Limited asset market participation and the consumption-real exchange rate anomaly

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Abstract. Under efficient consumption risk sharing, as assumed in standard international business cycle models, a country's aggregate consumption rises relative to foreign consumption, when the country's real exchange rate depreciates. Yet empirically, relative consumption and the real exchange rate are essentially uncorrelated. This paper shows that this 'consumption-real exchange rate anomaly' can be explained by a *simple* model in which a subset of households trade in complete financial markets, while the remaining households lead hand-to-mouth (HTM) lives. HTM behaviour also generates greater volatility of the real exchange rate and of net exports, which likewise brings the model closer to the data. JEL classification: F41, F36

Participation limitée au marché des actifs et anomalie dans la corrélation entre la consommation relative et le taux de change réel. S'il y avait un partage efficace du risque, tel que supposé dans des modèles standard du cycle des affaires international, alors la consommation agrégée d'un pays augmenterait, par rapport à la consommation étrangère, lorsque le taux de change réel du pays se déprécie. Cependant, empiriquement, la corrélation entre la consommation relative et le taux de change réel est proche de zéro. Cette étude montre que ce phénomène peut être expliqué par un modèle simple dans lequel une partie des ménages

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a accès à des marchés financiers complets, tandis que les ménages restants 'vivent au jour le jour' (VJJ). Un comportement VJJ engendre aussi une volatilité plus élevée du taux de change réel et des exportations nettes, ce qui accroît également la pertinence empirique du modèle.

1. Introduction

There is overwhelming evidence that consumption risk is not efficiently shared across countries. Under unrestricted trading in complete financial markets (as assumed in standard international business cycle models, e.g., Backus, Kehoe, and Kydland 1994), the real exchange rate is proportional to the ratio of domestic to foreign marginal utilities of consumption. This implies that, under optimal consumption risk sharing, a country's relative consumption *rises* when its real exchange rate *depreciates*. That prediction holds, regardless of frictions in goods markets (transportation costs, non-tradables, sticky prices, etc.). Yet, empirically, relative consumption and the real exchange rate are essentially uncorrelated (e.g., Backus and Smith 1993; Kollmann 1991, 1995). Limited international risk sharing, as reflected in that 'consumption-real exchange rate anomaly,' is one of the major puzzles in international macroeconomics; the solution of this puzzle would shed light on the functioning of international markets, with key potential implications for macro theory and policy (Obstfeld and Rogoff 2000; Obstfeld 2007).[1]

Past attempts to explain the consumption-real exchange rate anomaly have focused mostly on models in which only a restricted set of assets can be traded *internationally*, while it is assumed that each country is inhabited by a representative agent, thus postulating efficient *within-country* hedging of risks; see, for example, Baxter and Crucini (1995), Kollmann (1991, 1996), Obstfeld and Rogoff (1996), and Heathcote and Perri (2002). These modelling efforts have had only limited success. Even in structures in which only a riskless bond can be traded internationally, the national representative agents can typically achieve a surprising amount of cross-country risk pooling (by borrowing abroad when domestic output is low); as under complete markets, relative consumption thus rises whenever the real exchange rate depreciates. See, for example, Chari, Kehoe, and McGrattan (2002), who conclude, based on the detailed analysis of a rich two-country dynamic stochastic general equilibrium (DSGE) model, that 'the most widely used forms of asset market incompleteness do not eliminate – or even shrink – the anomaly' (561).

Recently, Benigno and Thoenissen (2008) and Corsetti, Dedola, and Leduc (2008) identified conditions (strong complementarities between domestic and

1 For empirical and theoretical discussions of this anomaly, see also Obstfeld (1993), Canova and Ravn (1996), Opazo (2006), Hoffmann (2004), Hadzi-Vaskov (2008), Devereux and Hnatkovska (2009), Coeurdacier, Kollmann, and Martin (2008, 2010), Cociuba and Ramanarayanan (2011), and other papers cited below.

foreign tradables or highly volatile/persistent tradables supply shocks without foreign spillovers) under which a two-country model with just one traded bond can generate realistic (low) correlations between relative consumption and the real exchange rate. However, Benigno and Küçük-Tuger (2010) show that these results are not robust to the introduction of a second traded asset; for example, with trade in *two* nominal bonds, the Benigno-Thoenissen model again predicts that relative consumption changes are almost perfectly correlated with the rate of real exchange rate depreciation (as under complete markets).[2]

This critique is relevant because, in reality, there is large-scale international trade in a wide array of assets (bonds denominated in different currencies and of different maturities, equities, derivatives). Finally, standard incomplete markets models also seem problematic because consumption risk sharing is limited not only across countries, but also among the residents of the same country (e.g., Crucini 1999; Santos Monteiro 2008).

This paper shows that the consumption-real exchange rate anomaly can be explained by a *simple* model in which only a subset of households trade freely in *complete* international financial markets; the remaining households do not participate in asset markets, and simply consume their labour income (modelled as an exogenous fraction of domestic output), thus leading 'hand-to-mouth' (HTM) lives. This 'limited participation' set-up provides a very transparent integration of *within*-country heterogeneity into a model of the world economy. The results here suggest that the consumption-real exchange rate anomaly might be due not to the underdevelopment of (international) financial markets, but to the fact that a significant fraction of agents does not participate in those markets. Empirically, a sizable fraction of households holds zero financial assets (Haliassos 2006), and very few households have *foreign* assets (e.g., Christelis and Georgarakos 2009).

The HTM behaviour assumed here can reflect household myopia or simple rule-of-thumb decision making (Mankiw 2000). Empirically, aggregate consumption growth closely tracks income growth (Carroll and Summers 1989). The *closed* economy literature has argued that the presence of HTM households may explain that fact (Campbell and Mankiw 1989). That literature has also suggested that HTM households may rationalize the macroeconomic effects of fiscal policy (Galí, Lopez-Salido, and Vallès 2007) and the equity premium (Weil 1990). By contrast, the HTM assumption has received little attention in the *open* economy

2 As pointed out by Devereux, Smith, and Yetman (2011), the models proposed by Benigno and Thoenissen (2008) and Corsetti, Dedola, and Leduc (2008) also have the drawback that (in those structures) the *expected growth* rate of relative consumption is perfectly correlated with the *expected* rate of real exchange rate depreciation (this follows from agents' Euler equations if at least one asset is traded by *all* agents, as assumed in these models). That prediction holds even if the *unconditional* consumption-real exchange rate correlation is close to zero. Using survey data, Engel and Rogers (2008) and Devereux, Smith, and Yetman (2011) show that *expected* growth rates of relative consumptions and real exchange rates are uncorrelated.

macro literature, with the notable exception of Devereux, Smith, and Yetman (2011).[3]

The model here assumes a two-country world; each country produces a different tradable good and uses domestic and foreign inputs for consumption and physical investment; there is a local bias in consumption and investment spending. There are country-specific shocks to output, to investment spending, and to the share of GDP received by HTM households.

In the HTM structure here, as in a structure with full risk sharing (no HTM households), shocks to output and investment *individually* induce *negative* co-movement between a country's relative aggregate consumption and its real exchange rate, defined as the ratio of the country's CPI to the foreign CPI (expressed in common currency): in both structures, an exogenous increase in the output of country 'Home,' say, raises Home (relative) consumption, and depreciates (lowers) the Home real exchange rate; a Home investment boom crowds out Home consumption and appreciates the real exchange rate (owing to the local spending bias). With full risk sharing, relative consumption and the real exchange rate are perfectly negatively correlated when there are *simultaneous* output and investment shocks. The presence of HTM households breaks that perfect negative correlation (under simultaneous shocks). For, when there are HTM households, a positive shock to Home investment triggers a stronger real exchange rate appreciation and a more muted fall in Home relative consumption than under full risk sharing. Intuitively, the presence of HTM households lowers the price elasticity of relative world demand for Home (vs. Foreign) produced goods, because Home HTM households' real income (in consumption units) rises when the Home terms of trade improve; as Home consumption is biased towards the Home good, this income effect counteracts the negative substitution effect of the terms of trade change. With HTM households, a stronger terms of trade (and real exchange rate) adjustment is thus needed to clear the goods market, in response to investment shocks (and there is weaker crowding out of domestic consumption). In addition, the model here assumes shocks to the share of GDP received by the HTM households (as mentioned above); those shocks are a source of *positive* co-movement between relative consumption and the real exchange rate.

The model is calibrated to data for the US and an aggregate of the remaining G7 countries. The baseline calibration assumes that HTM consumption accounts for 50% of total consumption, on average, which is in the range of empirical

3 Using a model that differs from the present structure, Devereux, Smith, and Yetman (2011) argue that the presence of HTM agents can explain why, in the data, *expected* changes in relative consumption are uncorrelated with *expected* real exchange rate changes (see earlier footnote). The paper here was written simultaneously and independently of that study; it analyzes the effect of HTM agents on a broader set of macro facts, and provides more detailed analytical and numerical results. Some large multi-country policy models assume HTM agents, mainly to match empirical responses to fiscal shocks (Erceg, Guerrieri, and Gust 2006; Ratto, Roeger, and in't Veld 2008; Forni, Monteforte, and Sessa 2009; Forni and Pisani 2010), but the role of the HTM feature for international risk sharing has not yet been analyzed using these models.

estimates of that share (Mankiw 2000). The baseline HTM model predicts that a country's relative consumption is, essentially, uncorrelated with its real exchange rate, as is consistent with the data. In addition, the presence of HTM agents increases the volatility of the real exchange rate and of net exports, and it lowers the predicted cross-country correlation of consumption (compared with a setting without HTM households). This too brings the model closer to the data.

2. The model

2.1. Preferences, endowments, and markets

There are two ex ante symmetric countries, Home (H) and Foreign (F). Country i = H,F produces Y_i units of a traded good i. Country i is inhabited by two households. The first agent is a hand-to-mouth household, HTM, who receives an exogenous fraction λ_i of local output, Y_i. The second household receives $(1-\lambda_i)Y_i$, and she trades in a complete financial market with her foreign counterpart; this household is referred to as a 'risk sharer' (RS). The Home and Foreign RS households also finance real investment (non-consumption) spending. The HTM and RS households can be interpreted as a worker and as an entrepreneur, respectively. Household h = HTM,RS in country i has the utility function $U(C_i^h) = \{(C_i^h)^{1-\sigma} - 1\}/(1-\sigma)$, where C_i^h is real consumption, a composite of local and imported inputs:

$$C_i^h = \left[\alpha^{1/\phi}\left(c_i^{i,h}\right)^{(\phi-1)/\phi} + (1-\alpha)^{1/\phi}\left(c_i^{j,h}\right)^{(\phi-1)/\phi}\right]^{\phi/(\phi-1)}, \quad j \neq i; \tag{1}$$

$c_i^{j,h}$ is the household's consumption of good j. $\sigma > 0$ and $\phi > 0$ are the risk aversion coefficient and the substitution elasticity between goods, respectively. There is a preference bias for the local good: $1/2 < \alpha < 1$. The utility-based CPI is $P_i \equiv [\alpha(p_i)^{1-\phi} + (1-\alpha)(p_j)^{(1-\phi)}]^{1/(1-\phi)}$, where p_i is the price of good i.

The Home terms of trade and real exchange rate are defined as $q \equiv p_H/p_F$ and $RER \equiv P_H/P_F$, respectively. (Note that an increase in RER is an *appreciation* of the Home real exchange rate.)

The real consumption of the HTM household is

$$C_i^{HTM} = p_i \lambda_i Y_i / P_i. \tag{2}$$

Efficient risk sharing between Home and Foreign RS households implies that the ratio of their marginal utilities of consumption is equated to the real exchange rate (Kollmann 1991, 1995; Backus and Smith 1993):

$$\left(C_H^{RS}\right)^{-\sigma} / \left(C_F^{RS}\right)^{-\sigma} = RER. \tag{3}$$

This implies that (up to a linear approximation) the relative consumption of the Home (vs. Foreign) RS household, C_H^{RS}/C_F^{RS}, is perfectly negatively correlated with the Home real exchange rate.

Real investment in country i, denoted by I_i, is a composite good that has the same structure as aggregate consumption (1). Spending is allocated to inputs H and F so that marginal rates of substitution between these goods are equated to their relative price. Thus,

$$c_i^{i,h} = \alpha(p_i/P_i)^{-\phi} C_i^h,\, c_i^{j,h} = (1-\alpha)(p_j/P_i)^{-\phi} C_i^h \quad (j \neq i) \tag{4a}$$

for $i,j = H,F$ and $h = HTM$, RS. Similarly,

$$\iota_i^i = \alpha(p_i/P_i)^{-\phi} I_i,\, \iota_i^j = (1-\alpha)(p_j/P_i)^{-\phi} I_i \quad (j \neq i), \tag{4b}$$

where ι_i^j is country i investment demand for good j.

Market clearing requires

$$\sum_{j=H,F} \{c_j^{i,HTM} + c_j^{i,RS} + \iota_j^i\} = Y_i \quad \text{for } i = H, F.$$

The above equations pin down consumptions and the terms of trade, given output, investment, and the HTM share of GDP in the two countries (Y_i, I_i, λ_i for $i = H, F$).[4] Here, Y_i, I_i, λ_i are not endogenized. The focus is on the behaviour of consumption and the real exchange rate, *conditional* on these forcing variables. The second moments of the forcing variables are set equal to observed second moments for the US and an aggregate of the remaining G7 countries.[5] The expected value of output is normalized at $EY_i = 1$; mean investment and the mean HTM share of GDP are denoted by $\Xi \equiv EI_i > 0$ and $\Lambda \equiv E\lambda_i$, respectively, where $0 < \Lambda + \Xi < 1$.

2.2. *Model solution*

The model is linearized around mean values of the forcing variables. The expression $\widehat{z} \equiv (z - \overline{z})/\overline{z}$ is the relative deviation of variable z from the point

4 For simplicity, the paper considers only two components of aggregate absorption: consumption and investment; that is, it abstracts from government purchases. Model variants that also include exogenous government purchases yield quantitative results similar to those shown below (as those purchases are markedly less volatile than investment and represent a small share of GDP).

5 The conditions that, in the present static model, pin down consumption and the real exchange rate (as functions of output, investment and the HTM share of GDP) would continue to hold in a dynamic extension of this model, with the same asset markets set-up and identical preferences. Thus, such a dynamic model would generate the *same* consumption-real exchange rate correlations (as the static model here), if the dynamic model reproduces the empirical moments of Y_i, I_i, λ_i (that are *calibrated* here). (See Kollmann 2009 for a dynamic HTM model with endogenous production and investment.)

of linearization, $\bar{z}$. The following variables without subscripts represent ratios of Home to Foreign variables: $C^{HTM} \equiv C_H^{HTM}/C_F^{HTM}$, $C^{RS} \equiv C_H^{RS}/C_F^{RS}$, $I \equiv I_H/I_F$, $Y \equiv Y_H/Y_F$, $\lambda \equiv \lambda_H/\lambda_F$.

The real exchange rate obeys: $\widehat{RER} = (2\alpha - 1)\widehat{q}$. Since consumers in each country prefer the local good ($\alpha > 0.5$), an increase in the relative price of the Home good, a Home terms of trade improvement, drives up the Home price index relative to the Foreign price index – a Home real exchange rate appreciation.

Equation (2) implies that the relative (Home/Foreign) consumption of HTM households is

$$\widehat{C^{HTM}} = \widehat{Y} + \widehat{\lambda} + 2(1 - \alpha)\widehat{q}. \tag{5}$$

An increase in (relative) Home GDP and in the fraction of GDP received by the Home HTM household and a Home terms of trade improvement all raise the relative consumption of the Home (vs. Foreign) HTM household. By contrast, the relative (Home/Foreign) consumption of RS households is a *decreasing* function of the terms of trade, as (3) implies

$$\widehat{C^{RS}} = -(1/\sigma)(2\alpha - 1)\widehat{q}. \tag{6}$$

From equations (4a) and (4b), relative world demand for good H (relative to demand for good F) obeys

$$d = q^{-\phi}\{\alpha RER^{\phi} A + 1 - \alpha\}/\{(1 - \alpha)RER^{\phi} A + \alpha\}, \tag{7}$$

where $A \equiv A_H/A_F$, with $A_i \equiv C_i^{HTM} + C_i^{RS} + I_i$ being absorption in country i. This implies

$$\widehat{d} = -\phi\widehat{q} + (2\alpha - 1)(\phi\widehat{RER} + \widehat{A}) = -4\alpha(1 - \alpha)\phi\widehat{q} + (2\alpha - 1)\widehat{A}. \tag{8}$$

By using (5)–(8), relative demand can be expressed as

$$\widehat{d} = -\Gamma\widehat{q} + (2\alpha - 1)\Lambda(\widehat{\lambda} + \widehat{Y}) + (2\alpha - 1)\Xi\widehat{I}, \tag{9}$$

where $\Gamma \equiv 4\alpha(1 - \alpha)\phi + (1 - 2\alpha)^2(1 - \Lambda - \Xi)/\sigma - 2(2\alpha - 1)(1 - \alpha)\Lambda$ is the elasticity of relative world demand for the Home traded good with respect to the Home terms of trade, q. (To get (8) and (9), $\overline{A} = \overline{RER} = 1$ is used, due to symmetry, and $\widehat{A} = \Lambda\widehat{C^{HTM}} + (1 - \Lambda - \Xi)\widehat{C^{RS}} + \Xi\widehat{I}$.)

$\Gamma > 0$ holds under full risk sharing, that is, when there are no HTM households ($\Lambda = 0$). Γ is decreasing in Λ, the mean share of GDP received by HTM households. The presence of HTM households thus lowers the price elasticity of relative demand. Intuitively, an improvement of the Home terms of trade raises the relative income of the Home HTM household; as Home consumption spending is biased towards the Home good, this income effect counteracts the negative substitution effect of the terms of trade improvement on the relative world demand for good H. The income effect of a terms of trade improvement is stronger, the greater is Λ, which explains why $\partial\Gamma/\partial\Lambda < 0$. However, $\Gamma > 0$ holds for plausible values of Λ(see the appendix). The following discussions thus assume $\Gamma > 0$.

Market clearing requires that relative demand equals relative output: $d = Y$. A rise in Home relative output Y triggers a deterioration of the equilibrium Home terms of trade: at *unchanged* terms of trade, a 1% increase in Y raises relative demand for good H by less than 1%, namely, by $(2\alpha - 1)\Lambda$% (see (9)); market clearing thus requires a fall of the relative price of good H (provided $\Gamma > 0$). Equation (9) shows that increases in Home relative real investment spending (I) and in the relative share of GDP received by Home (vs. Foreign) HTM households (λ) raise the relative demand for good H; those shocks trigger thus an equilibrium improvement of the Home terms of trade and an appreciation of the Home real exchange rate. Hence (see the appendix):

$$\widehat{RER} = \underset{(-)}{a_Y}\,\widehat{Y} + \underset{(+)}{a_I}\,\widehat{I} + \underset{(+)}{a_\lambda}\,\widehat{\lambda}. \tag{10}$$

Relative 'national' consumption $C \equiv C_H/C_F$, with $C_i \equiv C_i^{HTM} + C_i^{RS}$ $(i = H, F)$, obeys

$$\widehat{C} = \underset{(+)}{b_Y}\,\widehat{Y} + \underset{(-)}{b_I}\,\widehat{I} + \underset{(+)}{b_\lambda}\,\widehat{\lambda}. \tag{11}$$

An increase in Home relative output Y raises Home relative consumption C, while a rise in relative investment I lowers C, for plausible parameter values (see the appendix). As an increase in λ improves the Home terms of trade, it is accompanied by an increase in Home relative consumption.[6]

When there are no HTM households ($\Lambda = 0$), relative consumption is perfectly negatively correlated with the real exchange rate, and thus $a_Y/a_I = b_Y/b_I < 0$. In the calibrated model (see below) an increase in the expected share of GDP received by the HTM households (Λ) has a weak effect on a_Y, b_Y (for plausible parameter values, a_Y, b_Y can be increasing or decreasing in Λ). A rise in Home investment improves the Home terms of trade more strongly, the greater is Λ (as the price elasticity of relative world demand for good H is decreasing in Λ). Owing to the positive income effect received by the Home HTM household, when the Home terms of trade improve, Home relative consumption falls less strongly in response to a Home investment shock, the greater is Λ. Thus, the response coefficients a_I, b_I (see (10) and (11)) are increasing in Λ. This mechanism, owing to the presence of HTM households, breaks the perfect negative

6 (8) and $Y = d$ imply that any shock that improves the Home terms of trade, at unchanged Home relative output, has to be associated with a rise in Home relative absorption A. Thus, an increase in λ (for given Y,I) raises C.

correlation between relative consumption and the real exchange rate, when the economy is *simultaneously* subjected to output and investment shocks. A 1% rise in the relative GDP share of the Home/Foreign HTM agent (λ) appreciates the Home real exchange rate and raises Home relative consumption more strongly, the greater is Λ (i.e., a_λ and b_λ are increasing functions of Λ; see the appendix).

2.3. Model calibration

Following Kollmann (2004), the model is calibrated to data for the US and an aggregate of the remaining G7 countries, referred to as the 'G6.'[7] All data are *annual* and (unless stated otherwise) cover 1972–2003.

2.3.1. Preference parameters, investment, and HTM consumption shares

US exports to [imports from] the G6 amounted to 3.10% [4.64%] of US GDP and 2.44% [3.71%] of G6 GDP, on average, during 1980–2003.[8] The mean of these four trade shares is used to calibrate $(1 - \alpha) = 3.5\%$. Across G7 countries, the mean investment/GDP ratio is 22%; thus, Ξ is set at $\Xi = 0.22$. ϕ corresponds to the price elasticity of imports and exports. In macro models, ϕ is typically set at values roughly between 1 and 2. Hooper and Marquez (1995) survey a large number of econometric estimates of ϕ, based on aggregate trade flows, for the US, Japan, Germany, the UK, and Canada; the median estimates (post-Bretton Woods) for these countries are 0.97, 0.80, 0.57, 0.60, and 1.01, respectively; the median estimate across all five countries is 0.9. In the baseline calibration, $\phi = 0.9$ is thus assumed (results are also reported for $\phi = 2$). Estimates of the risk aversion coefficient (σ) in the range of 2 or greater are common for industrialized countries (Barrionuevo 1992); the baseline calibration uses $\sigma = 2$.

The baseline calibration assumes that, on average, 50% of total consumption accrues to HTM households, consistent with estimates of the HTM consumption share, based on the fact that aggregate consumption time series closely track aggregate income (in the US and other industrialized countries); see, for example, Campbell and Mankiw (1989, 1990, 1991) and Mankiw (2000).[9] Aggregate models with financial frictions typically set the mean HTM consumption share (C_i^{HTM}/C_i) at 50%; for example, Galí, Lopez-Salido, and Vallès (2007) and Colciago (2011). Note that a 50% HTM consumption share implies that HTM

7 G6 variables are geometric weighted averages of individual countries' data (weights: mean shares in G6 GDP).

8 From IMF Directions of Trade Statistics electronic database (that reports bilateral trade flows starting in 1980).

9 Micro data also suggest substantial HTM behaviour. Using US household data (CEX), Johnson, Parker, and Souleles (2006) show that the predictable (pre-announced) temporary US tax rebate of 2001 triggered strong short-run increases in non-durables consumption (especially by households with low holdings of liquid assets); the overall marginal propensity to consume (MPC) was two-thirds. Based on CEX data, Souleles (2002) reports an MPC of 0.6–0.9 to pre-announced Reagan tax cuts.

TABLE 1
Parameter values

Preferences, technology, HTM income share (benchmark values)
$\sigma = 2$ (coefficient of relative risk aversion)
$\phi = 0.9$ (substitution elasticity between local and imported goods)
$1 - \alpha = 0.035$ (mean trade share)
$\Xi = 0.22$ (mean investment share)
$\Lambda = 0.39$ (mean HTM income share)

Moments of relative (Home/Foreign) forcing variables
$Std(\widehat{Y}) = 1.70\%$, $Std(\widehat{I}) = 7.69\%$, $Std(\widehat{\lambda}) = 1.41\%$,
$Corr(Y, I) = 0.86$, $Corr(Y, \lambda) = 0.09$, $Corr(I, \lambda) = -0.16$.

Moments of forcing variables in individual countries
$Std(\widehat{Y}_i) = 1.76\%$, $Std(\widehat{I}_i) = 6.84\%$, $Std(\widehat{\lambda}_i) = 1.04\%$,
$Corr(Y_i, I_i) = 0.90$, $Corr(Y_i, \lambda_i) = -0.28$, $Corr(I_i, \lambda_i) = -0.36$,
$Corr(Y_i, Y_j) = 0.53$, $Corr(I_i, I_j) = 0.36$, $Corr(\lambda_i, \lambda_j) = 0.09$, $Corr(Y_i, I_j) = 0.42$,
$Corr(Y_i, \lambda_j) = -0.34$, $Corr(I_i, \lambda_j) = -0.24$ for $i, j = H, F; i \neq j$.

NOTES: *Std*: standard deviation. *Corr*: correlation. Y_i, I_i, λ_i : GDP, investment and HTM income share in country i. $Y \equiv Y_H/Y_F$, $I \equiv I_H/I_F$, $\lambda \equiv \lambda_H/\lambda_F$ are relative Home/Foreign quantities. $\widehat{z}$ is the relative deviation of variable z from the point of linearization. Calibrated moments of relative Home/Foreign forcing variables equal the moments of annual growth rates of the corresponding *relative* US/G6 quantities (1972–2003); the calibrated moments of forcing variable in countries i, j correspond to *averages*, across the US and G6, of moments of growth rates of the corresponding empirical variables.

consumption represents a fraction $\Lambda = 0.39(= 0.5 \cdot (1 - \Xi))$ of GDP, on average. A sensitivity analysis with respect to the (mean) HTM consumption share is conducted. Table 1 summarizes the baseline calibration.

2.3.2. Stochastic properties of the forcing variables

Empirically, participation in financial markets is highly positively correlated with household wealth; households whose main source of income is labour income are much less likely to hold internationally traded assets (e.g., Christelis and Georgarakos 2009). Thus, *fluctuations* in a country's labour share (fraction of GDP received by labour) are taken as a proxy for *movements* in the fraction of GDP received by the local HTM household, λ_i.

US and G6 GDP, investment, and labour shares undergo persistent fluctuations. Second moments of (annual) *growth rates* of these series (1972–2003) are used to calibrate the second moments of the model's forcing variables.[10] Specifically, the moments of relative Home/Foreign forcing variables (in the model) are set equal to moments of (growth rates of) the corresponding *relative* US/G6 quantities; the moments of forcing variables in individual country $i = H,F$ ($\widehat{Y}_i, \widehat{I}_i, \widehat{\lambda}_i$) are set at *averages* (across the US and G6) of the corresponding empirical statistics. Table 1 documents the moments used in the

10 Source of all data (unless stated otherwise): International Financial Statistics and OECD National Accounts. The empirical measure of the labour share is (compensation of employees) / (GDP-indirect taxes).

calibration. The standard deviations of *relative* GDP, investment and labour shares are 1.70%, 7.69%, and 1.41%, respectively; relative investment is thus more volatile than relative output; the relative labour share is less volatile. The correlation between relative Home/Foreign GDP and investment is 0.86; the relative labour share is only weakly correlated with relative output (0.09) and relative investment (−0.16). Investment in each country is more volatile than output or the labour share. Investment is strongly procyclical, while the labour share is countercyclical.

3. Consumption and the real exchange rate: facts and model predictions

3.1. Business cycle facts

Column (5) of table 2 reports other key business cycle moments. The statistics pertain to annual growth rates (1972–2003) of US and G6 variables (exception: the statistic for [bilateral] net exports, normalized by GDP, refers to the first-differenced series). The empirical correlation between (growth rates of) relative US/G6 consumption of non-durables and services and the real exchange rate is 0.24 (with a standard error of 0.13).[11] The US-G6 real exchange rate (standard deviation: 8.25%) is more volatile than output. Consumption and net exports (standard deviations: 1.06%, 0.29%) are less volatile than output (1.76%). In the data, consumption is highly positively correlated with domestic output (correlation: 0.71). However, consumption is only weakly correlated across the US and the G6 (0.19).

3.2. Model predictions

3.2.1. Baseline calibration

Under the baseline calibration of the HTM model, the real exchange rate and relative consumption obey

$$\widehat{RER} = -2.23\widehat{Y} + 0.71\widehat{I} + 1.27\widehat{\lambda}, \qquad \widehat{C} = 0.97\widehat{Y} - 0.15\widehat{I} + 0.23\widehat{\lambda}.$$

By contrast, with full risk sharing (no HTM households):

$$\widehat{RER} = -2.02\widehat{Y} + 0.40\widehat{I}, \qquad \widehat{C} = 1.01\widehat{Y} - 0.20\widehat{I}.$$

Note that, in *both* structures, shocks to relative output and investment (Y,I) drive the real exchange rate (RER) and relative consumption (C) in opposite directions. Under full risk sharing $a_Y/b_Y = a_I/b_I < 0$ holds (as discussed above).

11 For other individual G7 countries (compared with corresponding rest-of-G7 aggregates), the correlation between relative consumption and the real exchange rate (in growth rates) ranges between −0.18 (Japan) and 0.12 (Germany); the mean correlation is 0.03.

TABLE 2
Predicted moments generated by model and empirical statistics (US, G6)

	HTM model Shocks to:			Full risk-sharing model Shocks to:	
	Y, I, λ (1)	Y, I (2)	Y, λ (3)	Y, I (4)	Data (5)
a) Model predictions: baseline calibration					
$Corr(RER, C_H/C_F)$	−0.07	−0.39	−0.79	−1.00	0.24
$Std(\widehat{RER})$ in%	2.69	2.94	4.06	1.74	8.25
$Std(\widehat{C}_i)$ in%	0.96	0.91	2.15	0.91	1.06
$Std(NX_i/(p_i Y_i))$ in%	0.13	0.13	0.08	0.06	0.29
$Corr(C_i, Y_i)$	0.63	0.65	0.99	0.57	0.71
$Corr(C_H, C_F)$	0.40	0.54	0.67	0.54	0.19
b) High HTM income share, $\Lambda = 0.6$					
$Corr(RER, C_H/C_F)$	0.63	0.40	−0.24	−1.00	0.24
$Std(\widehat{RER})$ in%	6.04	5.78	6.01	1.74	8.25
$Std(\widehat{C}_i)$ in%	1.11	0.98	2.17	0.91	1.06
$Std(NX_i/(p_i Y_i))$ in%	0.24	0.23	0.16	0.06	0.29
$Corr(C_i, Y_i)$	0.65	0.72	0.97	0.57	0.71
$Corr(C_H, C_F)$	0.04	0.33	0.64	0.54	0.19
c) Low HTM income share, $\Lambda = 0.25$					
$Corr(RER, C_H/C_F)$	−0.61	−0.77	−0.94	−1.00	0.24
$Std(\widehat{RER})$ in%	1.92	2.20	3.66	1.74	8.25
$Std(\widehat{C}_i)$ in%	0.93	0.91	2.15	0.91	1.06
$Std(NX_i/(p_i Y_i))$ in%	0.09	0.10	0.06	0.06	0.29
$Corr(C_i, Y_i)$	0.60	0.61	0.99	0.57	0.71
$Corr(C_H, C_F)$	0.49	0.56	0.68	0.54	0.19
d) High substitution elasticity between domestic and foreign goods, $\phi = 2$					
$Corr(RER, C_H/C_F)$	0.12	−0.14	−0.71	−1.00	0.24
$Std(\widehat{RER})$ in%	1.72	1.88	2.60	1.32	8.25
$Std(\widehat{C}_i)$ in%	0.96	0.90	2.10	0.87	1.06
$Std(NX_i/(p_i Y_i))$ in%	0.23	0.25	0.25	0.14	0.29
$Corr(C_i, Y_i)$	0.65	0.68	0.98	0.58	0.71
$Corr(C_H, C_F)$	0.40	0.59	0.75	0.71	0.19
e) High risk aversion, $\sigma = 5$					
$Corr(RER, C_H/C_F)$	0.20	−0.02	−0.66	−1.00	0.24
$Std(\widehat{RER})$ in%	4.35	4.76	6.57	3.12	8.25
$Std(\widehat{C}_i)$ in%	0.96	0.90	2.09	0.86	1.06
$Std(NX_i/(p_i Y_i))$ in%	0.17	0.18	0.16	0.09	0.29
$Corr(C_i, Y_i)$	0.65	0.69	0.97	0.58	0.71
$Corr(C_H, C_F)$	0.39	0.60	0.79	0.73	0.19

NOTES: Columns (1)–(3) show predicted statistics generated by the model with hand-to-mouth (HTM) households. Col. (1): shocks to (Home and Foreign) output, investment and GDP shares received by HTM households; Col. (2): only output and investment shocks; Col. (3) only shocks to output and to GDP shares received by HTM households. Col. (4) shows predictions of model variant with full risk sharing (no HTM households, $\Lambda = 0$), under simultaneous output and investment shocks. Correlated shocks are assumed – the second moments of the shocks match empirical moments of forcing variables in the US and an aggregate of the remaining G7 countries ('G6'); see section 2.3. Col. (5) reports empirical statistics for the US and the G6, based on annual data (1972–2003). Empirical statistics for the US-G6 real exchange rate (RER), for consumption (C_i) and for output (Y_i) pertain to growth rates; empirical statistics for net exports ($NX_i/(p_i Y_i)$) pertain to bilateral net export series (1980–2003) that were normalized by nominal domestic GDP and then first differenced. The empirical standard deviation of consumption in country i ($Std(\widehat{C}_i)$) and the correlation between consumption and domestic output ($Corr(C_i, Y_i)$) reported in col. (5) are *averages* of statistics for the US and for the G6. The empirical consumption measure is real purchases of non-durables and services; the US-G6 real exchange rate is defined using non-durables and services deflators (exception: the German quantity and price series, used to construct G6 consumption and the G6 price index, pertain to total consumption).

In the baseline structure with HTM households the Home real exchange appreciates 77% more strongly than under full risk sharing, in response to a given rise in Home relative investment, while the drop of Home relative consumption is 25% weaker; this breaks the perfect negative correlation between $\widehat{RER}$ and $\widehat{C}$, when there are simultaneous output and investment shocks. In addition, in the baseline HTM structure, a 1% increase in λ (relative Home/Foreign HTM GDP share) appreciates the Home real exchange rate by 1.27% and it raises Home relative consumption by 0.23%.

Columns (1)–(4) of table 2 reports moments predicted by the model. As shown in panel (a) of the table, the baseline HTM model, with all shocks, predicts that the correlation between (relative) consumption and the real exchange rate is −0.07 (see col. (1)). Thus, relative consumption is predicted to be essentially uncorrelated with the real exchange rate. With only output and investment shocks, the predicted *C-RER* correlation is −0.39 (see col. (2)); hence, even when there are no λ-shocks, the HTM-model generates a *C-RER* correlation that is markedly above the correlation under complete markets (−1.00). Consistent with the theoretical analysis above, the simultaneous presence of output and investment shocks is important for the ability of the HTM model to generate a realistic *C-RER* correlation: when the investment shock is eliminated, the correlation drops to −0.79 (see col. (3)).

The predicted standard deviation of the real exchange rate is 2.69%, in the baseline HTM structure (all shocks), compared with 1.74% under full risk sharing. The real exchange rate is thus more volatile in the presence of HTM households (see discussion above). Regarding the other predicted statistics reported in table 2, the main differences between the baseline HTM structure and the variant with full risk sharing are as follows.

1. In the baseline HTM structure, the standard deviation of net exports (0.13%) is about twice as large as under full risk sharing (0.06%) and thus is closer to the empirical standard deviation (0.29%). Home net exports obey $NX_H = \{(1-\alpha)/(2\alpha-1)\}[\{1-2\alpha\phi/(2\alpha-1)\}\widehat{RER}-\widehat{Y}]$; intuitively, NX is more volatile in the HTM structure, owing to the greater volatility of the real exchange rate.
2. The cross-country consumption correlation is lower in the HTM structure, 0.40 (compared with 0.54 under full risk sharing) and thus is likewise closer to the empirical correlation (0.19).

In the baseline HTM structure, the predicted standard deviation of consumption (0.96%) and the correlation between domestic consumption and output (0.63) are likewise higher than under full risk sharing (corresponding statistics: 0.91% and 0.57), but here the difference between the two model structures is less strong. However, the presence of HTM households moves these predicted statistics closer to the moments of the actual data (1.06% and 0.71).

3.2.2. Model variant with a larger expected income share of HTM households ($\Lambda = 0.6$)

The predicted *C-RER* correlation is increasing in the expected share of HTM income in GDP, Λ. In panel (b) of table 2, Λ is set at a larger value than in the baseline calibration, namely, at the average empirical labour share (in US and G6): $\Lambda = 0.6$ (implied mean share of HTM consumption in total consumption: 77%). Under that calibration, the predicted correlation between relative consumption and the real exchange rate (with all shocks) is 0.63, which is greater than the empirical correlation (0.24); with only output and investment shocks, the predicted correlation between relative consumption and the real exchange rate remains sizable: 0.40.

When $\Lambda = 0.6$, the predicted standard deviation of the real exchange rate is 6.04% (with all shocks); predicted real exchange rate volatility is thus much closer to the empirical volatility (8.25%) than under the baseline HTM calibration (2.69%).[12] The model variant with a high HTM income share also generates higher standard deviations of consumption (1.11%) and net exports (0.24%) than the baseline calibration – these predicted statistics too are closer to the empirical moments.

3.2.3. Model variant with lower expected income share of HTM households ($\Lambda = 0.25$)

Panel (c) of table 2 reports results for a model variant with a lower expected share of HTM income in GDP: $\Lambda = 0.25$. The implied mean share of HTM consumption in total consumption is 32%. The predicted *C-RER* correlation generated by the HTM structure now is -0.61 (with all shocks), while the standard deviation of the real exchange rate is 1.92%. Thus, the predicted *C-RER* correlation remains noticeably larger than under full risk sharing (-1.0). However, manifestly, a higher mean HTM income share is required to generate a realistic correlation between relative consumption and the real exchange rate.[13]

3.2.4. Variant with higher substitution elasticity between Home & Foreign goods ($\phi = 2$)

Panel (d) reports results for a model variant with $\phi = 2$, that is, in which Home and Foreign tradables are more substitutable than in the baseline calibration. (Λ is again set at its baseline value: $\Lambda = 0.39$.) The HTM structure now generates a

12 For $\Lambda = 0.6$, the real exchange rate is more sensitive to I & λ shocks (than in baseline calibration); relative consumption is less sensitive to I shocks, but more sensitive to λ shocks ($a_I = 1.18$, $a_\lambda = 3.23$, $b_I = -0.06$, $a_\lambda = 0.58$).

13 Several recent papers estimate *closed economy* DSGE *fiscal policy* models with HTM agents (e.g., Forni, Monteforte, and Sessa 2009; Cogan et al. 2010); the implied HTM consumption shares are mostly in the range 30%–40%. The HTM share in panel (c), 32%, is at the low end of that range; a model variant with a 40% HTM consumption share yields a higher C-RER correlation, -0.39 (with all shocks). (The DSGE estimation studies that were just mentioned focus on macro-fiscal interactions and do not seek to match the empirical C-RER correlation – no relative consumption and real exchange rate data are used.)

correlation between relative consumption and the real exchange rate of 0.12, with all three types of shocks (and of −0.14 with only output and investment shocks). Thus, the predicted correlation is higher than under the baseline calibration and closer to the empirical correlation (0.24).

The real exchange rate and relative consumption respond less strongly to output and investment shocks when the two goods are closer substitutes, while net exports respond more strongly. The predicted standard deviation of the real exchange rate is thus lower than in the baseline calibration; however, the predicted standard deviation remains larger in the HTM structure (1.72%) than under full risk sharing (1.32%). The predicted standard deviation of net exports (0.23%) is higher than in the baseline model (0.13%), and closer to the empirical standard deviation (0.29%).

3.2.5. Model variant with greater risk aversion ($\sigma = 5$)

Panel (e) shows results for a model variant in which the risk aversion coefficient is increased to $\sigma = 5$ (all other parameters are set at baseline values). With the three types of shocks, the HTM structure now generates a predicted *C-RER* correlation of 0.20, which is very close to the empirical correlation, 0.24 (with only output and investment shocks, the predicted correlation is −0.02). With greater risk aversion, relative world demand for the Home good is less sensitive to the terms of trade (as the relative consumption of Home/Foreign RS households responds less to the terms of trade, see (6)). Thus, the standard deviation of the real exchange rate (4.35%) is noticeably higher (and closer to the empirical statistics) than under the baseline calibration. The predicted standard deviation of net export (0.17%) too is higher, and closer to the empirical statistic.

4. Conclusion

This paper has investigated whether the presence of hand-to-mouth (HTM) households might help to solve a key puzzle in international macroeconomics – the fact that relative consumption and the real exchange rate are essentially uncorrelated. To match this fact, the model here requires that the share of HTM consumption in total consumption is about 50%. The results suggest that the consumption-real exchange rate anomaly might be due not to the underdevelopment of international financial markets, but to the fact that a significant fraction of agents does not participate in those markets. Especially when agents are highly risk averse, the presence of HTM households also generates greater volatility of the real exchange and of net exports, which likewise brings the model closer to the data.

Appendix: Solutions for real exchange rate and relative national consumption

The solutions for the Home real exchange rate and for Home relative consumption are

$$\widehat{RER} = a_Y\widehat{Y} + a_I\widehat{I} + a_\lambda\widehat{\lambda} \text{ with } a_Y \equiv [\Lambda(2\alpha-1)^2 + (1-2\alpha)]/\Gamma,$$
$$a_I \equiv \Xi(2\alpha-1)^2/\Gamma, \quad a_\lambda \equiv \Lambda(2\alpha-1)^2/\Gamma,$$

and $\widehat{C} = b_Y\widehat{Y} + b_I\widehat{I} + b_\lambda\widehat{\lambda}$, with

$$b_Y \equiv \{(1-\Xi)^{-1}\sigma^{-1}\}[(1-\Lambda-\Xi)(2\alpha-1) - \sigma\Lambda 2(1-\alpha)(1-2\phi\alpha)]/\Gamma,$$
$$b_I \equiv \{\Xi(1-\Xi)^{-1}\sigma^{-1}\}[-(1-\Lambda-\Xi)(2\alpha-1)^2 + \sigma\Lambda 2(2\alpha-1)(1-\alpha)]/\Gamma,$$
$$b_\lambda \equiv (1-\Xi)^{-1}\Lambda 4\alpha(1-\alpha)\phi/\Gamma.$$

$\Gamma \equiv (1-2\alpha)^2(1-\Lambda-\Xi)/\sigma - 2(2\alpha-1)(1-\alpha)\Lambda + 4\alpha(1-\alpha)\phi$ is the price elasticity of relative world demand for good H. When $\Lambda = 0$ (full risk sharing), then $\Gamma > 0$. $\Gamma > 0$ also holds when there are HTM households, if Λ (mean share of HTM income in GDP) is not too big. Note that

$$\Gamma > 0 \Leftrightarrow \Lambda < \{\phi\sigma 4\alpha(1-\alpha)/(2\alpha-1) + (1-\Xi)(2\alpha-1)\}/\{2(1-\alpha)\sigma + (2\alpha-1)\}.$$

The right-hand side of this inequality is positive. Assume the baseline parameter values $\alpha = 0.965$, $\Xi = 0.22$, $\phi = 0.9$, $\sigma = 2$; then $\Gamma > 0$ holds for all feasible values of Λ (i.e., for $0 \leq \Lambda < 1-\Xi$). Alternatively, note that $\Gamma > 0$ holds iff $\phi > \Lambda \cdot (2\alpha-1)/(2\alpha) - (1-2\alpha)^2(1-\Lambda-\Xi)/(4\alpha(1-\alpha)\sigma)$. The right-hand side of this inequality cannot exceed $0.5 \cdot (1-\Xi)$ (as $\alpha < 1$ and $\Lambda < 1-\Xi$); when $\Xi = 0.22$, then a *sufficient* condition for $\Gamma > 0$ is $\phi > 0.39$. As discussed in the text, median estimates of ϕ based on aggregate trade data are mostly in the range of unity. Thus, $\Gamma > 0$ is plausible. $\Gamma > 0$ implies $a_Y < 0$, $a_I > 0$, and $a_\lambda > 0, b_\lambda > 0$ (when $\Lambda > 0$).

An increase in Home relative output (Y) raises relative consumption ($b_Y > 0$), for plausible parameter values: when $\Gamma > 0$ holds, then $b_Y > 0$ obtains for $\phi > 1/(2\alpha) - \{(1-\Lambda-\Xi)/(\sigma\Lambda)\}\{(2\alpha-1)/(4\alpha(1-\alpha))\}$. Assume the baseline values of α, ϕ, σ, Ξ. Then $b_Y > 0$ holds for all values of Λ such that $0 \leq \Lambda < 1-\Xi$.

An increase in Home relative investment lowers relative consumption ($b_I < 0$) when $\Lambda < \{(1-\Xi)(2\alpha-1)\}/\{2(1-\alpha)\sigma + (2\alpha-1)\}$. Under the baseline values of α, Ξ, ϕ, σ, we have $b_I < 0$ when $\Lambda < 0.677$.

A.1. Effect of changes in Λ on real exchange rate and relative consumption responses to shocks

At constant terms of trade, an increase in Home output creates an excess supply in the market for good H; the greater is Λ, the smaller is that excess supply (a greater Λ means that Home HTM household income rises more strongly in response to the increase in Home output, which raises demand for good H more strongly. However, as an increase in Λ also lowers the price elasticity Γ, its effect on the sensitivity of the real exchange rate to relative output Y is ambiguous. $\partial a_Y/\partial\Lambda < 0$, $\partial b_Y/\partial\Lambda < 0$ hold iff $\sigma < [(2\alpha - 1)^2\Xi + 2(2\alpha - 1)(1 - \alpha)]/[2(1 - \alpha)(2\alpha\phi - 1)]$. This condition is met when α is sufficiently close to unity.

As $\partial\Gamma/\partial\Lambda < 0$, we see that $\partial a_I/\partial\Lambda, \partial b_I/\partial\Lambda, \partial a_\lambda/\partial\Lambda, \partial b_\lambda/\partial\Lambda > 0$. Thus, an increase in I and λ induce a stronger appreciation of the Home real exchange rate, but a *weaker* fall in Home relative consumption, the greater is Λ.

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