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A Monetary Model of the Exchange Rate with Informational Frictions*

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Abstract

Data for the U.S. and the Euro-area during the post-Bretton Woods period shows that nominal and real exchange rates are more volatile than consumption, very persistent, and highly correlated with each other. Standard models with nominal rigidities match reasonably well the volatility and persistence of the nominal exchange rate, but require an average contract duration above 4 quarters to approximate the real exchange rate counterparts. I propose a two-country model with financial intermediaries and argue that: First, sticky and asymmetric information introduces a lag in the consumption response to currently unobservable shocks, mostly foreign. Accordingly, the real exchange rate becomes more volatile to induce enough expenditure-switching across countries for all markets to clear. Second, differences in the degree of price stickiness across markets and firms weaken the correlation between the nominal exchange rate and the relative CPI price. This correlation is important to match the moments of the real exchange rate. The model suggests that asymmetric information and differences in price stickiness account better for the stylized facts without relying on an average contract duration for the U.S. larger than the current empirical estimates.

JEL codes: F31, F37, F41

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1 Introduction

The current empirical evidence indicates that the bilateral nominal and real exchange rates have been excessively volatile and highly persistent during the post-Bretton Woods period. Nominal and real exchange rates have also been highly correlated. I use data for the U.S. Dollar and a synthetic aggregate of the Euro-zone to quantify these moments. However, similar patterns have been consistently uncovered between the U.S. and other major OECD countries (e.g., Chari *et al.*, 2002, Selaive and Tuesta, 2003). These facts take their own place among the notable puzzles in international macroeconomics under the tag of the *excess volatility-high persistence anomaly*.

I develop a two-country, general equilibrium bond economy with traded goods in the spirit of Chari *et al.* (2002). I investigate the role of frictions in the goods market in the form of sticky prices in local currency (e.g., G. Benigno, 2004) and the role of asset market incompleteness with intermediation (e.g., P. Benigno, 2001). I show that this class of models is capable of replicating the volatility relative to consumption and the first-order autocorrelation of the real exchange rate. Matching these two moments requires an average contract duration of $4-5$ quarters (alternatively, a Calvo parameter of $0.75-0.8$)[1]. Still, this range is significatively above the estimates in the literature for the U.S. and lies at the upper bound for Europe (see, e.g., Galí *et al.*, 2001).

The model predictions are broadly consistent with the existing literature on the real exchange rate, but they are accompanied by counterfactual results along other dimensions. Notably, too much volatility on the nominal exchange rate, the CPI prices, and terms of trade. As with most models in the open economy macroeconomics literature, it presumes that all economic agents agree on their expectations about the future state of the economy (i.e., forecasts are homogeneous). In this paper I conjecture that such an assumption has non-negligible consequences for the determination of the nominal and real exchange rates.

I consider an environment where each agent makes his forecast based on private information about the current state and all public information. Private information differs across agents (is asymmetric). Public information summarizes the state of the world economy, but gets revealed with a short delay. Agents must resolve a non-trivial signal extraction problem and decide their optimal commitment choices simultaneously. Heterogeneity across types of agents based on information content, then, gives rise to forecasting disagreements (i.e., heterogeneous forecasts). In this way, asymmetric information diffusion opens up a new channel for the transmission of shocks in the economy.

My work suggests that asymmetrically-dispersed information explains better the volatility of the real and nominal exchange rates relative to consumption. In other words, it shows that it is possible to place the volatilities in the ballpark for the data with an average contract duration of $3-3.5$ quarters which seems much closer to the empirical estimates. I also find that the correlation between the real and nominal exchange rates is high, although not as much as in the data.

When information becomes scarce, the ability of any agent to adjust its response to current shocks is also more limited. If information is asymmetrically-dispersed, private information acquires a new role as a signal in place of other private information not currently available to the agent. This contributes to create a lagged response to unobservable shocks (which become public information with a delay) and to higher reliance on a subset of observable shocks. In this context, the model generates less volatile consumption,

[1] I find support for G. Benigno's (2004) claim that differences in price stickiness across the markets in which a firm operates can be a conduit for higher real exchange rate persistence.

while the expenditure-switching effects become less sensitive to relative prices.

Expenditure-switching is important in general equilibrium in order for markets to clear properly whenever the economy is hit with different country-specific shocks. Therefore, the real exchange rate (and terms of trade also) become more volatile to ensure a large enough expenditure-switch to accommodate the current shocks. In crude terms, this is the main channel through which asymmetric information operates on the volatility of the real exchange rate in the model.

I also document empirically a tight relationship between the first-order autocorrelation of the real exchange rate and the degree of price stickiness. The difference between the observed persistence of the real exchange rate and the estimated degree of price stickiness cannot be explained away neither by asymmetric information, nor by habit formation or with risk-averse financial intermediaries. Instead, I show that the price-setting framework introduced by G. Benigno (2004), which allows for differences in price stickiness across markets, offers an alternative to increase the persistence of the real exchange rate without requiring a larger contract average duration.

I argue that models in which each variety is produced in one location and firm's face the same contract duration in all markets (for local consumption or for exports) result in a strong link between the nominal exchange rate and the relative CPI prices. This is the case because: (a) the price-setting rule depends on the same weighting scheme of current and future marginal costs, and (b) marginal costs are identical but selling prices in each market are expressed in the local currency. Hence, pricing differences across markets are reduced to a particular function of the current and future nominal exchange rate.

G. Benigno's (2004) framework changes the weighting scheme across markets and as a result introduces a wedge between the price in each market that is functionally related to the local marginal cost. The persistence coming from marginal costs and the lower correlation between the nominal exchange rate and relative prices feed back into the real exchange rate pushing up its first-order autocorrelation. In this context, asymmetric information has also a small contribution to play. Equilibrium in the labor and output markets ties marginal costs to consumption. Therefore, disagreements in the forecast of consumption as well as the nominal exchange rate become a more relevant friction now.

In summary, in the paper I discuss how asymmetric information and nominal rigidities affect the volatility and persistence of the exchange rates. I explain the constraints that most directly influence the outcomes of the model. I observe that asymmetric information and price rigidities can improve the fit of the model and give an interpretation for the *excess volatility-high persistence anomaly*. I also discuss other key statistics. For instance, I argue that these two frictions partially account for the systematic and pervasive violations of perfect international risk-sharing (the *real exchange rate-relative consumption anomaly*). I also explore the complementary role of other features of the model like intermediation through risk-averse firms and habit formation on the consumer side.

The present model indicates that asymmetric information and nominal rigidities are central to understanding the *excess volatility-high persistence anomaly*, and that the properties of the data are easier to reconcile with the theoretical predictions of the open macro literature if this two frictions are combined together.

2 Literature Review

Chari *et al.* (2002) develop a general equilibrium monetary model with sticky prices, capital accumulation and financial incompleteness to account for the observed volatility and persistence of real exchange rates. They show that if risk aversion is high, preferences are separable in leisure and prices are fixed for 4 quarters, then their model can explain the volatility of real exchange rates but is less persistent than the data. Bergin and Feenstra (2001) argue that translog preferences amplify the persistence of shocks, but they still need to impose an implausibly large contract length of $8-12$ quarters in order to match the empirical autocorrelations.

Kollmann (2001) considers a semi-small open-economy model with Calvo (1983) price- and wage-setting, and no capital. If both prices and wages are fixed over an average of 4 quarters and monetary shocks are the dominant force, his model generates variability in the real and nominal exchange rates that is consistent with the data (and similar to the results of Chari *et al.*, 2002). G. Benigno (2004) uses a two-country general equilibrium model with nominal price stickiness and local-currency pricing to show that a wide range of Taylor-type policy rules can generate real exchange rate autocorrelations around the ones observed in the data. Therefore, the consensus appears to be that the volatility and persistence of the real exchange rate are directly linked to frictions in the goods market.

Motivated by the empirical failure of the law of one price, the reasonable success of staggered prices to explain the real exchange rate, and in particular by widespread local-currency pricing behavior (e.g., Knetter, 1993, Gopinath and Rigobon, 2006), I assume that nominal prices are sticky à la Calvo (1983) and firms are price-discriminating monopolists. Moreover, firms set prices in the local currency and confront a different average contract length in the domestic and foreign markets (e.g., G. Benigno, 2004).

With complete markets, the real exchange rate is equal to the ratio of marginal utilities of consumption in each country (up to a constant). Hence, real exchange rates and relative consumption are tightly linked. Chari *et al.* (2002) replace the assumption of complete international asset markets with a *nominal bond economy* to break the connection, but they still find a high positive cross-correlation between the real exchange rate and relative consumption unlike that observed in the data[2]. P. Benigno (2001) proposes, instead, an alternative characterization of the bond economy with *ad hoc* costs of international borrowing (recently applied by Selaive and Tuesta, 2003, and G. Benigno and Thoenissen, 2006, among others).

G. Benigno and Thoenissen (2006) explain that costs of borrowing coupled with non-traded goods would explain the negative correlations found in the data. Similarly, Selaive and Tuesta (2003) argue that costs of borrowing and distribution costs for traded goods generate violations of the law of one price (intermediate degrees of pass-through), deviations from uncovered interest rate parity and sensible cross-correlations. Hence, current research seems to favor incomplete markets and borrowing costs as necessary devices to fit the key cross-correlations in the data. The exact role of non-traded goods or non-traded distribution services is, however, still being debated.

My model assumes that all goods are traded based on the empirical evidence that fluctuations of the real exchange rate arise mostly from deviations of the law of one price on traded goods (e.g., Engel, 1999, and Chari *et al.*, 2002). Gagnon's (1996) findings point out a significant and robust long-run link between the real exchange rate and the net foreign asset position. This evidence and its potential impact on the structure

[2] I refer to this puzzle as the *real exchange rate-relative consumption anomaly.* Backus and Smith (1993) originally reported this as evidence of lack of international risk-sharing (in a model with non-traded goods). Kollmann (1995), Ravn (2001) and Head *et al.* (2004) have also found little connection between the real exchange rate and relative consumption.

of cross-correlations motivates me to also introduce financially-constrained households and international borrowing costs. However, I do not merely impose an *ad hoc* cost as suggested by P. Benigno (2001). I build up a simple problem of portfolio choice with fully rational financial intermediaries[3]. I model these intermediaries in the spirit of Evans and Lyons (2007), but I view their role simply as that of myopic traders (or currency speculators).

Several recent papers, including Mankiw and Reis (2002, 2006) argue that sticky information resolves some stylized business cycle models (for instance, on the dynamics of inflation). In this paper I conjecture that, indeed, such informational frictions have non-negligible consequences for the determination of the nominal and real exchange rates. I also learn from Evans and Lyons (2007) that fundamental information is not symmetrically observed by all agents. Naturally, this fact can alter the exchange rate dynamics "even controlling for information availability and assuming rational pricing, by changing the way (asset) prices respond to information" (Carlson and Osler, 2000).

Bacchetta and van Wincoop (2004a, 2004b, 2006) rely on two distinct types of noise (noisy signals about fundamentals and *ad hoc* non-fundamental noise) to model information dissemination, to induce rational confusion about the source of exchange rate fluctuations and to explain heterogeneous forecasting along the equilibrium path[4]. Naturally, they claim that the information structure is essential to explain the nominal exchange rate dynamics (particularly, the excess volatility) and other features of the data.

Bacchetta and van Wincoop (2006) also argue that fundamentals play a small role in the short- and medium-run, but are dominant in the long-run as more information becomes available, and that exchange rates are a weak predictor of future fundamentals. With these results in mind, I am led to consider the role of information diffusion in my general equilibrium model too. The logic being that heterogenous forecasts add an additional channel for the transmission of shocks. Therefore, they alter the second-order moments of the endogenous variables and help replicate the dynamics of the (nominal and real) exchange rates.

However, unlike Kaplan (2005) and Bacchetta and van Wincoop (2006), I do not require non-fundamental noise to induce rational confusion. Instead, in my setup information is asymmetrically-dispersed across agents, and no one is sufficiently well-informed to infer which shocks drive the fluctuations of each endogenous variable at a given point in time. I adapt my model to investigate the role that heterogeneous information plays in the dynamics of the economy (especially the exchange rates) and the correlations of per capita consumption, CPI prices, exchange rates and terms of trade.

2.1 Stylized Facts of the Exchange Rate

Here, I document the properties of the bilateral exchange rate between the United States (home country) and the 12 member country Euro-zone (foreign country). My measure of the nominal exchange rate, S_t, is U.S. Dollars (USD) per Euro (EUR). Prior to 2001, the synthetic nominal exchange rate is computed as a GDP-weighted function of the USD per National Currency rates. The U.S. real exchange rate relative to the Euro-zone is simply $RS_t \equiv \frac{S_t P_t^*}{P_t}$, where P_t and P_t^* are the CPI prices in the United States and the Euro-zone, respectively. I proxy the U.S. terms of trade, TOT_t, as the world import-to-export price ratio in

[3] These financial intermediaries allow me to separate the consumption-savings decision of households from the portfolio choice. Most importantly, it permits both decisions to be made under different information sets. Up to a first-order approximation, the equilibrium conditions are identical to those of P. Benigno (2001) except for the different information structure.

[4] For more technical details of the partially revealing equilibrium, see also the research of Kasa (2000) and Kasa *et al.* (2005).

USD. Hence, a decrease in the nominal exchange rate means that the USD has appreciated in value relative to the EUR, and U.S. terms of trade improve only if the import-to-export price ratio decreases.

All quarterly series are obtained from the Organization for Economic Cooperation and Development (OECD) and the Board of Governors of the Federal Reserve System/Federal Reserve Bank of New York (FRB/FRBNY), and span the post-Bretton Woods period from 1973:I until 2006:III[5].

Volatility and Persistence. In Tables 1 and 2 I present some statistics on exchanges rates, U.S. terms of trade, CPI prices and per capita consumption for the U.S. and the Euro-zone. The data is expressed in logs, multiplied by 100 and Hodrick-Prescott (H-P) filtered[6]. I note from Table 1 that the standard deviation of the real and nominal exchange rates is more than 6 times larger than the volatility of the U.S. per capita consumption. In turn, the volatility of U.S. terms of trade and CPI prices is no larger than 2.5 times the volatility of U.S. per capita consumption.

I observe in Table 1 that the real and nominal exchange rates and the U.S. terms of trade are also highly persistent, with autocorrelations of 0.848, 0.859 and 0.817 respectively. Furthermore, the per capita consumption and CPI price series are also very persistent with autocorrelations ranging from 0.800 to 0.933. These numbers are similar to the ones found by Bergin and Feenstra (2001) and Chari *et al.* (2002) for several European countries. The inability of conventional models to match these standard deviations and autocorrelations constitutes the origin of the *excess volatility-high persistence anomaly.* My theory focuses specifically on rationalizing this anomaly in the presence of asymmetric diffusion of information and nominal rigidities.

Cross-correlations. From Table 2 I observe that an appreciation of the U.S. bilateral exchange rate or an improvement in the U.S. terms of trade is positively correlated with the U.S. per capita consumption and negatively correlated with the Euro-zone per capita consumption. The cross-correlation between U.S. and Euro-zone per capita consumption is just 0.426, although this is still larger than the value of 0.16 between the U.S. and a weighted aggregate of European countries reported by Selaive and Tuesta (2003). The failure of risk-sharing, however, transpires blatantly in the negative correlation between the exchange rates and the relative per capita consumption between the U.S. and the Euro-zone, with cross-correlations of −0.233 and −0.338 respectively[7]. This is known as the *real exchange rate-relative consumption anomaly.* My model explores the potential contribution of asymmetrically-dispersed information to explain this feature of the data.

Furthermore, I also investigate the impact (if any) that the theory has along other dimensions. First,

[5] Chari *et al.* (2002) explore the bilateral relationships between the U.S. and eleven other major European countries (Austria, Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Spain, and Switzerland). In my dataset I find evidence of similar patterns between the U.S. and the U.K. as well as between the U.S. and the Euro-zone.

[6] Many macroeconomic time series, notably the nominal exchange rate, are suspected of being non-stationary with near-unit roots. In any event, King and Rebelo (1993) show that the H-P filter is capable of rendering stationary any integrated process up to fourth order.

[7] The cross-correlation of the (real) exchange rate with relative consumption is often found to be negative in the literature. Chari *et al.* (2002) show that the median bilateral cross-correlation between the U.S. and the four largest economies in Europe is −0.07. Corsetti *et al.* (2004) argue that the median estimate for a selection of OECD countries is −0.3. G. Benigno and Thoenissen (2006) compute a median cross-correlation of −0.288 for 14 industrialized nations relative to the U.S., and Selaive and Tuesta (2003) report −0.17 for the U.S. and an aggregate of European countries.

the U.S. CPI price is negatively correlated (but small in absolute value) with the USD per EUR nominal exchange rate. The sign is reversed for the USD per U.K. Pound (UKP) rate. In either case, it suggests *incomplete pass-through* of the nominal exchange rate. Second, the nominal *and real exchange rates are highly correlated* with each other at 0.987. Third, the nominal exchange rate correlation with the relative consumption prices between the Euro-zone and the U.S. is only -0.314 while it is expected to be -1 under power-purchasing parity (PPP). This shows in a simple way that *PPP violations* matter. Finally, the nominal and real exchange rates are both positively correlated with the U.S. terms of trade around $0.275 - 0.367$. Failure to capture this feature tends to be identified as a *terms of trade anomaly*, which is exacerbated in models of local-currency pricing (e.g., Obstfeld and Rogoff, 2000a).

3 Basic Structure of the Monetary Model

I specify a stochastic, two-country general equilibrium model populated by a continuum of infinitely lived households. There is also a continuum of monopolistically competitive firms located in each country, which produce a differentiated, tradable good. Households and firms in the home country lie on the interval $[0, n]$, while foreign households and firms are placed on the interval $(n, 1]$. The population size n is equal to the range of produced goods. The description is completed with a continuum of financial intermediaries, located in the home country, and indexed on the interval $[0, n]$.

Frictions in the goods market are modelled through nominal price stickiness with exogenous partial adjustment rates à la Calvo (1983). Deviations of the real exchange rate from power-purchasing parity (henceforth, PPP) arise because prices are sticky in the local currency and firms can effectively discriminate across markets (e.g., G. Benigno, 2004). Frictions in the assets market are due to incompleteness and intermediation in a way that merges some key insights on foreign exchange microstructure within a fully-fledged macroeconomic model. I postulate a *bond economy* (e.g., P. Benigno, 2001, Chari *et al.*, 2002, Obstfeld and Rogoff, 2002, and Thoenissen, 2003) where portfolio management is delegated to (myopic and risk-averse) financial intermediaries[8]. This assets market structure provides limited possibilities to pool consumption risks between the two countries, and depends on financial intermediaries to hedge risks internationally.

I model each economic agent as atomistic and informationally-constrained to account for differences in the information set available to households, firms and financial intermediaries. This feature distinguishes my work from other general equilibrium models, and serves me to explore how asymmetrically-dispersed information becomes embedded (and revealed) through the actions of each agent. Here, the timing of actions and information arrival becomes crucial. I assume that the stochastic dynamics of the exogenous shocks are common knowledge. Nonetheless, at time t each agent only observes the realization of a subset of current shocks and the public record of the exogenous and endogenous variables up to time $t - 1$.

Based on his own private information set and all publicly-available data, each agent chooses an optimal schedule at time t to solve his optimization problem. Once the policy rule on the control variables is decided, he is fully committed (or pre-committed) to follow through with it. Then all markets open up, and

[8] This framework replaces *ad hoc* costs of international borrowing (see, e.g., P. Benigno, 2001, Selaive and Tuesta, 2003, and G. Benigno and Thoenissen, 2006) with a simple model of financial intermediation in the spirit of Carlson and Osler (2000) and Evans and Lyons (2007).

the equilibrium prices ensure that demand and supply schedules equate. Simultaneously, the government collects all the information on the time t endogenous variables and the exogenous shocks to be reported from time $t+1$ onwards.

3.1 The Intertemporal Consumption and Savings Problem

The lifetime utility for household j in the home country is additively separable in aggregate consumption, $C_{j,t}$, real money balances, $\frac{M^d_{j,t}}{P_t}$, and labor supply, $L^s_{j,t}$. Each individual household j maximizes,

$$\sum\nolimits_{\tau=0}^{\infty} \beta^{\tau}\mathbb{E}\left[U\left(C_{j,t+\tau}, C_{t+\tau-1}, \xi_{t+\tau}\right) + \chi N\left(\frac{M^d_{j,t+\tau}}{P_{t+\tau}}, \xi_{t+\tau}\right) - \kappa V\left(L^s_{j,t+\tau}, \xi_{t+\tau}\right) \mid \mathcal{H}_t\right], \quad (1)$$

$$U\left(C_{j,t+\tau}, C_{t+\tau-1}, \xi_{t+\tau}\right) \equiv \exp\left(-\xi_{t+\tau}\right)\frac{1}{1-\gamma}\left(C_{j,t+\tau} - bC_{t+\tau-1}\right)^{1-\gamma},$$

$$N\left(\frac{M^d_{j,t+\tau}}{P_{t+\tau}}, \xi_{t+\tau}\right) \equiv \exp\left(-\xi_{t+\tau}\right)\frac{1}{1-\gamma}\left(\frac{M^d_{j,t+\tau}}{P_{t+\tau}}\right)^{1-\gamma},$$

$$V\left(L^s_{j,t+\tau}, \xi_{t+\tau}\right) \equiv \exp\left(-\xi_{t+\tau}\right)\frac{1}{1+\varphi}\left(L^s_{j,t+\tau}\right)^{1+\varphi},$$

where ξ_t is a country-specific shock to preferences in logs, and $\beta \in (0,1)$ is the subjective discount factor. Alternatively, β and ξ_t can be interpreted as the time-trend and random components of a stochastic discount factor. The conditional expectations operator $\mathbb{E}\left[\cdot \mid \mathcal{H}_t\right]$ reflects the (public and private) information available at time t to all domestic households. The coefficients of relative risk aversion satisfy $\gamma > 0$ ($\gamma \neq 1$) and $\varphi > 0$, while the coefficients χ and κ are nonnegative.

The money-in-the-utility-function approach is based on the idea that the liquidity service of money increases the 'utility' of households by reducing their transaction costs. $N(\cdot)$ is an increasing and concave function of the real balances, $\frac{M^d_{j,t}}{P_t}$. The catching-up-with-the-Joneses external habit is proportional to one-period lagged per capita consumption. The parameter b measures the degree of habit persistence[9].

Households have well-defined preferences over foreign and home varieties of goods. The home and foreign consumption bundles of the domestic household, $C^H_{j,t}$ and $C^F_{j,t}$, are aggregated by means of a CES index as,

$$C^H_{j,t} = \left[\left(\frac{1}{n}\right)^{\frac{1}{\theta}}\int_0^n C_{j,t}(h)^{\frac{\theta-1}{\theta}}dh\right]^{\frac{\theta}{\theta-1}}, \; C^F_{j,t} = \left[\left(\frac{1}{1-n}\right)^{\frac{1}{\theta}}\int_n^1 C_t(f)^{\frac{\theta-1}{\theta}}df\right]^{\frac{\theta}{\theta-1}}, \quad (2)$$

while aggregate consumption, $C_{j,t}$, is defined with another CES index as,

$$C_{j,t} = \left[n^{\frac{1}{\sigma}}\left(C^H_{j,t}\right)^{\frac{\sigma-1}{\sigma}} + (1-n)^{\frac{1}{\sigma}}\left(C^F_{j,t}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}. \quad (3)$$

Thus, the elasticity of substitution across varieties produced within a country is $\theta > 1$, the elasticity of intratemporal substitution between the home and foreign bundles of varieties is $\sigma > 0$, and $n \in (0,1)$ represents the relative weight on domestically-produced goods (and the population size).

[9] Habit formation alters the coefficient of relative risk aversion on consumption. A more detailed discussion on the role of habits (and other alternative specifications) can be found in Campbell and Cochrane (1999) and Fuhrer (2000).

The foreign household has identical preferences, with the exception of the preference shock ξ_t^*. Foreign households consume their own basket of goods among all varieties, $C_{j,t}^*$, hold their own real balances, $\frac{M_{j,t}^{d*}}{P_t^*}$, and supply their own labor market, $L_{j,t}^{s*}$. On top of that, the (private and public) information available to foreign households is collected in the information set $\mathcal{H}_t^*$. The asterisk specifically denotes foreign variables (or foreign parameters).

The Consumer Price Indexes, Exchange Rates and Relative Prices. The domestic CPI index, P_t, is defined as the minimum expenditure needed to buy one unit of the consumption index $C_{j,t}$. Under standard results on functional separability, the indexes which correspond to my specification of preferences are,

$$P_t = \left[n\left(P_t^H\right)^{1-\sigma} + (1-n)\left(P_t^F\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}, \tag{4}$$

$$P_t^H = \left[\frac{1}{n}\int_0^n P_t(h)^{1-\theta}\,dh\right]^{\frac{1}{1-\theta}},\ P_t^F = \left[\frac{1}{1-n}\int_n^1 P_t(f)^{1-\theta}\,df\right]^{\frac{1}{1-\theta}}, \tag{5}$$

where P_t^H and P_t^F are the price sub-indexes for the home- and foreign-produced bundle of goods in units of the home currency. Home and foreign households have identical tastes and, therefore, the respective price indexes are symmetric abroad.

Furthermore, I define the terms of trade in both countries as,

$$ToT_t \equiv \frac{P_t^F}{S_t P_t^{H*}},\ ToT_t^* \equiv \frac{S_t P_t^{H*}}{P_t^F} = \frac{1}{ToT_t}, \tag{6}$$

and the real exchange rate as,

$$RS_t \equiv \frac{S_t P_t^*}{P_t}, \tag{7}$$

where S_t denotes the nominal exchange rate. I represent the relative price in each country[10] by,

$$T_t \equiv \frac{P_t^F}{P_t^H},\ T_t^* \equiv \frac{P_t^{H*}}{P_t^{F*}}. \tag{8}$$

The relative price T_t represents the value of imported goods (quoted in the domestic market) relative to the value of the domestic good supplied locally. This ratio is the 'local market' cost of replacing one unit of imports with one unit of the domestically-produced good. Instead, terms of trade ToT_t represents the value of imported goods (quoted in the domestic market) relative to the value of the domestic good exported to the foreign market. but expressed in units of the local currency. This ratio measures the 'foreign market' cost of replacing one unit of imports with one unit of exports. Similarly for T_t^* and ToT_t^*.

The Budget Constraint. Household j in the home country allocates his financial wealth between domestic currency, $M_{j,t}^d$, and a nominal risk-free domestic bond, $B_{j,t}$. One-period bonds are in zero net-supply, but involve the promise to pay one unit of the local currency at maturity. Each household maximizes its

[10] Terms of trade and relative prices are identical and the real exchange rate is equal to one only if the law of one price (LOOP) holds in both countries. Since the LOOP condition fails in the model, fluctuations of the real exchange rate arise and the distinction between terms of trade and relative prices matters.

lifetime utility subject to the sequence of budget constraints,

$$\frac{B_{j,t}}{\exp\left(i_{t}\right)}+M_{j,t}^{d}\leq B_{j,t-1}+M_{j,t-1}^{d}+W_{t}L_{j,t}^{s}+\Pi_{j,t}+TR_{j,t}-P_{t}C_{j,t}, \tag{9}$$

where W_t is the competitive nominal wage, i_t is the log nominal interest rate, $TR_{j,t}$ is a nominal transfer received from the government, and $\Pi_{j,t}$ are nominal profits. I assume that each domestic household holds an equal share in every local firm, and that there is no trade in shares. Therefore, the aggregate profits of domestic firms, i.e.

$$\Pi_{j,t}=\frac{1}{n}\int_{0}^{n}\left[P_{t}\left(h\right)nC_{t}\left(h\right)+S_{t}P_{t}^{*}\left(h\right)\left(1-n\right)C_{t}^{*}\left(h\right)\right]dh-W_{t}\frac{1}{n}\int L_{t}^{d}\left(h\right)dh, \tag{10}$$

are distributed equally among domestic households[11]. $C_t(h)$ and $C_t^*(h)$ denote the per capita output consumption of variety h in the domestic and foreign market, and $P_t(h)$ and $P_t^*(h)$ are the corresponding prices. $L_t^d(h)$ denotes the domestic labor demand of firm h.

Similarly, household j in the foreign country allocates his wealth on foreign currency, $M_{j,t}^{d*}$, and a risk-free nominal bond denominated in the foreign currency, $B_{j,t}^*$. I also assume that foreign households receive an aliquot share of profits of all foreign firms, $\Pi_{j,t}^*$, and that trade in foreign firms' shares is not allowed. In other words, the model imposes upon the households a strict home bias in asset-holdings.

The Initial Conditions. I assume that the initial conditions are identical across all households within a country, although differences may still arise between the two countries. Households earn a competitive wage, which is equalized in their local labor market, and share equally on the profits of the local producers (for whom they work). Households receive the same type of information. The combination of all these assumptions implies that the maximization problem is identical for all households located in a given country, and therefore they must choose the same optimal consumption, labor supply and money demand paths. Hence, I can drop the index j and simply consider a representative household in each country.

3.2 The Price-Setting Problem under Sticky Prices

Each firm supplies the home and foreign market, sets prices in the local currency (henceforth, LCP pricing) and, consequently, invoices exports in the currency of the importer. Frictions in the goods market are modelled with nominal price stickiness à la Calvo (1983). Furthermore, firms engage in third-degree price discrimination across markets and enjoy monopolistic power in their own variety. These assumptions require a degree of international market segmentation which prevents the equalization of prices across borders, and opens up an important channel for deviations of the real exchange rate from PPP (e.g., Betts and Devereux, 1996, 2000, Thoenissen, 2003, and G. Benigno, 2004).

Here, I focus on fluctuations in real exchange rates arising solely from deviations of the law of one price (henceforth, LOOP) on traded goods. I abstract from non-traded goods altogether to be consistent with the evidence documented by Engel (1999) and Chari *et al.* (2002). I also do without the iceberg-type trading costs proposed by Obstfeld and Rogoff (2000b), and the home-product bias preferences favored by Warnock

[11] Domestic households also own the stock of financial intermediaries. However, by construction financial intermediaries generate no dividend for their shareholders.

(2003). Since consumption baskets between the U.S. and Europe are quite similar and vary little over time, I cannot entirely rely on composition effects to account for all the real exchange rate fluctuations.

The Technology and the Net Discounted Profits. With probability $\alpha^{H}, \alpha^{H*} \in [0,1]$, at time t the domestic firm h is forced to maintain its previous period prices in the domestic and foreign markets[12], respectively. With probability $\left(1-\alpha^{H}\right)$ at home and $\left(1-\alpha^{H*}\right)$ abroad, the firm receives a signal to optimally reset each price. Firm $h \in [0,n]$ produces a differentiated (and tradable) variety with a linear-in-labor technology, i.e.

$$Y_t^s(h) = \exp(a_t) L_t^d(h), \tag{11}$$

where a_t is a country-specific productivity shock (or TFP shock) in logs. The labor market is perfectly competitive, the labor force is homogeneous and immobile across borders, and wages equalize in each country.

Households are charged a different price for the same variety in each country, but they still face a constant price within a country for all units of output purchased. Re-selling across borders is banned. A domestic firm h has to choose the price charged domestically, $\widetilde{P}_t(h)$, and the price charged abroad (in units of the foreign currency), $\widetilde{P}_t^*(h)$. The objective is to maximize the expected discounted value of its net profits subject to a demand constraint in each goods market,

$$\begin{aligned}
&n \sum\nolimits_{\tau=0}^{\infty} \left(\beta\alpha^{H}\right)^{\tau} n\mathbb{E}\left[\Xi_{t,t+\tau} \widetilde{Y}_{t,t+\tau}^{d}(h)\left(\widetilde{P}_t(h) - \frac{W_{t+\tau}}{\exp(a_{t+\tau})}\right) \mid \mathcal{F}_t\right] + \\
&+ (1-n)\sum\nolimits_{\tau=0}^{\infty} \left(\beta\alpha^{H*}\right)^{\tau} \mathbb{E}\left[\Xi_{t,t+\tau} \widetilde{Y}_{t,t+\tau}^{d*}(h)\left(S_{t+\tau}\widetilde{P}_t^*(h) - \frac{W_{t+\tau}}{\exp(a_{t+\tau})}\right) \mid \mathcal{F}_t\right],
\end{aligned} \tag{12}$$

where

$$\beta^{\tau}\Xi_{t,t+\tau} \equiv \beta^{\tau}\exp\left(-\left(\xi_{t+\tau}-\xi_t\right)\right)\left(\frac{C_{t+\tau}-bC_{t+\tau-1}}{C_t - bC_{t-1}}\right)^{-\gamma}\frac{P_t}{P_{t+\tau}}, \tag{13}$$

is the corresponding intertemporal marginal rate of substitution for the domestic representative household. The conditional expectations operator $\mathbb{E}[\cdot \mid \mathcal{F}_t]$ reflects the (private and public) information available to all domestic firms at time t. $\widetilde{Y}_{t,t+\tau}^{d}(h)$ and $\widetilde{Y}_{t,t+\tau}^{d*}(h)$ indicate the demand for any variety h respectively at home and abroad, given that prices $\widetilde{P}_t(h)$ and $\widetilde{P}_t^*(h)$ remain unchanged between time t and $t+\tau$. Thus, each firm faces a downward-sloping demand curve for its output.

The problem for foreign firm f is analogous. The degree of nominal price stickiness of the foreign firm's contract is determined by α^{F} and α^{F*}, while the discount factor for profits is the intertemporal marginal rate of substitution of the foreign representative household. Wages and TFP shocks, W_t^* and a_t^* respectively, are country-specific. The information set available to foreign firms is denoted $\mathcal{F}_t^*$.

The Initial Conditions. I assume that initial conditions are identical for firms within a country, but may differ across countries. Firms pay a competitive wage, and distribute profits among the local households. In addition, firms within a country share the same information. These assumptions imply that the maximization problem is symmetric for all firms in a given country. Therefore, they should choose the same optimal price-

[12] Under the Calvo specification, the probability of setting a new price, $1-\alpha^{i}$, is the same for all firms of type i and is independent of the time elapsed since the last price change. Hence, the average time under fixed prices is equal to $\frac{1}{1-\alpha^{i}}$. Wolman (1999) discusses a variant of the model where probabilities are state-dependent. Golosov and Lucas (2007) derive similar predictions with a menu-cost model.

setting rule. Hence, I can drop the indexes h and f among the firms that re-optimize their prices at a given period.

3.3 The Portfolio Choice Problem with Myopic Intermediaries

The portfolio choice is entirely delegated to rational financial intermediaries (e.g., Evans and Lyons, 2007). Moreover, portfolio allocations become insulated from the consumption-savings decision of households. Intermediaries are all located in the home country, an assumption loosely based on the patterns of geographical specialization that can be observed in the current financial markets. Financial intermediation can be conducted by a broad class of agents which includes interbank traders, foreign-exchange dealers, mutual fund managers, or managers of international bond and portfolio funds. However, I model my financial intermediaries simply as currency speculators who exploit nominal exchange rate fluctuations and arbitrage opportunities in the asset markets for profit.

The pre-eminent characteristics of these speculators are: (i) they invest internationally and thereby incur an exchange rate risk, (ii) they get compensated on the basis of net profits, and (iii) they are impatient in the short-run and tend to implement (quasi-) myopic portfolio strategies. These currency speculators provide a convenient (and natural) alternative to the *ad hoc* notion of borrowing costs introduced by P. Benigno (2001).

The Expected Profits. Myopic intermediaries are firms that maximize next-period expected profits minus a quadratic disutility term. Hence, the problem for currency speculator z at time t is to maximize,

$$\mathbb{W}_{z,t} \equiv \mathbb{E}\left[\pi^{I}_{z,t+1} - \frac{\lambda}{2}\left(S_t B^{F}_{z,t}\right)^2 \mid \mathcal{I}_t\right], \tag{14}$$

where $B^{F}_{z,t}$ denotes the nominal asset position taken in the foreign bonds market, and $\mathbb{E}\left[\cdot \mid \mathcal{I}_t\right]$ is the expectations operator conditional on the (private and public) information available at time t. I denote $\pi^{I}_{z,t+1}$ the nominal profits of intermediation for z. Nominal profits are naturally defined as,

$$\pi^{I}_{z,t+1} \equiv X_{z,t+1} - \exp\left(i_t\right) X_{z,t}, \tag{15}$$

and are calculated as the nominal wealth at time $t+1$, $X_{z,t+1}$, minus the opportunity cost of simply holding the time t wealth domestically for one period.

The management of a portfolio with a non-negligible foreign asset position reduces the 'utility' of currency speculators because it increases the risk in their transactions. I model this disutility effect as a quadratic function of the foreign asset position (expressed in units of the domestic currency), to penalize the exposure of the firm to exchange rate (and other foreign) risks. The coefficient of the quadratic disutility term is $\lambda \geq 0$.

The Budget Constraint. I define the per-period budget constraints of a financial intermediary z between time t and $t+1$ as follows,

$$\frac{B^H_{z,t}}{\exp(i_t)} + \frac{S_t B^F_{z,t}}{\exp(i^*_t)} \leq X_{z,t}, \tag{16}$$

$$X_{z,t+1} \leq B^H_{z,t} + S_{t+1} B^F_{z,t}. \tag{17}$$

Here, $B^H_{z,t}$ and $B^F_{z,t}$ denote the nominal position taken by a given intermediary in the domestic and foreign bond markets, respectively. As a result, the intertemporal budget constraint faced by currency speculator z can be summarized as,

$$X_{z,t+1} \leq \exp(i_t) X_{z,t} + S_t B^F_{z,t} \left[\frac{S_{t+1}}{S_t} - \exp(i_t - i^*_t) \right]. \tag{18}$$

Unlimited *short-selling* is allowed every period with full use of the proceeds, and all investments are fully reversible. Intermediaries do not receive any outside source of income (or transfer) to complement their revenues. Hence, if the budget constraints hold with equality, the following relationship must be satisfied in the aggregate,

$$\left[\frac{1}{\exp(i_t)} \int_0^n B^H_{z,t} dz - \int_0^n B^H_{z,t-1} dz \right] = -S_t \left[\frac{1}{\exp(i^*_t)} \int_0^n B^F_{z,t} dz - \int_0^n B^F_{z,t-1} dz \right]. \tag{19}$$

Equation (19) indicates that there is a precise reciprocal link between the net investment in foreign bonds (expressed in units of the local currency) and the net investment in domestic bonds.

The management protocol of the currency speculators requires them to re-invest every period the wealth accumulated one period before. Because wealth is continuously re-invested *ex post* net profits are zero, and the domestic households who own the stock on these intermediaries receive no dividends. Moreover, households cannot make deposits or withdraw part of their wealth as they would in a conventional bank. Therefore, currency speculators are reduced to be merely asset market 'arbitrageurs'. They trade in international asset markets and in doing so they allow for some degree of cross-country risk sharing. This trading service is what makes intermediation relevant to households, anyway.

The Initial Conditions. I assume that the same initial amount of wealth (in domestic and foreign bonds) is equally endowed to each intermediary. Financial intermediaries earn profits from arbitraging the difference between the market interest rate spread and the expected nominal exchange rate depreciation. They also obtain the same information in each period. These assumptions guarantee that all financial intermediaries solve an identical problem, and choose the same optimal bond portfolio allocation. Hence, I can drop the index z and simply consider the case of a representative (myopic) currency speculator.

3.4 The Exogenous Monetary Policy Rules

The government does not issue bonds, but supplies the local currency through the central bank[13]. Fiat money is an unbacked asset that serves as a unit of account, and promises one unit of the local currency in period $t+1$ in exchange for one unit of the local currency in period t. The money market clearing condition requires that,

$$n \exp(m_t) = \int_0^n M_{j,t}^d dj, \tag{20}$$

where m_t denotes the domestic per capita money supply in logs.

The domestic government's consolidated budget constraint is such that total transfers to the households, $TR_{j,t}$, are exactly equal to seigniorage revenues in every period,

$$n \left[\exp(m_t) - \exp(m_{t-1})\right] = \int_0^n TR_{j,t} dj. \tag{21}$$

In a pure float regime, monetary policy is set independently from developments in the foreign exchange market. Hence, to be consistent with the implicit assumption that the exchange rate floats freely, I treat the monetary policy variable, m_t, as an exogenously given, stochastic process. For a discussion of alternative policy regimes (target zones, fixed exchange rates, etc.) and their implications for exchange rate volatility, see Jeanne and Rose (2002).

This set-up characterizes the government's role as fully exogenous instead of building up anew a pair of informationally-constrained, non-atomistic agents. This simplification, though convenient, does not suffice to close down the model. I also assume that the government correctly observes all endogenous variables and exogenous shocks at time t. Then, after one period, the government reveals all the information collected up to time t. It must be noted, however, that a public record of the exogenous shocks is necessary only whenever the economic agents have asymmetric and private information about them.

The setting for the foreign government is similar. Accordingly, the foreign monetary policy is identified with the money supply rule m_t^*, which is only legally tendered in the foreign country. Foreign bonds are also in zero-net supply, and the foreign government's budget is balanced each period. The public record of the foreign government is the obvious counterpart to the domestic one.

4 Methodology of the Market Solution

An equilibrium in this model is described by: (i) a consumption-savings decision that maximizes the expected utility of the households in both countries[14]; (ii) a pair of price-setting rules that maximizes discounted profits for the monopolistic firms, subject to the demand constraints and a linear-in-labor technology; (iii) a portfolio choice that maximizes next-period net profits and accounts for foreign risk exposure for the financial intermediaries; (iv) a set of prices, interest rates and a nominal exchange rate that clears all markets, given the optimal strategies of the households, firms, and financial intermediaries; and (v) rational expectations

[13] This assumption, however, simplifies the model at the expense of ruling out a role for government debt in the dynamics of the economy.

[14] Also a commitment to optimal labor supply and money demand rules, given the prevailing CPI prices and wages.

based on the information available to each agent, and consistent with the laws of motion for the endogenous variables and the exogenous shocks.

The mathematical derivation of the equilibrium conditions of the model is discussed in the appendix and a companion technical note. I linearize those equations around the deterministic zero-inflation, zero-current account steady state (see also King *et al.*, 1988). In the steady state, exchange rate depreciation is also zero, PPP holds and consumption is equalized across countries. I approximate all variables in logs, except the real net foreign asset position of financial intermediaries (in levels) (e.g., P. Benigno, 2001, and Thoenissen 2003). I denote $\widehat{x}_t \equiv \ln X_t - \ln \overline{X}$ the deviation of a variable in logs from its steady state, and $\widehat{X}_t \equiv \frac{X_t - \overline{X}}{\overline{C}}$ the deviation of a variable in levels from its steady state relative to steady state consumption.

The appendix summarizes the first-order approximation of the model in the *IS*, *MM*, *AS*, *RP*, *RS*, *CA* and *UIP* equations. This system fully determines the dynamics of per capita consumption, interest rates, CPI prices, relative prices, exchange rates and the (real) net foreign asset position in the presence of sticky prices, incomplete asset markets and asymmetrically-informed agents. I adapt the *undetermined coefficients* methodology of Townsend (1983) and Christiano (2002) to handle the added complexity of the signal extraction problem for households, firms and financial intermediaries.

4.1 The Dynamic System

The original system is composed of 13 different equations. If I replace the *MM* equations and the *RP* and *RS* definitions inside the *IS*, *AS*, *CA* and *UIP* equations, I reduce the size of the system to just 8 fundamental equations. Let me denote the proper (8×1) vector of endogenous variables[15] determined at time t as $\widehat{z}_t$, i.e.

$$\widehat{z}_t = \left(\widehat{c}_t, \widehat{c}_t^*, \widehat{p}_t^H, \widehat{p}_t^{H*}, \widehat{p}_t^F, \widehat{p}_t^{F*}, \widehat{s}_t, \widehat{B}_t^{RF}\right)^T. \tag{22}$$

Let $\widehat{x}_t$ be the $(r \times 1)$ vector of all exogenous variables, which may include current and lagged observations of the TFP, the monetary, and the preference shocks. The elements in $\widehat{z}_t$ and $\widehat{x}_t$ are expressed in deviations relative to their deterministic steady state values. Note that the composition of $\widehat{x}_t$ depends on the information structure of the problem, while the elements pertaining to $\widehat{z}_t$ are unchanged.

The linearized equilibrium conditions fit into a vector system of 8 linear stochastic difference equations of order 2, and take the canonical form,

$$\mathcal{E}_t \left[\alpha_0 \widehat{z}_{t+1} + \alpha_1 \widehat{z}_t + \alpha_2 \widehat{z}_{t-1} + \beta_0 \widehat{x}_{t+1} + \beta_1 \widehat{x}_t\right] = 0, \tag{23}$$

for all $t = 0, 1, 2, ...$ and $\widehat{z}_{-1}$ given. The law of motion of $\widehat{x}_t$ is,

$$\widehat{x}_t = P\widehat{x}_{t-1} + \epsilon_t, \tag{24}$$

where ϵ_t has zero-mean and is uncorrelated with $\epsilon_{t-\tau}$, $\widehat{x}_{t-\tau}$ for all $\tau > 0$. The symbol $\mathcal{E}_t$ in (23) represents a conditional expectations operator, which allows the conditioning information set to vary across equations. I view α_i, β_i, and P as given matrices of dimensions (8×8), $(8 \times r)$ and $(r \times r)$, respectively. I assume that

[15] The vector $\widehat{z}_t$ is a complete and sufficient description of all the endogenous variables at time t. There are other endogenous variables not included in the vector that are of interest (e.g., nominal interest rates, real exchange rates, relative prices, etc.), but all such variables are known functions of $\widehat{z}_t$.

the rank of α_0 is greater than zero and that the (8×24) matrix $[\alpha_0, \alpha_1, \alpha_2]$ has full row rank. The matrix P varies depending on the information structure.

The Exogenous Variables and the Information Sets. I define the collection of 6 exogenous shocks driving the economy as follows,

$$\widehat{\theta}_t = \left(\widehat{m}_t, \widehat{m}_t^*, \Delta\widehat{\xi}_t, \Delta\widehat{\xi}_t^*, \widehat{a}_t, \widehat{a}_t^*\right)^T, \tag{25}$$

each one of them expressed in deviations from the steady state. I conjecture that the dynamics of the exogenous shocks in the model follow a proper $VAR(1)$ process. I assume that the time series representation for $\widehat{\theta}_t$ is given by[16],

$$\widehat{\theta}_t = \rho\widehat{\theta}_{t-1} + \varepsilon_t,\ \mathbb{E}\left[\varepsilon_t \varepsilon_t^T\right] = \Omega, \tag{26}$$

where the zero-mean random vector of innovations ε_t is uncorrelated with $\varepsilon_{t-\tau}$, $\widehat{\theta}_{t-\tau}$ for all $\tau > 0$. Obviously, the autoregressive component, ρ, and the covariance, Ω, are both (6×6) matrices.

In the standard case with only *public information* all the information sets are identical, i.e.

$$\mathcal{H}_t = \mathcal{H}_t^* = \mathcal{F}_t = \mathcal{F}_t^* = \mathcal{I}_t = \left\{\widehat{z}_{t-1}, \widehat{\theta}_t\right\}.$$

Therefore, the vector of exogenous variables $\widehat{x}_t$ only contains the current shocks. I can identify,

$$\widehat{x}_t = \widehat{\theta}_t,\ P = \rho,\ \epsilon_t = \varepsilon_t,\ r = 6, \tag{27}$$

and find the market solution. This is the typical informational structure for linear rational expectations models in international macroeconomics, where all exogenous shocks are perfectly observable to all economic agents before they choose their optimal actions. I argue that to make this specification consistent I need to rely on a public mechanism to record and reveal macroeconomic information at all times. But, if the diffusion of information on the exogenous shocks is neither instantaneous nor symmetric across agents, this solution is no longer valid.

My claim that information diffusion is inherently asymmetric is based on the notion that private information (on a subset of exogenous shocks) and delays in the release of public data are intrinsic characteristics of financial investments and economic activity. If any of the information sets in (23) does not contain the whole of $\widehat{\theta}_t$, then the vector of exogenous variables $\widehat{x}_t$ must be constructed in a slightly different way (from current and lagged realizations of $\widehat{\theta}_t$).

In the benchmark case with *private asymmetric information* (exotic information sets), governments release the information always with a one-period (one-quarter) delay. In other words, exogenous shocks are treated essentially as private information to some agents at time t, but information on all of them is only made public at time $t + 1$. I assume that local households observe their corresponding preference shocks, local firms know their TFP shocks and financial intermediaries have direct knowledge of the monetary supply

[16] For more details on how to extend the methodology to any stochastic $ARMA(p, q)$ process, see Christiano (2002, footnote 8).

shocks. Hence, I can say that

$$\mathcal{H}_t = \left\{\widehat{z}_{t-1}, \Delta\widehat{\xi}_t, \widehat{\theta}_{t-1}\right\}, \mathcal{H}_t^* = \left\{\widehat{z}_{t-1}, \Delta\widehat{\xi}_t^*, \widehat{\theta}_{t-1}\right\},$$
$$\mathcal{F}_t = \left\{\widehat{z}_{t-1}, \widehat{a}_t, \widehat{\theta}_{t-1}\right\}, \ \mathcal{F}_t^* = \left\{\widehat{z}_{t-1}, \widehat{a}_t^*, \widehat{\theta}_{t-1}\right\},$$
$$\mathcal{I}_t = \left\{\widehat{z}_{t-1}, \widehat{m}_t, \widehat{m}_t^*, \widehat{\theta}_{t-1}\right\},$$

reflects the information available to each type of agent. I also explore several alternatives to this benchmark in my simulations.

No economic agent has complete information on the current realization of the exogenous shocks whenever he forecasts the endogenous variables of the system and makes his choices. Therefore, a non-trivial signal extraction problem arises. In this setting, the vector of exogenous variables $\widehat{x}_t$ is

$$\widehat{x}_t = \begin{pmatrix} \widehat{\theta}_t \\ \widehat{\theta}_{t-1} \end{pmatrix}, \ P = \begin{bmatrix} \rho & 0 \\ I_6 & 0 \end{bmatrix}, \ \epsilon_t = \begin{pmatrix} \varepsilon_t \\ 0 \end{pmatrix}, \ r = 12, \tag{28}$$

where I_6 denotes the 6−dimensional identity matrix. Obviously, the dimensionality of the solution becomes more difficult to handle the longer it takes for private information to turn into public (or common knowledge) data.

4.2 The Solution of the Dynamic System

The solution I postulate for the model is a linear feedback rule relating current endogenous variables to a set of state variables[17] (i.e., $\widehat{z}_{t-1}$ and $\widehat{x}_t$),

$$\widehat{z}_t = A\widehat{z}_{t-1} + B\widehat{x}_t, \tag{29}$$

where the (8×8) matrix A (the *feedback* part) and the $(8 \times r)$ matrix B (the *feedforward* part) are the 'coefficients to be determined'. Matrix A characterizes the impact of lagged endogenous variables, while matrix B determines the influence of current and lagged exogenous shocks. The solution is a sequence $\{\widehat{z}_t\}$ which is consistent with: (i) the system $(23)-(24)$ for all $\widehat{z}_{t-1}$, $\widehat{x}_t$, and the initial condition $\widehat{z}_{-1}$, and (ii) the transversality condition $\lim_{\tau\to\infty} \mathcal{E}_t\widehat{z}_{t+\tau} = 0$. The transversality condition arises naturally from these linearized equilibrium conditions, since the model I propose is stationary and should converge towards the steady state in the long-run.

The Method of Undetermined Coefficients. In order to verify the conjecture in (29), I need to solve the restrictions that the model imposes on the coefficients A and B. First, I get that the *feedback* matrix A must be the zero of a particular matrix polynomial. That is, A satisfies that

$$\alpha(A) \equiv \alpha_0 A^2 + \alpha_1 A + \alpha_2 = \mathbf{0}_{8\times 8}, \tag{30}$$

[17] Given this solution, each economic agent can infer all the contemporaneous endogenous variables $\widehat{z}_t$ from the state variables (i.e., $\widehat{z}_{t-1}$ and $\widehat{x}_t$) under *public information*. Notice, however, that this is not true under *private asymmetric information*.

where $\alpha(A)$ is a second-order matrix polynomial in A. An important question is whether any of the many roots of this polynomial satisfies the eigenvalue restriction needed to obtain a stable (no-bubbles) solution and, if so, how many. Finding the eigenvalues of a polynomial equation $\alpha(A) = \mathbf{0}_{8\times 8}$ is a fairly standard problem. For details on how to obtain the coefficient A whose eigenvalues are less than one in absolute value, see Anderson and Moore (1985) and Christiano (2002).

Secondly, the *feedforward* matrix B is the solution to a linear system of equations conditional on A. Let me define the matrix F as,

$$F = [\beta_0 + \alpha_0 B] P + [\beta_1 + (\alpha_0 A + \alpha_1) B] I_r, \tag{31}$$

where I_r is the $(r \times r)$ identity matrix. In the benchmark case of *private asymmetric information*, I define $\widetilde{F}$ by

$$\mathcal{E}_t [F\widehat{x}_t] = \widetilde{F}\widehat{x}_t, \tag{32}$$

while $F = \widetilde{F}$ in the standard case of *public information*. Then, the $(8 \times r)$ matrix B must solve the restriction,

$$\widetilde{F} = \mathbf{0}_{8\times r}. \tag{33}$$

Christiano (2002) shows that the system of equations defined in (33) is linear in the non-zero components of B, and has a solution. The matrix Ω is needed for this mapping whenever some elements of $\widehat{\theta}_t$ are observed contemporaneously and others not. In that case, the elements that are not observed must be projected onto the ones that are, and these projection formula requires the covariance between the various shock innovations.

In other words, the solution to the model is obtained under the assumption that rational agents recognize the signal extraction problem they face and act accordingly to exploit all the information they have about the shocks and the stochastic processes driving the economy.

5 Model Simulation

I calibrate the model in two steps. First, I employ micro estimates to pin down the structural parameters. In Table 3 I describe my benchmark parameterization, which follows to a degree the calibrations of Chari *et al.* (2002), Selaive and Tuesta (2003), G. Benigno (2004) and G. Benigno and Thoenissen (2006). I choose the structural parameters to be broadly consistent with the current empirical evidence. Also to highlight the effects of frictions in the goods and assets markets, and the role of asymmetrically-dispersed (macroeconomic) information.

Second, I proxy the exogenous shocks using observable variables. I derive a time series realization which is consistent with the basic structure of the model, and I fit the series to a $VAR(1)$ process. Finally, I estimate the parameters for the shocks driving the economy (i.e., the autocorrelation matrix, ρ, and the variance-covariance matrix, Ω). The literature provides only limited guidance to calibrate the productivity, money supply and preference shocks simultaneously. Solving the signal extraction problem that arises whenever current information is private and asymmetrically-dispersed depends crucially on these parameters. Therefore, the approach described here identifies the autocorrelation matrix and the correlations between innovations directly from the data. This suffices to simulate the model and compute the key moments of interest.

5.1 The Benchmark Parameterization

Table 3 summarizes my choice of structural parameters. I set the quarterly discount factor, β, equal to 0.99264. This implies an annualized real rate of return of 3% in steady state. I calibrate the model assuming that the home country is the U.S. and the foreign country is the Euro-zone. Hence, I assume a symmetric population size, n, equal to 0.5.

I use the value of 1.5 for the elasticity of intratemporal substitution, σ, and the value of 5 for the coefficient of relative risk aversion, γ, already applied by Chari *et al.* (2002) and Selaive and Tuesta (2003). The value of the coefficient γ is somewhat of a compromise since the parameter choices range between 0.5 and 3 in Eichenbaum *et al.* (1988), between 2.81 and 4.69 in Lubik and Schorfheide (2006), and larger than 5 in Hall (1998).

Bergin and Feenstra (2001) suggest that the elasticity of substitution across varieties, θ, must be equal to 3 in order to approximate the 60% average mark-up estimated by Domowitz *et al.* (1988). Chari *et al.* (2002) and G. Benigno (2004), instead, propose a value as high as 10. They target a mark-up of merely 11% based on the findings of Basu (1996). Following the estimates of Rotemberg and Woodford (1998a, 1998b), I choose a degree of monopolistic competition equal to 7.88 for an average mark-up of 14.53%.

I use the value of 0.47 proposed by Selaive and Tuesta for the inverse of the Frisch elasticity of labor supply, φ. However, this parameter is not an easy pick. On one hand, Rotemberg and Woodford (1998a, 1998b) explain that the inverse of the Frisch elasticity needs to be as low as 0.1052 to match the relatively weak observed-response of real wages to monetary disturbances and other macro features of the labor market. On the other hand, this is at odds with the empirical micro literature (e.g., Card, 1994, and Browning *et al.*, 1999). Micro studies indicate that the inverse of the Frisch elasticity lies significatively above 1. This evidence has compelled Bergin and Feenstra (2001) and Lubik and Schorfheide (2006) to choose a value of 1, Gust *et al.* (2006) to select 1.5 and G. Benigno (2004) to favor 2. Instead, my selection emphasizes the macroeconomic role of the parameter.

A composite of the Bayesian estimates in Lubik and Schorfheide (2006)[18] suggests that a reasonable rate of habit formation, b, ranges between 0.0098 and 0.3358. Boldrin *et al.* (2001), instead, defend that habit persistence should be as high as 0.73. In the benchmark, I select the habit rate to be equal to 0 in order to avoid excessive consumption smoothing. I also experiment with values between 0 and 0.7 to assess the significance of habits for the dynamics of the real and nominal exchange rates.

Galí *et al.* (2001) report that the degree of nominal price rigidity in the U.S. lies in the interval between 0.407 and 0.66 (the average is 0.5335) for the sample period 1970:I-1998:II. They also locate the price rigidity for the E.M.U. in the interval between 0.67 and 0.77 (the average is 0.72) for the same period range[19]. In the benchmark, I fix the price rigidity of contracts to be equal across firms and markets, setting its value to 0.62. This parametric choice is the equally-weighted average of the mean price rigidity in the U.S. and the E.M.U. based on Galí *et al.*'s (2001) findings. Accordingly, the corresponding contract average duration

[18] The rate of habit formation in Lubik and Schorheide (2006) is decomposed into the product of habit persistence, h, and the steady state growth rate of a world-wide technology shock, γ.

[19] Galí *et al.*'s (2001) estimates are broadly consistent with the current consensus in the literature which suggests that the Calvo-parameter in the U.S. is consistently lower than in Europe. Other references include Bils and Klenow (2004), Galí and Rabanal (2005), Schorfheide (2005), and Rabanal and Rubio-Ramírez (2003, 2005) for the U.S. For European estimates of the degree of price stickiness I should also mention the works of Benigno and López-Salido (2002), Angeloni *et al.* (2004), and Rabanal and Rubio-Ramírez (2003, 2005).

is of 2.63 quarters (or 7.89 months). I also explore different degrees of price rigidity based on Galí *et al.*'s (2001) range of estimates for each market.

P. Benigno (2001), Selaive and Tuesta (2003) and G. Benigno and Thoenissen (2006) among others favor a value of 0.001 for the cost of borrowing, $\delta \equiv \lambda \frac{1}{1-b} \left(\frac{1-\beta}{\chi} \right)^{\frac{1}{\gamma}}$, which corresponds to a 10 basis points spread (per quarter) of the domestic interest rate in the foreign currency over the foreign rate. Still, this is slightly lower than the Bayesian estimate of 0.007 provided by Rabanal and Tuesta (2006). In the benchmark, I choose a conservative value of 0 to ensure that financial intermediaries are risk-neutral. I also study the response of the model under values as high as 0.007.

5.2 The Dynamics of the Exogenous Shocks

To simulate the model, I still need to calibrate the parameters of the $VAR(1)$ process for $\widehat{\theta}_t$. I do so by relying on proxies for the shocks to estimate (26). The time series data used in these calculations is described in the appendix, and the estimation results are summarized in Tables 4 (a), 4 (b) and 4 (c).

A Time Series Realization of Proxies. I identify three different types of exogenous shocks. First, the monetary policy shocks, $\widehat{m}_t$ and $\widehat{m}_t^*$. The time series realization of the (per capita) money supply or money with zero maturity is obtained directly from the data. Second, the so-called TFP shocks, $\widehat{a}_t$ and $\widehat{a}_t^*$. Since I assume that the production technology is linear-in-labor, the TFP series is constructed as (per capita) real GDP relative to (per capita) employment.

Finally, I interpret the preference shocks, $\Delta\widehat{\xi}_t$ and $\Delta\widehat{\xi}_t^*$, as unanticipated changes in the subjective discount factor. I assume these shocks are proportional to *ex post* deviations of the (gross) real interest rate from its long-run trend (i.e., from its steady state). Hence, it follows that,

$$\exp\left(-\xi_{t+\tau}\right) \quad \propto \quad \left[\frac{\left(\frac{P_{t+\tau}}{P_{t-1}}\right) \prod_{j=0}^{\tau-1} \exp\left(-i_{t+\tau-1}\right)}{\exp\left(-\bar{i}\tau\right)} \right]^{\mu}, \ \forall \tau \geq 0,$$

$$\exp\left(-\xi^*_{t+\tau}\right) \quad \propto \quad \left[\frac{\left(\frac{P^*_{t+\tau}}{P^*_{t-1}}\right) \prod_{j=0}^{\tau-1} \exp\left(-i^*_{t+\tau-1}\right)}{\exp\left(-\bar{i}^*\tau\right)} \right]^{\mu}, \ \forall \tau \geq 0,$$

where $\mu \in (0,1)$ is a constant scaling factor, and $\beta = \exp\left(-\bar{i}\right) = \exp\left(-\bar{i}^*\right)$. Taking logs on both expressions and re-writing the variables in deviations from their steady state values, I describe the preference shocks simply as,

$$\Delta\widehat{\xi}_{t+1} \quad \approx \quad \mu\left(\widehat{i}_t - \widehat{\pi}_{t+1}\right), \tag{34}$$

$$\Delta\widehat{\xi}^*_{t+1} \quad \approx \quad \mu\left(\widehat{i}^*_t - \widehat{\pi}^*_{t+1}\right). \tag{35}$$

I anticipate the subjective discount factor shocks to be very persistent, but of low volatility. I pick a small scaling factor of $\mu = 0.1$ to dampen the magnitude of the fluctuations. The specification in equations (34) – (35) implicitly treats the preference shocks, $\widehat{\xi}_t$ and $\widehat{\xi}_t^*$, as a pair of $I(1)$ random processes.

Estimation of the Exogenous Vector of Shocks $\widehat{\theta}_t$. I collect the transformed data proxying for the shocks in the vector $\widehat{\theta}_t = \left(\widehat{m}_t, \widehat{m}_t^*, \Delta\widehat{\xi}_t, \Delta\widehat{\xi}_t^*, \widehat{a}_t, \widehat{a}_t^*\right)^T$. Consistent with the specification in equation (26), I argue that the time series representation of $\widehat{\theta}_t$ is given by,

$$\widehat{\theta}_t = \rho\widehat{\theta}_{t-1} + \varepsilon_t,\ \mathbb{E}\left[\varepsilon_t\varepsilon_t^T\right] = \Omega, \tag{36}$$

where the zero-mean random variable ε_t is uncorrelated with $\varepsilon_{t-\tau}$, $\widehat{\theta}_{t-\tau}$ for all $\tau > 0$. I use E-views 6 to estimate this unrestricted, stationary $VAR(1)$ with a sample ranging between 1974:I and 2006:III, and no constant term. This allows me to directly estimate the matrix $\widehat{\rho}$. I compute the matrix of variance-covariances, $\widehat{\Omega}$, from the residual series. Then, I assume that both $\widehat{\rho}$ and $\widehat{\Omega}$ correspond to the true matrices ρ and Ω that characterize the dynamics of the exogenous shocks[20].

6 Quantitative Findings[21]

Figure 1 plots the volatility relative to domestic consumption and the first-order autocorrelation of the real exchange rate under the assumption that price stickiness is identical across markets and firms (i.e., $\alpha^H = \alpha^{H*} = \alpha^F = \alpha^{F*} = \alpha$). I calibrate all parameters according to my benchmark parameterization, except for α that takes different values along the unit interval (horizontal axis). I report the predictions of the model for the benchmark of asymmetric information and the alternative of symmetric information. I also interpolate the approximate contour of the volatility ratio and the autocorrelation as if it was a function of α.

The first-order autocorrelation of the real exchange rate is almost identical under either symmetric or asymmetric information. Furthermore, the mapping of the autocorrelation function lies on top of the 45 degree line for values of α up to $0.60 - 0.65$, and is only slightly lower for Calvo parameters above that. Further exploration reveals that this tight link survives in the presence of other frictions (e.g., habit formation or risk-averse financial intermediaries) and even if nominal rigidities vary across firms depending on their location. This may explain why models that rely on Calvo (1983) price-setting firms have a difficult time matching the persistence of the real exchange rate, because matching the persistence requires $\alpha > 0.84$ (or an average contract duration above 6.25 quarters).

Table 5 indicates that differences in the degree of price stickiness across markets and firms (e.g., G. Benigno, 2004) provide a way to increase the persistence of the real exchange rate without requiring a degree of price stickiness well above the estimates in Galí *et al.* (2001) and others. For example, in columns SSM and DSFM of Table 5 the average degree of price stickiness is somewhere around 0.62, and yet the model generates significatively more real exchange rate persistence (between 0.695 and 0.796). These findings clearly suggests that differences in price stickiness across markets are crucial to generate the desired persistence[22].

[20] I tried alternative ways to infer the dynamics of $\widehat{\theta}_t$, for instance, using other proxies for the preference shocks. Naturally, the coefficients ρ and Ω vary depending on the choice of proxies.

[21] I exclude habit formation on the part of households and treat the financial intermediaries as risk-neutral firms in the benchmark model. In this sense, the structure of the bond economy is somewhat comparable to that of Chari *et al.* (2002).

[22] For instance, the autocorrelation of the real exchange rate is as high as 0.93 whenever $\delta = 0.001$, $\alpha^H = 0.407$, $\alpha^F = 0.69$, $\alpha^{H*} = 0.66$ and $\alpha^{F*} = 0.75$. This calibration produces very persistent series across the board.

Figure 1 also shows that the real exchange rate volatility relative to consumption is non-linear in the degree of price stickiness α. The volatility of the nominal exchange rate remains stable for most α's. For low values of α, instead, the volatility on consumption tends to be quite high and decreasing rapidly, while the volatility of the real exchange rate is low and grows more gradually. The raise in the volatility ratio seen in Figure 1 is mostly due to the drop in the volatility of consumption. For middle values of α, the reduction in the volatility of consumption becomes smaller and the increase in the volatility of the real exchange rate picks up some speed. For high values of α, the volatility of the real exchange rates stabilizes while the volatility of consumption slightly edges up. This explains the levelling of the volatility ratio in Figure 1.

Seemingly, the model insulates fluctuations of the nominal exchange rate from nominal rigidities. Therefore, changes in the degree of price stickiness are absorbed mostly by increases in the volatility of the real exchange rate, and reductions in the volatility of per capita consumption and relative CPI prices. Nonetheless, matching the volatility ratio still requires $\alpha > 0.75$ (or an average contract duration above 4 quarters). However, the message of Figure 1 is that asymmetric information introduces more real exchange rate volatility relative to consumption for any given α. For example, in column SSFM of Table 5 the degree of price stickiness is 0.62 (my benchmark calibration), and the model generates a volatility ratio of 5.029 under asymmetric information compared against 3.634 under symmetric information. This evidence clearly suggests that informational frictions are crucial to generate the desired exchange rate volatility.

Table 5 contains other interesting predictions. The model attains a high correlation between the nominal and the real exchange rates, except in cases where the contract average duration is asymmetric across markets. Most first-order autocorrelations remain largely unaffected by the structure of the information set except for terms of trade. The drop in the persistence of terms of trade can be as high as 20 percent relative to the case of symmetric information. The model produces encouraging results for different measures of international risk-sharing too. Most specifications match well the volatility and persistence of relative consumption and the correlation between consumption in each country. Moreover, the model produces a very low correlation between relative consumption and the real exchange rate. The correlation tends to be larger when the degree of price stickiness varies across markets, but lower under asymmetric information[23].

Hence, the model predictions appear to fit the data better and are either consistent with or improve upon the findings of Bergin and Feenstra (2001), Chari *et al.* (2002) and Selaive and Tuesta (2003).

6.1 The Role of Asymmetric Information[24]

Asymmetric information makes households less responsive to current shocks, other than preference shocks. That means that consumption responses come with a lag, although they could be very sensitive to random shifts in preferences. The portfolio allocation of the financial intermediaries is essentially responsible for the determination of the nominal exchange rate. The model retains the feature that nominal exchange rates

[23] The less public information there is about current shocks, the worst agents are in forecasting the state of the economy. Therefore, agents are less likely to find ways to share risks across countries by trading. For instance, the benchmark of asymmetric information induces a correlation between the real exchange rate and relative consumption which is as much as 34 percent lower than in the case of symmetric information. This finding supports the notion that informational frictions are a relevant part in the explanation of the *real exchange rate-relative consumption anomaly.*

[24] Further exploration not reported here indicates that the predictions under either asymmetric information or asymmetric information plus common knowledge about productivity shocks are quite similar. This suggets that lack of current information on preference shocks and particularly on monetary policy dominates the findings.

are primarily driven by monetary supply shocks[25]. Arguably, the volatility of the nominal exchange rate does not vary too much because intermediaries have full access to current information on monetary policy shocks under the benchmark of asymmetric information. Similarly, the pricing rules of the re-optimizing firms become less responsive too.

The evidence on prices shows, for instance, that the volatility of the relative CPI price over domestic consumption in Table 5 drops by as much as 10 percent under asymmetric information. Nonetheless, the dynamics of equilibrium prices are much more complex than what this number alone reveals. The volatility of the real exchange rate relative to consumption is up to 38 percent higher and the volatility of terms of trade relative to consumption is up to 28 percent higher under asymmetric information. These predictions reflect the increasing reliance on terms of trade and the real exchange rate to switch expenditures across countries and adjust the current account in response to country-specific shocks.

These expenditure-switching effects acquire a larger role whenever informational frictions make consumption less responsive. I describe the linearization of the resource constraint in the appendix and the companion technical note. Simple algebra with the CA, RS and RP equations in the appendix allows me to re-write the constraint as follows,

$$\beta \widehat{B}_t^{RF} \approx \widehat{B}_{t-1}^{RF} + (1-n)\left[(\sigma - 1)\widehat{tot}_t + \sigma \widehat{rs}_t - (\widehat{c}_t - \widehat{c}_t^*)\right], \tag{37}$$

where σ denotes the elasticity of intratemporal substitution, $\widehat{B}_t^{RF} \equiv \frac{S_t B_t^F}{P_t}\frac{1}{\overline{C}}$ represents the (real) per capita net foreign asset position instrumented by the representative financial intermediary relative to steady state consumption, and the expression within the brackets determines the current account in real terms.

One robust feature of the model is that the real net foreign asset position tends to be very persistent. Then, not surprisingly, most of the adjustment of the current account required for the goods markets in both countries to clear has to come from fluctuations of terms of trade and/or the real exchange rate. In other words, the higher volatility of the real exchange rate and terms of trade has to do with the fact that both variables respond more in order to ensure that the less sensitive household's demands remain optimal at equilibrium and all markets clear.

Why Relative CPI prices (and Terms of Trade) are so Volatile? My interpretation is that Calvo staggered prices may be less restrictive than we thought. The high volatility of relative CPI prices, also noted by Chari *et al.* (2002), partly indicates that consumption prices provide a great deal of the adjustment needed to hedge against shocks[26]. This is so even in the presence of nominal rigidities and informational frictions. Calvo (1983) imposes a "restriction" on the timing of price adjustments, but it does not constraint the size or the sign of the price adjustment when it occurs. This is probably what matters most, because due to the inherent symmetry of their problem and the unconstrained nature of their choice, the action of individual re-optimizing firms can compensate in the aggregate for the firms who cannot change prices (if need be).

CPI prices and terms of trade can be accommodated by the actions of the subset of re-optimizing firms in

[25] A variance decomposition for the benchmark of asymmetric information shows that monetary policy shocks account for approximately 50% of the volatility of the nominal exchange rate.

[26] A subtle implication is that because trade in the goods market (and the corresponding movement of prices) provides sufficient insurance to households, the benefits of participating in the asset market are greatly reduced. Consequently, asset market frictions often have quantitatively small effects.

order to help consumers attain an "appropriate" consumption path. This, in turn, ensures an optimal profile of profits for each firm. Aggregate consumption in both countries influences the equilibrium in the labor market, and hence the wages paid by each firm. Re-optimizing firms set their prices, aggregate prices respond in kind, and their fluctuations provide households with some degree of "insurance" in the goods markets against country-specific shocks. As a result, firms obtain a smoother profile of wages and marginal costs over time. Firms are aware that re-optimization events are infrequent, but they internalize their influence on aggregate variables (particularly, consumption and CPI prices) in their expectations and act accordingly.

In summary, firms are capable of moving aggregate prices as much as it is required to accomplish their goals, and they greatly depend on large movements in relative prices (real exchange rate, terms of trade, etc.) to induce the appropriate expenditure switches across markets. These expenditure-switching effects (for instance, on the current account) are needed for all markets to clear given the optimal plans of each agent. Hence, I would argue that the channel through which asymmetric information operates to increase the real exchange rate volatility depends crucially on the particular model of nominal rigidities devised by Calvo (1983).

6.2 The Role of Nominal Rigidities

The excessive volatility of relative CPI prices (even under symmetric information) reveals a deeper issue about nominal rigidities. Based on equation RS in the appendix, the variance of the real exchange rate relative to consumption can be decomposed as,

$$\frac{\sigma^2\left(\widehat{rs}\right)}{\sigma^2\left(\widehat{c}\right)} \approx \frac{\sigma^2\left(\widehat{s}\right)}{\sigma^2\left(\widehat{c}\right)} + \frac{\sigma^2\left(\widehat{p}^* - \widehat{p}\right)}{\sigma^2\left(\widehat{c}\right)} + 2\rho\left(\widehat{s}, \widehat{p}^* - \widehat{p}\right)\frac{\sigma\left(\widehat{s}\right)}{\sigma\left(\widehat{c}\right)}\frac{\sigma\left(\widehat{p}^* - \widehat{p}\right)}{\sigma\left(\widehat{c}\right)}, \tag{38}$$

which holds true up to a first-order approximation on CPI prices (and rounding-up error). Similarly, I approximate the correlation between the nominal and real exchange rates as,

$$\rho\left(\widehat{rs}, \widehat{s}\right) \approx \frac{\sigma\left(\widehat{s}\right)}{\sigma\left(\widehat{rs}\right)} + \rho\left(\widehat{s}, \widehat{p}^* - \widehat{p}\right)\frac{\sigma\left(\widehat{p}^* - \widehat{p}\right)}{\sigma\left(\widehat{rs}\right)}, \tag{39}$$

while the theoretical first-order autocorrelation of the real exchange rate can be expressed in the following terms[27],

$$\rho\left(\widehat{rs}\right) \approx \frac{\sigma^2\left(\widehat{s}\right)}{\sigma^2\left(\widehat{rs}\right)}\rho\left(\widehat{s}\right) + \frac{\sigma^2\left(\widehat{p}^* - \widehat{p}\right)}{\sigma^2\left(\widehat{rs}\right)}\rho\left(\widehat{p}^* - \widehat{p}\right) + 2\rho\left(\widehat{s}, \widehat{p}^* - \widehat{p}\right)\frac{\sigma\left(\widehat{s}\right)\sigma\left(\widehat{p}^* - \widehat{p}\right)}{\sigma^2\left(\widehat{rs}\right)}\frac{\sigma\left(\widehat{s}, \widehat{p}^*_{-1} - \widehat{p}_{-1}\right)}{\sigma\left(\widehat{s}, \widehat{p}^* - \widehat{p}\right)}. \tag{40}$$

Notice that the correlation between the nominal exchange rate and the relative CPI price appears in all three equations.

If the law of one price holds, then the nominal exchange rate equals $\widehat{s} = \widehat{p}^* - \widehat{p} \equiv -\widehat{p}^R$, and the correlation with the relative CPI price becomes $\rho\left(\widehat{s}, \widehat{p}^* - \widehat{p}\right) = -1$. The law fails due to LCP pricing coupled with nominal rigidities. However, Table 5 indicates that the correlation still ranges between -0.728 and -0.929. The model gets the sign right, and is capable of reducing the absolute value of the correlation by more than 20 percent for certain specifications. But these numbers are too far apart from the correlation of -0.314

[27] Equation (40) is derived based on the fact that if a solution to the model exists, then the vector of endogenous variables given by (29) is covariance-stationary.

found in the data[28]. Mechanically, the model approximates the variance of the exchange rates relative to consumption by balancing out a highly negative cross-correlation with an excessively large volatility of the relative CPI price. The correlation between the nominal exchange rate and the current (and lagged) relative CPI price has also a non-negligible impact on the measured and predicted values of $\rho\left(\widehat{rs}, \widehat{s}\right)$ and $\rho\left(\widehat{rs}\right)$.

The bottom line is that in order to produce realistic second-order moments is critical to match certain correlations too. In turn, this means that it is necessary to understand how nominal rigidities affect the dynamics of CPI prices in this class of models. I describe the linearization of the first-order conditions of the firm and the corresponding coefficients in the appendix and the companion technical note. After simple algebra on equations AS^H, AS^{H*}, AS^F, and AS^{F*} in the appendix, it can be shown that the pricing discrepancy across markets for an average firm located in the home country satisfies that,

$$\begin{aligned} \widehat{\pi}_t^H - \widehat{\pi}_t^{H*} \approx\ & \beta \mathbb{E}\left[\widehat{\pi}_{t+1}^H - \widehat{\pi}_{t+1}^{H*} \mid \mathcal{F}_t\right] + \Phi^{H*}\left[\mathbb{E}\left[\widehat{s}_t \mid \mathcal{F}_t\right] - \left(\widehat{p}_t^H - \widehat{p}_t^{H*}\right)\right] + \\ & + \mathbb{E}\left[\Omega^H\left(\widehat{\pi}_t^H, \widehat{\pi}_t^{H*}, \widehat{c}_t, \widehat{c}_{t-1}, \widehat{c}_t^*, \widehat{rs}_t, \widehat{t}_t, \widehat{t}_t^*, \widehat{a}_t; \alpha^H - \alpha^{H*}\right) \mid \mathcal{F}_t\right], \end{aligned} \tag{41}$$

while the pricing difference for an average firm located in the foreign market satisfies that,

$$\begin{aligned} \widehat{\pi}_t^F - \widehat{\pi}_t^{F*} \approx\ & \beta \mathbb{E}\left[\widehat{\pi}_{t+1}^F - \widehat{\pi}_{t+1}^{F*} \mid \mathcal{F}_t^*\right] + \Phi^{F}\left[\mathbb{E}\left[\widehat{s}_t \mid \mathcal{F}_t^*\right] - \left(\widehat{p}_t^F - \widehat{p}_t^{F*}\right)\right] + \\ & + \mathbb{E}\left[\Omega^F\left(\widehat{\pi}_t^F, \widehat{\pi}_t^{F*}, \widehat{c}_t, \widehat{c}_t^*, \widehat{c}_{t-1}^*, \widehat{rs}_t, \widehat{t}_t, \widehat{t}_t^*, \widehat{a}_t^*; \alpha^F - \alpha^{F*}\right) \mid \mathcal{F}_t^*\right]. \end{aligned} \tag{42}$$

The functions $\Omega^i\left(\cdot; \alpha^i - \alpha^{i*}\right)$ for $i = H, F$ are linear in the variables, reflect local marginal costs in the location of the producer, and satisfy that $\Omega^H\left(\cdot; 0\right) = \Omega^F\left(\cdot; 0\right) = 0$.

As noted by G. Benigno (2004), these functions imply that the difference in the firms' price-setting rules across markets no longer depends solely on fluctuations of the nominal exchange rate. Assuming that nominal rigidities are the same across firms (i.e., $\alpha^H = \alpha^{H*}$ and $\alpha^F = \alpha^{F*}$) implies that the equilibrium path of the pricing differential becomes tied down to the fluctuations of the equilibrium nominal exchange rate. Assuming that the nominal rigidities are the same across firms (i.e., $\alpha^H = \alpha^{H*}$ and $\alpha^F = \alpha^{F*}$), the pricing differential of each firm can be re-stated as follows,

$$\widehat{p}_t^{H*} - \widehat{p}_t^H \approx \frac{1}{1+\beta+\Phi^H}\left[\widehat{p}_{t-1}^{H*} - \widehat{p}_{t-1}^H\right] + \frac{\beta}{1+\beta+\Phi^H}\mathbb{E}\left[\widehat{p}_{t+1}^{H*} - \widehat{p}_{t+1}^H \mid \mathcal{F}_t\right] - \frac{\Phi^H}{1+\beta+\Phi^H}\mathbb{E}\left[\widehat{s}_t \mid \mathcal{F}_t\right] \tag{43}$$

$$\widehat{p}_t^{F*} - \widehat{p}_t^F \approx \frac{1}{1+\beta+\Phi^F}\left[\widehat{p}_{t-1}^{F*} - \widehat{p}_{t-1}^F\right] + \frac{\beta}{1+\beta+\Phi^F}\mathbb{E}\left[\widehat{p}_{t+1}^{F*} - \widehat{p}_{t+1}^F \mid \mathcal{F}_t^*\right] - \frac{\Phi^F}{1+\beta+\Phi^F}\mathbb{E}\left[\widehat{s}_t \mid \mathcal{F}_t^*\right] \tag{44}$$

This formula is somewhat unusual because it involves a forecast of the current nominal exchange rate, instead of the nominal exchange rate itself. Arguably, asymmetries of information may have an impact on the firm's forecast and, consequently, also on the *ex post* observed degree of pass-through. If the forecasts are systematically less volatile than the nominal exchange rate, this may induce a lower pass-through. This is a finer point that I will not pursue further because it goes beyond the purpose of the paper. In any event, the equilibrium path of the pricing differential is clearly tied down to the fluctuations of the equilibrium nominal exchange rate.

[28] My experiments suggest that asymmetric information plays a role, albeit a limited one, in toning down the correlation between the nominal exchange rate and the relative CPI price.

For expositional purposes, let me further simplify things by assuming that all current information is public (i.e., $\mathcal{H}_t = \mathcal{H}_t^* = \mathcal{F}_t = \mathcal{F}_t^* = \mathcal{I}_t$) and that price stickiness is identical across firms and markets (i.e., $\alpha^H = \alpha^{H*} = \alpha^F = \alpha^{F*} = \alpha$). Hence, using equation RS in the appendix, equations (41) and (42), and the log-linearization of the CPI index in (4), I can write the relative CPI price and the real exchange rate as follows,

$$\widehat{p}_t^R \approx \frac{1}{1+\beta+\Phi}\widehat{p}_{t-1}^R + \frac{\beta}{1+\beta+\Phi}\mathbb{E}\left[\widehat{p}_{t+1}^R \mid \mathcal{F}_t\right] + \frac{\Phi}{1+\beta+\Phi}\widehat{s}_t, \tag{45}$$

$$\begin{aligned} \widehat{rs}_t \approx\ & \frac{1}{1+\beta+\Phi}\widehat{rs}_{t-1} + \frac{\beta}{1+\beta+\Phi}\mathbb{E}\left[\widehat{rs}_{t+1} \mid \mathcal{F}_t\right] + \frac{1}{1+\beta+\Phi}\left[\widehat{s}_t - \widehat{s}_{t-1}\right] - \\ & - \frac{\beta}{1+\beta+\Phi}\left[\mathbb{E}\left[\widehat{s}_{t+1} \mid \mathcal{F}_t\right] - \widehat{s}_t\right], \end{aligned} \tag{46}$$

where $\Phi \equiv \left(\frac{(1-\beta\alpha)(1-\alpha)}{\alpha}\right)$. These pair of equations reveal the strong linkage that exists between the relative CPI price and the real exchange rate with the nominal exchange rate. Asymmetric information and differences in price stickiness across firms are bound to have an impact. However, the dramatic break occurs only when the nominal rigidities differ across at least one market. In that case, the function $\Omega^i\left(\cdot; \alpha^i - \alpha^{i*}\right)$ is no longer equal to zero for some $i = H, F$, and the implicit relationship between the nominal exchange rate and the pricing differential no longer holds tightly.

Indeed, the evidence from Tables 5, 6 and 7 suggests that this pricing "wedge" lowers (in absolute value) the correlations with the nominal exchange rate. However, in most instances the change in the correlation between the real and nominal exchange rate is proportionally greater. The effects introduced by this pricing "wedge" are mixed. On one hand, it improves the ability of the model to match the persistence and, most importantly, the volatility of the real exchange rate as can be seen in Table 5. For comes from lowering the correlation of the relative CPI price with the nominal exchange rate (see equations (38) and (40)). On the other hand, it often generates another anomaly in the form of too little correlation between the nominal and the real exchange rates because it reduces the volatility of the nominal exchange rate while increasing the relative CPI price[29] (see equation (39)).

Once more, the approach to model nominal rigidities in the spirit of Calvo (1983) in the version proposed by G. Benigno (2004) proves to have far reaching implications for the exchange rate predictions of the model.

7 Sensitivity Analysis

The Contribution of Risk-Averse Financial Intermediaries. I describe the linearization of the first-order condition of the representative financial intermediary in the appendix and the companion technical note. In the presence of risk-averse financial intermediaries (i.e., if $\delta > 0$), deviations of the uncovered interest rate parity (UIP) condition occur and are proportional to the real net position in foreign assets $\widehat{B}_t^{RF}$, i.e.

$$\mathbb{E}\left[\Delta\widehat{s}_{t+1} - \widehat{i}_t^R - \delta\widehat{B}_t^{RF} \mid \mathcal{I}_t\right] \approx 0. \tag{47}$$

[29] Table 5 shows that the correlation may be better approximated if the uncovered interest rate parity condition fails in the presence of risk-averse financial intermediaries.

This corresponds to equation *UIP* in the appendix. A natural conjecture would be that the persistence of $\widehat{B}_t^{RF}$ may carry over to the nominal exchange rate. In fact, the evidence reported in Table 6 indicates that the choice of the δ parameter has little to do with the persistence of the nominal exchange rate partially because it is already quite high when $\delta = 0$.

However, the volatility of the exchange rates, the relative CPI price and the terms of trade relative to consumption tends to be lower for larger values of δ. The more risk averse financial intermediaries are (or conversely, the larger δ is), the costlier it gets for financial intermediaries to bear the exchange rate risk. Hence, financial markets become closer to "autarky" and the nominal exchange rate becomes less volatile. The downward bias of the real exchange rate and the relative CPI price comes from the linkages to the nominal exchange rate explored in equations $(41) - (42)$.

I describe the linearization of the Euler equations of the representative households in the appendix and the companion technical note. I use equation RS in the appendix and the assumption of symmetric information across households (i.e., $\mathcal{H}_t = \mathcal{H}_t^*$) to describe the dynamics of relative consumption in a slightly simpler equation, i.e.

$$\frac{\gamma}{1-b}\mathbb{E}\left[\Delta\widehat{c}_{t+1}^R - b\Delta\widehat{c}_t^R \mid \mathcal{H}_t\right] \approx -\mathbb{E}\left[\Delta\widehat{\xi}_{t+1} - \Delta\widehat{\xi}_{t+1}^* \mid \mathcal{H}_t\right] + \underbrace{\mathbb{E}\left[\Delta\widehat{rs}_{t+1} \mid \mathcal{H}_t\right]}_{PPP \text{ fails}} + \underbrace{\mathbb{E}\left[\widehat{i}_t^R - \Delta\widehat{s}_{t+1} \mid \mathcal{H}_t\right]}_{UIP \text{ fails}}. \quad (48)$$

The *international risk-sharing* condition in (48) can be combined with the *UIP* equation in (47) as follows,

$$\begin{aligned}\tfrac{\gamma}{1-b}\mathbb{E}\left[\Delta\widehat{c}_{t+1}^R - b\Delta\widehat{c}_t^R \mid \mathcal{H}_t\right] + \mathbb{E}\left[\Delta\widehat{\xi}_{t+1} - \Delta\widehat{\xi}_{t+1}^* \mid \mathcal{H}_t\right] &\approx \mathbb{E}\left[\Delta\widehat{rs}_{t+1} \mid \mathcal{H}_t\right] - \delta\mathbb{E}\left[\widehat{B}_t^{RF} \mid \mathcal{I}_t\right] + \\ &+ \underbrace{\left[\mathbb{E}\left[\Delta\widehat{s}_{t+1} - \widehat{i}_t^R \mid \mathcal{I}_t\right] - \mathbb{E}\left[\Delta\widehat{s}_{t+1} - \widehat{i}_t^R \mid \mathcal{H}_t\right]\right]}_{\text{Forecasting disagreements}}.\end{aligned} \quad (49)$$

Independently of the information structure, consumption fails to equalize across countries in expectations whenever preference shocks are asymmetric, PPP fails or the UIP condition is violated. Equation (48) shows that a weakened link between the real exchange rate and relative consumption can be rationalized with forecasting disagreements arising from asymmetrically-informed households and financial intermediaries or with risk-averse intermediaries (i.e., $\delta > 0$).

Table 6 shows that the contribution of δ to explain the *real exchange rate-relative consumption anomaly* is very modest. In most of my experiments, the real net foreign asset position tends to be very persistent over time. This means that movements in $\widehat{B}_t^{RF}$ are not very sensitive to the dynamics of the other endogenous variables. Therefore, this channel becomes not very relevant in practice (see also Selaive and Tuesta, 2003).

The Contribution of Habit Formation on Consumption. Table 7 shows that habit formation plays only a limited role. As the parameter b raises, the volatility of relative consumption goes down, the correlation between domestic and foreign consumption goes up, and the volatility of the exchange rate and the terms of trade increases. A natural conjecture is that habits increase the persistence of consumption and this has spillover effects on other endogenous variables. In practice, the model already generates very persistent series for consumption without requiring habits. Therefore, there is little room for this channel to work. In the end, habit formation has mainly the effect of increasing the correlation of the business cycle across countries.

8 Concluding Remarks

I show that access to information plays a critical role in shaping the second-order moments of the model. Neither goods market frictions (sticky prices and LCP pricing) nor asset market frictions (incomplete markets coupled with intermediation) fully replicate the dynamics of the exchange rates. In fact, the international borrowing costs of intermediation (see also P. Benigno, 2001) play only a marginal role in my benchmark of asymmetric information. The pricing wedge in LCP pricing postulated by G. Benigno (2004) has, however, a notable effect on persistence, the correlation of the nominal exchange rate with the relative CPI price and other key correlations.

I find that the model with frictions on both assets and goods markets, but no informational friction, approximates the volatility and persistence of the real exchange rate only for large degrees of price stickiness corresponding to an average contract duration above 4 quarters. These predictions are comparable to those of Chari *et al.* (2002), Selaive and Tuesta (2003) and Benigno and Thoenissen (2006). However, the model fails to replicate the volatilities of the nominal exchange rate, the CPI price and the terms of trade. Among other counterfactual predictions, it also generates evidence of risk-sharing across countries beyond the values found in the data and a slightly lower correlation between the nominal and real exchange rates.

In response to these observations, I adapt the model to account for sticky and asymmetric information across agents. These frictions are relevant to explain the data precisely along the dimensions where the standard model fails allowing me to better understand the dynamics of the exchange rates. I argue that the model operates the way it does because whenever agents are informationally-constrained, their responses are lagged and re-balancing consumption expenditures across countries requires a more volatile exchange rate.

G. Benigno's (2004) framework of asymmetric price stickiness between the local and the exports markets is shown to have a direct impact on the persistence of the real exchange rate and other key correlations. This also allows forecasting disagreements due to asymmetric information to play an indirect role in the formation of prices and, therefore, in the persistence of the exchange rates and the correlation with each other. Arguably, the most notable contribution of this approach is to weaken the link between the nominal exchange rate and the relative CPI price embedded in most models of Calvo price-setting.

My investigation shows that informational frictions or limited diffusion of information can closely approximate the volatility, the persistence and the correlation of the exchange rates. Moreover, it can be accomplished without imposing an average contract duration that is well above the best-known estimates in the empirical literature (see, e.g., Galí *et al.*, 2001). It also simultaneously produces sensible predictions for the structure of cross-correlations among the endogenous variables. Nevertheless, two major challenges remain largely unresolved.

On one hand, the model with asymmetric information improves in terms of the *real exchange rate-relative consumption anomaly*, although it does not provide a complete answer to the puzzle. On the other hand, I still detect the strong effects of the *terms of trade anomaly* under LCP pricing (see Obstfeld and Rogoff, 2000a). I leave these two elusive problems for future research. A possible extension to deal with these two puzzles could be to augment the model with distribution services (e.g., Corsetti *et al.*, 2004) and to move from a LCP pricing framework to a mix of PCP (or producer-currency) pricing and LCP pricing (e.g., Devereux and Engel, 2006).

References

[1] Anderson, Gary S. and George Moore (1985): "A Linear Algebraic Procedure for Solving Linear Perfect Foresight Models". *Economic Letters*, vol. **17**, pp. 247-252.

[2] Angeloni, Ignazio, Luc Aucremanne, Michael Ehrmann, Jordi Galí, Andrew Levin and Frank Smets (2004): "Inflation Persistence in the Euro Area: Preliminary Summary of Findings". *Inflation Persistence Network (IPN)* Working Papers, European Central Bank.

[3] Bacchetta, Philippe and Eric van Wincoop (2004a): "Higher Order Expectations in Asset Pricing". *Mimeo*, Study Center Gerzensee, University of Lausanne.

[4] _______ and _______ (2004b): "A Scapegoat Model of Exchange Rate Fluctuations". *American Economic Review*, vol. **94** (2), pp. 114-118.

[5] _______ and _______ (2006): "Can Information Heterogeneity Explain the Exchange Rate Determination Puzzle?". *American Economic Review*, vol. **96** (3), pp. 552-576.

[6] Backus, David and G. Smith (1993): "Consumption and Real Exchange Rates in Dynamic Economies with Non-Traded Goods". *Journal of International Economics*, vol. **35**, pp. 297-316.

[7] Basu, S. (1996): "Procyclical Productivity: Increasing Returns or Cyclical Utilization?". *Quarterly Journal of Economics*, vol. **111**, pp. 719-751.

[8] Benigno, Pierpaolo (2001): "Price Stability with Imperfect Financial Integration". *CEPR* Working Paper, No. 2854.

[9] _______ (2004): "Optimal Monetary Policy in a Currency Area". *Journal of International Economics*, vol. **63** (2), pp. 293-320.

[10] _______ and David López-Salido (2002): "Inflation Persistence and Optimal Monetary Policy in the Euro Area". *International Finance Discussion Papers*, No. 749, Board of Governors of the Federal Reserve System.

[11] Benigno, Gianluca (2004): "Real Exchange Rate Persistence and Monetary Policy Rules". *Journal of Monetary Economics*, vol. **51**, pp. 473-502.

[12] _______ and Christoph Thoenissen (2006): "Consumption and Real Exchange Rates with Incomplete Markets and Non-Traded Goods". *CEPR*, International Macroeconomics Series, Discussion Paper No. 5580.

[13] Bergin, P. R. and R. C. Feenstra (2001): "Pricing to Market, Staggered Contracts, and Real Exchange Rate Persistence". *Journal of International Economics*, vol. **54**, pp. 333-359.

[14] Betts, Caroline and Michael B. Devereux (1996): "The Exchange Rate in a Model of Pricing to Market". *European Economic Review*, vol. **40**, pp. 1007-1021.

[15] _______ and _______ (2000): "Exchange Rate Dynamics in a Model of Pricing to Market". *Journal of International Economics*, vol. **50** (1), pp. 215-244.

[16] Bils, Mark and Peter Klenow (2004): "Some Evidence on the Importance of Sticky Prices". *Journal of Political Economy*, vol. **112**, pp. 947-985.

[17] Boldrin, Michele, Lawrence J. Christiano and Jonas D. M. Fisher (2001): "Habit Persistence, Asset Returns, and the Business Cycle". *American Economic Review*, vol. **91** (1), pp. 149-166.

[18] Browning, Martin, Lars Peter Hansen and James J. Heckman (1999): "Micro Data and General Equilibrium Models", in J. B. Taylor and M. Woodford (eds.) *Handbook of Macroeconomics*, vol. **1**. Elsevier Science B.V.

[19] Calvo, Guillermo A. (1983): "Staggered Prices in a Utility-Maximizing Framework". *Journal of Monetary Economics*, vol. **12**, pp. 383-398.

[20] Campbell, John Y. and John H. Cochrane (1999): "By Force of Habit: A Consumption-Based Explanation of Aggregate Stock Market Behavior". *Journal of Political Economy*, vol. **107** (2), pp. 205-251.

[21] Card, David (1994): "Intertemporal Labor Supply: An assessment", in Chris Sims (ed.) *Advances in Econometrics*. Cambridge University Press: New York, USA.

[22] Carlson, John A. and C. L. Osler (2000): "Rational Speculators and Exchange Rate Volatility". *European Economic Review*, vol. **44**, pp. 231-253.

[23] Chari, V.V., Patrick J. Kehoe and Ellen R. McGrattan (2002): "Can Sticky Price Models Generate Volatile and Persistent Real Exchange Rates?". *Review of Economic Studies*, vol. **69**, pp. 533-563.

[24] Christiano, Lawrence J. (2002): "Solving Dynamic Equilibrium Models by a Method of Undetermined Coefficients". *Computational Economics*, vol. **20**, pp. 21-55.

[25] Cole, Harold L. and Maurice Obstfeld (1991): "Commodity Trade and International Risk Sharing: How Much Do Financial Markets Matter?". *Journal of Monetary Economics*, vol. **28**, pp. 3-24.

[26] Corsetti, Giancarlo and P. Pesenti (2001): "Welfare and Macroeconomic Interdependence". *Quarterly Journal of Economics*, **116**, pp. 421-446.

[27] _______, Luca Dedola and Sylvain Leduc (2004): "International Risk Sharing and the Transmission of Productivity Shocks". *CEPR* Discussion Papers, No. 4746.

[28] Devereux, Michael B. and Charles Engel (2006): "Expenditure Switching vs. Real Exchange Rate Stabilization: Competing Objectives for Exchange Rate Policy". *NBER* Working Paper, No. 12215, National Bureau of Economic Research, Inc.

[29] Domowitz, Ian, R. Glenn Hubbard and Bruxe C. Petersen (1988): "Market Structure and Cyclical Fluctuations in U.S. Manufacturing". *Review of Economics and Statistics*, vol. **70** (1), pp. 55-66.

[30] Eichenbaum, Martin, P. Hansen and K. Singleton (1988): "A Time Series Analysis of Representative Agent Models of Consumption and Leisure Choice Under Uncertainty". *Quarterly Journal of Economics*, vol. **103**, pp. 51-78.

[31] Engel, Charles (1999): "Accounting for U.S. Real Exchange Rate Changes". *Journal of Political Economy*, vol. **107**, pp. 507-538.

[32] Evans, Martin D. D. and Richard K. Lyons (2007): "Exchange Rate Fundamentals and Order Flow". *NBER* Working Paper, No. 13151, National Bureau of Economic Research, Inc.

[33] Fuhrer, Jeffrey C. (2000): "Habit Formation in Consumption and its Implications for Monetary-Policy Models". *American Economic Review*, vol. **90** (3), pp. 367-390.

[34] Gagnon, Joseph (1996): "Net Foreign Assets and Equilibrium Exchange Rates: Panel Evidence". *International Finance Discussion Paper*, No. 574, Board of Governors of the Federal Reserve System.

[35] Galí, Jordi, M. Gertler and David López-Salido (2001): "European Inflation Dynamics". *European Economic Review*, vol. **45**, pp. 1237-1270.

[36] _______ and Pau Rabanal (2005): "Technology Shocks and Aggregate Fluctuations: How Well Does the RBC Model Fit the Postwar U.S. Data", in Mark Gertler and Kenneth Rogoff (eds.) *NBER Macroeconomics Annual 2004*, vol. **19**, pp. 225-288. MIT University Press: Cambridge, Massachusetts, USA.

[37] Golosov, Mikhail and Robert E. Lucas (2007): "Menu Costs and Phillips Curves". *Journal of Political Economy*, vol. **115** (2), pp. 171-199.

[38] Gopinath, Gita and Roberto Rigobon (2006): "Sticky Borders". *NBER* Working Paper, No. 12095, National Bureau of Economic Research, Inc.

[39] Gust, Christopher, Sylvain Leduc and Robert J. Vigfusson (2006): "Trade Integration, Competition, and the Decline in Exchange-Rate Pass-Through". *International Finance Discussion Papers*, No. 864, Board of Governors of the Federal Reserve System.

[40] Hall, Robert (1998): "Intertemporal Substitution in Macroeconomics". *Journal of Political Economy*, **96**, pp. 339-357.

[41] Hamilton, James D. (1994): "Time Series Analysis". Princeton University Press, Princeton, New Jersey.

[42] Head, Allen, Todd Mattina and Gregor W. Smith (2004): "Real Exchange Rates, Preferences, and Incomplete Markets: Evidence, 1961-2001". *Canadian Journal of Economics*, vol. **37** (3), pp. 782-801.

[43] Jeanne, Olivier and Andrew K. Rose (2002): "Noise Trading and Exchange Rate Regimes". *Quarterly Journal of Economics*, vol. **117** (2), pp. 537-569.

[44] Kaplan, Ethan (2005): "Imperfect Common Knowledge and Exchange Rate Determination". *Mimeo*, Department of Economics, University of California at Berkeley.

[45] Kasa, Kenneth (2000): "Forecasting the Forecast of Others in the Frequency Domain". *Review of Economics Dynamics*, vol. **3**, pp. 726-756.

[46] _______, Todd B. Walker and Charles H. Whiteman (2005): "Asset Pricing with Heterogeneous Beliefs: A Frequency-Domain Approach". *Mimeo*, Simon Fraser University.

[47] King, Robert G., C. Plosser, and Sergio T. Rebelo (1988): "Production, Growth and Business Cycles: I The Basic Neoclassical Model". *Journal of Monetary Economics*, vol. **21**, pp. 195-232.

[48] _______ and Sergio T. Rebelo (1993): "Low Frequency Filtering and Real Business Cycles". *Journal of Economic Dynamics and Control*, vol. **17**, pp. 207-231.

[49] Knetter, M. (1993): "International Comparison of Pricing to Market Behavior". *American Economic Review*, vol. **83**, pp. 473–486.

[50] Kollmann, Robert (1995): "Consumption, Real Exchange Rates and the Structure of International Asset Markets". *Journal of International Money and Finance*, vol. **14**, pp. 191-211.

[51] _______ (2001): "The Exchange Rate in a Dynamic Optimizing Current Account Model with Nominal Rigidities: A Quantitative Investigation". *Journal of International Economics*, vol. **55**, pp. 243-262.

[52] Lubik, Thomas A. and Frank Schorfheide (2006): "A Bayesian Look at New Open Economy Macroeconomics", in Mark Gertler and Kenneth Rogoff (eds.) *NBER Macroeconomics Annual 2005*, vol. **20**, pp. 313-366. MIT University Press: Cambridge, Massachusetts, USA.

[53] Mankiw, N. Gregory, and Ricardo Reis (2002): "Sticky Information versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve". *Quarterly Journal of Economics*, vol. **117**, pp. 1295-1328.

[54] _______ and _______ (2006): "Pervasive Stickiness". *American Economic Review*, vol. **96** (2), pp. 164-169.

[55] Obstfeld, Maurice and Kenneth Rogoff (1996): "Foundations of International Macroeconomics". MIT University Press: Cambridge, Massachusetts, USA.

[56] _______ and _______ (2000a): "New Directions for Stochastic Open Economy Models". *Journal of International Economics*, vol. **50**, pp. 117-153.

[57] _______ and _______ (2000b): "The Six Major Puzzles in International Macroeconomics: Is There a Common Cause?", in Ben S. Bernanke and Kenneth Rogoff (eds.) *NBER Macroeconomics Annual 2000*, vol. **15**, pp. 339-390. MIT University Press: Cambridge, Massachusetts, USA.

[58] _______ and _______ (2002): "Risk and Exchange Rates", in Elhanan Helpman and Effraim Sadka (eds.) *Contemporary Economic Policy: Essays in Honor of Assaf Razin*. Cambridge University Press: Cambridge, UK.

[59] Rabanal, Pau and Juan F. Rubio-Ramírez (2003): "Comparing New Keynesian Models in the Euro Area: A Bayesian Approach". *Federal Reserve Bank of Atlanta* Working Paper, No. 2003-30.

[60] _______ and _______ (2005): "Comparing New Keynesian Models of the Business Cycle: A Bayesian Approach". *Journal of Monetary Economics*, vol. **52** (6), pp. 1151-1166.

[61] _______ and Vicente Tuesta (2006): "Euro-Dollar Real Exchange Rate Dynamics in an Estimated Two-Country Model: What Is Important and What Is Not". *International Monetary Fund* Working Paper, No. 06/177.

[62] Ravn, Morten O. (2001): "Consumption Dynamics and Real Exchange Rate". *CEPR* Discussion Paper No. 2940.

[63] Rotemberg, Julio J. and Michael Woodford (1998a): "An Optimization-Based Econometric Model for the Evaluation of Monetary Policy", in Ben S. Bernanke and Julio Rotemberg (eds.) *NBER Macroeconomics Annual 1997*, vol. **12**, pp. 297-346. MIT University Press: Cambridge, Massachusetts, USA.

[64] _______ and _______ (1998b): "Interest Rate Rules in an Estimated Sticky Price Model", in J. B. Taylor (ed.) *Monetary Policy Rules*. University of Chicago Press: Chicago, USA.

[65] Schorfheide, Frank (2005): "Learning and Monetary Policy Shifts". *Review of Economic Dynamics*, vol. **8**, pp. 392-419.

[66] Selaive, Jorge and Vicente Tuesta (2003): "Net Foreign Assets and Imperfect Pass-Through: The Consumption Real Exchange Rate Anomaly". *International Finance Discussion Papers*, No. 764, Board of Governors of the Federal Reserve System.

[67] Thoenissen, Christoph (2003): "Real Exchange Rates, Current Accounts and the Net Foreign Asset Position". *Mimeo*, University of St. Andrews.

[68] Townsend, Robert M. (1983): "Forecasting the Forecast of Others". *Journal of Political Economy*, vol. **91**, pp. 546-588.

[69] Warnock, Francis E. (2003): "Exchange Rate Dynamics and the Welfare Effects of Monetary Policy in a Two-Country Model with Home-Product Bias". *Journal of International Money and Finance*, vol. **22**, pp. 343-363.

[70] Wolman, A. L. (1999): "Sticky Prices, Marginal Cost, and the Behavior of Inflation". Federal Reserve Bank of Richmond, *Economic Quarterly*, vol. **85**, pp. 29-48.

Appendix

A Equilibrium Conditions

Here, I present the relevant equilibrium conditions of the model. Since the model is built around two mostly symmetric countries, all the equations reported correspond to the home country unless otherwise noted. More details can be found in the companion technical note.

A.1 The Households' First-Order Conditions

The Demand Functions of Household j. Each household j decides how much to allocate to the different varieties of home and foreign goods. Given the structure of preferences, the solution to the sub-utility maximization problem implies that the home and foreign households' demands for each variety are given by,

$$C_{j,t}(h) = \frac{1}{n}\left(\frac{P_t(h)}{P_t^H}\right)^{-\theta} C_{j,t}^H,\ C_{j,t}^*(h) = \frac{1}{n}\left(\frac{P_t^*(h)}{P_t^{H*}}\right)^{-\theta} C_{j,t}^{H*},\ \text{if } h \in [0,n], \tag{A.1}$$

$$C_{j,t}(f) = \frac{1}{1-n}\left(\frac{P_t(f)}{P_t^F}\right)^{-\theta} C_{j,t}^F,\ C_{j,t}^*(f) = \frac{1}{1-n}\left(\frac{P_t^*(f)}{P_t^{F*}}\right)^{-\theta} C_{j,t}^{F*},\ \text{if } f \in (n,1], \tag{A.2}$$

while the demands for the bundles of home and foreign goods are simply equal to,

$$C_{j,t}^H = n\left(\frac{P_t^H}{P_t}\right)^{-\sigma} C_{j,t},\ C_{j,t}^{H*} = n\left(\frac{P_t^{H*}}{P_t^*}\right)^{-\sigma} C_{j,t}^*, \tag{A.3}$$

$$C_{j,t}^F = (1-n)\left(\frac{P_t^F}{P_t}\right)^{-\sigma} C_{j,t},\ C_{j,t}^{F*} = (1-n)\left(\frac{P_t^{F*}}{P_t^*}\right)^{-\sigma} C_{j,t}^*. \tag{A.4}$$

The Optimization Problem for the Representative Household. The (interior) optimal allocation in each country is characterized by the following necessary and sufficient first-order conditions,

$$\beta \mathbb{E}\left[\exp\left(i_t - \Delta\xi_{t+1}\right)\left(\frac{C_{t+1} - bC_t}{C_t - bC_{t-1}}\right)^{-\gamma} \frac{P_t}{P_{t+1}} \mid \mathcal{H}_t\right] = 1, \tag{A.5}$$

$$\beta \mathbb{E}\left[\exp\left(i_t^* - \Delta\xi_{t+1}^*\right)\left(\frac{C_{t+1}^* - bC_t^*}{C_t^* - bC_{t-1}^*}\right)^{-\gamma} \frac{P_t^*}{P_{t+1}^*} \mid \mathcal{H}_t^*\right] = 1, \tag{A.6}$$

and

$$\left(\frac{M_t^d}{P_t\left(C_t-bC_{t-1}\right)}\right)^{-\gamma} = \chi\left(\frac{\exp\left(i_t\right)-1}{\exp\left(i_t\right)}\right), \tag{A.7}$$

$$\left(\frac{M_t^{d*}}{P_t^*\left(C_t^*-bC_{t-1}^*\right)}\right)^{-\gamma} = \chi\left(\frac{\exp\left(i_t^*\right)-1}{\exp\left(i_t^*\right)}\right), \tag{A.8}$$

$$\frac{W_t}{P_t} = \kappa\left(C_t-bC_{t-1}\right)^{\gamma}\left(L_t^s\right)^{\varphi}, \tag{A.9}$$

$$\frac{W_t^*}{P_t^*} = \kappa\left(C_t^*-bC_{t-1}^*\right)^{\gamma}\left(L_t^{s*}\right)^{\varphi}, \tag{A.10}$$

plus the appropriate no-Ponzi games, transversality conditions and the budget constraint of both representative households. Equations $(A.5)$ and $(A.6)$ represent the home and foreign Euler equations obtained by optimally choosing the holdings of the local bonds denominated in their respective currencies. Equations $(A.7)$ and $(A.8)$ define the money demand functions (similar to Cagan's own). Households pre-commit to equating the marginal rate of substitution between real money balances and consumption to the opportunity cost of holding real money balances. Finally, equations $(A.9)$ and $(A.10)$ determine the labor supply functions. Households pre-commit to equating the marginal rate of substitution between consumption and labor to real wages.

A.2 The Firms' First-Order Conditions

The Downward-Slopping Demand Constraint. I derive the demand of variety h in the home and foreign markets by combining equations $(A.1)-(A.4)$ and aggregating across all households. Then, $\widetilde{Y}_{t,t+\tau}^d(h)$ and $\widetilde{Y}_{t,t+\tau}^{d*}(h)$ indicate the per capita demand for any variety h at home and abroad respectively, given that prices $\widetilde{P}_t(h)$ and $\widetilde{P}_t^*(h)$ remain unchanged between time t and $t+\tau$, i.e.

$$\widetilde{Y}_{t,t+\tau}^d(h) = \left(\frac{\widetilde{P}_t(h)}{P_{t+\tau}^H}\right)^{-\theta}\left(\frac{P_{t+\tau}^H}{P_{t+\tau}}\right)^{-\sigma} C_{t+\tau}, \tag{A.11}$$

$$\widetilde{Y}_{t,t+\tau}^{d*}(h) = \left(\frac{\widetilde{P}_t^*(h)}{P_{t+\tau}^{H*}}\right)^{-\theta}\left(\frac{P_{t+\tau}^{H*}}{P_{t+\tau}^*}\right)^{-\sigma} C_{t+\tau}^*. \tag{A.12}$$

Similarly, I obtain $\widetilde{Y}_{t,t+\tau}^d(f)$ and $\widetilde{Y}_{t,t+\tau}^{d*}(f)$ to characterize the demand constraints of the foreign firms.

The Optimal Price-Setting Rule. The necessary and sufficient first-order conditions for the domestic firm producing variety h give me the following price-setting formulas,

$$\widetilde{P}_t(h) = \frac{\theta}{\theta-1}\frac{\sum_{\tau=0}^{\infty}\left(\beta\alpha^H\right)^{\tau}\mathbb{E}\left[\Xi_{t,t+\tau}\widetilde{Y}_{t,t+\tau}^d(h)\left(\frac{W_{t+\tau}}{\exp(a_{t+\tau})}\right)\mid\mathcal{F}_t\right]}{\sum_{\tau=0}^{\infty}\left(\beta\alpha^H\right)^{\tau}\mathbb{E}\left[\Xi_{t,t+\tau}\widetilde{Y}_{t,t+\tau}^d(h)\mid\mathcal{F}_t\right]}, \tag{A.13}$$

$$\widetilde{P}_t^*(h) = \frac{\theta}{\theta-1}\frac{\sum_{\tau=0}^{\infty}\left(\beta\alpha^{H*}\right)^{\tau}\mathbb{E}\left[\Xi_{t,t+\tau}\widetilde{Y}_{t,t+\tau}^{d*}(h)\left(\frac{W_{t+\tau}}{\exp(a_{t+\tau})}\right)\mid\mathcal{F}_t\right]}{\sum_{\tau=0}^{\infty}\left(\beta\alpha^{H*}\right)^{\tau}\mathbb{E}\left[\Xi_{t,t+\tau}\widetilde{Y}_{t,t+\tau}^{d*}(h)S_{t+\tau}\mid\mathcal{F}_t\right]}, \tag{A.14}$$

where I allow for differences in the degree of nominal price rigidity across and within countries. Under proper aggregation rules, the price sub-indexes under sticky prices on domestic varieties, P_t^H and P_t^{H*}, are

$$P_t^H = \left[\frac{1}{n}\int_0^n P_t(h)^{1-\theta}\,dh\right]^{\frac{1}{1-\theta}} = \left[\alpha^H \left(P_{t-1}^H\right)^{1-\theta} + \left(1-\alpha^H\right)\left(\widetilde{P}_t(h)\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}, \tag{A.15}$$

$$P_t^{H*} = \left[\frac{1}{n}\int_0^n P_t^*(h)^{1-\theta}\,dh\right]^{\frac{1}{1-\theta}} = \left[\alpha^{H*} \left(P_{t-1}^{H*}\right)^{1-\theta} + \left(1-\alpha^{H*}\right)\left(\widetilde{P}_t^*(h)\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}. \tag{A.16}$$

The price-setting rule is symmetric for all firms who can re-optimize at time t. The lagged term reflects the aggregate behavior of all domestic firms who cannot re-set prices. Similar conditions, pricing rules and price sub-indexes hold for the foreign firms.

A.3 The Financial Intermediaries' First-Order Conditions

The necessary and sufficient first-order condition for the representative financial intermediary produces the following investment rule,

$$\mathbb{E}\left[\frac{S_{t+1}}{S_t} - \exp\left(i_t - i_t^*\right) - \lambda S_t B_t^F \mid \mathcal{I}_t\right] = 0. \tag{A.17}$$

Hence, financial intermediaries are the only agents with a non-trivial portfolio choice problem. Although their strategy is purely myopic and does not incorporate an intertemporal hedging component, they still arbitrage any (and all) profit opportunities available in the bond markets such that $(A.17)$ holds true. In turn, this introduces a risk premium on the uncovered interest rate parity condition which depends linearly on the disutility from foreign risk, λ.

A.4 The Resource Constraint

If I aggregate the budget constraint of the domestic households with the consolidated domestic government budget constraint, I obtain

$$\frac{B_t}{\exp\left(i_t\right)} = B_{t-1} + P_t\left[\left(\frac{P_t^H}{P_t}\right)^{1-\sigma} nC_t + RS_t\left(\frac{P_t^{H*}}{P_t^*}\right)^{1-\sigma}\left(1-n\right)C_t^*\right] - P_tC_t, \tag{A.18}$$

which defines the home country resource constraint. The resource constraint of the foreign country is redundant by Walras' law, having assumed that profits from financial intermediation are purely re-invested. The difference between total income and total consumption in the home country is defined as the current account.

Let B_t^H denote the per capita net domestic asset position of the representative financial intermediary. If I combine equations $(A.18)$ and (19) with the market clearing condition in the domestic bonds market, i.e.

$$B_t + B_t^H = 0, \tag{A.19}$$

I can re-write the resource constraint as,

$$\frac{1}{\exp\left(i_t^*\right)}B_t^{RF} = \frac{S_t}{S_{t-1}}\frac{P_{t-1}}{P_t}B_{t-1}^{RF} + \left[\left(\frac{P_t^H}{P_t}\right)^{1-\sigma} nC_t + RS_t\left(\frac{P_t^{H*}}{P_t^*}\right)^{1-\sigma}\left(1-n\right)C_t^* - C_t\right], \tag{A.20}$$

where $B_t^{RF} \equiv \frac{S_t B_t^F}{P_t}$ represents the (real) per capita net foreign asset position instrumented by the representative financial intermediary.

B The Linearized Equilibrium Conditions

Here, I discuss the linearized equilibrium conditions of the model. The linearization of the sticky-price, intermediated-asset market model with asymmetrically-informed agents is expressed in the following system of equations,

	The Optimal Decision of Households and Firms:
$\mathbf{IS^H}$	$\frac{\gamma}{1-b}\mathbb{E}\left[\Delta\widehat{c}_{t+1} - b\Delta\widehat{c}_t \mid \mathcal{H}_t\right] \approx \mathbb{E}\left[\widehat{i}_t - n\widehat{\pi}^H_{t+1} - (1-n)\,\widehat{\pi}^F_{t+1} \mid \mathcal{H}_t\right] - \mathbb{E}\left[\Delta\widehat{\xi}_{t+1} \mid \mathcal{H}_t\right],$
$\mathbf{IS^F}$	$\frac{\gamma}{1-b}\mathbb{E}\left[\Delta\widehat{c}^*_{t+1} - b\Delta\widehat{c}^*_t \mid \mathcal{H}^*_t\right] \approx \mathbb{E}\left[\widehat{i}^*_t - n\widehat{\pi}^{H*}_{t+1} - (1-n)\,\widehat{\pi}^{F*}_{t+1} \mid \mathcal{H}^*_t\right] - \mathbb{E}\left[\Delta\widehat{\xi}^*_{t+1} \mid \mathcal{H}^*_t\right],$
$\mathbf{MM^H}$	$\widehat{m}_t - n\widehat{p}^H_t - (1-n)\,\widehat{p}^F_t \approx \frac{1}{1-b}\left[\widehat{c}_t - b\widehat{c}_{t-1}\right] - \frac{1}{\gamma}\left(\frac{\beta}{1-\beta}\right)\mathbb{E}\left[\widehat{i}_t \mid \mathcal{H}_t\right],$
$\mathbf{MM^F}$	$\widehat{m}^*_t - n\widehat{p}^{H*}_t - (1-n)\,\widehat{p}^{F*}_t \approx \frac{1}{1-b}\left[\widehat{c}^*_t - b\widehat{c}^*_{t-1}\right] - \frac{1}{\gamma}\left(\frac{\beta}{1-\beta}\right)\mathbb{E}\left[\widehat{i}^*_t \mid \mathcal{H}^*_t\right],$
$\mathbf{AS^H}$	$\begin{aligned}\widehat{\pi}^H_t \approx{}& \beta\mathbb{E}\left[\widehat{\pi}^H_{t+1} \mid \mathcal{F}_t\right] + k^H_\pi\widehat{\pi}^H_t + k^H_{\pi^*}\widehat{\pi}^{H*}_t + \mathbb{E}\left[k^H_{rs}\widehat{rs}_t + k^H_t\widehat{t}_t + k^H_{t^*}\widehat{t}^*_t \mid \mathcal{F}_t\right] + \\ &+k^H_c\mathbb{E}\left[\frac{\gamma}{1-b}\left(\widehat{c}_t - b\widehat{c}_{t-1}\right) + \varphi\widehat{c}^W_t - (1+\varphi)\,\widehat{a}_t \mid \mathcal{F}_t\right],\end{aligned}$
$\mathbf{AS^{H*}}$	$\begin{aligned}\widehat{\pi}^{H*}_t \approx{}& \beta\mathbb{E}\left[\widehat{\pi}^{H*}_{t+1} \mid \mathcal{F}_t\right] + k^{H*}_\pi\widehat{\pi}^H_t + k^{H*}_{\pi^*}\widehat{\pi}^{H*}_t + \mathbb{E}\left[k^{H*}_{rs}\widehat{rs}_t + k^{H*}_t\widehat{t}_t + k^{H*}_{t^*}\widehat{t}^*_t \mid \mathcal{F}_t\right] + \\ &+k^{H*}_c\mathbb{E}\left[\frac{\gamma}{1-b}\left(\widehat{c}_t - b\widehat{c}_{t-1}\right) + \varphi\widehat{c}^W_t - (1+\varphi)\,\widehat{a}_t \mid \mathcal{F}_t\right],\end{aligned}$
$\mathbf{AS^F}$	$\begin{aligned}\widehat{\pi}^F_t \approx{}& \beta\mathbb{E}\left[\widehat{\pi}^F_{t+1} \mid \mathcal{F}^*_t\right] + k^F_\pi\widehat{\pi}^F_t + k^F_{\pi^*}\widehat{\pi}^{F*}_t + \mathbb{E}\left[k^F_{rs}\widehat{rs}_t + k^F_t\widehat{t}_t + k^F_{t^*}\widehat{t}^*_t \mid \mathcal{F}^*_t\right] + \\ &+k^F_c\mathbb{E}\left[\frac{\gamma}{1-b}\left(\widehat{c}^*_t - b\widehat{c}^*_{t-1}\right) + \varphi\widehat{c}^W_t - (1+\varphi)\,\widehat{a}^*_t \mid \mathcal{F}^*_t\right],\end{aligned}$
$\mathbf{AS^{F*}}$	$\begin{aligned}\widehat{\pi}^{F*}_t \approx{}& \beta\mathbb{E}\left[\widehat{\pi}^{F*}_{t+1} \mid \mathcal{F}^*_t\right] + k^{F*}_\pi\widehat{\pi}^F_t + k^{F*}_{\pi^*}\widehat{\pi}^{F*}_t + \mathbb{E}\left[k^{F*}_{rs}\widehat{rs}_t + k^{F*}_t\widehat{t}_t + k^{F*}_{t^*}\widehat{t}^*_t \mid \mathcal{F}^*_t\right] + \\ &+k^{F*}_c\mathbb{E}\left[\frac{\gamma}{1-b}\left(\widehat{c}^*_t - b\widehat{c}^*_{t-1}\right) + \varphi\widehat{c}^W_t - (1+\varphi)\,\widehat{a}^*_t \mid \mathcal{F}^*_t\right],\end{aligned}$
RS	$\widehat{rs}_t \approx \widehat{s}_t + n\left(\widehat{p}^{H*}_t - \widehat{p}^H_t\right) + (1-n)\left(\widehat{p}^{F*}_t - \widehat{p}^F_t\right).$
RP	$\widehat{t}_t = \widehat{p}^F_t - \widehat{p}^H_t,\ \widehat{t}^*_t = -\left(\widehat{p}^{F*}_t - \widehat{p}^{H*}_t\right),\ \widehat{t}^W_t = n\widehat{t}_t - (1-n)\,\widehat{t}^*_t,$
	The Resource Constraint:
CA	$\beta\widehat{B}^{RF}_t \approx \widehat{B}^{RF}_{t-1} + (1-n)\left[(\sigma-1)\,\widehat{t}^W_t + \widehat{rs}_t - \left(\widehat{c}_t - \widehat{c}^*_t\right)\right].$
	The Optimal Decision of the Financial Intermediaries:
UIP	$\mathbb{E}\left[\Delta\widehat{s}_{t+1} - \left(\widehat{i}_t - \widehat{i}^*_t\right) - \delta\widehat{B}^{RF}_t \mid \mathcal{I}_t\right] \approx 0.$
	Variable Definitions:
	$\widehat{c}^W_t \equiv n\widehat{c}_t + (1-n)\,\widehat{c}^*_t,\ \widehat{\pi}^H_t \equiv \widehat{p}^H_t - \widehat{p}^H_{t-1},\ \widehat{\pi}^{H*}_t \equiv \widehat{p}^{H*}_t - \widehat{p}^{H*}_{t-1},$ $\widehat{\pi}^F_t \equiv \widehat{p}^F_t - \widehat{p}^F_{t-1},\ \widehat{\pi}^{F*}_t \equiv \widehat{p}^{F*}_t - \widehat{p}^{F*}_{t-1}.$

Composite Parameters:	
$k_{\pi}^{H} \equiv -\left(\frac{\alpha^{H*}-\alpha^{H}}{\alpha^{H*}}\right)\left(\frac{\varphi\theta(1-n)}{1+\varphi\theta}\right)\varphi\theta n,$	$k_{\pi}^{H*} \equiv \left(\frac{\alpha^{H*}-\alpha^{H}}{\alpha^{H*}}\right)\left(\frac{1-\alpha^{H*}}{1-\alpha^{H}}\right)\left(\frac{1+\varphi\theta n}{1+\varphi\theta}\right)\varphi\theta n,$
$k_{\pi^*}^{H} \equiv \left(\frac{\alpha^{H}-\alpha^{H*}}{\alpha^{H}}\right)\left(\frac{1-\alpha^{H}}{1-\alpha^{H*}}\right)\left(\frac{1+\varphi\theta(1-n)}{1+\varphi\theta}\right)\varphi\theta\left(1-n\right),$	$k_{\pi^*}^{H*} \equiv -\left(\frac{\alpha^{H}-\alpha^{H*}}{\alpha^{H}}\right)\left(\frac{\varphi\theta n}{1+\varphi\theta}\right)\varphi\theta\left(1-n\right),$
$k_{c}^{H} \equiv \Phi^{H}\left(\frac{1+\varphi\theta(1-n)}{1+\varphi\theta}\right)-\Phi_{H}^{H*}\left(\frac{\varphi\theta(1-n)}{1+\varphi\theta}\right),$	$k_{c}^{H*} \equiv \Phi^{H*}\left(\frac{1+\varphi\theta n}{1+\varphi\theta}\right)-\Phi_{H*}^{H}\left(\frac{\varphi\theta n}{1+\varphi\theta}\right),$
$k_{rs}^{H} \equiv \Phi_{H}^{H*}\left(\frac{\varphi\theta(1-n)}{1+\varphi\theta}\right),$	$k_{rs}^{H*} \equiv -\Phi^{H*}\left(\frac{1+\varphi\theta n}{1+\varphi\theta}\right),$
$k_{t}^{H} \equiv \begin{bmatrix} \Phi^{H}\left(\frac{(1-n)(1+\varphi\theta(1-n))(1+\varphi\sigma n)}{1+\varphi\theta}\right)- \\ -\Phi_{H}^{H*}\left(\frac{(1-n)^2\varphi\theta(\varphi\sigma n)}{1+\varphi\theta}\right) \end{bmatrix},$	$k_{t}^{H*} \equiv \begin{bmatrix} \Phi^{H*}\left(\frac{(1-n)n\varphi\sigma(1+\varphi\theta n)}{1+\varphi\theta}\right)- \\ -\Phi_{H*}^{H}\left(\frac{(1-n)n\varphi\theta(1+\varphi\sigma n)}{1+\varphi\theta}\right) \end{bmatrix},$
$k_{t^*}^{H} \equiv \begin{bmatrix} \Phi_{H}^{H*}\left(\frac{(1-n)^2(1+\varphi\sigma(1-n))\varphi\theta}{1+\varphi\theta}\right)- \\ -\Phi^{H}\left(\frac{(1-n)^2(1+\varphi\theta(1-n))\varphi\sigma}{1+\varphi\theta}\right) \end{bmatrix},$	$k_{t^*}^{H*} \equiv \begin{bmatrix} \Phi_{H*}^{H}\left(\frac{(1-n)^2(\varphi\theta n)\varphi\sigma}{1+\varphi\theta}\right)- \\ -\Phi^{H*}\left(\frac{(1-n)(1+\varphi\theta n)(1+\varphi\sigma(1-n))}{1+\varphi\theta}\right) \end{bmatrix},$
$k_{\pi}^{F} \equiv -\left(\frac{\alpha^{F*}-\alpha^{F}}{\alpha^{F*}}\right)\left(\frac{\varphi\theta(1-n)}{1+\varphi\theta}\right)\varphi\theta n,$	$k_{\pi}^{F*} \equiv \left(\frac{\alpha^{F*}-\alpha^{F}}{\alpha^{F*}}\right)\left(\frac{1-\alpha^{F*}}{1-\alpha^{F}}\right)\left(\frac{(1+\varphi\theta n)\varphi\theta n}{1+\varphi\theta}\right),$
$k_{\pi^*}^{F} \equiv \left(\frac{\alpha^{F}-\alpha^{F*}}{\alpha^{F}}\right)\left(\frac{1-\alpha^{F}}{1-\alpha^{F*}}\right)\left(\frac{\varphi\theta(1-n)(1+\varphi\theta(1-n))}{1+\varphi\theta}\right),$	$k_{\pi^*}^{F*} \equiv -\left(\frac{\alpha^{F}-\alpha^{F*}}{\alpha^{F}}\right)\left(\frac{(\varphi\theta n)\varphi\theta(1-n)}{1+\varphi\theta}\right),$
$k_{c}^{F} \equiv \Phi^{F}\left(\frac{1+\varphi\theta(1-n)}{1+\varphi\theta}\right)-\Phi_{F}^{F*}\left(\frac{\varphi\theta(1-n)}{1+\varphi\theta}\right),$	$k_{c}^{F*} \equiv \Phi^{F*}\left(\frac{1+\varphi\theta n}{1+\varphi\theta}\right)-\Phi_{F*}^{F}\left(\frac{\varphi\theta n}{1+\varphi\theta}\right),$
$k_{rs}^{F} \equiv \Phi^{F}\left(\frac{1+\varphi\theta(1-n)}{1+\varphi\theta}\right),$	$k_{rs}^{F*} \equiv -\Phi_{F*}^{F}\left(\frac{\varphi\theta n}{1+\varphi\theta}\right),$
$k_{t}^{F} \equiv \begin{bmatrix} \Phi_{F}^{F*}\left(\frac{n^2\varphi\theta(1-n)\varphi\sigma}{1+\varphi\theta}\right)- \\ -\Phi^{F}\left(\frac{n(1+\varphi\theta(1-n))(1+\varphi\sigma n)}{1+\varphi\theta}\right) \end{bmatrix},$	$k_{t}^{F*} \equiv \begin{bmatrix} \Phi_{F*}^{F}\left(\frac{n^2\varphi\theta(1+\varphi\sigma n)}{1+\varphi\theta}\right)- \\ -\Phi^{F*}\left(\frac{n^2(1+\varphi\theta n)\varphi\sigma}{1+\varphi\theta}\right) \end{bmatrix},$
$k_{t^*}^{F} \equiv \begin{bmatrix} \Phi^{F}\left(\frac{n\varphi\sigma(1-n)(1+\varphi\theta(1-n))}{1+\varphi\theta}\right)- \\ -\Phi_{F}^{F*}\left(\frac{n\varphi\theta(1-n)(1+\varphi\sigma(1-n))}{1+\varphi\theta}\right) \end{bmatrix},$	$k_{t^*}^{F*} \equiv \begin{bmatrix} \Phi^{F*}\left(\frac{n(1+\varphi\theta n)(1+\varphi\sigma(1-n))}{1+\varphi\theta}\right)- \\ -\Phi_{F*}^{F}\left(\frac{n\varphi\sigma(1-n)(\varphi\theta n)}{1+\varphi\theta}\right) \end{bmatrix},$
$\Phi_{H*}^{H} \equiv \left(\frac{\left(1-\beta\alpha^{H}\right)\left(1-\alpha^{H*}\right)}{\alpha^{H}}\right),$	$\Phi_{H}^{H*} \equiv \left(\frac{\left(1-\beta\alpha^{H*}\right)\left(1-\alpha^{H}\right)}{\alpha^{H*}}\right),$
$\Phi_{F*}^{F} \equiv \left(\frac{\left(1-\beta\alpha^{F}\right)\left(1-\alpha^{F*}\right)}{\alpha^{F}}\right),$	$\Phi_{F}^{F*} \equiv \left(\frac{\left(1-\beta\alpha^{F*}\right)\left(1-\alpha^{F}\right)}{\alpha^{F*}}\right),$
$\Phi^{i} \equiv \left(\frac{\left(1-\beta\alpha^{i}\right)\left(1-\alpha^{i}\right)}{\alpha^{i}}\right),\ i=H,H^*,F,F^*,$	
$\delta \equiv \lambda\frac{1}{1-b}\left(\frac{1-\beta}{\chi}\right)^{\frac{1}{\gamma}}.$	

B.1 The Demand- and Supply-Side of the Economy

The *IS* Equations. The IS equations, IS^H and IS^F, are derived directly from a log linear approximation of the Euler equations $(A.5)$ and $(A.6)$. I also use the definition of the price indexes, P_t and P_t^*. These formulas show that the price dynamics matter in order to determine the consumption path for each representative household. Therefore, the structure of firms becomes relevant to understand the path of consumption. Habit formation and monetary policy, in as much as it influences the evolution of the nominal interest rate, are important constraints too.

The relative IS equation, IS^R, is obtained by substracting the IS^F from the IS^H equation, i.e.

$$\begin{aligned}
&\frac{\gamma}{1-b}\left\{\mathbb{E}\left[\Delta\widehat{c}_{t+1}-b\Delta\widehat{c}_t \mid \mathcal{H}_t\right]-\mathbb{E}\left[\Delta\widehat{c}^*_{t+1}-b\Delta\widehat{c}^*_t \mid \mathcal{H}^*_t\right]\right\} \\
&\approx\left\{\mathbb{E}\left[\widehat{i}_t-n\widehat{\pi}^H_{t+1}-(1-n)\,\widehat{\pi}^F_{t+1} \mid \mathcal{H}_t\right]-\mathbb{E}\left[\widehat{i}^*_t-n\widehat{\pi}^{H*}_{t+1}-(1-n)\,\widehat{\pi}^{F*}_{t+1} \mid \mathcal{H}^*_t\right]\right\}- \\
&-\left\{\mathbb{E}\left[\Delta\widehat{\xi}_{t+1} \mid \mathcal{H}_t\right]-\mathbb{E}\left[\Delta\widehat{\xi}^*_{t+1} \mid \mathcal{H}^*_t\right]\right\}, \qquad \text{(B.1)}
\end{aligned}$$

where I denote the inflation of the bundle $i=H,F$ as $\widehat{\pi}^i_{t+1}\equiv\widehat{p}^i_{t+1}-\widehat{p}^i_t$. I argue that the expected consumption growth rate differential across countries is affected by the habit, the nominal interest rates, the dynamics of prices for domestic and foreign firms, and preference shocks. I interpret the arguments inside the first bracket on the right-hand side of the equation as the difference between Fisher's real interest rate at home and abroad. This *risk-sharing* condition also depends on the different information available to households in either country.

The *MM* Equations. The MM equations, MM^H and MM^F, are easily derived from the money-market clearing conditions. A pair of stable money demand functions à la Cagan is obtained from the log linear approximation of the representative household's first-order conditions in $(A.7)$ and $(A.8)$. The demand for real balances depends on the nominal interest rate, per capita consumption (instead of aggregate output), habit formation, consumption prices, and monetary shocks.

If I take the difference between the MM^H and MM^F equations, I can express the interest rate differential as,

$$\widehat{i}^R_t\approx\gamma\left(\frac{1-\beta}{\beta}\right)\left[\frac{1}{1-b}\left(\widehat{c}^R_t-b\widehat{c}^R_{t-1}\right)-\left(\widehat{m}_t-\widehat{m}^*_t\right)+\left(\widehat{p}_t-\widehat{p}^*_t\right)\right], \qquad \text{(B.2)}$$

where the relative consumption is defined as $\widehat{c}^R_t\equiv\widehat{c}_t-\widehat{c}^*_t$ and the interest rate spread as $\widehat{i}^R_t\equiv\widehat{i}_t-\widehat{i}^*_t$. In other words, the interest rate differential moves with relative monetary shocks, relative consumption (adjusted by the habit) across countries, and relative CPI prices.

The *AS* Equations[30]. The AS equations, AS^H, AS^{H*}, AS^F and AS^{F*}, come from a model with Calvo-style price-setting firms and LCP pricing. The pair of equations AS^H and AS^{H*} is obtained from the log linearization of the optimal price-setting rules, equations $(A.13)$ and $(A.14)$, and the home and foreign price sub-indexes of the domestic bundle, equations $(A.15)$ and $(A.16)$. Similarly, I derive the pair AS^F and AS^{F*} from the log linearization of the foreign firms' first-order conditions and the price sub-indexes of the foreign bundle of goods.

The inflation dynamics depend on the expectations of the future inflation rate given all the available information, and deviations of the real marginal cost from steady state. The specification of the real marginal cost is linked to output demand through the market clearing conditions and the linearity of technology. I obtain the log linear approximation of the labor supply functions from the representative household's first-order conditions in $(A.9)$ and $(A.10)$. I also approximate the domestic output demand described in $(A.11)$ and $(A.12)$, and the corresponding counterparts for the foreign output demand. Then, I observe that the

[30] An important feature of my model is that while preferences and technologies are symmetric, the nominal side (pricing contracts) is more asymmetric. This shows up on the aggregate supply (or AS) equations.

real marginal cost moves with relative prices in both currencies, per capita consumption, the real exchange rate, and random TFP shocks.

Other Definitions. The RP equations, *RP*, are directly derived from the definitions of relative prices in (8). They show that movements in relative prices depend on the inflation differential between imported goods and local goods expressed in units of the local currency. These definitions point out that relative prices are directly linked to the price-setting strategy of firms. The model is completed with the RS equation, *RS*, which approximates the real exchange rate as a weighted combination of the nominal exchange rate and the firms' pricing differences across markets. This characterization is based upon the log linear approximation of the domestic CPI price in (4), its symmetric foreign counterpart, and the definition of the real exchange rate itself in (7).

B.2 The Current Account and the Role of Financial Intermediaries

The *CA* Equation. I linearize the resource constraint, equation (A.20), around its deterministic steady state. The approximation is with respect to the level of real net foreign assets and the log of per capita consumption and prices. As a consequence, I derive the fundamental CA equation, *CA*, as follows

$$\begin{aligned} \beta \widehat{B}_t^{RF} &\approx \widehat{B}_{t-1}^{RF} + \widehat{ca}_t, \\ \widehat{ca}_t &\equiv (1-n)\left[(\sigma-1)\,\widehat{t}_t^{W} + \widehat{rs}_t - \widehat{c}_t^{R}\right], \end{aligned} \tag{B.5}$$

where $\widehat{ca}_t$ measures the per capita (real) current account and $\widehat{t}_t^W \equiv n\widehat{t}_t - (1-n)\,\widehat{t}_t^*$ tracks the world relative prices[31]. $\widehat{B}_t^{RF} \equiv \frac{S_t B_t^F}{P_t}\frac{1}{C}$ represents the real per capita net foreign asset position instrumented by the representative financial intermediary, relative to domestic steady state consumption. Hence, changes in $\widehat{B}_t^{RF}$ can be interpreted as movements in the capital account. The *CA* equation is similar to the expression derived by Thoenissen (2003) around the zero-current account steady state.

The *UIP* Condition. The UIP equation, *UIP*, comes from the log linearization of the representative financial intermediary's first-order condition in (A.17). Deviations of the *UIP* condition, hence, are proportional to the position in real net foreign assets taken by the intermediary, and unrelated to the LOOP condition. Unless the current account is balanced each period, the *UIP* condition does not hold, i.e.

$$\mathbb{E}\left[\Delta \widehat{s}_{t+1} - \widehat{i}_t^R - \delta \widehat{B}_t^{RF} \mid \mathcal{I}_t\right] \approx 0, \tag{B.6}$$

and the spread in nominal interest rates reflects movements in the expected exchange rate and a foreign exchange risk premium. The premium is time-varying and depends on the size of the real net foreign asset position, $\widehat{B}_t^{RF}$, and the cost of bond-holdings, $\delta \equiv \lambda \frac{1}{1-b}\left(\frac{1-\beta}{\chi}\right)^{\frac{1}{\gamma}}$. The composite parameter δ measures the elasticity of the interest rate differential to movements in real net foreign assets. The risk premium is positive or negative depending on whether the financial intermediary is a borrower or a lender for the home country.

[31] Whenever $\widehat{t}_t^W > 0$, then foreign-produced goods are relatively more expensive and world demand is shifted towards home-produced goods.

C Description of the Dataset

I identify the United States with the home country and the 12 member country Euro-zone (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain) with the foreign country. I also report some data for the United Kingdom for comparison purposes. Whenever possible I use data sources comparable to those of Chari *et al.* (2002), and similarly collect all quarterly data spanning the post-Bretton Woods period of 1973:I-2006:III (for a total of 135 observations per series). The sample period considered ends up before Slovenia became a member of the Euro-zone in January 2007. All data (except nominal prices, interest rates and exchange rates) is seasonally adjusted.

The Euro currency was introduced in non-physical form (travellers' checks, electronic transfers, banking, etc.) and the bilateral exchange rates where locked for all participating countries on January 1, 1999 (on June 19, 2000 for Greece). The new notes and coins did not circulate until January 1st, 2002. Whenever available, I rely on aggregate data computed by the OECD methodology to preclude exchange rate movements from affecting the real variables. I also construct a synthetic GDP-weighted series for the U.S. Dollar/Euro nominal exchange rate and the EURIBOR prior to 2001 based on country-by-country data. More details can be found in the dataset's companion description file.

Data Series. I collect information on real output (rgdp), real consumption (rcons), consumer price indexes (cpi), nominal exchange rates (ner), employment (emp), short-term nominal interest rates (i), population size (n), U.S. terms of trade (tot), and money with zero maturity (mzm).

∘ Real output (rgdp). Data at quarterly frequency, transformed to millions of national currency, and seasonally adjusted. Source: OECD's *Main Economic Indicators*, and OECD's *Quarterly National Accounts*.

∘ Real consumption (rcons). Data at quarterly frequency, transformed to millions of national currency, and seasonally adjusted. Source: OECD's *Main Economic Indicators*, and OECD's *Quarterly National Accounts*.

∘ Consumer price indexes (cpi). Data at quarterly frequency, expressed in percentages, and not seasonally adjusted. Source: OECD's *Main Economic Indicators*.

∘ Nominal exchange rate (ner). Data at quarterly frequency, transformed to be quoted as U.S. Dollars per National Currency (US$/National Currency), and not seasonally adjusted. Sources: Board of Governors of the Federal Reserve System, IMF's *International Financial Statistics*, and OECD's *Annual National Accounts*.

∘ Employment (emp). Data at quarterly frequency, expressed in thousands of employees and self-employed individuals, and seasonally adjusted. Source: OECD's *Economic Outlook*.

∘ (Working-age) Population between 15-64 years old (pop): Data at quarterly frequency, expressed in thousands of individuals, and seasonally adjusted. Source: OECD's *Economic Outlook*.

∘ Money market interest rates at 3-month maturity (i): Data at quarterly frequency, expressed in percentages, and not seasonally adjusted. Source: Eurostat.

∘ U.S. terms of trade (for all goods and services) = U.S. import deflator (for all goods and services) / U.S. export deflator (for all goods and services) (tot): Data at quarterly frequency, expressed in percentages, and not seasonally adjusted. Source: OECD's *Economic Outlook*.

∘ Money with zero maturity (mzm): Data at quarterly frequency, expressed in millions of the national currency, and seasonally adjusted. Source: Board of Governors of the Federal Reserve System, Bank of

England, and European Central Bank.

Updating Procedure. The real output (rgdp), real consumption (rcons), employment (emp), and the money with zero maturity (mzm) are expressed in per capita terms dividing each one of these series by the population size (n). I compute the ratio of CPI indexes, $P_t^R \equiv \left(\frac{P_t^*}{P_t}\right)^{-1}$, the real exchange rate, $RS_t \equiv \frac{S_t P_t^*}{P_t}$, and the consumption differential across countries, $C_t^R \equiv \frac{C_t}{C_t^*}$, from the dataset described before. Similarly, I proxy the exogenous shocks as follows,

$$\begin{aligned}
\text{productivity shocks } \{a, a^*\} &\equiv \text{ per capita rgdp / per capita emp}, \\
\text{preference shocks } \{\xi, \xi^*\} &\equiv \mu \cdot [i(-1) - 100 \cdot (\ln(cpi) - \ln(cpi(-1)))], \ \mu = 0.1, \\
\text{monetary supply shocks } \{m, m^*\} &\equiv \text{ mzm}.
\end{aligned}$$

I express all variables in logs, except the nominal short-term interest rates and the preference shocks. I also multiply all data by 100, except the nominal short-term interest rates (which come already in percentages) and the preference shocks. Finally, all series are Hodrick-Prescott (H-P) filtered to eliminate their underlying trend. I use the H-P smoothing parameter at 1600 for my quarterly dataset.

Tables

Table 1: The Standard Deviations and First-order Autocorrelations of the Exchange Rates.

Historical Statistics: Standard Deviations									
Foreign Country	$\sigma(\widehat{c})$	$\sigma(\widehat{c}^{*})$	$\sigma(\widehat{c}^{R})$	$\sigma(\widehat{p})$	$\sigma(\widehat{p}^{*})$	$\sigma(-\widehat{p}^{R})$	$\sigma(\widehat{rs})$	$\sigma(\widehat{s})$	$\sigma(\widehat{tot})$
U.K.	1.236	1.535	1.568	1.373	1.744	1.544	7.533	7.795	2.709
Euro12	1.236	1.044	1.232	1.373	0.908	1.287	7.683	7.989	2.709
Historical Statistics: First-Order Autocorrelations									
Foreign	$\rho(\widehat{c})$	$\rho(\widehat{c}^{*})$	$\rho(\widehat{c}^{R})$	$\rho(\widehat{p})$	$\rho(\widehat{p}^{*})$	$\rho(-\widehat{p}^{R})$	$\rho(\widehat{rs})$	$\rho(\widehat{s})$	$\rho(\widehat{tot})$
U.K.	0.866	0.788	0.748	0.933	0.823	0.774	0.823	0.843	0.817
Euro12	0.866	0.822	0.800	0.933	0.918	0.928	0.848	0.859	0.817

The standard deviations and first-order autocorrelations of the exchange rates, the CPI prices, the terms of trade and the per capita consumption in the U.S., the U.K. and the Euro-zone (12). Quarterly sample: 1973:I-2006:III. Sources: OECD and FRB/FRBNY.

This table reports the statistics after each series has been expressed in logs, multiplied by 100 and H-P filtered (smoothing parameter=1600). The superscript "*" denotes the foreign country, while no superscript indicates the U.S. The superscript "R" denotes a relative variable, computed as the ratio of the U.S. value over the foreign value.

Table 2: The Cross-correlation of the Exchange Rates.

Historical Statistics: The Correlation Matrix for the US-UK.									
	$\widehat{c}$	$\widehat{c}^*$	$\widehat{c}^R$	$\widehat{p}$	$\widehat{p}^*$	$-\widehat{p}^R$	$\widehat{rs}$	$\widehat{s}$	$\widehat{tot}$
$\widehat{c}$	1	0.376	0.421	-0.770	-0.499	0.121	-0.188	-0.206	-0.447
$\widehat{c}^*$		1	-0.683	-0.193	-0.543	-0.441	0.320	0.397	0.074
$\widehat{c}^R$			1	-0.419	0.138	0.528	-0.462	-0.551	-0.425
$\widehat{p}$				1	0.531	-0.289	0.209	0.260	0.595
$\widehat{p}^*$					1	0.657	0.103	-0.031	0.192
$-\widehat{p}^R$						1	-0.070	-0.266	-0.312
$\widehat{rs}$							1	0.980	0.481
$\widehat{s}$								1	0.527
$\widehat{tot}$									1

The cross-correlation of the exchange rates, the CPI prices, the terms of trade and the per capita consumption in the U.S. and the U.K. Quarterly sample: 1973:I-2006:III. Sources: OECD and FRB/FRBNY.

This table reports the statistics after each series has been expressed in logs, multiplied by 100 and H-P filtered (smoothing parameter=1600). The superscript "*" denotes the U.K., while no superscript indicates the U.S. The superscript "R" denotes a relative variable, computed as the ratio of the U.S. value over the U.K. value.

Historical Statistics: The Correlation Matrix for the US-Euro12.									
	$\widehat{c}$	$\widehat{c}^*$	$\widehat{c}^R$	$\widehat{p}$	$\widehat{p}^*$	$-\widehat{p}^R$	$\widehat{rs}$	$\widehat{s}$	$\widehat{tot}$
$\widehat{c}$	1	0.426	0.642	-0.770	-0.560	0.427	-0.007	-0.076	-0.447
$\widehat{c}^*$		1	-0.420	-0.138	-0.681	-0.334	0.266	0.309	0.164
$\widehat{c}^R$			1	-0.656	0.015	0.711	-0.233	-0.338	-0.587
$\widehat{p}$				1	0.423	-0.769	-0.176	-0.045	0.595
$\widehat{p}^*$					1	0.254	-0.492	-0.514	-0.004
$-\widehat{p}^R$						1	-0.160	-0.314	-0.637
$\widehat{rs}$							1	0.987	0.275
$\widehat{s}$								1	0.367
$\widehat{tot}$									1

The cross-correlation of the exchange rates, the CPI prices, the terms of trade and the per capita consumption in the U.S. and the Euro-zone (12). Quarterly sample: 1973:I-2006:III. Sources: OECD and FRB/FRBNY.

This table reports the statistics after each series has been expressed in logs, multiplied by 100 and H-P filtered (smoothing parameter=1600). The superscript "*" denotes the Euro-zone (12), while no superscript indicates the U.S. The superscript "R" denotes a relative variable, computed as the ratio of the U.S. value over the Euro-zone value.

Table 3: The Benchmark Parametrization.

		Benchmark	Sensitivity Analysis
Parameters on Households' Preferences:			
Discount Factor	$\beta =$	0.99264	$=$
Elasticity of Intratemporal Substitution	$\sigma =$	1.5	$=$
Elasticity of Substitution across Varieties	$\theta =$	7.88	$=$
Coeff. of Relative Risk Aversion on Consumption	$\gamma =$	5	$=$
Elasticity of Labor Supply	$\varphi =$	0.47	$=$
Home Population Size	$n =$	0.5	$=$
Rate of Habit Formation	$b=$	0	$(0, 0.7)$
Parameters on Contract Duration for Firms:			
Domestic Firms, Domestic Market	$\alpha^{H}=$	0.62	$(0.407, 0.77)$
Foreign Firms, Domestic Market	$\alpha^{H*}=$	0.62	$(0.407, 0.77)$
Domestic Firms, Foreign Market	$\alpha^{F}=$	0.62	$(0.407, 0.77)$
Foreign Firms, Foreign Market	$\alpha^{F*}=$	0.62	$(0.407, 0.77)$
Parameters of the Financial Intermediaries:			
Cost of Borrowing	$\delta =$	0	$(0, 0.007)$

The table defines benchmark parameterization and the choice of a range of values to perform a sensitivity analysis on the structural parameters.

The results of the sensitivity analysis for a given parameter are discussed in the paper, but not always reported. They can be obtained directly from the author upon request.

Table 4: The VAR(1) Estimate for the Exogenous Shocks.

Unrestricted Vector Autoregression: VAR Estimates.						
	$\widehat{a}$	$\widehat{a}^*$	$\widehat{\xi}$	$\widehat{\xi}^*$	$\widehat{m}$	$\widehat{m}^*$
$\widehat{a}\,(-1)$	0.629733	0.230683	0.026259	0.006613	−0.410905	0.154250
	(0.06884)	(0.08196)	(0.00998)	(0.00873)	(0.22729)	(0.09927)
	[9.14727]	[2.81468]	[2.63128]	[0.75745]	[−1.80787]	[1.55382]
$\widehat{a}^*\,(-1)$	−0.036490	0.625283	0.011617	0.016107	−0.508933	0.052552
	(0.06738)	(0.08022)	(0.00977)	(0.00854)	(0.22246)	(0.09716)
	[−0.54155]	[7.79507]	[1.18935]	[1.88505]	[−2.28779]	[0.54088]
$\widehat{\xi}\,(-1)$	−1.013730	0.732993	0.411090	0.045075	1.172220	−0.332070
	(0.66246)	(0.78864)	(0.09603)	(0.08401)	(2.18709)	(0.95525)
	[−1.53026]	[0.92944]	[4.28080]	[0.53656]	[0.53597]	[−0.34763]
$\widehat{\xi}^*\,(-1)$	−0.994457	−1.520153	−0.002674	0.779898	0.774224	0.514914
	(0.50616)	(0.60257)	(0.07337)	(0.06419)	(1.67108)	(0.72987)
	[−1.96470]	[−2.52276]	[−0.03644]	[12.1503]	[0.46331]	[0.70548]
$\widehat{m}\,(-1)$	0.006538	−0.007544	−0.014241	−0.002399	0.929400	−0.005039
	(0.02070)	(0.02465)	(0.00300)	(0.00263)	(0.06835)	(0.02986)
	[0.31576]	[−0.30609]	[−4.74484]	[−0.91362]	[13.5968]	[−0.16877]
$\widehat{m}^*\,(-1)$	−0.048203	−0.003948	−0.002418	−0.006407	0.220953	0.623044
	(0.05947)	(0.07080)	(0.00862)	(0.00754)	(0.19635)	(0.08576)
	[−0.81052]	[−0.05576]	[−0.28047]	[−0.84948]	[1.12532]	[7.26515]
R-squared	0.597871	0.610109	0.658485	0.672485	0.821959	0.452414
Adj. R-squared	0.581656	0.594388	0.644715	0.659279	0.814780	0.430334
Sum sq. resids	33.75111	47.83320	0.709245	0.542760	367.8790	70.17849
S.E. equation	0.521715	0.621089	0.075629	0.066160	1.722430	0.752300
F-statistic	36.87179	38.80756	47.81766	50.92168	114.4941	20.48966
Log likelihood	−96.80814	−119.4741	154.2588	171.6485	−252.0763	−144.3900
Akaike AIC	1.581664	1.930370	−2.280904	−2.548438	3.970404	2.313692
Schwarz SC	1.714011	2.062718	−2.148556	−2.416090	4.102752	2.446040
Mean dependent	−0.034542	−0.025263	−0.001005	0.000151	−0.001382	0.006440
S.D. dependent	0.806616	0.975211	0.126882	0.113343	4.002195	0.996738
Determinant resid covariance (dof adj.)			$1.80E-06$			
Determinant resid covariance			$1.36E-06$			
Log likelihood			−228.5377			
Akaike information criterion			4.069811			
Schwarz criterion			4.863897			

The table identifies the unrestricted VAR(1) estimates used to calibrate the structure of the stochastic process for the exogenous shocks in the model. Quarterly sample (adjusted): 1974:II-2006:III. Included observations: 130 after adjustments. Standard errors in () and t-statistics in [].

This table reports the estimates after each series (except the preference shocks) has been expressed in logs and multiplied by 100. All series are H-P filtered (smoothing parameter=1600). The superscript "*" denotes the Euro-zone (12), while no superscript indicates the U.S.

The results may be sensitive to the data used to represent (or proxy) for the exogenous shocks of the model. I have experimented with other alternative datasets and specifications, but chose not to report the findings here. More details can be obtained directly from the author upon request.

Restricted Vector Autoregression: VAR Estimates.

	$\widehat{a}$	$\widehat{a}^{*}$	$\widehat{\xi}$	$\widehat{\xi}^{*}$	$\widehat{m}$	$\widehat{m}^{*}$
$\widehat{a}\,(-1)$	0.617028 (0.064006) [9.640096]	0.206849 (0.078309) [2.641440]	0.031405 (0.008628) [3.639724]	0	-0.479832 (0.212063) [-2.262687]	0.139174 (0.081528) [1.707062]
$\widehat{a}^{*}\,(-1)$	0	0.664639 (0.058219) [11.41627]	0	0.018137 (0.006086) [2.980305]	-0.366607 (0.171143) [-2.142105]	0
$\widehat{\xi}\,(-1)$	-1.297907 (0.409074) [-3.172792]	0	0.417548 (0.091137) [4.581546]	0	0	0
$\widehat{\xi}^{*}\,(-1)$	-0.878547 (0.495679) [-1.772413]	-1.072500 (0.545799) [-1.965007]	0	0.823080 (0.052647) [15.63402]	0	0
$\widehat{m}\,(-1)$	0	0	-0.015047 (0.002923) [-5.147325]	0	0.904611 (0.042473) [21.29839]	0
$\widehat{m}^{*}\,(-1)$	0	0	0	0	0	0.648903 (0.066385) [9.774887]
R-squared	0.589306	0.599965	0.653438	0.656416	0.819224	0.449022
Adj. R-squared	0.582839	0.593665	0.647981	0.653732	0.816377	0.444717
Sum sq. resids	34.46999	49.07775	0.719726	0.569389	373.5311	70.61317
S.E. equation	0.520977	0.621642	0.075280	0.066696	1.714990	0.742742
Log likelihood	-98.17806	-121.1436	153.3052	168.5351	-253.0674	-144.7914
Akaike AIC	1.556585	1.909902	-2.312388	-2.562079	3.939498	2.258329
Schwarz SC	1.622759	1.976076	-2.246214	-2.517963	4.005672	2.302444
Mean dependent	-0.034542	-0.025263	-0.001005	0.000151	-0.001382	0.006440
S.D. dependent	0.806616	0.975211	0.126882	0.113343	4.002195	0.996738

The table identifies the restricted VAR(1) estimates for the exogenous shocks in the model. Quarterly sample (adjusted): 1974:II-2006:III. Included observations: 130 after adjustments. Standard errors in () and t-statistics in [].

This table reports the estimates after each series (except the preference shocks) has been expressed in logs and multiplied by 100. All series are H-P filtered (smoothing parameter=1600). The superscript "*" denotes the Euro-zone (12), while no superscript indicates the U.S.

The results may be sensitive to the data used to represent (or proxy) for the exogenous shocks of the model. I have experimented with other alternative datasets and specifications, but chose not to report the findings here. More details can be obtained directly from the author upon request.

Unrestricted VAR: Residual Covariance Matrix.						
	$\widehat{a}$	$\widehat{a}^*$	$\widehat{\xi}$	$\widehat{\xi}^*$	$\widehat{m}$	$\widehat{m}^*$
$\widehat{a}$	0.272186	0.048630	−0.002570	−0.005888	0.074790	0.032637
$\widehat{a}^*$		0.385752	−0.002300	−0.004776	−0.057794	0.270317
$\widehat{\xi}$			0.005720	0.001600	−0.064035	−0.006385
$\widehat{\xi}^*$				0.004377	−0.016485	−0.008619
$\widehat{m}$					2.966766	0.090339
$\widehat{m}$						0.565956

The table reports the residual covariance matrix for the estimated, unrestricted VAR(1) process. For convenience, I use the same notation to identify the residual of a shock that I use for the shock itself. Notice, however, that this table simply represents the covariance of the residuals. Quarterly sample (adjusted): 1974:II-2006:III. Included observations: 130 after adjustments.

This table reports the statistics after each series (except the preference shocks) has been expressed in logs and multiplied by 100. All series are H-P filtered (smoothing parameter=1600). The superscript "*" denotes the Euro-zone (12), while no superscript indicates the U.S.

Unrestricted VAR: Residual Correlation Matrix.						
	$\widehat{a}$	$\widehat{a}^*$	$\widehat{\xi}$	$\widehat{\xi}^*$	$\widehat{m}$	$\widehat{m}^*$
$\widehat{a}$	1	0.150077	−0.065136	−0.170585	0.083228	0.083155
$\widehat{a}^*$		1	−0.048967	−0.116228	−0.054024	0.578533
$\widehat{\xi}$			1	0.319814	−0.491575	−0.112220
$\widehat{\xi}^*$				1	−0.144664	−0.173174
$\widehat{m}$					1	0.069717
$\widehat{m}$						1

The table reports the residual correlation matrix for the estimated, unrestricted VAR(1) process. For convenience, I use the same notation to identify the residual of a shock that I use for the shock itself. Notice, however, that this table simply represents the correlation of the residuals. Quarterly sample (adjusted): 1974:II-2006:III. Included observations: 130 after adjustments.

This table reports the statistics after each series (except the preference shocks) has been expressed in logs and multiplied by 100. All series are H-P filtered (smoothing parameter=1600). The superscript "*" denotes the Euro-zone (12), while no superscript indicates the U.S.

Table 5: The Theoretical Moments of the Model.

		Benchmark				Public Monetary Policy			
Statistics	Data	SSFM	SSF	SSM	DSFM	SSFM	SSF	SSM	DSFM
Standard Deviations relative to U.S. Consumption									
$\sigma\left(\widehat{c}^R\right)/\sigma\left(\widehat{c}\right)$	0.997	1.011	1.056	1.038	0.783	0.965	1.001	1.047	0.769
$\sigma\left(-\widehat{p}^R\right)/\sigma\left(\widehat{c}\right)$	1.041	4.854	5.038	8.301	6.126	5.338	5.530	8.629	6.251
$\sigma\left(\widehat{rs}\right)/\sigma\left(\widehat{c}\right)$	6.216	5.029	5.554	4.946	4.341	3.903	4.335	4.219	3.625
$\sigma\left(\widehat{s}\right)/\sigma\left(\widehat{c}\right)$	6.464	8.272	8.980	6.559	5.571	8.270	8.914	6.453	5.299
$\sigma\left(\widehat{tot}\right)/\sigma\left(\widehat{c}\right)$	2.192	6.237	6.732	4.323	4.084	5.266	5.737	3.360	3.386
First-Order Autocorrelation									
$\rho\left(\widehat{c}^R\right)$	0.800	0.886	0.875	0.916	0.905	0.845	0.830	0.894	0.882
$\rho\left(-\widehat{p}^R\right)$	0.928	0.952	0.951	0.947	0.964	0.950	0.949	0.947	0.964
$\rho\left(\widehat{rs}\right)$	0.848	0.576	0.590	0.695	0.719	0.576	0.597	0.758	0.763
$\rho\left(\widehat{s}\right)$	0.859	0.828	0.829	0.833	0.824	0.831	0.831	0.837	0.827
$\rho\left(\widehat{tot}\right)$	0.817	0.693	0.683	0.599	0.679	0.819	0.782	0.721	0.733
Cross-Correlation									
$\rho\left(\widehat{rs},\widehat{c}^R\right)$	-0.233	0.272	0.301	0.708	0.660	0.410	0.448	0.830	0.780
$\rho\left(\widehat{tot},\widehat{c}^R\right)$	-0.587	-0.314	-0.335	-0.090	0.058	-0.335	-0.371	-0.150	0.039
$\rho\left(\widehat{c},\widehat{c}^*\right)$	0.426	0.496	0.428	0.571	0.793	0.549	0.492	0.561	0.810
$\rho\left(\widehat{s},-\widehat{p}^R\right)$	-0.314	-0.831	-0.831	-0.803	-0.728	-0.925	-0.926	-0.883	-0.815
$\rho\left(\widehat{s},\widehat{rs}\right)$	0.987	0.843	0.863	-0.022	0.255	0.854	0.876	-0.276	0.056

Exchange rates, CPI prices and per capita consumption statistics under the benchmark of asymmetric information or asymmetric information with common knowledge about monetary policy. This table reports the selected theoretical moments for each series given my calibration of the structural parameters and the estimation of the stochastic process for the exogenous variables. I use Matlab 7.4.0 to compute the equilibrium, and DYNARE v3.065 for the stochastic simulation. SSMM indicates that the parameterization is $\alpha^H = \alpha^{H*} = \alpha^F = \alpha^{F*} = 0.62$. SSF indicates that the parameterization is $\alpha^H = \alpha^{H*} = 0.5335$ and $\alpha^F = \alpha^{F*} = 0.72$. SSM indicates that the parameterization is $\alpha^H = 0.5335$, $\alpha^{H*} = 0.7$, $\alpha^F = 0.5335$ and $\alpha^{F*} = 0.7$. DSFM indicates that the parameterization is $\alpha^H = 0.407$, $\alpha^{H*} = 0.67$, $\alpha^F = 0.66$ and $\alpha^{F*} = 0.77$. All parameterizations introduce G. Benigno's (2004) pricing wedge between the local and foreign prices of a given good, except SSFM and SSF. The superscript "*" denotes the Euro-zone (12), while no superscript indicates the U.S. The superscript "R" denotes a relative variable, computed as the ratio of the U.S. value over the Euro-zone value.

Statistics	Data	Public Productivity				All Public Information			
		SSFM	SSF	SSM	DSFM	SSFM	SSF	SSM	DSFM
Standard Deviations relative to U.S. Consumption									
$\sigma\left(\widehat{c}^R\right)/\sigma\left(\widehat{c}\right)$	0.997	1.003	1.046	1.054	0.801	0.971	1.009	1.172	0.831
$\sigma\left(-\widehat{p}^R\right)/\sigma\left(\widehat{c}\right)$	1.041	4.778	4.963	8.334	6.149	5.264	5.523	9.026	6.452
$\sigma\left(\widehat{rs}\right)/\sigma\left(\widehat{c}\right)$	6.216	4.896	5.364	4.919	4.270	3.634	4.062	4.356	3.639
$\sigma\left(\widehat{s}\right)/\sigma\left(\widehat{c}\right)$	6.464	8.134	8.784	6.455	5.456	7.955	8.648	6.605	5.326
$\sigma\left(\widehat{tot}\right)/\sigma\left(\widehat{c}\right)$	2.192	6.023	6.493	4.223	4.019	4.985	5.392	3.388	3.337
First-Order Autocorrelation									
$\rho\left(\widehat{c}^R\right)$	0.800	0.880	0.869	0.908	0.892	0.861	0.847	0.893	0.892
$\rho\left(-\widehat{p}^R\right)$	0.928	0.950	0.950	0.944	0.961	0.953	0.952	0.949	0.964
$\rho\left(\widehat{rs}\right)$	0.848	0.595	0.607	0.717	0.745	0.605	0.626	0.793	0.796
$\rho\left(\widehat{s}\right)$	0.859	0.837	0.837	0.841	0.832	0.848	0.848	0.854	0.844
$\rho\left(\widehat{tot}\right)$	0.817	0.695	0.683	0.614	0.691	0.837	0.790	0.761	0.752
Cross-Correlation									
$\rho\left(\widehat{rs},\widehat{c}^R\right)$	-0.233	0.293	0.320	0.727	0.683	0.320	0.354	0.832	0.758
$\rho\left(\widehat{tot},\widehat{c}^R\right)$	-0.587	-0.315	-0.336	-0.085	0.073	-0.359	-0.016	-0.049	0.117
$\rho\left(\widehat{c},\widehat{c}^*\right)$	0.426	0.520	0.457	0.557	0.782	0.537	0.485	0.469	0.769
$\rho\left(\widehat{s},-\widehat{p}^R\right)$	-0.314	-0.836	-0.837	-0.808	-0.735	-0.929	-0.929	-0.890	-0.826
$\rho\left(\widehat{s},\widehat{rs}\right)$	0.987	0.845	0.863	-0.057	0.219	0.843	0.865	-0.328	-0.001

Exchange rates, CPI prices and per capita consumption statistics under the asymmetric information with common knowledge about productivity or symmetric information with common knowledge of all the shocks. This table reports the selected theoretical moments for each series given my calibration of the structural parameters and the estimation of the stochastic process for the exogenous variables. I use Matlab 7.4.0 to compute the equilibrium, and DYNARE v3.065 for the stochastic simulation. SSMM indicates that the parameterization is $\alpha^H = \alpha^{H*} = \alpha^F = \alpha^{F*} = 0.62$. SSF indicates that the parameterization is $\alpha^H = \alpha^{H*} = 0.5335$ and $\alpha^F = \alpha^{F*} = 0.72$. SSM indicates that the parameterization is $\alpha^H = 0.5335$, $\alpha^{H*} = 0.7$, $\alpha^F = 0.5335$ and $\alpha^{F*} = 0.7$. DSFM indicates that the parameterization is $\alpha^H = 0.407$, $\alpha^{H*} = 0.67$, $\alpha^F = 0.66$ and $\alpha^{F*} = 0.77$. All parameterizations introduce G. Benigno's (2004) pricing wedge between the local and foreign prices of a given good, except SSFM and SSF. The superscript "*" denotes the Euro-zone (12), while no superscript indicates the U.S. The superscript "R" denotes a relative variable, computed as the ratio of the U.S. value over the Euro-zone value.

Table 6: The Theoretical Moments of the Model with Risk-Averse Financial Intermediaries.

		$\delta = 0$			$\delta = 0.001$			$\delta = 0.007$		
Statistics	Data	SSFM	SSF	DSFM	SSFM	SSF	DSFM	SSFM	SSF	DSFM
Standard Deviations relative to U.S. Consumption										
$\sigma\left(\widehat{c}^R\right)/\sigma\left(\widehat{c}\right)$	0.997	1.011	1.056	0.783	0.944	0.981	1.060	1.006	1.023	1.087
$\sigma\left(-\widehat{p}^R\right)/\sigma\left(\widehat{c}\right)$	1.041	4.854	5.038	6.126	4.536	4.630	4.484	3.738	3.780	4.290
$\sigma\left(\widehat{rs}\right)/\sigma\left(\widehat{c}\right)$	6.216	5.029	5.554	4.341	4.817	5.194	4.617	4.135	4.345	3.883
$\sigma\left(\widehat{s}\right)/\sigma\left(\widehat{c}\right)$	6.464	8.272	8.980	5.571	7.844	8.337	6.698	6.606	6.896	5.910
$\sigma\left(\widehat{tot}\right)/\sigma\left(\widehat{c}\right)$	2.192	6.237	6.732	4.084	5.694	6.098	4.768	4.844	5.132	4.204
First-Order Autocorrelation										
$\rho\left(\widehat{c}^R\right)$	0.800	0.886	0.875	0.905	0.858	0.849	0.9076	0.868	0.862	0.911
$\rho\left(-\widehat{p}^R\right)$	0.928	0.952	0.951	0.964	0.950	0.949	0.9511	0.948	0.948	0.953
$\rho\left(\widehat{rs}\right)$	0.848	0.576	0.590	0.719	0.575	0.588	0.6607	0.572	0.584	0.631
$\rho\left(\widehat{s}\right)$	0.859	0.828	0.829	0.824	0.824	0.824	0.8260	0.815	0.816	0.824
$\rho\left(\widehat{tot}\right)$	0.817	0.693	0.683	0.679	0.663	0.662	0.6761	0.656	0.661	0.684
Cross-Correlation										
$\rho\left(\widehat{rs}, \widehat{c}^R\right)$	−0.233	0.272	0.301	0.660	0.338	0.364	0.457	0.363	0.385	0.457
$\rho\left(\widehat{tot}, \widehat{c}^R\right)$	−0.587	−0.314	−0.335	0.058	−0.166	−0.219	−0.274	−0.067	−0.153	−0.264
$\rho\left(\widehat{c}, \widehat{c}^*\right)$	0.426	0.496	0.428	0.793	0.539	0.467	0.529	0.452	0.380	0.465
$\rho\left(\widehat{s}, -\widehat{p}^R\right)$	−0.314	−0.831	−0.831	−0.728	−0.828	−0.828	−0.727	−0.820	−0.824	−0.754
$\rho\left(\widehat{s}, \widehat{rs}\right)$	0.987	0.843	0.863	0.255	0.849	0.866	0.745	0.856	0.870	0.689

Exchange rates, CPI prices and per capita consumption statistics under the benchmark of asymmetric information. This table reports the selected theoretical moments for each series given my calibration of the structural parameters and the estimation of the stochastic process for the exogenous variables. I use Matlab 7.4.0 to compute the equilibrium, and DYNARE v3.065 for the stochastic simulation. SSMM indicates that the parameterization is $\alpha^H = \alpha^{H*} = \alpha^F = \alpha^{F*} = 0.62$. SSF indicates that the parameterization is $\alpha^H = \alpha^{H*} = 0.5335$ and $\alpha^F = \alpha^{F*} = 0.72$. DSFM indicates that the parameterization is $\alpha^H = 0.407$, $\alpha^{H*} = 0.67$, $\alpha^F = 0.66$ and $\alpha^{F*} = 0.77$ whenever $\delta = 0$. Alternatively, DSFM indicates that the paremeterization is $\alpha^H = 0.407$, $\alpha^{H*} = 0.77$, $\alpha^F = 0.66$ and $\alpha^{F*} = 0.67$ whenever $\delta = 0.001$ or 0.007 to avoid the indeterminacy/non-existence region. Only the DSFM parameterization introduces G. Benigno's (2004) pricing wedge between the local and foreign prices of a given good. The superscript "*" denotes the Euro-zone (12), while no superscript indicates the U.S. The superscript "R" denotes a relative variable, computed as the ratio of the U.S. value over the Euro-zone value.

Table 7: The Theoretical Moments of the Model with Habit Formation.

		$b=0$		$b=0.25$		$b=0.7$	
Statistics	Data	SSM	DSFM	SSM	DSFM	SSM	DSFM
Standard Deviations relative to U.S. Consumption							
$\sigma\left(\widehat{c}^R\right)/\sigma\left(\widehat{c}\right)$	0.997	1.038	0.783	1.025	0.765	0.892	0.604
$\sigma\left(-\widehat{p}^R\right)/\sigma\left(\widehat{c}\right)$	1.041	8.301	6.126	8.556	6.251	10.306	6.936
$\sigma\left(\widehat{rs}\right)/\sigma\left(\widehat{c}\right)$	6.216	4.946	4.341	5.110	4.450	6.237	5.062
$\sigma\left(\widehat{s}\right)/\sigma\left(\widehat{c}\right)$	6.464	6.559	5.571	6.799	5.699	8.473	6.673
$\sigma\left(\widehat{tot}\right)/\sigma\left(\widehat{c}\right)$	2.192	4.323	4.084	4.490	4.212	5.593	4.984
First-Order Autocorrelation							
$\rho\left(\widehat{c}^R\right)$	0.800	0.916	0.905	0.935	0.938	0.963	0.971
$\rho\left(-\widehat{p}^R\right)$	0.928	0.947	0.964	0.947	0.964	0.946	0.963
$\rho\left(\widehat{rs}\right)$	0.848	0.695	0.719	0.695	0.721	0.690	0.709
$\rho\left(\widehat{s}\right)$	0.859	0.833	0.824	0.833	0.824	0.832	0.824
$\rho\left(\widehat{tot}\right)$	0.817	0.599	0.679	0.601	0.684	0.603	0.689
Cross-Correlation							
$\rho\left(\widehat{rs},\widehat{c}^R\right)$	-0.233	0.708	0.660	0.713	0.661	0.642	0.596
$\rho\left(\widehat{tot},\widehat{c}^R\right)$	-0.587	-0.090	0.058	-0.062	0.075	0.016	0.114
$\rho\left(\widehat{c},\widehat{c}^*\right)$	0.426	0.571	0.793	0.582	0.805	0.666	0.864
$\rho\left(\widehat{s},-\widehat{p}^R\right)$	-0.314	-0.803	-0.728	-0.802	-0.726	-0.796	-0.724
$\rho\left(\widehat{s},\widehat{rs}\right)$	0.987	-0.022	0.255	-0.013	0.260	0.043	0.326

Exchange rates, CPI prices and per capita consumption statistics under the benchmark of asymmetric information. This table reports the selected theoretical moments for each series given my calibration of the structural parameters and the estimation of the stochastic process for the exogenous variables. I use Matlab 7.4.0 to compute the equilibrium, and DYNARE v3.065 for the stochastic simulation. SSM indicates that the parameterization is $\alpha^H = 0.5335$, $\alpha^{H*} = 0.7$, $\alpha^F = 0.5335$, and $\alpha^{F*} = 0.7$. DSFM indicates that the parameterization is $\alpha^H = 0.407$, $\alpha^{H*} = 0.67$, $\alpha^F = 0.66$ and $\alpha^{F*} = 0.77$. Both parameterizations introduce G. Benigno's (2004) pricing wedge between the local and foreign prices of a given good. The superscript "*" denotes the Euro-zone (12), while no superscript indicates the U.S. The superscript "R" denotes a relative variable, computed as the ratio of the U.S. value over the Euro-zone value.

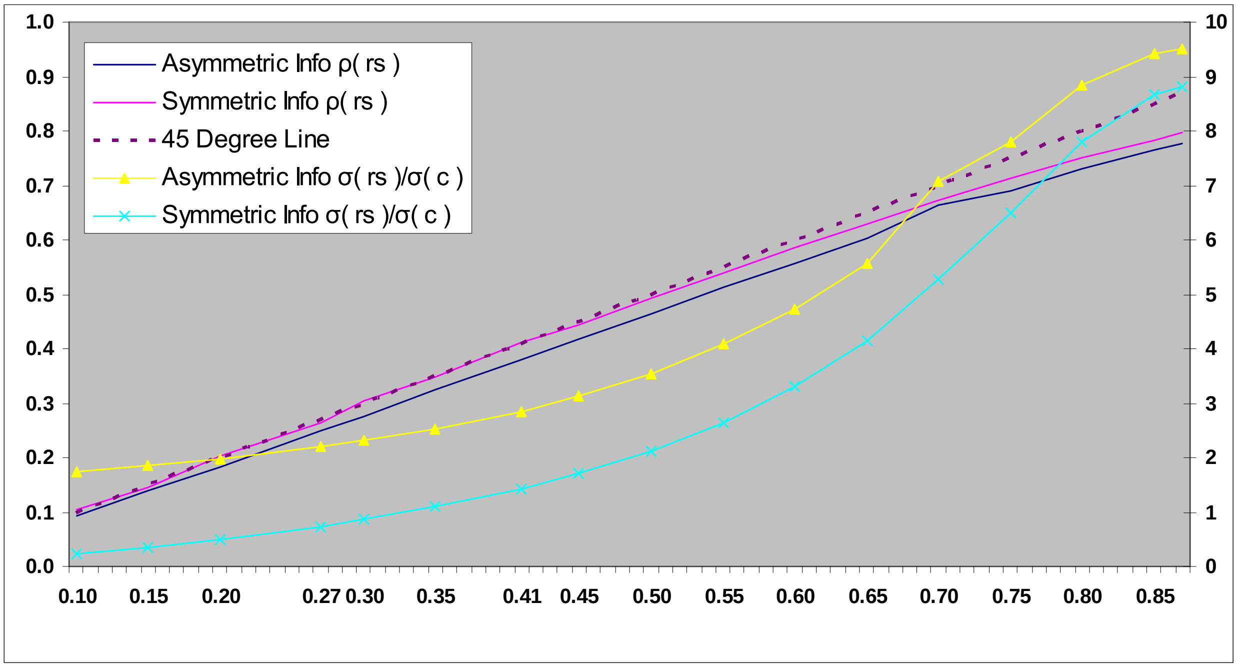
Table 8: The Theoretical Cross-correlations of the Model.

Statistics: The Correlation Matrix.									
The Benchmark under Asymmetrically-Dispersed Information.									
	$\widehat{c}$	$\widehat{c}^*$	$\widehat{c}^R$	$\widehat{p}$	$\widehat{p}^*$	$-\widehat{p}^R$	$\widehat{rs}$	$\widehat{s}$	$\widehat{tot}$
$\widehat{c}$	1	0.496^* (0.426)	0.490^* (0.642)	-0.649^* (-0.770)	-0.754^* (-0.560)	0.243^* (0.427)	-0.067^* (-0.007)	-0.183^* (-0.076)	-0.287^* (-0.447)
$\widehat{c}^*$		1	-0.514^* (-0.420)	-0.704^* (-0.138)	-0.700^* (-0.681)	0.337 (-0.334)	-0.336 (0.266)	-0.402 (0.309)	0.030^* (0.164)
$\widehat{c}^R$			1	0.065 (-0.656)	-0.042 (0.015)	-0.098 (0.711)	0.272 (-0.233)	0.223 (-0.338)	-0.314^* (-0.587)
$\widehat{p}$				1	0.434^* (0.423)	-0.828^* (-0.769)	0.420 (-0.176)	0.741 (-0.045)	0.362^* (0.595)
$\widehat{p}^*$					1	0.146^* (0.254)	0.097 (-0.492)	-0.027^* (-0.514)	-0.098^* (-0.004)
$-\widehat{p}^R$						1	-0.401^* (-0.160)	-0.831^* (-0.314)	-0.459^* (-0.637)
$\widehat{rs}$							1	0.843^* (0.987)	-0.486 (0.275)
$\widehat{s}$								1	-0.026 (0.367)
$\widehat{tot}$									1
The Benchmark under Public Monetary Policy.									
	$\widehat{c}$	$\widehat{c}^*$	$\widehat{c}^R$	$\widehat{p}$	$\widehat{p}^*$	$-\widehat{p}^R$	$\widehat{rs}$	$\widehat{s}$	$\widehat{tot}$
$\widehat{c}$	1	0.549^* (0.426)	0.448^* (0.642)	-0.602^* (-0.770)	-0.761^* (-0.560)	0.160^* (0.427)	-0.101^* (-0.007)	-0.151^* (-0.076)	-0.273^* (-0.447)
$\widehat{c}^*$		1	-0.501^* (-0.420)	-0.700^* (-0.138)	-0.690^* (-0.681)	0.303 (-0.334)	-0.481 (0.266)	-0.422 (0.309)	0.049^* (0.164)
$\widehat{c}^R$			1	0.125 (-0.656)	-0.050 (0.015)	-0.158 (0.711)	0.410 (-0.233)	0.296 (-0.338)	-0.335^* (-0.587)
$\widehat{p}$				1	0.338^* (0.423)	-0.823^* (-0.769)	0.617 (-0.176)	0.822 (-0.045)	0.405^* (0.595)
$\widehat{p}^*$					1	0.255^* (0.254)	0.069 (-0.492)	-0.132^* (-0.514)	-0.173^* (-0.004)
$-\widehat{p}^R$						1	-0.592^* (-0.160)	-0.925^* (-0.314)	-0.520^* (-0.637)
$\widehat{rs}$							1	0.854^* (0.987)	-0.195 (0.275)
$\widehat{s}$								1	0.244^* (0.367)
$\widehat{tot}$									1

Exchange rates, CPI prices and per capita consumption statistics under the benchmark of asymmetric information or asymmetric information with common knowledge about monetary policy. This table reports the selected theoretical moments for each series given my calibration of the structural parameters and the estimation of the stochastic process for the exogenous variables. I use Matlab 7.4.0 to compute the equilibrium, and DYNARE v3.065 for the stochastic simulation. I assume symmetric nominal rigidities across countries and firms, i.e. $\alpha^H = \alpha^{H*} = \alpha^F = \alpha^{F*} = 0.62$. This parameterization does not introduce G. Benigno's (2004) pricing wedge between the local and foreign prices of a given good. The superscript "*" denotes the Euro-zone (12), while no superscript indicates the U.S. The superscript "R" denotes a relative variable, computed as the ratio of the U.S. value over the Euro-zone value.

$(*)$ The superscript indicates that the theoretical cross-correlation has the same sign as the corresponding empirical one. For comparison purposes, the true cross-correlations are also included within parenthesis.

Figure 1: The Volatility and Persistence of the Real Exchange Rate under a Common Degree of Price Stickiness.



The autocorrelation of the real exchange rate and the ratio of the standard deviation of the real exchange rate over the standard deviation of domestic per capita consumption. This figure plots the selected statistics over a grid of points that spans the parameter space (between 0.1 and 0.9). The linear interpolation of the values between two realization is added for illustrative purposes. However, it does not take into account the fact that for some values of the parameter space a solution may not exist or may be indeterminate. The horizontal axis represents a particular choice of the degree of price stickiness under the assumption that $\alpha^H = \alpha^{H*} = \alpha^F = \alpha^{F*}$. All values correspond to the theoretical moments implied by the model. I use Matlab 7.4.0 to compute the equilibrium, and DYNARE v3.065 for the stochastic simulation. No superscript indicates the U.S.