External Habits and the International Risk Sharing Puzzle

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(Preliminary version, comments are welcome)

Abstract

Preferences with external habits are assumed in the measurement of bilateral international risk sharing for the G7 countries in order to address the puzzle described by Brandt, Cochrane and Santa-Clara (2006). According to their index, international risk sharing is in the order of 95% when measured with asset market data, but typically lower than 40% if computed with consumption data and standard preferences. This paper shows that when habit formation depends on the evolution of consumption growth in both the domestic and the foreign country, it is possible to reconcile both risk sharing measurements not only in terms of risk sharing levels but also in terms of total risk levels. A nonlinear GMM estimation is performed to show that the assumed external habit framework is not rejected by actual currency excess return data.

Keywords: International risk sharing; Exchange rate volatility; Discount factor; Habits

JEL Classification: G12; G15; F31

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1. Introduction

This paper provides an alternative solution to the international risk sharing puzzle described by Brandt, Cochrane and Santa-Clara (2006) by assuming a slightly modified version of the external habit framework defined by Campbell and Cochrane (1999) and extended to the open economy by Verdelhan (2007).

External habit preferences are assumed such that habit formation depends on consumption growth in both the domestic and the foreign country. This specification is used to compute a bilateral international risk sharing index for the G7 countries with the US as base country and with annual consumption data from 1975 to 2006. While the standard exponential utility specification produces indices typically below 40%, risk sharing indices computed with external habits stand around 95% similarly to those calculated with asset market data.

These results show the existence of a specification of preferences such that the implied degree of international risk sharing computed with consumption data resembles the one computed with asset market data. Therefore they represent a solution to the puzzle described in Brandt, Cochrane and Santa-Clara (2006). These calculations are also a contribution to the debate on the lack of empirical evidence of international consumption risk sharing described by Karen Lewis (1996, 1999) and examined recently by Marianne Baxter (2006). With external habit preferences, bilateral consumption risk sharing turns out to be significant.

This research introduces a new element to the habit formation process, namely, foreign consumption growth is allowed, along with domestic consumption, to influence domestic consumers' evaluation of their habit consumption levels. This kind of effect has not been considered before in the literature on macroeconomic models with habits. Therefore, this paper presents an econometric exercise which shows some evidence that such effect is actually consistent with the observed evolution of foreign currency returns under the assumption of optimal asset pricing. Specifically, it is performed a country by country, non linear GMM estimation of the asset pricing equation for currency excess returns.

This paper is organized in the following way. A summary of related research is presented in section 2. The international risk sharing puzzle is described in section 3. External habit preferences and the way they solve the puzzle are presented in section 4. Some implications of the calibrated model on real exchange rate evolution are analyzed in Section 5. The nonlinear GMM estimation is presented in Section 6. Finally, section 7 concludes.

2. Related Literature

Although the empirical literature on risk sharing is quite substantial, this section will focus on papers on international risk sharing which are closely related. The most recent literature review on international risk sharing is presented in Lewis (1999). The most related papers are Baxter (2006), Brandt, Cochrane and Santa-Clara (2006), Kang (2004) and Colacito and Croce (2007).

Baxter (2006) extends and refines the empirical investigation on international risk sharing for OECD countries. She explores and analyzes several risk sharing testing methods on both short and long run time horizons. In particular, tests based on habit preferences are performed with mixed results. Furthermore, it is shown the importance of performing direct and bilateral risk sharing measurements. Direct tests allow observing the precise degree of risk sharing in contrast to indirect tests where it is decided whether or not full risk sharing holds. By applying bilateral tests it is possible to analyze what kinds of country pairs are more likely to share risks better. Finally, Baxter (2006) shows that most of the positive international risk sharing evidence is concentrated on short run horizons.

In the paper by Brandt, Cochrane and Santa-Clara (2006)[1], a new index for the measurement of international risk sharing is proposed on the basis of asset pricing theory. This index is then computed with asset market data implying a high degree of risk sharing between several pairs of developed countries. However, when the index is computed with consumption data assuming a CRRA utility function, it shows in contrast a low degree of risk sharing. This puzzle remains even when incomplete markets are assumed so that quest

[1] An early version was published in 2001 in the NBER working paper series #8404

for a new specification of preferences is suggested by the authors as the next step. Detailed computations about this puzzle are presented below in section 3.

Kang (2004) explores a habit based solution to the international risk sharing puzzle by assuming preferences with external habits following closely the specification of Campbell and Cochrane (1999). However, this specification does not change risk sharing measurements very much with respect to the standard CRRA utility function. Kang also tries a recursive utility specification which allows a partial solution to the puzzle but without matching the volatility of the stochastic discount factors. I follow Kang's external habit idea but including a modified habit formation process.

A complete solution to the international risk sharing puzzle is provided by Colacito and Croce (2007) by assuming recursive preferences in the spirit of Epstein and Zin (1989), and introducing persistent and unobserved long run components to the consumption growth process in which shocks are perfectly cross-country correlated. They show, simulating a model that matches US-UK data, that under these assumptions it is possible to obtain a high risk sharing index with appropriate levels of stochastic discount factor volatility. Below, I show an alternative approach which does not require imposing such specific structure on the data generating process of consumption growth and works with observed consumption data.

3. The International Risk Sharing Puzzle

In this section first, I define the method for international risk sharing measurement, then the computations with asset market and consumption data are described.

3.1. The International Risk Sharing Index

An index was devised by Brandt, Cochrane and Santa-Clara (2006) on the basis of Equation (1) which relates real exchange rate variations with the stochastic discount factor in both countries.

$$q_{t+1} - q_t = m^*_{t+1} - m_{t+1} \tag{1}$$

Throughout this paper lower case letters are logs of the original variables. In (1), m_{t+1}, m^*_{t+1} are the domestic and foreign log stochastic discount factors respectively. This equation says that the log variation in the real exchange rate is equal to the difference between the log stochastic discount factor in the foreign country and in the US[2].

As shown originally by Backus and Smith (1993), this equation results from a two-country endowment economy with complete markets. Assume that in each country a representative investor has access to a domestic bond that pays off one unit of domestic consumption next period in each state of the world. Additionally, these investors have access to a foreign bond that pays a stochastic return R^*_{t+1}. Assume as well that the investors choose their optimal portfolios by solving a standard problem of dynamic optimization of utility. Then the Euler equation for a foreign investor buying a foreign bond is $E_t(M^*_{t+1}R^*_{t+1}) = 1$. The Euler equation for a domestic investor buying the same foreign bond is $E_t(M_{t+1}R^*_{t+1}\, Q_{t+1}/Q_t) = 1$. Since under complete markets stochastic discount factors are unique, we must have from these Euler equations: $M^*_{t+1} = M_{t+1}\, Q_{t+1}/Q_t$. Taking natural logarithms at both sides we get (1)[3].

Perfect risk sharing is defined as the right hand side of (1) being equal to 0 as implied by complete market models with no frictions to international trade. Therefore, an absolute measure of risk sharing is the variance of the left hand side of (1). In order to have a relative measure of the extent of risk sharing, Brandt, Cochrane and Santa-Clara (2006) divide the variance of real exchange rate changes on the sum of stochastic discount factor variances.

$$1 - \frac{\sigma^2\left(q_{t+1} - q_t\right)}{\sigma^2(m^*_{t+1}) + \sigma^2(m_{t+1})} \tag{2}$$

The denominator of the index defined in Equation (2) measures the sum of the variances of the stochastic discount factors and is interpreted as the total risk to share. The numerator is interpreted as the extent of not shared risk. Thus the index reaches 100% when

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[2] The real exchange rate Q_t is defined as the number of necessary foreign goods to buy one unit of US good. It is measured with the nominal exchange rate and the consumer price level in both countries. Stochastic discount factors are defined as the time preference parameter multiplied by marginal utility growth in each country.

[3] See Cochrane (2004, chapter 4), for a proof of the existence and unicity of the stochastic discount factor in asset pricing economies under complete markets.

there are not any real exchange rate fluctuations, but as these fluctuations get as volatile as the discount factors are, the index decreases to 0%. Therefore, (2) can be interpreted as the risk percentage which is actually shared between a pair of countries as measured by relating the real exchange rate and the discount factors variances. [4]

3.2. Computation with Asset Market Data

In this subsection the international risk sharing index in (2) is computed for pairs of G7 countries using data on real exchange rates, real stock returns, real risk free rates and real foreign currency returns.

Brandt, Cochrane and Santa-Clara (2006) show that (2) can be computed as in the following formula:

$$1-\frac{\Sigma^{ee}}{\mu'\Sigma^{-1}\mu+\mu^{*}{}'\Sigma^{-1}\mu^{*}} \tag{3}$$

In Equation (3), Σ^{ee} is the variance of real exchange rate variations, $\mu'\Sigma^{-1}\mu$ and $\mu^{*}{}'\Sigma^{-1}\mu^{*}$ are respectively, the variances of the domestic and foreign stochastic discount factors. Three assets are considered for the computation of the denominator in (3): domestic stock, foreign currency and foreign stock. Therefore, μ and μ^{*} are the vectors of expected excess returns for each one of these assets from the point of view of a domestic and a foreign investor, respectively[5]. The covariance matrix for these three excess returns is Σ which is equal for both investors because the rows are arranged such that a domestic shock for the foreign investor is the foreign shock for the domestic investor and vice versa.

The expressions in the denominator of (3) are the result from recovering the minimum variance stochastic discount factor in a continuous time setting including domestic

[4] An alternative measure, used in Colacito and Croce (2006), is the correlation between foreign and domestic log stochastic discount factors. The index defined in (2) is a more strict measure of risk sharing because a perfect correlation does not always lead to a 100% value of the index. For instance, if $m^{*}_{t+1}=2m_{t+1}\ \forall t$, then the index in (2) is equal to 0.8 despite a perfect correlation.

[5] Note that these are (3×1) vectors of constants. The risk free rate is subtracted from the gross returns in order to compute excess returns for these three kinds of assets.

and foreign assets and assuming complete markets. Log discount factors are then constructed via Ito's lemma. See Brandt, Cochrane and Santa-Clara (2006, p. 676) for details.

Equation (3) is computed with data for pairs of G7 countries with US as the domestic country. Annual data from 1975 through 2006 are used in all computations. Table A1, in the appendix, show summary statistics for mean returns as well as return volatilities and correlations among countries. Table 1 shows results from the computation of the international risk sharing index.

From Table 1 it is possible to conclude that, for the G7 countries, the extent of international risk sharing is quite high. This is because only less than 5% of the available market risk is not shared or in other words, the index is higher than 95% in all cases. The intuitive explanation for this result is that computed stochastic discount factors are much more volatile than real exchange rate movements. Thus, in Table 1, while the standard deviation of stochastic discount factors fluctuates between 35% and 52%, the standard deviation of the real exchange rate is less than 11% in all cases.

TABLE 1 - RISK SHARING INDEX FROM ASSET MARKET DATA
Span of annual data: 1975-2006; Base Country: US

	UK	GERMANY	JAPAN	CANADA	FRANCE	ITALY
Risk Sharing Index	0.984	0.964	0.976	0.991	0.959	0.954
Standard Deviation of SDF						
Domestic	0.524	0.406	0.524	0.386	0.396	0.372
Foreign	0.496	0.404	0.551	0.375	0.369	0.355
Standard Deviation of RER	0.090	0.108	0.116	0.051	0.109	0.110

This table shows the international risk sharing index described in equation (3), the standard deviation of the stochastic discount factors and the standard deviation of Real Exchange Rate (RER) appreciation. The domestic country is the US. The investable assets are the domestic interest rate, the domestic stock market, the foreign interest rate and the foreign stock market.
Domestic discount factor variance is calculated with this formula: $\mu'\Sigma^{-1}\mu$
Foreign discount factor variance is calculated with this formula: $\mu^{*}'\Sigma^{-1}\mu^{*}$

It is important to note that computations in Table 1 do not make any assumption about the specific form of consumer preferences. They only assume an economy with complete markets and three assets such that a unique discount factor exists and can be recovered from asset market data.

3.3. Computation with Consumption Data

A first approach to measuring risk sharing with consumption data is assuming standard CRRA preferences and then finding an expression to compute the analogous index to (3). Marginal utility of consumption in this case is $U'(C_t) = C_t^{-\gamma}$, where γ is the risk aversion coefficient. Log marginal utility growth is then $-\gamma(c_{t+1} - c_t) \equiv -\gamma \Delta c_{t+1}$, which is the risk aversion coefficient multiplied by the variation in log consumption. The variance of this expression is also the variance of the log stochastic discount factor. Further, from (1), we know that we can use the difference of stochastic discount factors between countries as a measure of the unshared risk. With these elements, it is possible to obtain the following equation for the risk sharing index in this case:

$$1 - \frac{\sigma^2(\Delta c_{t+1} - \Delta c^*_{t+1})}{\sigma^2(\Delta c_{t+1}) + \sigma^2(\Delta c^*_{t+1})} \tag{4}$$

In Equation (4), it is assumed that both countries have the same risk aversion coefficient so that it cancels out in the formula. This index has the same interpretation as in (3), i.e. it measures the percentage of risk effectively shared across countries. Using annual real consumption per capita data for the G7 countries, Table 2 shows computations of this risk sharing index which are comparable to those in Table 1.

TABLE 2 - RISK SHARING INDEX FROM CONSUMPTION DATA WITH CRRA UTILITY FUNCTION
Span of annual data: 1975-2006; Base Country: US

	UK	GERMANY	JAPAN	CANADA	FRANCE	ITALY
Risk Sharing Index	0.446	0.078	0.280	0.610	0.204	-0.096
Log Consumption Growth Correlations	0.460	0.079	0.282	0.613	0.218	-0.096
Average Log Consumption Growth (%)	2.233	1.606	1.674	1.470	1.634	2.400
Standard Deviation of Log Consumption Growth (%)						
Domestic	1.858	1.858	1.858	1.858	1.858	1.858
Foreign	2.397	1.577	2.054	2.072	1.284	2.017

This table shows statistics for domestic and foreign log consumption growth and the corresponding risk sharing index. Consumption is real per-capita consumption of non-durables and services form the International Monetary Fund's IFS database. Nominal consumption is deflated with the CPI price index and turned per-capita with population statistics. Both CPI and population were also retrieved fom the IFS database. Annual data from 1975 through 2006. The risk sharing index is calculated according to Equation (4). The implied stochastic discount factor can be computed as the product of the risk aversion coefficient and the standard deviation of log consumption growth.

From table 2 it is clear that the risk sharing indices with consumption data are very different to those computed with asset market data. Only in the case of Canada, the index is higher than 0.5. It is close to zero in the case of Germany and slightly negative for Italy. The interpretation of a negative index is that the unshared risk is greater than the sum of total market risk. This contrasting difference between risk sharing indices is the core of the puzzle described by Brandt, Cochrane and Santa-Clara (2006).

Table 2 also shows that the correlation of log consumption growth turns out to be very similar to the risk sharing index. It is important to note that they are still different measures and their similarity is not a general feature. The volatility of consumption growth is also reported in Table 2. While this volatility lays around 2%, volatility of the stochastic discount factor fluctuates between 36% and 52% in Table 1. Therefore, in order to reconcile both computations we would need risk aversion coefficients varying between 18 and 26 approximately. These high implied risk aversion coefficients represent the second aspect of the risk sharing puzzle.

Three alternative types of explanations can be provided for the puzzle. First, the complete markets assumption is too strong for real markets. Second, economic agents actually deviate from the behavior predicted by first order conditions. Third, a CRRA utility function is not an accurate description of agents' preferences.

Brandt, Cochrane and Santa-Clara (2006) show that it would be necessary to assume extremely volatile non-market risks in order to explaining the puzzle in the context of incomplete asset markets. Some recent works show models of international economies with low risk sharing which result from combining incomplete markets and additional supply side shocks[6]. The second alternative has been explored in the risk sharing literature by analyzing different types of deviations from first order conditions by assuming frictions or transaction costs[7]. In this paper, I follow the third path by assuming an alternative specification of preferences under the motivation that introducing habits has been useful to explain the

[6] Corsetti, Dedola and Leduc (2008), built a real business cycle model consistent with low risk sharing and with the Backus-Smith (1993) puzzle by combining incomplete markets and productivity shocks. Benigno and Thoenissen (2008) used a similar approach where incomplete markets and a non tradable sector are combined.
[7] For example, Lewis (1996) introduces capital market restrictions and Becker and Hoffman (2006) allow for transaction costs in international financial markets.

equity premium puzzle and the forward premium puzzle as shown by Campbell and Cochrane (1999) and Verdelhan (2007) respectively.

4. External Habit Framework

In this section, I describe the basic external habit preferences framework and its implications for the measurement of international risk sharing with consumption data. Next, I add a simple modification to the habit formation dynamics which allows reconciling both risk sharing measurement approaches: asset market and consumption data[8].

4.1. The Basic Model

I follow initially, the specification of external habits as in Campbell and Cochrane (1999) along with its extension to an international context by Verdelhan (2007). Consider a model with one consumption good and two countries whose representative agents maximize:

$$E\sum_{t=0}^{\infty}\beta^t \frac{(C_t - H_t)^{1-\gamma} - 1}{1-\gamma} \tag{5}$$

In Equation (5), γ denotes the risk aversion coefficient, H_t the external habit level and C_t consumption. The intuition for introducing habits in the specification is that agents do not evaluate only the total level of consumption but also its difference with respect to a given habit level which depends on past consumption and can be considered as a social externality. In each country the habit level is related to consumption through an autoregressive process for the surplus consumption ratio:

$$s_{t+1} = (1-\phi)\overline{s} + \phi s_t + \lambda(s_t)(\Delta c_{t+1} - g) \tag{6}$$

Where the level of surplus consumption ratio is defined by: $S_t \equiv (C_t - H_t)/C_t$. In Equation (6), lowercase letters correspond to logs, g is the average consumption growth

[8] External habit preferences have been used recently in papers studying international finance puzzles. Moore and Roche (2007, 2008) assume deep habits to study exchange rate volatility and persistence, the forward premium puzzle and the Meese-Rogoff (1983) puzzle. Aydemir (2008) uses external habits to explain the countercyclical stock market correlations across countries.

rate and the sensitivity function $\lambda(s_t)$ measures the effect of consumption growth on habit formation. Following Campbell and Cochrane (1999), the sensitivity function is defined by:

$$\lambda(s_t) = \frac{1}{\overline{S}}\sqrt{1-2(s_t - \overline{s})} - 1 \text{, when } s \le s_{MAX}\text{, } 0 \text{ elsewhere,} \tag{7}$$

In Equation (7), $\overline{S}$ is the steady state level of the surplus consumption ratio and s_{MAX} is its upper bound measured in logs. These variables are defined in the following way.

$$\overline{S} = \sigma\sqrt{\frac{\gamma}{1-\phi - B/\gamma}} \tag{8}$$

$$s_{MAX} = \overline{s} + (1-\overline{S}^2)/2 \tag{9}$$

Where $B = 0$ implies that the risk free rate is constant. If $B < 0$, the model becomes compatible with the forward premium puzzle as explained by Verdelhan (2007). Intuitively, $\overline{S}$ measures the average percentage gap between consumption and habit levels in each country. The higher the persistence parameter ϕ, the slower is the convergence of s_t to its steady state value. If s_t happens to reach s_{MAX}, the adjustment process toward the steady state ends up depending only on past values of s_t as (7) describes.

The formulas in (7), (8) and (9) were specified by Campbell and Cochrane (1999) in order to satisfy three conditions: i) the risk free rate is a linear function of s_t [9]; ii) the habit is predetermined at the steady-state $(s_t = \overline{s})$; iii) the habit moves nonnegatively with consumption everywhere. It is possible to show that using (7) and (8) it is possible to compute the following expression for the risk free rate which accords with condition i):

$$r_t^f = -\ln(\delta) + \gamma g - \frac{\gamma}{2}(1-\phi) - B(s_t - \overline{s}) \tag{10}$$

The specification of the sensitivity function for $s_t > s_{\max}$ in (7) ensures that $\lambda(s_t)$ is always nonnegative. Furthermore, that specific functional form for the sensitivity function satisfies the following conditions: $\lambda(\overline{s}) = -1 + 1/\overline{S}$, and $\lambda'(\overline{s}) = -1/\overline{S}$, which allow the habit

[9] For the computation of the risk free rate it is necessary to assume that, in both countries, consumption growth is i.i.d log normally distributed i.e. $\Delta c_{t+1} = g + u_{t+1}$, where $u_{t+1} \sim i.i.d.\ N(0,\sigma^2)$.

level to be predetermined at the steady state and to depend non negatively on consumption everywhere else.

The convenience of the external habit framework stems from the presence of slow and countercyclical movements in the local risk aversion. Let η_t be the local curvature of the utility function with external habits, and it can be solved in the following way:

$$\eta_t \equiv -\frac{C_t u_{cc}(C_t, H_t)}{u_c(C_t, H_t)} = \frac{\gamma}{S_t} \tag{11}$$

Therefore, in bad times, as S_t gets close to zero because consumption gets close to its habit level, the consumer's risk aversion becomes very high. Similarly, S_t increases in good consumption times so that the local risk aversion decreases. These countercyclical movements are the core phenomena that the external habit framework captures which allowed Campbell and Cochrane (1999) explaining the equity premium puzzle and other aspects of the aggregate stock market behavior.

4.2. Measuring Risk Sharing with Habits

The utility function with external habits in (5) is a modified CRRA where the difference between consumption and habit level $(C_t - H_t)$ is what consumers evaluate instead of just the consumption level. Note also that we have the following equivalence: $S_t C_t \equiv (C_t - H_t)$. Therefore, with (5) all computations should be performed similarly to a CRRA function but using $S_t C_t$ instead of C_t.

In particular, we can compute the log stochastic discount factor for any country using the following equation:

$$m_{t+1} = \ln(\delta) - \gamma(\Delta s_{t+1} + \Delta c_{t+1}) \tag{12}$$

In Equation (12), δ is the time preference parameter. Assuming equal risk aversion coefficient across countries, the international risk sharing index can be easily computed analogously to (4):

$$1 - \frac{\sigma^2(\Delta c_{t+1} + \Delta s_{t+1} - \Delta c^*_{t+1} - \Delta s^*_{t+1})}{\sigma^2(\Delta c_{t+1} + \Delta s_{t+1}) + \sigma^2(\Delta c^*_{t+1} + \Delta s^*_{t+1})} \tag{13}$$

I compute the international risk sharing index in Equation (13) using the same real consumption data for G7 countries in Table 2. For the simulation of the log surplus consumption ratio, I use equations (6)-(9) assuming initially the same parameter values as in Verdelhan (2007), namely, $\gamma = 2$, $\phi = 0.961$ and $B = -0.01$[10]. Average consumption growth and its volatility are computed from each country's observed data. Table 3 shows the results from international risk sharing measurement with external habits.

TABLE 3 - RISK SHARING INDEX FROM CONSUMPTION DATA WITH EXTERNAL HABITS
Span of annual data: 1975-2006; Parameters as in Verdelhan (2007)

	UK	GERMANY	JAPAN	CANADA	FRANCE	ITALY
Risk Sharing Index	0.387	0.156	0.230	0.590	0.192	-0.084
Correlation of Consumption Surplus Growth	0.392	0.172	0.239	0.597	0.197	-0.085
Standard Deviation of Stochastic Discount Factor (%)						
Domestic	26.98	26.98	26.98	26.98	26.98	26.98
Foreign	31.73	17.27	20.24	22.95	21.19	23.00

This table shows the risk sharing index computed with real consumption data assuming external habits as in equations 5 to 9. Simulation parameters follow Verdelhan (2007) . The correlation between consumption surplus growth across countries is also interpreted as the correlation between stochastic discount factors. The standard deviation of stochastic discount factors is defined as the risk aversion parameter multiplied by the standard deviation of consumption surplus growth. Annual data from 1975 through 2006. The risk sharing index is calculated according to (13).

Table 3 shows risk sharing indices which are comparable to those in Table 2. It is clear that the puzzle is still present since the indices with external habits remain in a similar level than in Table 2. The same also applies for the correlation of consumption surplus growth which is comparable to the correlation of consumption growth in Table 2. The new feature that external habits bring on to the computation is a higher volatility of the stochastic discount factors compared with the CRRA utility function. In Table 3, this measure shows approximated values between 17% and 32%, while the values implied in Table 2 are no larger than 5%[11]. The reason is that the presence of habits amplifies the fluctuations in marginal utility since the latter depends not only on the level of consumption but also on its difference with a slow moving habit. However, implied volatilities in Table 3 are still below the level suggested by asset market data in Table 1: between 36% and 52%. In summary, when external habits are assumed the risk sharing indices remain almost unchanged and

[10] This persistence parameter is the annual equivalent of the quarterly parameter used by Verdelhan (2007). Similar results are obtained by using the alternative parameter values assumed in Campbell and Cochrane (1999) and Wachter (2006). These results are available by request.

[11] With CRRA utility functions, the volatility of the stochastic discount factor is computed as $\gamma\sigma(\Delta c_{t+1})$.

therefore the first feature of the puzzle still persists. The volatility of stochastic discount factors is now higher though, which solves partially the second feature of the puzzle.

4.3. Including the Effect of Foreign Consumption Growth on Habits

In this section, I add a slight modification to the habit formation process described above. Assume that the representative consumer in each country takes in account not only domestic but also foreign consumption growth when evaluating her habit level. Such assumption can be interpreted as the open economy extension of the original "catching up with the Joneses" formulation in Abel (1990) from which Campbell and Cochrane's specification is based. The intuition is that in a globalized economy with external habits the consumer looks also at the business cycle situation in the foreign country in order to evaluate her habits. With this new assumption the consumer is allowed to evaluate differently, in terms of habits, a situation with high consumption growth everywhere and the case of good times at home but a deep recession abroad.

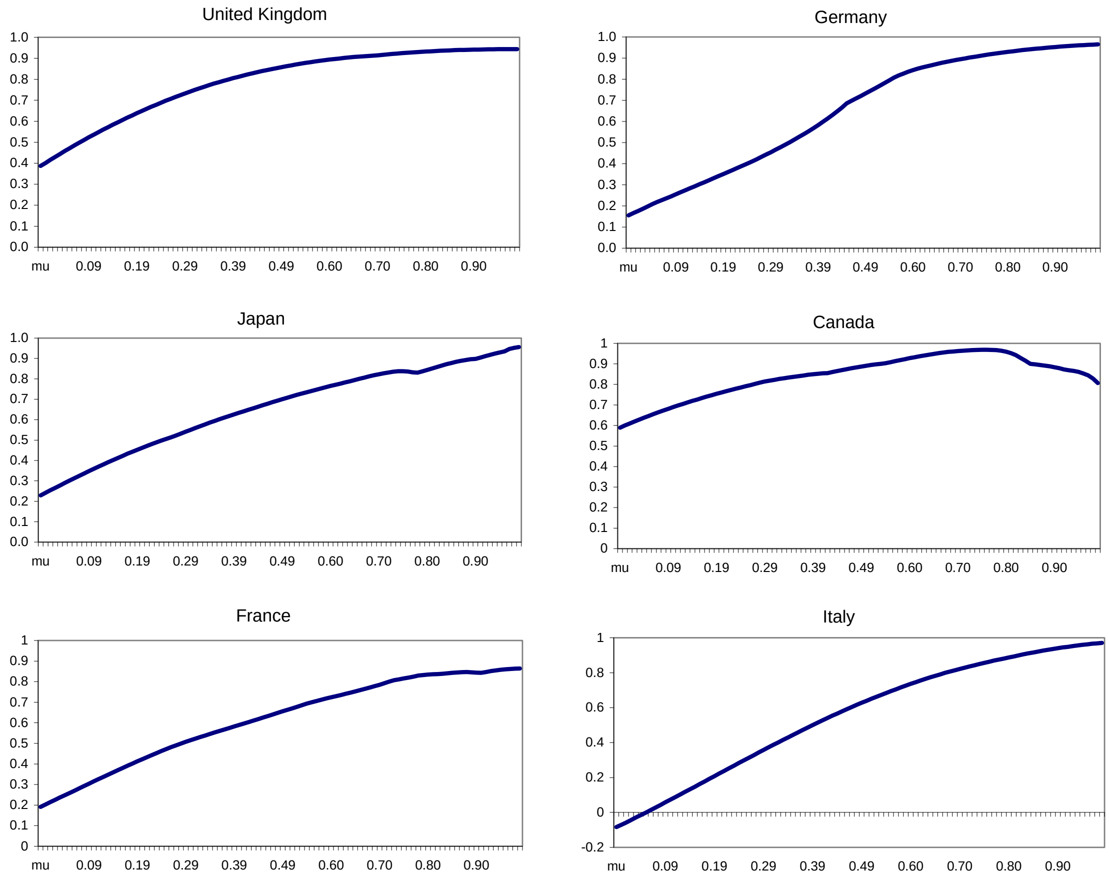
To formalize this new assumption, I rewrite (6) in the following way:

$$s_{t+1} = (1-\phi)\overline{s} + \phi s_t + \lambda(s_t)((\Delta c_{t+1} - g) + \mu(\Delta c^*_{t+1} - g^*)) \tag{14}$$

In Equation (14), the effect of foreign consumption growth on the dynamics of s_{t+1} is weighted by μ which is a positive parameter not greater than 1. In other words, the foreign effect is not allowed to be greater than the domestic consumption effect on habits. If $\mu = 0$, the specification remains equivalent to the one in Verdelhan (2007) and described in Section 4.2. More importantly, this modification does not affect the three desirable properties of the model described in Section 4.1 since the addition of foreign consumption growth does not change the derivatives with respect to domestic consumption or the expected value of the stochastic discount factor.

Note that (14) implies a higher consumption surplus when either domestic or foreign consumption growth are above their respective average level. Therefore, this specification allows recessions or booms abroad to have some effect on the domestic risk aversion. For example, if domestic consumption is equal to its average value (g), but there is a sharp recession in the foreign country, next period consumption surplus ratio will decrease leading to a higher local risk aversion as in Equation (11). Such implication accords with the idea of financial crisis contagion by mean of the propagation of shocks across countries as defined in Rigobon (2001).

FIGURE 1: RISK SHARING INDICES FOR DIFFERENT VALUES OF THE PARAMETER MU
Span of Annual Data: 1975-2006; Parameters as in Verdelhan (2007). Parameters are Symmetric for Both Countries



This figure shows how risk sharing indices change for different values of the parameter μ which measures the weight given to foreign consumption growth on the dynamics of habit formation as in Equation (14). μ can take values between 0 an 1 and is depicted on the horizontal axis. The implied risk sharing indices appear on the vertical axis. The remaining parameters are assumed as in Verdelhan (2007) and symmetric for all countries. Anuual real consumption growth per capita data spanning from 1975 to 2006.

Figure 1 shows implied risk sharing indices for different values of the parameter μ (from 0 to 1), assuming symmetric values of the parameters in each pair of countries. It is clear that when μ takes values above 0.5 the implied extent of risk sharing increase significantly with indices values above 0.6. This figure motivates making a country by country calibration of parameters so that both risk sharing levels and discount factor volatilities are matched with the results obtained with asset market data in Table 1.

TABLE 4 - RISK SHARING INDEX FROM CONSUMPTION DATA WITH EXTERNAL HABITS Habit Formation with Foreign Consumption Tracking Span of annual data: 1975-2006; Parameters: γ = 2, B = -0.01, φ and μ calibrated country by country	UK	GERMANY	JAPAN	CANADA	FRANCE	ITALY
Risk Sharing Index	0.968	0.960	0.971	0.966	0.896	0.955
Correlation of Consumption Surplus Growth	0.970	0.960	0.971	0.967	0.897	0.958
Standard Deviation of Stochastic Discount Factor (%)						
Domestic Country (US)	52.50	40.64	52.09	38.49	37.42	37.21
Foreign Country	49.98	41.05	52.16	37.10	37.08	34.35
Foreign Consumption Parameter (μ)						
Domestic country (US)	0.64	1.00	0.74	0.69	1.00	0.95
Foreign Country	0.95	0.62	1.00	0.76	0.17	0.82
Persistence Parameter (φ for both countries)	0.95	0.87	0.74	0.90	0.92	0.92

This table shows the risk sharing index computed with real consumption data assuming external habits with representative consumers who track foreign consumption growth as in Equation (14). The standard deviation of stochastic discount factors is defined as the risk aversion parameter multiplied by the standard deviation of consumption surplus growth. The persistence parameter is calibrated to match the volatility of stochastic discount factors as in Table 1. Foreign consumption parameters are allowed to be different across countries and are calibrated to match the risk sharing indices in Table 1.

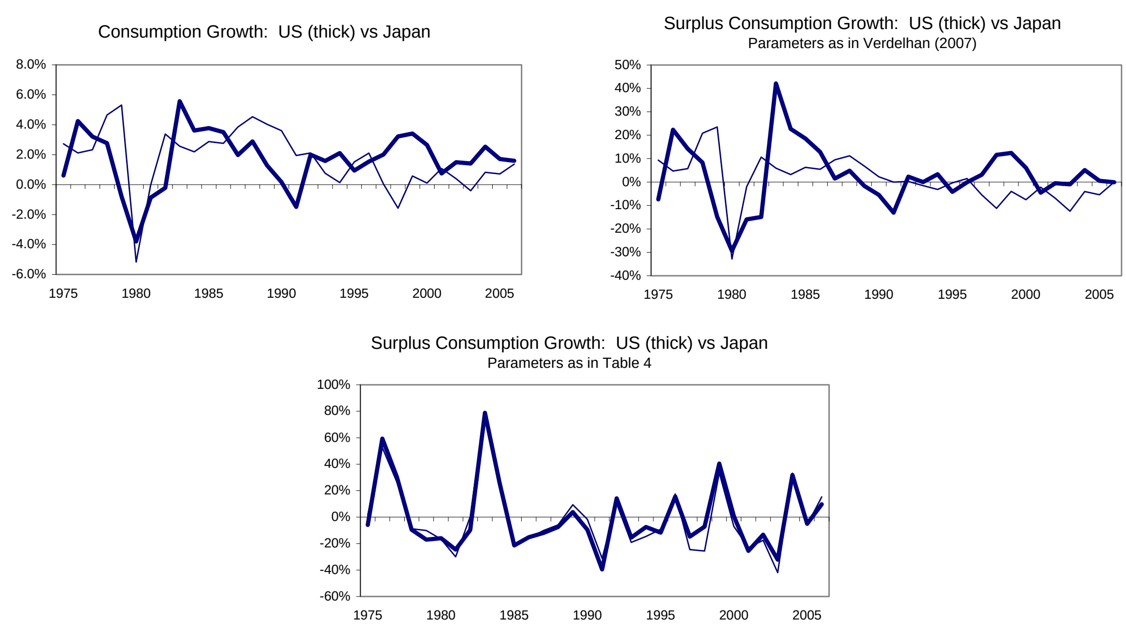
Table 4 shows the results of the country by country calibration exercise in which implied risk sharing indices and discount factor volatilities are close to the values obtained with asset market data. The implied values for μ at the US measure the effect of foreign consumption growth on US consumers' evaluation of habits; μ fluctuates between 0.64 for UK and 1 for Germany and France. Calibrated μ parameters at the foreign country measure the effect of US consumption growth on each country's habit formation; the lowest value corresponds to France (0.17) and the highest to Japan (1.0). The persistence parameter is calibrated symmetrically for both countries and its resulting value fluctuates between 0.74 in Japan and 0.95 in UK.

Summing up, Table 4 shows a full reconciliation of risk sharing measurements with Table 1 thus presenting an alternative solution to the puzzle described in Brandt, Cochrane and Santa-Clara (2006). The implied volatilities of the stochastic discount factor are also reconciled with the results from asset market data. This result is obtained by assuming preferences with external habits, by allowing foreign consumption growth to have an effect on habit formation and by calibrating country by country the persistence parameter.

The intuitive reason for this positive result is that when consumers in each country track foreign consumption growth, the implied consumption surpluses ($C_t - H_t$ and

$C_t^* - H_t^*$), end up having similar cycles so that their growth rates get very correlated. Figure 2 shows the evolution of these variables for US and Japan using two alternative calibrations of habits. One advantage this approach has compared to the one in Colacito and Croce (2006) is that it works for observed consumption data because no specific assumption on the data generating process is needed. Colacito and Croce (2006) must obtain their results with simulated data because they assume a perfect correlation between the long run components of consumption growth in both countries.

FIGURE 2: CONSUMPTION AND SURPLUS CONSUMPTION GROWTH FOR THE US-JAPAN CASE
Span of Annual Data: 1975-2006;



This figure compares the evolution of consumption growth and surplus consumption growth for the US and Japan. The thick line depicts US data, the thin line corresponds to Japan's data. Surplus consumption is defined as the difference between consumption and habit levels. Two simulations are presented for the surplus consumption growth: using parameters as in Verdelhan (2007) and using the parameters calibrated in Table 4.

5. Some Implications of the Calibrated Model

In this section I explore whether the external habits framework calibrated in Table 4 is compatible with some observed characteristics of real exchange rate data. Equation (1) allows simulating the theoretical real exchange rate growth as the difference between foreign and domestic log stochastic discount factors. This exercise is performed for each country using consumption data and the discount factors implied by the external habits framework with two alternative parameter sets: those as in Table 3 which assume $\mu = \mu^* = 0$, and those calibrated in Table 4 which includes foreign consumption effects.

The following moments for the real exchange rate growth are computed with both observed and simulated data: the standard deviation of real exchange growth, its autocorrelation and its correlation with relative real consumption growth. The latter moment is the key measure that Backus and Smith (1993) identified as essential to understand the relation between real exchange rates and consumption. In other words, this exercise aims to analyze whether simulated real exchange rate data is more correlated with relative consumption growth than the observed real exchange rate. Since many international finance models have failed to match this correlation, this exercise is known as the Backus-Smith Puzzle.[12]

TABLE 5 - REAL EXCHANGE RATE GROWTH AND THE BACKUS-SMITH PUZZLE
Span of annual data: 1975-2006; Observed Versus Simulated Real Exchange Rate Growth

MOMENT	TYPE OF DATA	UK	GERMANY	JAPAN	CANADA	FRANCE	ITALY	AVERAGE
Standard Deviation (%)								
	Observed	9.00	10.88	11.75	5.09	11.00	11.09	9.80
	Simulated with $\mu=\mu^*=0$	16.31	14.72	14.80	11.35	15.42	18.46	15.18
	Simulated as in Table 4	6.45	5.78	6.30	4.88	8.48	5.38	6.21
Autocorrelation								
	Observed	0.30	0.32	0.22	0.51	0.28	0.19	0.30
	Simulated with $\mu=\mu^*=0$	0.39	0.49	0.23	0.39	0.32	0.47	0.38
	Simulated as in Table 4	0.41	0.24	0.29	0.17	0.13	0.33	0.26
Correlation with ($\Delta C - \Delta C^*$)								
	Observed	-0.29	-0.10	0.13	0.07	-0.06	-0.08	-0.05
	Simulated with $\mu=\mu^*=0$	-0.94	-0.87	-0.92	-0.93	-0.95	-0.95	-0.93
	Simulated as in Table 4	-0.89	-0.77	-0.81	-0.57	-0.66	-0.81	-0.75

This table compares simulated versus observed real exchange rate growth moments. Computed moments are the standard deviation, autocorrelation, and the correlation with the relative consumption growth. Real exchange rate growth can also be interpreted as the rate of real appreciation with respect to the US Dollar. Two sets of parameters are used to simulate real exchange rate growth: First the parameters calibrated by Verdelhan (2007), second the parameters calibrated in Table 4. The latter parameters include some effect of foreign consumption on domestic habit formation. Both simulations use consumption growth data.

Table 5 shows the results of the simulation which allow comparing the performance of the model calibrated in Table 4 versus the model calibrated as in Verdelhan (2007). The calibration with foreign consumption effects does a good job matching the volatility of the real exchange rate growth for Canada and France. In average it is 3.6 percentage points

[12] Corsetti, Dedola and Leduc (2008) and Benigno and Thoenissen (2008) are recent papers which address the Backus-Smith puzzle by using models with incomplete markets and low international risk sharing. They show that it is necessary to add a new source of shocks to the model in order to obtain the desired correlations. For example, Corsetti, Dedola and Leduc (2008) add productivity shocks.

below the observed moment. When $\mu = \mu^* = 0$, the simulated volatility stands in average, 5.4 percentage points above the observed volatility.

In the case of the real exchange rate growth autocorrelation, the simulation with parameters as in Table 4 gives autocorrelations 4 percentage points below the average observed level. When this persistence measure is applied to the simulation with $\mu = \mu^* = 0$, autocorrelations are higher for all countries except for Canada. In average, it is 8 percentage points higher than the observed persistence.

When the Backus-smith puzzle is examined, it is observed that none of the simulated real exchange rates series is close to the observed ones in terms of the correlation with relative consumption growth. While this correlation is usually close to zero in observed data (-0.05 in average), it tends to be negative in external habit models. However the correlation with data simulated with parameters as in Table 4 is a little closer to the observed value than the correlation with data with no foreign consumption effect. The average for the former correlation is -70%, meanwhile the average for the latter correlation is -87%.

In summary, although it is not the main goal of this paper, the implied simulated real exchange rate growth does a slightly better job matching some observed real exchange rate moments compared with the standard external habit model described by Verdelhan (2007). Nonetheless, both frameworks are still far from solving the Backus-Puzzle.

6. Estimation of the Foreign Consumption Growth Parameters

In this section, I present results of a direct estimation of the foreign consumption growth parameter (μ) using data on foreign currency excess returns. The goal is looking for the parameter values that minimize the pricing errors of the country by country Euler equation. The general result is that the external habit framework with positive values for μ is not rejected by the data[13].

The method consists of computing the sample equivalent of the Euler equation:

[13] The estimation method in this section is similar to Verdelhan's (2007) GMM estimation of the structural parameters on the external habit framework. However, while he estimates 4 structural parameters, I focus only on estimating the new parameter country by country.

$$E_t\left[M_{t+1}R_{t+1}^{e,i}\right]=0 \qquad (15)$$

Where $R_{t+1}^{e}=(1+r_t^i)Q_{t+1}^i/Q_t^i-(1+r_t)$ represents the currency excess return for an American investor in country i, Q^i and r^i are respectively the real exchange rate and the real interest rate of country i. The real interest rate in the US is r_t. The stochastic discount factor M_{t+1} is computed using real consumption data and using the external habit framework described in Section 4, in particular, Equation (12) with the surplus consumption ratio calculated according to (14).

Estimations are run country by country with quarterly data spanning 1975Q1 to 2006Q4. Since the Euler condition in (15) holds as a conditional expectation, the US real interest rate (lagged one period) is used as instrument along with a constant. As a result, this setup gives two moment conditions for each country which allows estimating one variable. A two-step GMM estimation method is applied where the initial weighting matrix is proportional to Z the matrix of instruments: $W_0=(Z'Z)^{-1}$. In the second step, the optimal weighting matrix namely, the inverse of the spectral density matrix is applied to the estimation. Standard errors are computed following GMM asymptotic theory following Hansen (1982)[14]. Finally, the following parameter values were assumed for the computation of the stochastic discount factors: $\gamma=2$, $\varphi=0.961$ and $B=-0.01$.

TABLE 6 - COUNTRY BY COUNTRY GMM ESTIMATION RESULTS

Estimation of the Foreign Consumption Parameter (μ) for an American Investor - Parameters are Restricted to the [0,1] Interval

	UK	GERMANY	JAPAN	CANADA	FRANCE	ITALY
μ	0.82	0.00	0.64	0.00	1.00	1.00
Standard Error	5.09	1.05	3.54	4.23	3.44	1.69
Significance Test	0.84	0.00	0.18	0.00	0.29	0.59
p-value	0.40	1.00	0.86	1.00	0.77	0.55
J test	1.82	2.35	1.76	0.10	3.10	0.34
p-value	0.18	0.13	0.18	0.75	0.08	0.56

This table presents the estimated values of the foreign consumption parameter μ. This estimation consists of selecting the value that minimizes pricing errors in Equation (15) from a grid on the interval [0,1]. A constant and the US risk free real interest rate (lagged one period) are the instruments. The J-test's null hypothesis is is that the pricing errors are zero. It is distributed asymptotically as Chi-2 with one degree of freedom. Real consumption data per-capita is used to compute stochastic discount factors. Data sources are described in Table A1 at the appendix. This estimation is performed with quarterly data spanning 1975I-2006IV.

[14] Cochrane (2001) and Cliff (2003) were also used as references for assumptions and formulas in GMM estimation.

Table 6 presents the estimated values of μ, their standard errors, significance levels and the J-test. J tests the null hypothesis of zero pricing errors and corresponds to the sample size multiplied by the minimized value of the objective function. It is known as the test of over-identifying restrictions. In Table 6, μ is picked up as the value that minimize pricing errors from a grid of possible values in the interval [0,1].

The estimated parameters are equal to zero in Germany and Canada. For the remaining countries, μ are positive and their values are in line with the calibrations in Table 4. However, due to the non-linearities of the objective function, the estimates are not significantly different from zero since they have large standard errors. The J test shows that the zero pricing errors hypothesis cannot be rejected for any country at a 95% confidence level. In other words, actual data do not reject the external habit framework with foreign consumption effects as described in Section 4.3.

TABLE 7 - COUNTRY BY COUNTRY GMM ESTIMATION RESULTS

Estimation of the Foreign Consumption Parameter (μ) for an American Investor - Parameters are unrestricted

	UK	GERMANY	JAPAN	CANADA	FRANCE	ITALY
μ	2.37	-1.06	13.60	1.05	1.80	1.11
Standard Error	0.20	0.45	0.00	1.49	0.51	3.32
Significance Test	11.92	-2.35	63220.00	0.70	3.55	0.33
p-value	0.00	0.02	0.00	0.48	0.00	0.74
J test	0.01	0.06	2.22	0.40	3.37	0.44
p-value	0.92	0.81	0.14	0.53	0.07	0.51

This table presents the estimated values of the foreign consumption parameter μ. This estimation consists of selecting the value that minimizes pricing errors in Equation (15). Cliff's (2003) library in MATLAB is applied in this estimation. A constant and the US risk free real interest rate (lagged one period) are the instruments. μ=1 is the initial value of the optimization procedure. The J-test's null hypothesis is is that the pricing errors are zero. It is distributed asymptotically as Chi-2 with one degree of freedom. Real consumption data per-capita is used to compute stochastic discount factors. Data sources are described in Table A1 at the appendix. This estimation is performed with quarterly data spanning 1975I-2006IV.

Table 7 shows an alternative approach to the country by country GMM estimation of μ by allowing the parameter to take any value in the real line and by performing the estimation using a Gauss-Newton optimization algorithm[15]. An initial parameter value of 1 is applied for all countries. On each step it is assumed 100 as the maximum number of iterations. The tolerance level for the convergence of the objective function is 10^{-7}.

[15] Michael Cliff's GMM library for MATLAB was applied in this unrestricted estimation. See Cliff (2003) for a description of the software and directions of use.

Results in Table 7 show that the estimated μ are positive for all countries except Germany. Only for Canada and France they are not significantly different from zero. Thus this estimation shows that foreign consumption effects in habit formation, as described in Equation (14), are significant in the data for 4 out of 6 countries. However, the values estimated in Table 7 do not satisfy the restrictions assumed in the economic model: μ should lie in the [0,1] interval so that they are in line with international risk sharing evidence. Finally, estimations in Table 7 do not reject the zero pricing errors for any country with 95% confidence level.

7. Conclusions

International risk sharing levels are high (95% of total risk is shared), when measured with asset market data and assuming complete markets in the G7 countries. When measured with real consumption data and standard preferences not only risk sharing levels are lower (less than 40%) but there is too little risk to share as measured by the volatility of stochastic discount factors. This puzzle is studied in this paper by computing risk sharing indices with historic consumption data under the assumption of preferences with external habits as in Campbell and Cochrane (1999) and Verdelhan (2007), but adding a new element to the dynamics of habit formation. Namely, consumers track both domestic and foreign consumption growth when forming their consumption habits. This assumption captures the intuitive idea that consumers look also at foreign countries when evaluating their standards of consumption. Furthermore, since consumers have time varying local risk aversion in this framework, the new assumption implies that a recession abroad increases domestic risk aversion.

By including foreign consumption effects on habit formation, risk sharing computations with real consumption data are able to match those obtained with asset market data. Risk sharing indices confirm a very high level of international risk sharing between the US and the remaining G7 countries. Furthermore, the implied volatility of the stochastic discount factor also matches the one computed with asset marked data. These results are obtained by appropriately calibrating the foreign consumption parameters in each country along with the persistence parameter.

When compared with previous external habit frameworks, the real exchange rate growth series implied by the new calibrated model is slightly closer to the actual series in terms of volatility, persistence and correlation with relative consumption growth. However, this simulated correlation between real exchange rates and consumption is still high compared with the observed value in actual data. Additionally, the foreign consumption parameter is estimated country by country using a nonlinear GMM framework which minimizes pricing errors form an Euler equation. Although the estimated values differ from the calibrated ones, they are significantly different from zero in most countries.

These computations, using the calibrated framework, represent an alternative explanation for the puzzle described by Brandt, Cochrane and Santa-Clara (2006). They also constitute a contribution to the debate on the lack of evidence on consumption-based international risk sharing as described by Karen Lewis (1996, 1999). Colacito and Croce (2007) also addressed this puzzle for UK-US data, by assuming recursive preferences as in Epstein and Zin (1989), and assuming a long run component in the data generating process of consumption growth. However, an essential requirement for their results is a perfect cross-country correlation between shocks to the long run component. Furthermore, they are able to reconcile the risk sharing measurements by using simulated data but not using actual historical data.

Appendix: Additional Computations

Table A1 - Summary Statistics	US Stock	UK		Germany		Japan		Canada		France		Italy	
		Stock	X-rate	Stock	X-rate	Stock	X-rate	Stock	X-rate	Stock	X-rate	Stock	X-rate
returns (% annual)													
mean	6.78	7.56	1.87	8.44	0.7	6.62	-0.81	5.32	0.53	8.7	1.64	7.24	1.21
Std. Dev	13.06	11.25	9.72	21.72	11.69	18.39	12.16	17.24	5.25	20.67	11.72	31.05	11.76
Return Correlations (1 = 100%)													
US Stock	--	0.66	0.04	0.52	0.03	0.33	0.17	0.61	0.06	0.58	0.02	0.38	0.09
Foreign Stock	--	--	-0.23	--	0.46	--	0.27	--	0.26	--	-0.01	--	0.02

This table is a replication of "Table 1" in Brandt, Cochrane and Santa-Clara (2006) but adding more countries and using a longer span of data. It shows summary statistics for real excess returns on stock indices and exchange rates for G7 countries. The stock indices are total market returns from Datastream, the interest rates are for one-month Eurocurrency deposits from Datastream, and the CPI as well as exchange rates are from the International Monetary Fund's IFS database. The stock returns (Stock) are excess returns over the same country's one-month interest rates. The exchange rate returns (X-rate) are excess returns for borrowing in dollars, converting to the foreign currency, lending at the foreign interest rates, and converting the proceeds back to dollars. Annual data from 1975 through 2006.

TABLE A2 - COMPUTED SURPLUS CONSUMPTION RATIO LEVELS (%)
Span of annual data: 1975-2006;

	US [1]	UK	GERMANY	JAPAN	CANADA	FRANCE	ITALY
Parameters as in Verdelhan (2007)							
Steady State (%)	12.33	15.91	10.47	13.63	13.75	8.52	13.38
Upper Bound (%)	20.17	25.90	17.16	22.26	22.46	14.00	21.87
Parameters as in Table 4							
Steady State (%)	8.13	14.06	6.02	5.59	8.76	6.10	9.81
Upper Bound (%)	13.35	22.96	9.90	9.20	14.39	10.04	16.10

1/ In the case of the calibration as in Table 4, US results are the average of the bilateral computations with each country.
This table shows the implied levels of steady state and maximum consumption surplus ratio levels, as defined in equations (8) and (9), for two sets of parameters: those in Verdelhan (2007) and those in Table 4 which include foreign conusmption effects. The consumption surplus ratio is the extent of consumption above the habit level as a fraction of total consumption. Annual data on real per-capita consumption from 1975 through 2006 are used in this computation.

CHARACTERISTIC	TYPE OF DATA	UK	GERMANY	JAPAN	CANADA	FRANCE	ITALY
TABLE A3 - REAL EXCHANGE RATE AND THE BACKUS-SMITH (1993) PUZZLE Span of annual data: 1975-2006; Observed Versus Simulated Real Exchange Rate Growth							
Mean (%)							
	Observed	1.42	0.39	1.28	-0.27	0.63	0.81
	Simulated as in Verdelhan (2007)	0.40	-1.86	-1.59	-0.28	-0.63	-1.03
	Simulated as in Table 4	0.35	-1.57	-0.90	-0.29	-0.62	0.16
Correlation with ΔC							
	Observed	-0.22	0.15	0.39	0.01	0.01	0.01
	Simulated as in Verdelhan (2007)	-0.37	-0.81	-0.68	-0.52	-0.67	-0.80
	Simulated as in Table 4	-0.48	-0.51	-0.40	-0.28	-0.50	-0.69
Correlation with ΔC*							
	Observed	0.11	0.32	0.20	-0.04	0.11	0.11
	Simulated as in Verdelhan (2007)	0.60	0.35	0.44	0.32	0.52	0.61
	Simulated as in Table 4	0.47	0.54	0.57	0.22	0.31	0.52

This table compares simulated versus observed real exchange rate growth moments. Computed moments are the mean and the correlations with domestic and foreign consumption growth. Real exchange rate growth can also be interpreted as the rate of real appreciation with respect to the US Dollar. Two sets of parameters are used to simulate real exchange rate growth: First the parameters calibrated by Verdelhan (2007), second the parameters calibrated in Table 4. The latter set of parameters include some effect of foreign consumption on habit formation. Both simulations use real consumption growth data.

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