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EXCHANGE RATES AND INTERNATIONAL RELATIVE PRICES AND QUANTITIES IN EQUILIBRIUM MODELS WITH ALTERNATIVE PREFERENCE SPECIFICATIONS

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ABSTRACT

Dynamic open economy models with time separable, deterministic utilities fail to account for observed dynamics of exchange rates and international relative prices and quantities. This paper examines the ability of extensions of existing open economy models to account for exchange rates, international relative prices, and international trade quantities. The extensions involve preferences with taste shocks and non-time separable utilities in habit persistence form. Quantitative properties of calibrated versions of the models are examined in light of time series properties of key international variables.

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1. INTRODUCTION

Recent attention to international aspects of business cycles has given rise to analyses of dynamic equilibrium open economies using, typically, two country extensions of Kydland and Prescott's (1982) real business cycle model. Examples of recent work on international business cycles include Ahmed, Ickes, Wang, and Yoo (1993), Backus, Kehoe, and Kydland (1992, 1995), Baxter (1988), Baxter and Crucini (1993), Dellas (1986), Mendoza (1991), and Stockman and Tesar (1995). Most existing international business cycle models, inhabited by agents with time-additive preferences facing technology shocks, do not account for high volatility or persistence in exchange rate and terms of trade movements. This lack of accounting for key features of the dynamics of real exchange rates and relative goods prices has been labeled the *international relative price puzzle* by Backus, Kehoe, and Kydland (BKK) (1992, 1995). Monetary international real business cycle models retain the puzzle and include lack of accounting for nominal exchange rate dynamics, as shown in recent quantitative analyses by Schlagenhauf and Wrase (1995 a,b).

The difficulty encountered by existing models in accounting for relative price variabilities stems from the strong connection between international relative prices and quantities. According to optimality conditions governing domestic and foreign goods acquisitions, a representative household's intratemporal marginal rate of substitution (MRS) between domestic- and foreign- produced goods is equated with the relative price of the goods. Lacking sufficient volatility in international relative quantities, the models fail to generate the volatilities of relative goods prices and real exchange rates found in actual data. In monetary international models, when agents trade foreign exchange to facilitate the exchange of goods across countries, low volatility in international relative quantities carries over as well to model predictions of a low nominal exchange rate volatility.

Two possible remedies to the international relative price puzzle, which involve alternative preference specifications, are taste shocks and non-time-additive preferences. This paper builds on the existing literature by considering quantitative properties of a monetary open economy business cycle model with preference specifications that allow for taste shocks and non-time-additivity.

Stockman and Tesar (1995) have considered taste shocks in an open economy with a focus on issues other than the international relative price puzzle. They argue that international data properties "...cannot be explained by a model based on technology shocks alone."(p.182). As Schlagenhauf and Wrase (1995 a,b) show, many key properties of international data also cannot be explained by models that include monetary shocks. One environment considered in this paper includes taste shocks of the Stockman and Tesar variety, along with technology and money shock processes estimated from international data. Taste shocks introduce random shifters to agents' marginal utilities and, hence, to the intratemporal MRS that optimizing agents equate with the real exchange rate. Taste shocks consequently have the potential of enabling the model to account for exchange rate and international relative price volatilities. We assess a taste shock model's quantitative properties, including the variability of taste shocks required for a parameterized version of the model to quantitatively account for observed exchange rate and relative price volatilities.

Another environment that we consider incorporates non-time-additive preferences. Non-time-additivity, in the form of habit persistent preferences, has been used in a number of recent analyses that focus on asset pricing implications of general equilibrium models. We consider a variant of Constantinides (1990) habit persistence preferences in an open economy setting. Given habit preferences, a typical agent's consumption quantities chosen today will influence momentary utility today and in the future. As a consequence, the intratemporal MRS that an agent equates with the real exchange rate possesses dynamics that differ from those in a model with non-time-additive preferences. We consider, as with taste shocks, an environment in which agents trade currencies to facilitate goods trades across countries. We also discuss possible extensions of the habit model in which agents trade currencies to facilitate goods and financial asset trades. In such a setting, the nominal exchange rate is determined partly by international relative asset prices. Nominal and real exchange rate volatilities are potentially amplified because habit preferences increase the volatility of a typical agent's intertemporal MRS, which is equated to an asset's nominal return. Because of a link between asset prices and the nominal exchange rate, volatilities of the exchange rates are potentially amplified. Generating amplified exchange rate volatility by linking exchange and interest rates is undesirable in our habit model, however, given counterfactually high nominal interest rate volatilities implied by the model.

The paper proceeds as follows. Section 2 presents statistical properties of exchange rates and international relative prices. Quantitative implications of the models that we construct are evaluated relative to these data properties. Section 3 presents the economic environment. Section 4 provides alternative preference specifications and an evaluation of quantitative properties of parameterized versions of each model economy that we consider. Section 5 concludes.

2. STATISTICAL PROPERTIES OF INTERNATIONAL DATA

Table 1 presents international data features against which we will evaluate the models developed in subsequent sections. Moments in the table are of Hodrick-Prescott filtered quarterly observations of exchange rates, outputs, imports and exports, and relative prices for six major industrialized countries for various flexible exchange rate sample periods. The nominal exchange rate for each country is the bilateral exchange rate vis a vis the U.S. dollar. Real exchange rates are measured using nominal exchange rates and individual country consumer price indexes. The terms of trade, our relative price measure, are measured by the price of exports relative to imports for each country. Data are from the OECD's *Quarterly National Accounts* and the International Monetary Fund's *International Financial Statistics.*

The empirical regularities evident in Table 1 are that exchange rates, nominal and real, the terms of trade, and imports and exports are highly volatile with persistent movements. Averaging across countries in the full sample period 1974:1-1994:2, the standard deviation of the nominal and real exchange rates are close to five times higher than the standard deviation of output. The average terms of trade standard deviation is around 2.5 times that of output. On average, imports are close to three times as volatile as output, and exports over two times as volatile as output. Exchange rate and terms of trade variabilities are highest in the 1980:1-1987:4 period, during which the U.S. dollar experienced a large appreciation and subsequent depreciation. Even when that period is removed from consideration, however, standard deviations of exchange rates and the terms of trade are high relative to output standard deviations. Exchange rates are clearly much more variable than the quantity measures, and the terms of trade are more volatile than imports and exports.

Movements in exchange rates and the terms of trade are also highly persistent, as indicated by first-order autocorrelation coefficients of, on average, roughly 0.85 for exchange rates and 0.76 for the terms of trade across most countries and sample periods. On the quantity side, averaging across countries for the full sample period, the first order autocorrelations are .79 for GDP, imports, and exports.

The main empirical regularities against which the models in this paper are evaluated are that variabilities of nominal and real exchange rates are high relative to output variabilities; variabilities of imports and exports are high relative to output variabilities, but less so than exchange rates; and that exchange rate and international relative price variabilities exceed variabilities in goods flows across countries.[1]

3. EXCHANGE RATES AND RELATIVE PRICES IN EQUILIBRIUM OPEN ECONOMY MODELS

This section presents a series of open economy monetary models that differ according to the specification of preferences. Implications of each model for the dynamics of exchange rates and international relative prices are discussed and quantitative properties of parameterized versions of the models are evaluated. Each model involves two countries, domestic and foreign, linked by trades in goods and currencies. A multi-member household inhabits each country. Household members, referred to as shoppers, firm managers, workers, and financial intermediaries, have distinct tasks to perform in a period in the goods, labor, and financial markets. At each period's completion, all household members unite to pool resources so that all of a country's per household wealth resides with a representative household.

Trading Opportunities

The trading opportunities, objectives, and constraints of households across countries are assumed to be isomorphic. Consequently, for brevity, we provide details only for the representative domestic household's decisions and opportunities. The foreign analogs are straightforward, involving only obvious notation alterations. The representative domestic household begins period t with K_t^D units of capital and A_t^D units of domestic currency carried forward from the previous period.[2] At the beginning of period t, the domestic household divides nominal wealth A_t^D by sending a deposit of N_t^D currency units with its financial intermediary member to the domestic financial market. The remaining $A_t^D - N_t^D$ is allocated to trade in the currency exchange market. In the exchange market, domestic and foreign households trade currencies to arrange balances for use in purchasing consumption goods.

Domestic currency available to the domestic household in the exchange market consists of $A_t^D - N_t^D$, from the initial wealth allocation, along with the household worker's wages. The worker supplies $\tilde{H}_t^D$ labor units in the domestic labor market at nominal wage W_t^D. The household in the foreign exchange market divides $A_t^D - N_t^D + W_t^D \tilde{H}_t^D$ units of domestic currency into a domestic currency balance,

$M^D_{D,t}$, and a foreign currency balance, $M^D_{F,t}$, at nominal exchange rate e_t (expressed in domestic per foreign currency units). The household's nominal allocation in the foreign exchange market is:

$$(1)\quad A^D_t - N^D_t + W^D_t \tilde{H}^D_t = M^D_{D,t} + e_t M^D_{F,t}$$

The household shopper purchases $C^D_{D,t}$units of home produced goods at price P^D_t, and $C^D_{F,t}$ units of foreign goods at price P^F_tsubject to the cash constraints:

$$(2)\quad P^D_t C^D_{D,t} \leq M^D_{D,t}$$

$$(3)\quad P^F_t C^D_{F,t} \leq M^D_{F,t}$$

When the constraints bind as equalities, the shopper and worker combine to return home at the end of the period with goods, but no cash.[3]

The financial intermediary receives a monetary injection X^D_t in the financial market, which is deposited on behalf of the household. The intermediary then holds $N^D_t + X^D_t$ units of cash, which it lends to domestic firms. Loanable cash supplied by the intermediary is[4]:

$$(4)\quad \tilde{L}^D_t = N^D_t + X^D_t$$

The firm manager borrows, invests, hires workers, and holds the household's capital stock K^D_t. Prior to producing output, the firm borrows L^D_t domestic currency units from an intermediary to finance acquisition of H^D_t units of labor at wage W^D_t per unit, in the face of a cash constraint:

$$(5)\quad W^D_t H^D_t \leq L^D_t$$

The firm also purchases $I^D_t = K^D_{t+1} - (1-\delta)K^D_t$ units of home-produced goods to add to the household's capital stock. Capital and consumption goods are indistinguishable in the domestic goods market and sell at common price P^D_t.

Determining the household's nominal wealth evolution requires accounting for currency brought home at the end of the period by household members. From (1)-(3), the shopper and worker bring home goods but no cash when the constraints bind as equalities. The firm manager, after the close of the goods market trades, pays loan obligation $R^D_{L,t} L^D_t$, where $R^D_{L,t}$is the gross domestic loan rate. The manager brings home capital, and cash profits of:

(6) $P_t^D Y_t^D - R_{L,t}^D L_t^D - P_t^D I_t^D$,

Y_t^D is real output per domestic household.

The intermediary receives loan repayments $R_{L,t}^D \tilde{L}_t^D = R_{L,t}^D(N_t^D + X_t^D)$ and pays a gross deposit return $R_{D,t}^D(N_t^D + X_t^D)$. The intermediary returns home at the end of the period with its household's own deposit return, $R_{D,t}^D(N_t^D + X_t^D)$, plus cash derived from intermediary activities $R_{L,t}^D(N_t^D + X_t^D) - R_{D,t}^D(N_t^D + X_t^D)$. Thus, the intermediary brings home a cash balance of:

(7) $R_{L,t}^D(N_t^D + X_t^D)$.

Combining cash brought home by the firm manager in (6) and intermediary in (7) gives the household's end-of-period nominal wealth:

(8) $A_{t+1}^D = P_t^D Y_t^D - R_{L,t}^D L_t^D - P_t^D I_t^D + R_{L,t}^D(N_t^D + X_t^D)$.

Technology and Shocks

For output production, each domestic firm possesses the technology:

(9) $Y_t^D = f^D(K_t^D, Z_t^D H_t^D) = (K_t^D)^{\alpha^D}(Z_t^D H_t^D)^{1-\alpha^D},\ 0 < \alpha^D < 1,$
$Z_t^D = \exp(\mu^D t + \theta_t^D)$.

The exogenous shock to domestic labor productivity, Z_t^D, is the sum of a deterministic trend and random deviations about that trend. Foreign firms' technologies are the same as above except for notation.

The two types of shocks thus far are to labor productivities and money growth rates in the two countries. Shocks to labor productivities are assumed to follow the bivariate autoregression:

$$(10)\quad \begin{bmatrix} \theta_t^D \\ \theta_t^F \end{bmatrix} = \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} \begin{bmatrix} \theta_{t-1}^D \\ \theta_{t-1}^F \end{bmatrix} + \begin{bmatrix} \varepsilon_t^D \\ \varepsilon_t^F \end{bmatrix}$$

The innovations ε_t^D and ε_t^F are serially independent with covariance matrix V_ε. Monetary injections in the model are $X_t^D = M_{s,t+1}^D - M_{s,t}^D$ and $X_t^F = M_{s,t+1}^F - M_{s,t}^F$, where $M_{s,t}^D$ and $M_{s,t}^F$ are per own-country-household stocks of domestic and foreign currencies. The exogenous money growth rates $\chi_t^D = \frac{X_t^D}{M_{s,t}^D}$ and $\chi_t^F = \frac{X_t^F}{M_{s,t}^F}$ are assumed to follow the bivariate autoregression:

$$(11)\quad \begin{bmatrix} \chi_t^D \\ \chi_t^F \end{bmatrix} = \begin{bmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{bmatrix} \begin{bmatrix} \chi_{t-1}^D \\ \chi_{t-1}^F \end{bmatrix} + \begin{bmatrix} e_t^D \\ e_t^F \end{bmatrix}$$

Innovations e_t^D and e_t^F are serially independent and independent of labor productivity innovations, and have covariance matrix V_e.

The Economy's State and Equilibrium

The state of the world economy in period t is characterized by values for $M_{s,t}^D$, $M_{s,t}^F$, κ_t^D, κ_t^F, A_t^D, A_t^F, K_t^D, K_t^F, and, S_t. $M_{s,t}^D(M_{s,t}^F)$ and $\kappa_t^D(\kappa_t^F)$ are per domestic (foreign) household money and capital stocks. $A_t^D(A_t^F)$ and $K_t^D(K_t^F)$ are the domestic (foreign) representative household's beginning currency and capital stocks, respectively. S_t will be used to denote a vector of productivity and money growth innovations. Shocks to the economy form a Markov process with transition function $\Phi(S_{t+1} \mid S_t)$. An equilibrium involves state contingent prices, wages, interest and exchange rates, and optimal household decision rules satisfying market clearing and aggregate consistency conditions. Market clearing conditions are: $\tilde{H}_t^D = H_t^D$, $\tilde{H}_t^F = H_t^F$ for labor; $Y_t^D = C_{D,t}^D + C_{D,t}^F + I_t^D$, $Y_t^F = C_{F,t}^F + C_{F,t}^D + I_t^F$ for goods; $\tilde{L}_t^D = L_t^D$, $\tilde{L}_t^F = L_t^F$ for loans and $A_t^D + X_t^D = M_{D,t}^D + M_{D,t}^F$, $A_t^F + X_t^F = M_{F,t}^F + M_{F,t}^D$ for foreign exchange.[5] Aggregate consistency requires that $A_t^D = M_{S,t}^D$, $A_t^F = M_{S,t}^F$ for money stocks, and $K_t^D = \kappa_t^D$, $K_t^F = \kappa_t^F$ for capital stocks.

4. PREFERENCES AND QUANTITATIVE RESULTS

It remains to specify preferences of households in the model. We initially consider a simple benchmark model in which agents possess standard time-separable and deterministic utilities. The second model adds taste shocks to the benchmark model. The third model replaces preferences of the benchmark model with non-time-separable utilities in the form of habit persistence.

4.1. Benchmark Model Preferences

In the benchmark model the household maximizes utility measure:

$$(12)\quad U = E_t \sum_{j=0}^{\infty} (\beta_D)^{t+j} \mu(C_{t+j}^D, l_{t+j}^D), 0 < \beta_D < 1.$$

where domestic consumption of home-produced goods $C_{D,t}^D$ and foreign-produced goods $C_{F,t}^D$ are aggregated according to:

(13) $C_t^D = \left\{ \varpi (C_{D,t}^D)^\nu + (1-\varpi)(C_{F,t}^D)^\nu \right\}^{\frac{1}{\nu}}.$

and momentary utility takes the form:

(14) $\mu(C_{Dt}^D, C_{F,t}^D, 1-\tilde{H}_t^D) = \frac{1}{\psi} \left\{ (C_t^D)^\gamma (l_t^D)^{1-\gamma} \right\}^\psi.$

Leisure is $l_t^D = 1 - \tilde{H}_t^D$, with the time endowment normalized to unity. Foreign utility is the same as (12)-(14) except for obvious notation alterations.

Household Decisions and Quantitative Results

Since choice problems facing domestic and foreign households have the same form, we focus on the domestic household's problem. The household maximizes utility measure (12) subject to trading opportunities and constraints in (1)-(8), technology (9), and shock processes (10) and (11). A formal statement and solution of the household's dynamic program is provided in the Appendix. What is important for the purpose of identifying exchange rate and relative price implications of the model is the following condition associated with the household's choices of consumption goods[6]:

(15) $\frac{\mu_{C_{D,t}^D}(C_{D,t}^D, C_{f,t}^D, l_t^D)}{\mu_{C_{F,t}^D}(C_{D,t}^D, C_{F,t}^D, l_t^D)} = \frac{P_t^D}{e_t P_t^F},$

where $\mu_{C_{D,t}^D}$ and $\mu_{C_{F,t}^D}$ are period t marginal utilities of $C_{D,t}^D$ and $C_{F,t}^D$, respectively.

According to (15) the household equates the intratemporal marginal rate of substitution (MRS) between domestic and foreign consumption goods with the real exchange rate. Lacking sufficient variability in the intratemporal MRS between consumption quantities the benchmark model will not quantitatively account for observed exchange rate and international relative price volatilities. The intratemporal MRS is

(16) $\frac{\mu_{C_{D,t}^D}}{\mu_{C_{F,t}^D}} = \frac{\varpi}{1-\varpi} \left(\frac{C_{D,t}^D}{C_{F,t}^D} \right)^{\nu-1}.$

Given the preferences we have specified, it follows that insufficient variability in international relative quantities in the benchmark model will translate into model predictions of insufficient exchange rate and relative price variabilities relative to actual data. In addition to the dependence on relative quantities, (16) reveals that the intratemporal MRS depends on the elasticity of substitution between home-and foreign-produced goods $\frac{1}{1-\nu}$ and weight ϖ on home goods in the consumption aggregator.

To examine the benchmark model quantitatively, we simulated parameterized versions of the model. Parameter values that we use are presented in Table 2 along with features of actual data used to calibrate the model. We begin by considering a baseline parameterization. In the baseline case each country's elasticity of substitution between home and foreign goods is set to 1.5, a value used by Backus, Kehoe, and Kydland (1992, 1995) based on results in Deardorff and Stern (1990) and Whalley (1985). For the U.S. the elasticity is between one and two while for some European countries and Japan the elasticity is smaller. Each country is assigned a home-good weight ϖ so that the steady state ratio of imports to GDP equals .15, which is an import share close to those in the U.S. and the foreign country aggregate that we employ. In addition to the baseline parameterization, we provide an analysis of result sensitivities to two alternative parameterizations for the aggregator in (13) and its foreign analog. One is referred to as "low weight" and assigns less than baseline weight (lower ϖ value) to consumption of home-produced goods. The second, referred to as"low elasticity", has a value lower than the baseline value for each country's elasticity of substitution, $\frac{1}{1-\nu}$, between domestic and foreign goods.

Recall from Table 1 that the average, across countries, standard deviations of nominal and real exchange rates are 7.30 and 7.72, respectively. The average standard deviations of nominal and real exchange rates relative to output standard deviations are 4.68 and 4.95, respectively. Row 1 of Table 3 reveals that, in contrast to actual data, the baseline parameterization of the benchmark model generates nominal and real exchange rate standard deviations of 1.47 and .74, respectively. Relative to the standard deviation of output, the standard deviations of nominal and real exchange rates are 1.00 and .51 in the model, well below what is found in actual data. The failure of the model to account for exchange rate volatilities arises from the strong connection between exchange rates and quantity movements across countries in the model and the low variabilities implied by the model for imports and exports relative to actual data. Imports and exports in actual data are over four times as volatile as in the baseline version of the benchmark model. In addition, international goods trades, as summarized by imports and exports, are far less persistent in the model than in actual data. Imports, exports, the terms of trade, and exchange rates have lower autocorrelations in the model than in actual data.

Row 2 of Table 3 shows results for the "low weight" case in which the home good weight in the consumption aggregator in each country is reduced so that the steady state import ratio increases from .15 of the baseline model to .35. With lower weight on home goods, the model's implications for variabilities of exchange rates do not change much relative to the baseline case. The autocorrelation properties implied by the model are also largely unaffected.

Row 3 of Table 3 provides results for the "low elasticity" case where the elasticity of substitution between home and foreign goods is decreased from the baseline value of 1.5 to a value of .5. The reduction in substitutability between home and foreign goods in household consumption aggregators contributes greatly to the model's ability to account for actual data properties. The nominal exchange rate standard deviation increases by a factor of 3.5 and the real exchange rate standard deviation by a factor of over 8 relative to the baseline case. The increases in exchange rate variabilities are associated with increased import and export volatilities relative to the baseline. While lowering the substitution elasticity substantially improves the model's performance, exchange rate variabilities implied by the model continue to be well below what are found in actual data. Lowering the substitution elasticity further could lead to further increases in variabilities in exchange rates and international trade quantities, but the assumed substitutability between home and foreign goods would be below what seems plausible given available findings. There are, in addition, two difficulties in the results for the low elasticity case. First, the variability of consumption increases above actual data counterpart. Second, except for output and the terms of trade, all variables have less persistence as indicated by lower autocorrelations relative to the baseline case. Autocorrelations for exchange rates and international trade variables are well below their data counterparts.

One possible way of retaining a reasonable value for the elasticity of substitution assumed in the model between home and foreign goods and yet generate consumption variability close to what is observed in actual data is to allow for shocks to agents' marginal utilities. Next, we examine a model with taste shocks so as to identify quantitatively the variability of such shocks that would be necessary for a modified version of the benchmark model to account for observed exchange rate variabilities. We also consider the taste shock model's ability to account for standard deviations and autocorrelations of other key variables.

4.2. Taste Shock Model

We add taste shocks to the benchmark economy by assuming, as in Stockman and Tesar (1995), that consumption marginal utilities possess a stochastic element. The household maximizes the utility measure in (12) with the period utility functional form in (14), as in the benchmark model. Taste shocks are incorporated by replacing (13) with:

$$(17)\ C_t^D = \left\{\varpi(A_t^D \cdot C_{D,t}^D)^{\nu} + (1-\varpi)(B_t^D \cdot C_{F,t}^D)^{\nu}\right\}^{\frac{1}{\nu}},$$

where A_t^D and B_t^D are random variables evolving according to:

$$(18)\ A_t^D = \rho_{A^D}\overline{A}^D + (1-\rho_{A^D})A_{t-1}^D + \varepsilon_{A_t^D}$$

$$(19)\ B_t^D = \rho_{B^D}\overline{B}^D + (1-\rho_{B^D})B_{t-1}^D + \varepsilon_{B_t^D}.$$

$\overline{A}^D$ and $\overline{B}^D$ are nonstochastic steady state values, ρ_{A^D} and ρ_{B^D} are autoregression parameters, and ε_{A^D} and ε_{B^D} are innovations. The foreign household also has taste shocks of the form above with obvious notation alterations.

The shocks A_t^D and B_t^D serve as random shifters to the domestic household's consumption marginal utilities. For example, a positive unit innovation in A_t^D has the same effect on the marginal utility of consumption of the domestic-produced good, $\mu_{C_{D,t}^D}$ as a unit increase in $C_{D,t}^D$. The important modification to the benchmark model for the exchange rates and relative prices is that optimality condition (15) of the benchmark model now becomes:

$$(20)\ \frac{\mu_{C_{D,t}^D}(A_t^D, B_t^D, C_{D,t}^D, C_{F,t}^D, l_t^D)}{\mu_{C_{F,t}^D}(A_t^D, B_t^D, C_{D,t}^D, C_{F,t}^D, l_t^D)} = \frac{P_t^D}{e_t P_t^F}.$$

As before, the intratemporal MRS between consumptions of domestic- and foreign-produced goods is equated with the real exchange rate. In the benchmark model, lack of sufficient variability in relative consumption quantities causes low variability in the intratemporal MRS, and, consequently, the model implies counterfactually low exchange rate and relative price volatilities. In the taste shock model, however, the presence of random marginal utility shifters provides the potential for much more volatility in the intratemporal MRS. How much more depends, of course, on the variability assigned to the innovations ε_{A^D} and ε_{B^D} to the marginal utility shifters.

To determine the magnitude of volatility in the innovations to marginal utility shifters that are necessary for model implications for exchange rate variabilities to align with actual data, we simulated the taste shock model. Parameter values used in the simulations are the same as in the baseline case of the benchmark model, with the addition now of parameter values for the taste shock processes. The values used for taste shock process parameters are displayed in the second and third columns of Table 4. In row 1, a value of zero is assigned to the variances of taste shock innovations, in which case the model is simply the baseline case of the benchmark model. Rows 2 and 3 give results for a case in which we set the variances of taste shocks equal to the variance of the domestic technology innovation. Row 2 considers persistent taste shocks with first order autocorrelation coefficients of .9. Row 3 considers more transitory shocks, where the first order autocorrelation for each shock is set at .25. The results in rows 2 and 3 indicate that relative to the baseline case of the benchmark model there are only slight amplifications in variabilities of exchange rates and traded quantities. The amplifications are slightly greater when the taste shocks are assumed to be of a more permanent nature. Yet it remains that the model's implications for variabilities of exchange rates and international trade quantities are far from what we observe in actual data. In addition, autocorrelations of exchange rates, international trade quantities, and the terms of trade remain below their data counterparts. There is improvement, however, in the autocorrelations of imports and exports implied by the model relative to their actual data counterparts when the taste shock is assumed to be persistent.

In rows 4 and 5 of Table 4 we consider taste shocks that have standard deviations close to nine times the standard deviation of the domestic country's technology shock. This means very large shifters to marginal utilities. Row 4 considers the more permanent and row 5 the more transitory variants of the taste shock processes. As the results indicate, there is improvement in the model's ability to generate volatilities in imports and exports, as well as the terms of trade and exchange rates, that are closer to their data counterparts than the baseline case of the benchmark model. Furthermore, when the taste shocks are persistent, first order autocorrelations for exchange rates, the terms of trade, and international trade quantities move closer to their data counterparts. However, even by assuming that taste shocks are close to nine times more variable than technology shocks, the model implies exchange rate and terms of trade variabilities that are below what we observe in data. In addition, as might be expected from highly variable shocks that operate on consumption marginal utilities, the standard deviation of total consumption, C^D, in the model turns out to be far in excess of what is found in data. In addition, import and export volatilities rise above what are found in data. At the very least, the movements in consumption, imports, and exports required for the taste shock model to come close to accounting for exchange rate variabilities are counterfactually high.

4.3. Habit Persistence Model

An alternative to taste shocks for altering the benchmark model's intratemporal MRS between consumptions of home- and foreign-produced goods is habit persistent preferences. We incorporate habits, following Constantinides (1990), by assuming that today's consumption choices directly influence momentary utility today and in a future period. Utilities are consequently no longer time separable. Rather, we now assume that momentary utility for the domestic household in period t takes the form:

$$\mu(C_{D,t}^D, C_{F,t}^D, l_t^D, C_{D,t-1}^D, C_{F,t-1}^D) = \frac{1}{\psi}\left\{(C_t^D - b^D C_{t-1}^D)^\gamma (l_t^D)^{1-\gamma}\right\}^\psi$$

in place of momentary utility of the benchmark model in (14). A zero value for b^D reduces the model to the benchmark with time separable utility.

The household choice problem and optimality conditions given habit preferences are discussed in the appendix. With respect to model implications for exchange rate and relative price volatilities, the important modification to the benchmark model is that optimality condition (15) now becomes:

$$(21) \quad \frac{\left[\mu_{C_{D,t}^D}(t)+\beta_D \int \mu_{C_{D,t}^D}(t+1)\Phi(S_{t+1}|S_t)\right]}{\left[\mu_{C_{F,t}^D}(t)+\beta_D \int \mu_{C_{F,t}^D}(t+1)\Phi(S_{t+1}|S_t)\right]} = \frac{P_t^D}{e_t P_t^F}.$$

$\mu_{C_{D,t}^D}(t)$ and $\mu_{C_{F,t}^D}(t)$ are marginal utilities in period t of period t consumptions $C_{D,t}^D$ and $C_{F,t}^D$, respectively. $\mu_{C_{D,t}^D}(t+1)$ and $\mu_{C_{F,t}^D}(t+1)$ capture the marginal utility effects in period t+1 of period t consumptions, which arise because of habit preferences. The extent to which period t consumptions influence future utility is governed by the value of b^D in the momentary utility function.

One interest is in whether the marginal rate of substitution in (21) is sufficiently variable for the model to imply exchange rate variabilities that align with observations. We address this by simulating the habit model using benchmark model parameters along with values for the habit parameter b^D. Three values for

b^D are considered and the results of model simulations for these values are reported in Table 5. In row 1 a value of zero is assigned, in which case the model is simply the baseline case of the benchmark model. In row 2, somewhat weak habits are considered with b^D set at .35. Row 3 shows results for increasing the habit parameter to $b^D = .45$.

As the results indicate, including forces of habit in the model leads to reductions in the implied exchange rate standard deviations, as agents seek to smooth consumption. The nominal and real exchange rate standard deviations implied by the habit model are well below what are found in data. In addition, smoothing of consumption relative to the baseline model is consistent with smoothing of exports and imports, as well as smoothing of the terms of trade. As a result, the model with habits implies volatilities in exports, imports, and the terms of trade that are farther away from their actual data counterparts than in the baseline case of the benchmark model. Increasing the habit parameter above $b^D = .45$ does not change the features of the habit model just described.

Introducing habits into the model does lead to improvements in the model's ability to generate persistent movements in variables. The model with habits generates import, export, exchange rate, and terms of trade autocorrelations that are much closer to their actual data counterparts than in the baseline case of the benchmark model. The persistence stems from the strong desire by agents with habits to generate a smooth consumption sequence through time.

It is instructive to note that a possible way for the model with habits to generate exchange rate variances close to what are observed in actual data is to link exchange and interest rates. With habits, while agents seek to smooth consumption, the intertemporal marginal rate of substitution of a typical agent becomes more volatile the stronger is the force of habit. Since the intertemporal marginal rate of substitution is equated by an optimizing agent with the return on an asset, the volatility of asset returns will be increasing in the habit parameter b^D. This is shown for our habit model in Table 5 in the columns labeled R^D for the domestic nominal interest rate standard deviation and *inter* for the standard deviation of the domestic household's intertemporal marginal rate of substitution.[6] Both of these moments increase in the habit parameter b^D. However, increasing the value for b^D to .45 or above leads to model implications for the nominal interest rate volatility that are too high relative to actual data.

It is doubtful in the model with habits that we have considered that inclusion of currency exchanges to facilitate asset trades will lead to exchange rate series with volatilities high enough to align with actual data while, at the same time, generating nominal interest rate series with substantially lower volatility. The nominal money market rates in actual data seem too smooth relative to rates implied by the habit model. For the habit model to be able to simultaneously account for high exchange rate variabilities and relatively lower money market rate volatility, it may prove useful to introduce currency trades to facilitate trades in assets other than money market instruments. Such a framework is potentially useful to consider, especially given the improved ability of the model with habits, relative to the baseline case of the benchmark model, to account for autocorrelation properties of key international variables. Extending the habit model to allow for a wider range of available assets, say debt and equity, and perhaps heterogeneity across production sectors or agents may be useful steps in future research aimed at accounting for dynamics of exchange rates and other international variables.

5. Conclusion

This paper has considered abilities of monetary models with alternative preference specifications to account for key properties of exchange rates and goods trades across countries. The key properties are that variabilities of nominal and real exchange rates are high relative to output variabilities; variabilities of imports and exports are high relative to output variabilities, but less so than exchange rates; and that exchange rate and international relative price variabilities exceed variabilities in goods flows across countries. The alternative preference specifications we have considered are the standard nonstochastic and time separable preferences used in most existing dynamic open economy models; preferences with taste shocks to marginal utilities; and nontime separable preferences in the form of habit persistent preferences.

We confirm, with standard preferences, the difficulty encountered by existing dynamic international models in accounting for the key properties of international variables. Adding random marginal utility shifters using taste shocks to a basic open economy model allows the model to account for volatilities in exchange rates, the terms of trade, and international trade quantities only when taste shocks are assumed to be over nine times as variable as shocks to the production technology. Taste shocks with such high variability, however, imply a consumption sequence for a typical agent that is far more variable than its data counterpart. Adding habits to a basic open economy model leads to a substantial improvement in the model's ability to account for persistence properties of international variables. The model with habits that we have considered, however, does not generate sufficient volatility in exchange rates, the terms of trade, or international trade quantities. Given the habit model's success along the lines of persistence, it may prove useful in future work to consider a model with habits and with asset or goods market environments in which the set of available trades is expanded relative to the simple environment studied in this paper.

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ENDNOTES

1. In the models there is no distinction between the terms of trade and the real exchange rate. Moments for the two international relative price measures are provided in Table 1 to illustrate that in general, using alternative measures, international relative prices possess high volatilities.

2. The notation conventions are: A subscript denotes the country of origin of a good or money balance; a superscript denotes the residence of the household choosing the variable; a tilde "~" denotes a quantity supplied and household choice variables without tildes are quantities demanded.

3. In simulations, parameter values are used for which agents drive cash constraints to bind as strict equalities. That is, the gross nominal interest rates exceed unity.

4. As long as the gross loan rate exceeds unity, intermediaries lend all available cash to firms.

5. Foreign exchange market clearing arises as follows. From equations (1), (4), (5) for the domestic economy, along with loan and labor market clearing ($\tilde{L}_t^D = L_t^D, \tilde{H}_t^D = H_t^D$), we have $A_t^D + X_t^D = M_{D,t}^D + e_t M_{F,t}^D$. Since $e_t = \frac{M_{D,t}^F}{M_{F,t}^D}$ it follows that $A_t^D + X_t^D = M_{D,t}^D + M_{D,t}^F$. Similarly for the foreign currency.

5. The marginal utilities depend on the arguments listed in parentheses.

6. The domestic household's intertemporal marginal rate of substitution is $\int[\{\mu_{C_{D,t}^D}(t) + \beta_D \mu_{C_{D,t}^D}(t+1)\}/\beta_D\{\mu_{C_{D,t+1}^D}(t+1) + \beta_D \mu_{C_{D,t+1}^D}(t+2)\}]\Phi(S_{t+1} \mid S_t)$, where $\mu_{C_{D,t}^D}(t)$ and $\mu_{C_{D,t}^D}(t+1)$ denote the effect at the margin of a change in $C_{D,t}^D$ on momentary utility in period t and period t+1, respectively.

APPENDIX: THE HOUSEHOLD'S PROBLEM

Benchmark Model: Let $V^D(A_t^D, K_t^D, S_t)$ be the value function corresponding to the domestic household's problem, satisfying functional equation:

$$V^D(A_t^D, K_t^D, S_t) = \max_{N_t^D, K_{t+1}^D, M_{F,t}^D, \tilde{H}_t^D, L_t^D} \mu(C_t^D, 1-\tilde{H}_t^D) +$$

$$\beta_D \int V^D(A_{t+1}^D, K_{t+1}^D, S_{t+1}) \Phi(S_{t+1} \mid S_t)$$

A_{t+1}^D is given by wealth evolution(8). Binding cash constraints in (2), (3), and (5) are used to eliminate $C_{D,t}^D$, $C_{F,t}^D$, and H_t^D as separate decisions. Also, from foreign exchange market allocation (1) we have $A_t^D - N_t^D + W_t^D \tilde{H}_t^D = M_{D,t}^D + e_t M_{F,t}^D$. Consequently, choice of $M_{D,t}^D$is implied by choices of N_t^D, $\tilde{H}_t^D$, and $M_{F,t}^D$ since A_t^D is predetermined and e_t and W_t^D are taken by the household. Optimality conditions for N_t^D, K_{t+1}^D, $M_{F,t}^D$, $\tilde{H}_t^D$, L_t^D are:

A1) $-\mu_{C_{D,t}^D} \frac{1}{P_t^D} + \beta_D \int \mu_{C_{D,t+1}^D} \frac{R_{L,t}^D}{P_{t+1}^D} \Phi(S_{t+1} \mid S_t) = 0$

A2) $-\int \left\{ \mu_{C_{D,t+1}^D} \frac{P_t^D}{P_{t+1}^D} + \beta_D \mu_{C_{D,t+2}^D} \frac{P_{t+1}^D}{P_{t+2}^D} \left\{ f_{K_{t+1}^D}^D + 1 - \delta_D \right\} \Phi(S_{t+1} \mid S_t) \right\} = 0$

A3) $-\mu_{C_{D,t}^D} \frac{1}{P_t^D} + \mu_{C_{F,t}^D} \frac{1}{e_t P_t^F} = 0$

A4) $-\mu_{l_t^D} + \mu_{C_{D,t}^D} \frac{W_t^D}{P_t^D} = 0$

A5) $f_{H_t^D}^D - \frac{W_t^D}{P_t^D} R_{L,t}^D = 0$

where $\mu_{l_t^D}$ is the period t marginal utility of leisure and the period t marginal products of domestic labor and capital are denoted respectively by $f_{H_t^D}^D$ and $f_{K_t^D}^D$. A1, associated with the deposit choice, relates the nominal interest rate, anticipated inflation, and the household's intertemporal MRS. A2 governs the capital investment decision. A3 is associated with decisions on consumptions and the domestic and foreign currency balances to use in acquiring consumption goods. A4, from the work effort supply choice, equates the real wage and intratemporal MRS between a consumption quantity and leisure. A5, from the firm's loan demand decision, equates labor's marginal product and the real cost of an additional labor unit (real wage and interest cost of borrowing currency to hire labor).

Taste Shock Model: The forms of the household's problem and optimality conditions are identical to those in the benchmark model. The difference across models is that with taste shocks the marginal utilities contain random shifters not present in the benchmark model.

Habit Persistence Model: With (one period) habits, values chosen for $C^D_{D,t}$ and $C^D_{F,t}$ influence period t and period t+1 momentary utility. Optimality conditions in the habit model are the same as in A1-A5 with the exception of marginal utilities of $C^D_{D,t}$ and $C^D_{F,t}$. Let $\mu_{C^D_{D,t}}(t)$ and $\mu_{C^D_{D,t}}(t+1)$ denote the effect at the margin of a change in $C^D_{D,t}$ on momentary utility in period t and period t+1, respectively. Then, $\mu_{C^D_{D,t}}$ of the benchmark model would be replaced with $\mu_{C^D_{D,t}}(t) + \beta_D \int \mu_{C^D_{D,t}}(t+1)\Phi(S_{t+1} \mid S_t)$. Similarly, $\mu_{C^D_{F,t}}$ of the benchmark model would be replaced with $\mu_{C^D_{F,t}}(t) + \beta_D \int \mu_{C^D_{F,t}}(t+1)\Phi(S_{t+1} \mid S_t)$. Replacements in the habit model for $\mu_{C^D_{D,t+1}}$ and for $\mu_{C^D_{D,t+2}}$ of the benchmark model are straightforward updates of the expressions above. Replacements for the foreign household are similar with mere notation alterations.

TABLE 1

INTERNATIONAL DATA PROPERTIES[1]

		Standard Deviation						First Order Autocorrelation					
Country	Period	e	re	y	im	ex	tot	e	re	y	im	ex	tot
Canada	74:1-94:2	3.05	3.35	2.37	2.15	1.77	3.09	.86	.85	.63	.81	.67	.77
	74:1-79:4	2.82	2.87	1.20	3.19	4.21	3.11	.83	.81	.81	.63	.69	.69
	80:1-87:4	2.94	3.31	3.27	2.14	1.33	3.92	.89	.89	.53	.82	.64	.66
	88:1-94:2	3.09	3.50	1.80	1.72	1.73	1.52	.77	.75	.88	.78	.63	.89
France	74:1-94:2	9.29	8.59	1.03	3.58	2.68	2.52	.87	.85	.82	.75	.74	.82
	74:1-79:4	7.35	6.70	1.16	4.54	2.43	3.15	.79	.77	.75	.76	.67	.83
	80:1-87:4	12.33	11.31	0.80	3.64	3.77	3.26	.87	.85	.62	.56	.75	.84
	88:1-94:2	6.37	6.20	1.06	2.47	2.23	1.44	.57	.59	.89	.75	.63	.55
Germany	74:1-94:2	8.94	8.53	1.41	2.23	2.48	3.42	.86	.84	.81	.79	.75	.80
	74:1-79:4	7.32	7.02	1.64	1.64	1.81	3.45	.76	.75	.76	.63	.62	.70
	80:1-87:4	11.63	11.02	1.08	2.45	3.06	4.16	.84	.83	.67	.66	.79	.85
	88:1-94:2	6.33	6.05	1.59	2.63	2.73	1.92	.53	.51	.82	.82	.77	.56
Japan	74:1-94:2	9.07	9.28	1.12	4.84	3.89	8.91	.85	.85	.79	.85	.77	.75
	74:1-79:4	9.24	9.44	0.86	7.29	6.50	11.56	.86	.86	.60	.83	.72	.60
	80:1-87:4	9.77	9.92	0.85	4.98	5.30	8.59	.82	.81	.64	.76	.83	.80
	88:1-94:2	8.11	8.01	1.51	3.47	1.62	5.53	.75	.74	.84	.87	.62	.60
United Kingdom	74:1-94:2	9.27	8.86	1.71	2.51	1.67	1.88	.89	.81	.84	.71	.345	.67
	74:1-79:4	8.94	6.99	1.91	2.43	2.11	2.38	.85	.73	.69	.57	.36	.74
	80:1-87:4	10.91	10.89	1.13	3.61	2.18	1.96	.85	.84	.60	.50	.55	.76
	88:1-94:2	7.17	7.65	1.83	2.19	1.03	1.09	.60	.64	.91	.87	.28	-.12
United States	74:1-94:2	-	-	1.70	3.29	2.41	3.20	-	-	.85	.83	.85	.75
	74:1-79:4	-	-	1.98	3.53	1.79	3.20	-	-	.83	.81	.54	.60
	80:1-87:4	-	-	1.72	3.48	3.09	3.90	-	-	.79	.84	.88	.83
	88:1-94:2	-	-	1.27	2.37	1.84	1.47	-	-	.89	.73	.73	.30
Average[2]		7.30	7.72	1.56	2.92	2.33	3.89	.86	.84	.79	.79	.79	.76

[1]The series are: e, the nominal exchange rate; re, the real exchange rate; y, real GDP; im, imports; ex, exports; tot, the terms of trade. Real GDP data are from the OECD. The remaining data are taken from International Financial Statistics.

[2]The average is across countries for the full-sample period 1974:1-1994:2.

TABLE 2

PARAMETER VALUES

Parameter		Notation	Value[1]
Preferences:	Subjective Discount Factor	β	0.991
	Utility Curvature	ψ	-1.000
	Leisure Share	1-γ	0.760
	Aggregator Weight[2]	ϖ	0.710
	Elasticity[3]	1/(1-v)	1.500
Technology:	Capital Share	α	0.350
	Depreciation[4]	δ	0.020
	Scale Factor[5]	θ	1.000
Growth:	Trend Money Growth	μ	0.004
	Trend Money Growth		0.018
Shock Processes:	Autocorrelations and Spillovers	T_{11},T_{12},T_{21},T_{22}	0.987, -0.036, 0.002, 0.876
		M_{11},M_{12},M_{21},M_{22}	0.592, 0.007, 0.098, 0.695
	Covariance Matrices[6]	Technology	(.0136,.0019,.0019,.0126)
		Money	(.0039,.0003,.0003,.0062)

[1] Domestic and foreign

[2] Weights were chosen so that in the steady state each country has an import to GDP ratio of .15, which is in the range observed for the countries we consider.

[3] Elasticity of substitution between home and foreign produced goods.

[4] Annual depreciation is ten percent.

[5] Technology innovation steady state values, which are merely scale coefficients.

[6] The entries are, respectively, the standard deviation of the home measure, covariance between the home and foreign measure, covariance between the foreign and home measure, standard deviation of the foreign measure.

Most values are standard values used in closed economy real business cycle models. With the above values, the implied steady state values for each country are: nonsleep time devoted to market activity is 26 percent; the capital to output ratio is 10.7; and the ratio of imports to GDP is .15. These values are consistent with features of post Bretton Woods data for the U.S. The average growth of technologies are set to the average per capita real GDP growth in the U.S. over 1972-1994. Values for the bivariate productivity shock process are based on our estimates using Solow residuals for the U.S.(domestic country) and the five OECD countries in Table 1. Values for the bivariate money shock process are based on our estimates using U.S. monetary base and a monetary base variable constructed from data from the IMF's International Financial Statistics for the aforementioned OECD countries.

TABLE 3

Benchmark Model Economy

			Standard Deviation							First Order Autocorrelation						
row	Elasticity	im ratio	e	re	y^D	im	ex	c^D	tot	e	re	y^D	im	ex	c^D	tot
Baseline	1.5	.15	1.47	.74	1.47	.62	.66	.23	1.89	.71	.03	.77	.23	.23	.21	.44
Low weight	1.5	.35	1.92	2.72	1.42	1.08	.70	.72	1.89	.75	.02	.77	.21	.23	.26	.44
Low elast.	0.5	.15	5.22	6.37	1.42	2.26	2.39	.73	1.89	.05	.02	.77	.01	.07	.14	.46
US Data[2]	-	-	7.30	7.72	1.70	3.29	2.41	.45	3.89	.86	.84	.85	.83	.85	.85	.75

[1] Results are based on data that have been logged and then Hodrick-Prescott filtered. For c^D, im, and ex in this and the remaining tables, the standard deviation is stated relative to the standard deviation of y^D. It should be noted that in terms of the model notation, c_F^D is equivalent to im and c_D^F is equivalent to ex.

[2] U.S. data on exchange rates are trade weighted bilateral rates for the U.S. dollar vis a vis the Canadian dollar, French franc, German mark, Japanese yen, and British pound for the flexible exchange rate period 1974:1-1994:2.

TABLE 4

TASTE SHOCK ECONOMY

			standard deviation							first order autocorrelation						
Row	St. Dev.[1]	AR[2]	e	re	y^D	im	ex	c^D	tot	e	re	y^D	im	ex	c^D	tot
1	.0000	.00	1.47	.74	1.46	.62	.66	.23	1.89	.71	.03	.77	.23	.23	.21	.44
2	.0136	.90	1.69	1.07	1.46	.80	.83	.37	1.90	.69	.37	.77	.41	.40	.44	.44
3	.0136	.25	1.42	.86	1.45	.64	.69	.21	1.90	.63	.06	.77	.21	.21	.16	.44
4	.1223	.90	6.73	7.24	1.94	3.74	3.77	2.32	2.52	.61	.67	.71	.65	.65	.59	.52
5	.1223	.25	5.45	5.29	1.51	3.62	3.62	2.26	1.89	.17	.13	.72	.14	.16	.13	.44
Data	-	-	7.30	7.72	1.70	3.29	2.41	.45	3.20	.86	.84	.86	.83	.85	.85	.75

[1] Standard Deviation refers to the standard deviation of the taste shocks; .0136 is the standard deviation of productive innovations in U.S. data.

[2] AR refers to the first order autocorrelation coefficient of taste shocks: .9 for relatively permanent shocks and .25 for relatively transitory shocks.

TABLE 5

HABIT PERSISTENCE ECONOMY

		Standard Deviation									First order autocorrelation						
Row	Habit[1]	e	re	y^D	im	ex	c^D	tot	r^D	inter	e	re	y^D	im	ex	c^D	tot
1	0	1.47	.74	1.46	.62	.66	.23	1.89	.39	1.78	.71	.03	.77	.23	.23	.21	.44
2	.35	1.39	.42	1.56	.43	.44	.18	1.54	.41	2.34	.82	.55	.78	.70	.68	.45	.77
3	.45	1.39	.42	1.63	.41	.42	.18	1.54	.57	2.60	.82	.62	.74	.73	.73	.50	.79
Data	-	7.30	7.72	1.70	3.29	2.41	.45	3.20	.47[2]	-	.86	.84	.86	.83	.85	.85	.75

[1] The elasticity of substitution between home and foreign goods and the steady state import to GDP ratio are set at values for the benchmark economy's baseline case (row 1 of Table 3). Thus, row 1, with no habit is identical to row 1 of Table 3.

[2] The gross interest rate is defined as the money market rate as published in International Financial Statistics.