS (ULC definition because of length of sample for real effective exchange rate exceeds that based on CPIs).

Use first difference of logs

Sample: 1974:1 - 2007:4

Estimates: $\sigma(\Delta \log e) = 0.028$

$\sigma(\Delta \log q) = 0.029$

corr(Δ log e, Δ log q) = 0.943

b. Interest rate differentials

Data: Money market interest rates for United States, United Kingdom, Canada, Germany, and Japan (IFS).

Sample: 1974:1 - 2007:4

Estimates: σ(R) = 0.004

σ(R - R*) = .004 (average of the four)

c. CCAPM rate and Spread

The CCAPM rate (equivalently, β) is, of course, unobservable. In Canzoneri, Cumby, and Diba (2007a) we compute CCAPM rates for several specifications of preferences. The average of the five real CCAPM rates reported in Table 1 of that paper is 5.07 percent per annum. The real interest rate rate faced by the highest quality (prime or AAA) borrowers over the same sample that we use to estimate our monetary policy rule averages just under five percent. Over that same sample, the real rate on three-month Treasury bills averaged about 2.4 percent per annum, which implies a spread between the CCAPM rate and the rate of three-month Treasury bills of 2.6 percent per annum. We therefore set our real CCAPM rate to 1.25 percent per quarter (β = 1/1.0125) and our spread at 0.65 percent per quarter.

Data: Three-month constant maturity Treasury bill rate from 1982 on. Prior to 1983, the secondary market rate on three-month bill, converted from a discount basis to an investment basis. Inflation data are computed as quarterly percent changes in the CPI-U.

6. Asset ratios

a. Treasury Securities

Data: B_H = Private US holdings of Treasury Securities = Total outstanding less sum of central bank holdings, ROW holdings, and Government holdings.

Source: Flow of Funds, Table L.209.

$B_{H,t}^{G*}$ = Official ROW holdings of Treasury Securities.

Source Flow of Funds, Table L.107.

$B_{F,t}^{*}$ = Private ROW holdings of Treasury Securities.

Source Flow of Funds, Table L.107.

M_t = Currency held outside of banks.

Source Flow of Funds, Table L.108

C = Personal Consumption Expenditures. Source NIPA Table 1.1.5.

Sample: 1974:1 - 2007:4

$B_H/C = b_H/c = 1.00$

M/C = m/c = 0.28 (We round to 0.25)

$B^{G*}_{H,}/C = 0.63$ (2007:4)

$B^{*}_{F,t}/C = 0.30$ (2007:4)

We use a different sample for these two ratios to take into account the recent buildup in dollar balances both by foreign central banks and by the foreign private sector.

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Table 1: Calibration

Ratios, averages in the data

m/c	m*/c*	b_H/c	b_H^*/qc^*	b_F^*/qc^*	b_H^{G*}/qc^*	τ
0.25	0.25	1.00	0.30	0.70	0.59	0.008

Derived Parameters

ν	ν^*	A	A*	ς	ω_1	ω_2
0.31	0.44	0.007	0.005	0.42	0.42	0.41

Estimated Parameters (standard deviations of shock innovations are reported in the Appendix)

$\bar{\Pi},\bar{\Pi}^*$	ρ_B	ρ_g	ρ_x	ρ_M	ρ_R	ϕ_π	ϕ_y
1.007	0.96	0.98	0.90	0.5	0.8	2.0	0.2

Other Parameters

β, β^*	ξ, ξ^*	μ, μ^*	τ, τ^*	χ, χ^*	$\tilde{R}$ - R	ζ, ζ^*	η, η^*	ϕ_d
.988	.7	.8	.008	1	.0065	1.17	.9	0.024

Table 2: Unconditional Moments

Moment	Target Value	IRBC flexible prices	NOEM producer currency pricing	NOEM producer currency pricing	NOEM key currency pricing	Full Key Currency Model
		No demand shock				
$\sigma(\pi)$	0.28	0.84	0.36	0.39	0.29	0.29
$\sigma(\log c)$	1.3	0.89	0.81	0.82	0.84	0.90
$\sigma(R)$	0.36	0.28	0.23	0.24	0.26	0.27
$\sigma(R - R^*)$	0.38	0.30	0.20	0.23	0.26	0.32
$\sigma(\Delta\log e)$	2.84	0.92	0.94	1.22	1.36	1.85
$\sigma(\Delta\log q)$	2.85	0.89	0.53	0.73	1.03	1.52
Corr($\Delta\log e$, $\Delta\log q$)	0.94	0.31	0.89	0.94	0.96	0.98
Corr($\Delta\log q$,$\Delta\log(c/c^*)$)	(-0.6,0.2)	0.69	0.67	0.16	0.45	-0.43
Corr($\log c$,$\log c^*$)	(0.2, 0.5)	0.74	0.84	0.82	0.77	0.39
$\sigma(R - R^* - E\Delta\log e)$		0.00	0.00	0.00	0.00	0.11
Corr($R_{-1} - R^*_{-1}$, $\Delta\log e$)	< 0	0.35	0.31	0.18	0.23	0.21

Notes:
1. Volatilities are reported as percent per quarter (decimal values are multiplied by 100).
2. Target values for Corr($\Delta\log q$, $\Delta\log (c/c^*)$) are from Backus and Smith.
3. Target values for Corr($\log c$, $\log c^*$) are from Backus, Kehoe, and Kydland.
4. Target values for interest rates are computed from HP filtered data from 1980 - 2007, which is the data period for our estimate of the interest rate rule.
5. Target values for other variables are computed from HP filtered data from 1974 - 2007.

Figure 1: Home Tax Cut

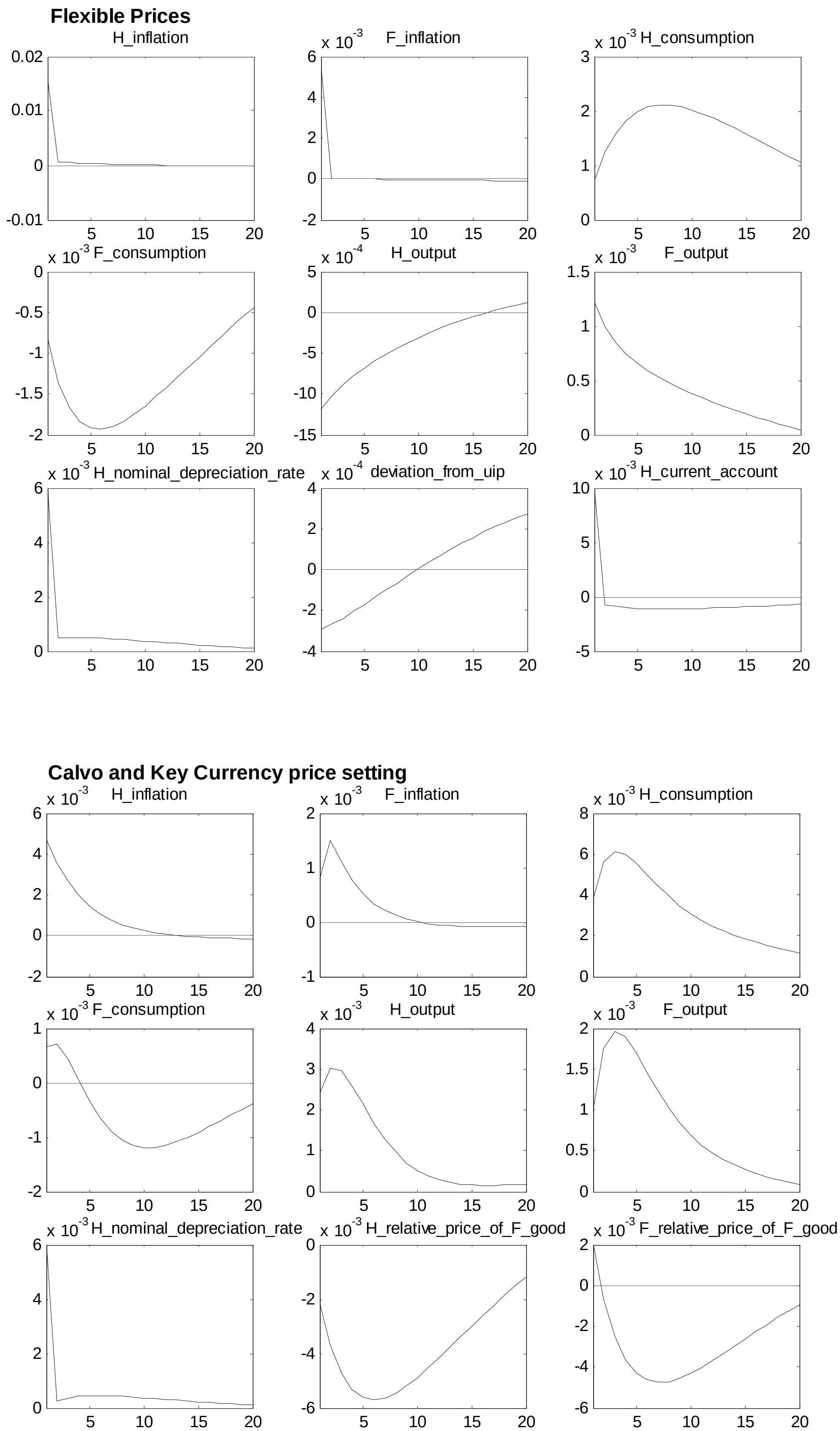


Figure 2: Foreign Tax Cut

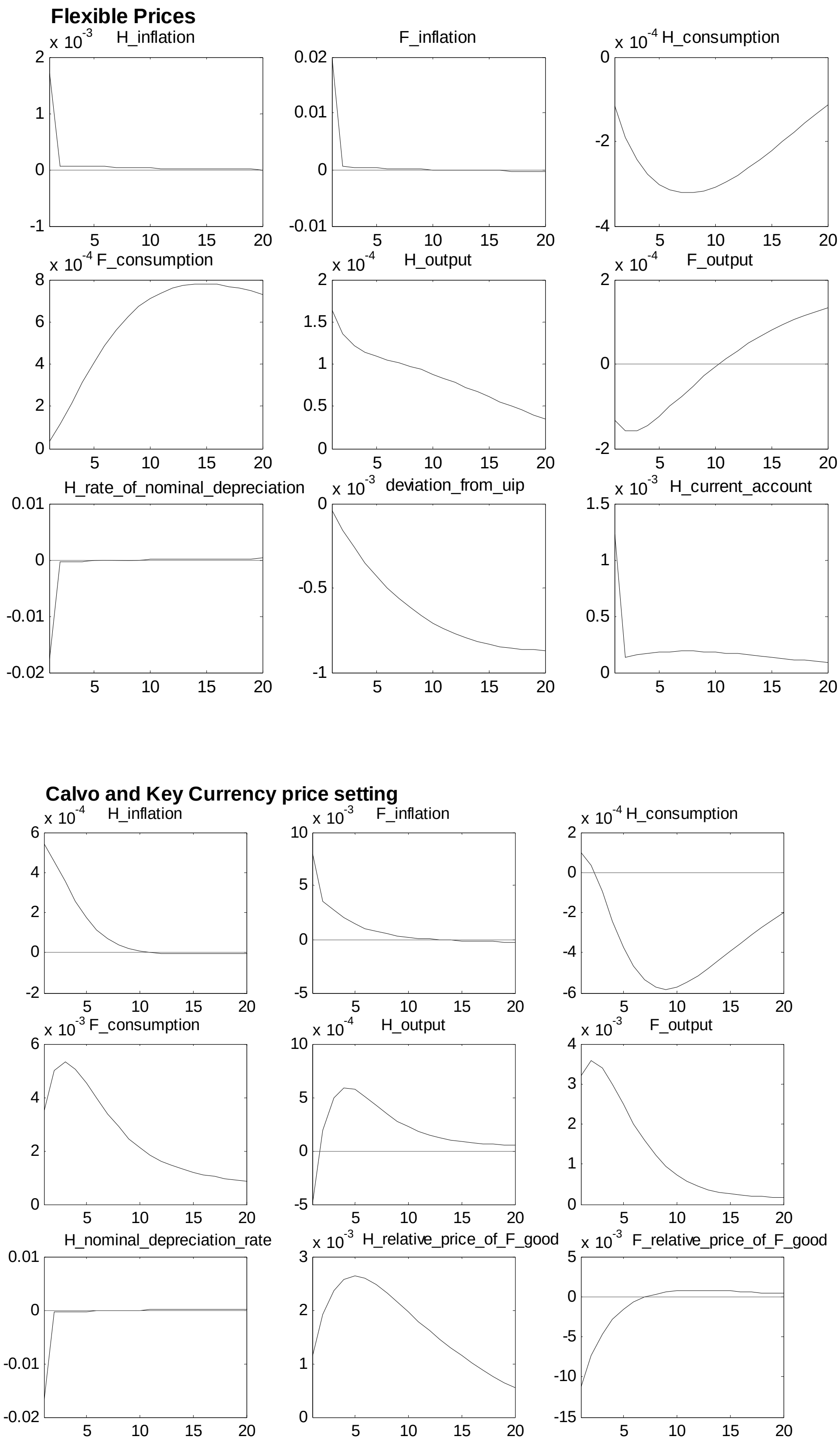


Figure 3: Money Growth Rate Shocks (Calvo and Key Currency price setting)

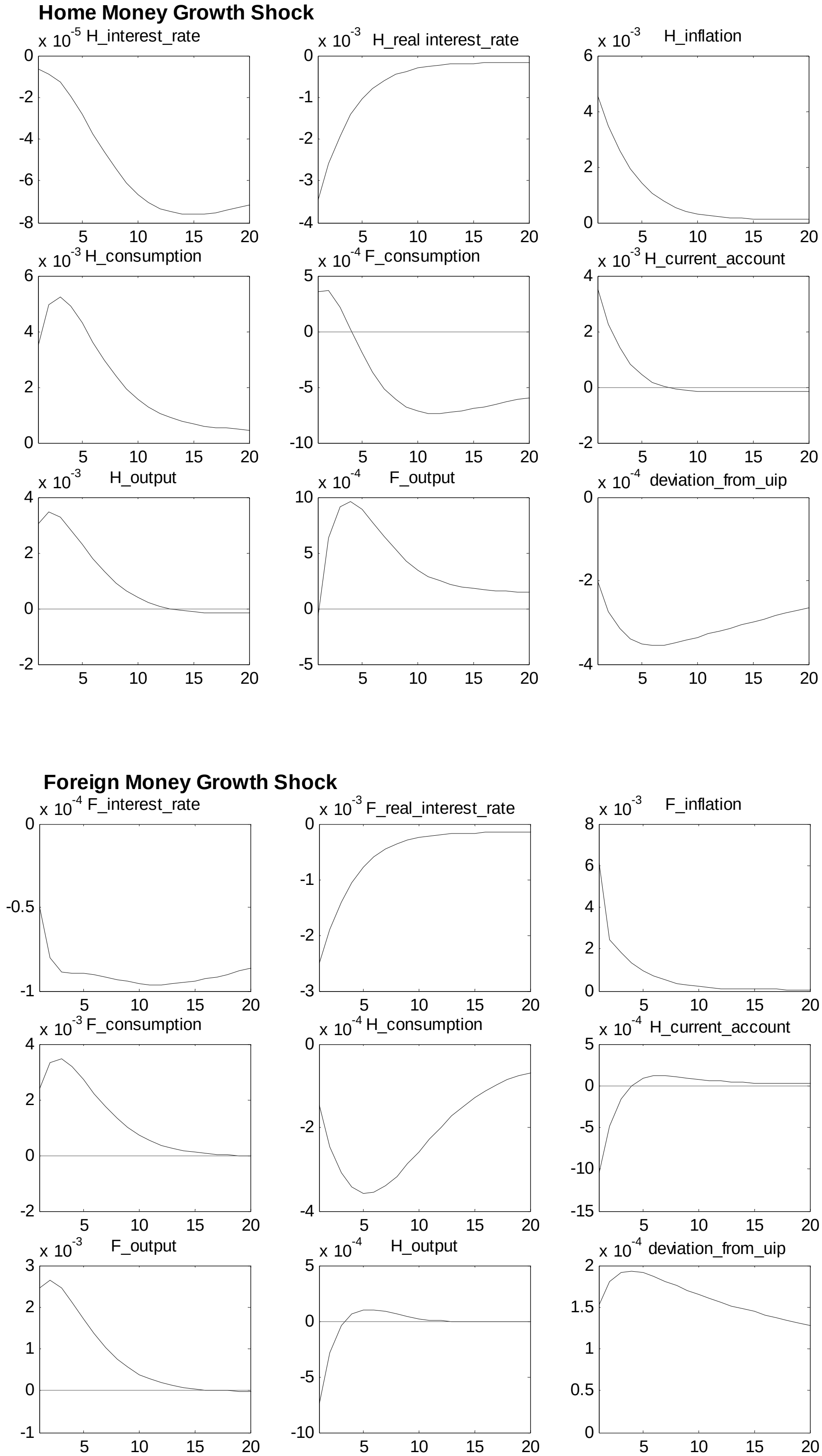


Figure 4: Foreign Government Sale of Home bonds (Calvo and Key Currency price setting)

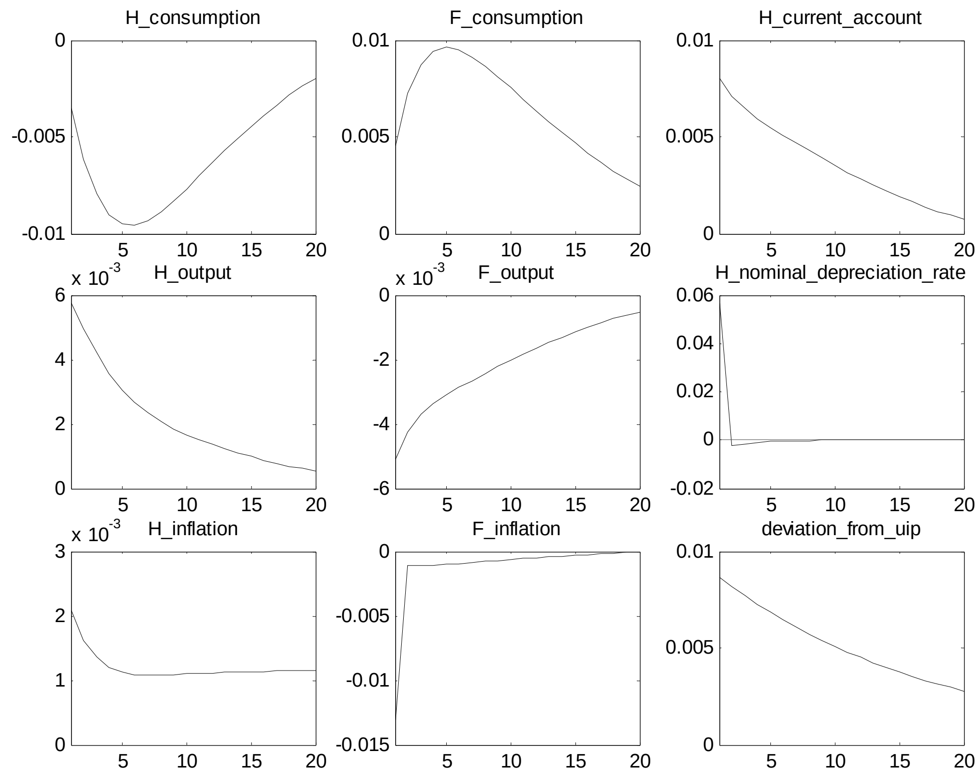
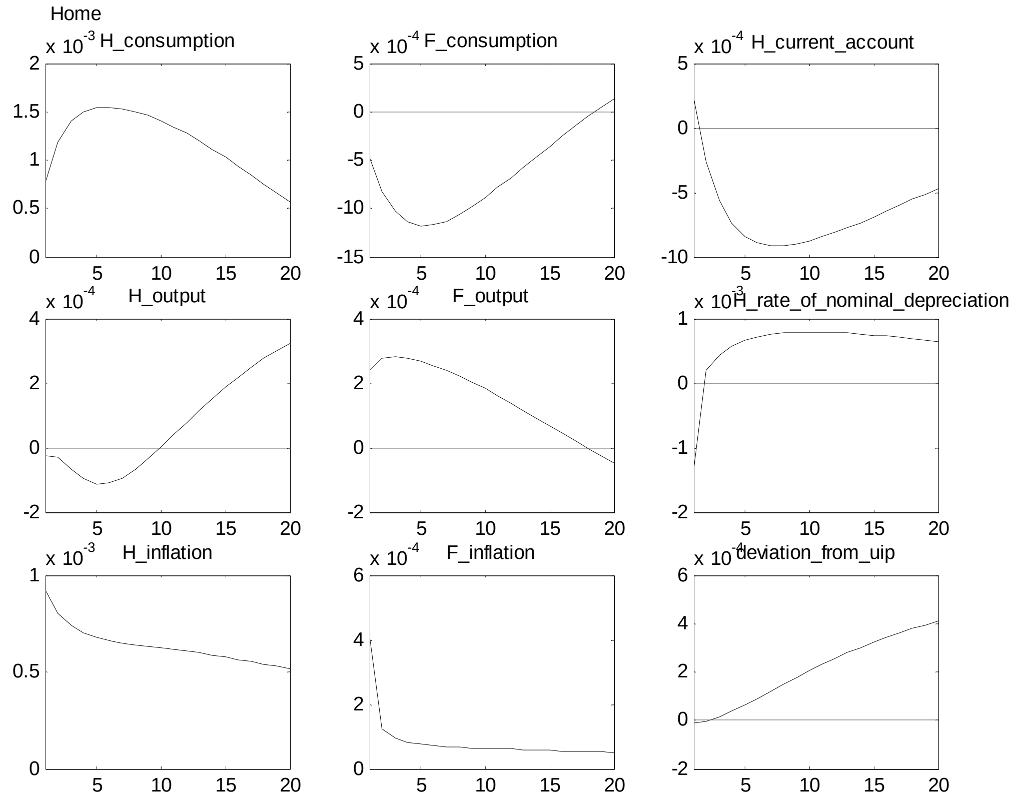


Figure 5: Tax Cut Shocks, Interest Rate Rules for Monetary Policy



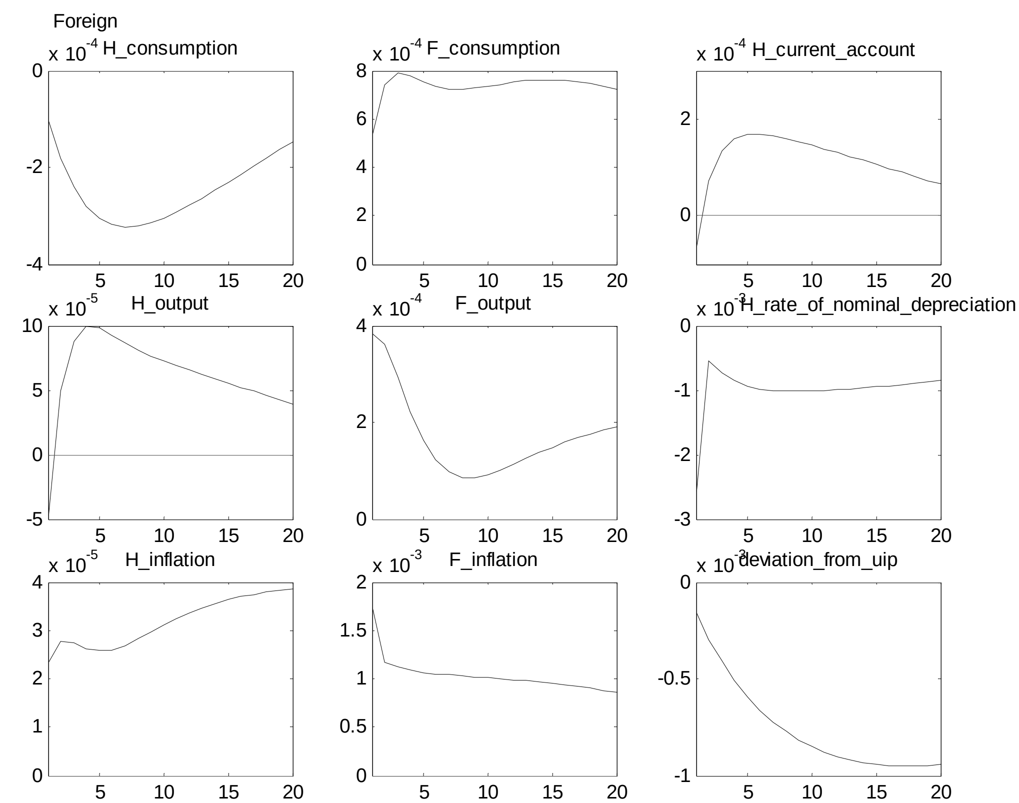
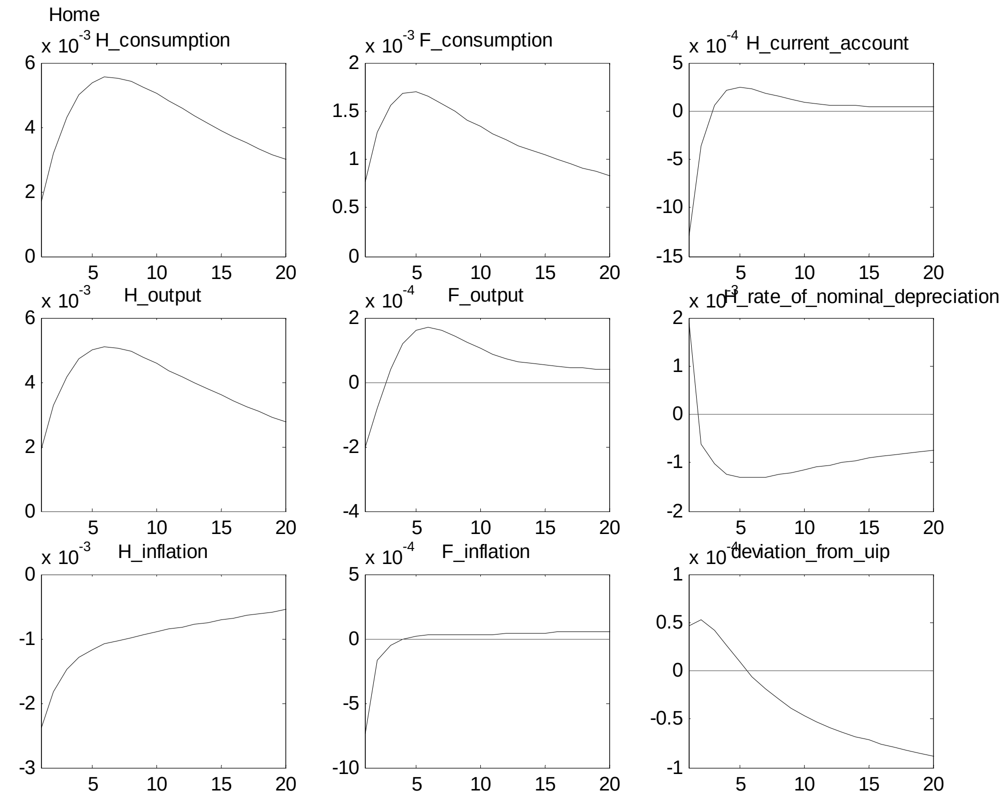
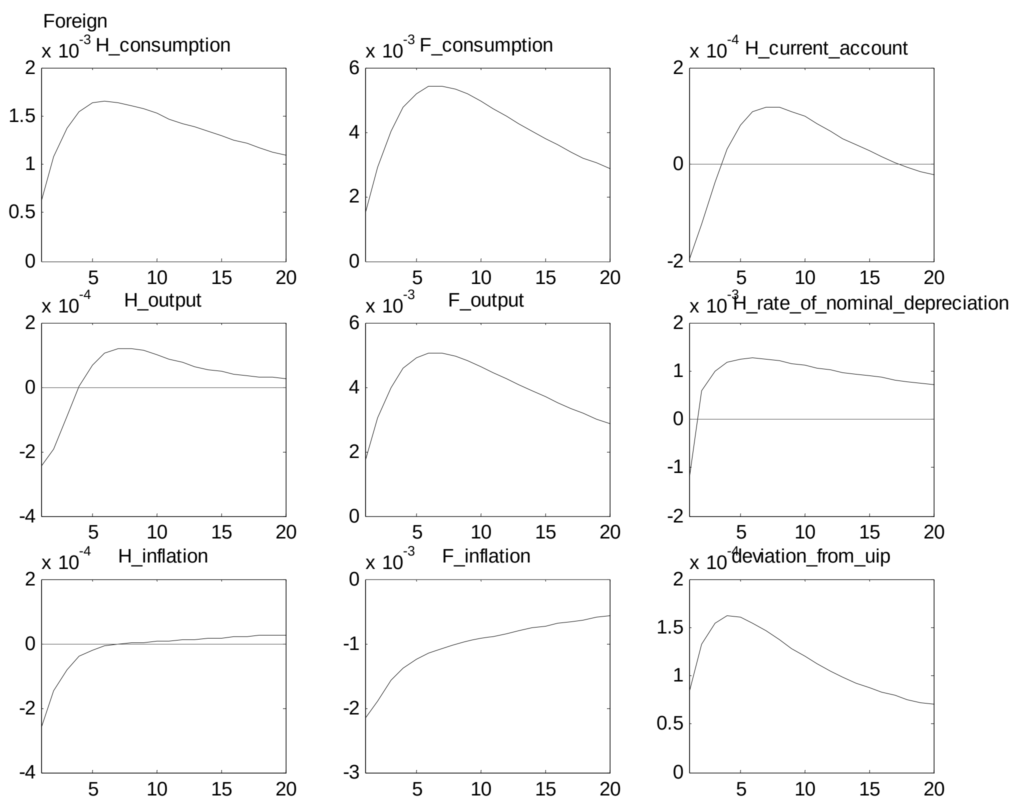


Figure 6: Productivity Shocks, Interest Rate Rules for Monetary Policy


Home
x 10^-3 H_consumption
x 10^-3 F_consumption
x 10^-4 H_current_account
x 10^-3 H_output
x 10^-4 F_output
x 10^-3 H_rate_of_nominal_depreciation
x 10^-3 H_inflation
x 10^-4 F_inflation
x 10^-4 deviation_from_uip


Foreign
x 10^-3 H_consumption
x 10^-3 F_consumption
x 10^-4 H_current_account
x 10^-4 H_output
x 10^-3 F_output
x 10^-3 H_rate_of_nominal_depreciation
x 10^-4 H_inflation
x 10^-3 F_inflation
x 10^-4 deviation_from_uip