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Understanding the Real Exchange Rate and Consumption: Limited Asset Market Participation*

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This paper sets up an open-economy new Keynesian model with limited asset market participation and expenditure delays to explore the real exchange rate and consumption anomaly. The main finding of the paper is that relative aggregate consumption move less closely with the real exchange rate defined as the marginal utility of consumption in foreign country relative to the marginal utility of consumption in home country when only some households with expenditure delays can protect themselves from risk by participating in the financial market and the rest of the households consume their current wage income. The correlation between the real exchange rate and relative consumption turns into a negative territory when households are less willing to substitute home goods with foreign goods.

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I. Introduction

In international finance, one of the well documented puzzles is the consumption - real exchange rate anomaly. Most existing international business cycle models such as real business cycle models and new open macroeconomic models predict that consumption differences across countries positively comove with the real exchange rate under the perfect financial markets, while consumption differences negatively comove with the real exchange rate in the data. (See Backus and Smith (1993) and Chari, Kehoe and McGrattan (2002, hereafter Chari et al.). In particular, Chari et al. (2002) shows that the main discrepancy between sticky price models

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with complete market and the data is the lack of risk-sharing across countries and this puzzle does not disappear even if one removes the perfect financial market assumption from the models.

There is a literature that studies the consumption - real exchange rate anomaly by introducing additional market frictions into the model. For example, Benigno and Thoenissen (2008) shows that the consumption - real exchange rate anomaly can be successfully addressed by flexible price models with an incomplete financial market and a nontraded as well as traded goods sector, while Selaive and Tuesta (2003) argues that financial frictions and net foreign asset position are important in disconnecting the close link between relative consumption and the real exchange rate in sticky price models. In contrast to these studies, Corsetti, Dedola, and Leduc (2008, hereafter Corsetti et al.) argues that asset market frictions and distribution costs are important in successfully addressing the anomaly in international business cycle models. They have common elements in breaking the close link between consumption differences and the relative prices in models with real shocks only by assuming that international asset trade is limited to riskless bonds and that households consume the nontraded goods as well as traded goods. However, it is questionable whether the real exchange rate - consumption puzzle can be successfully addressed in sticky price models with nominal shocks as well as real shocks because the monetary policy plays a key role in generating the volatile exchange rate movement in sticky price models. The real exchange rate and relative consumption show very similar responses to the monetary policy shock, irrespective of full risk-sharing under complete market assumption, resulting in a high correlation between the real exchange rate and relative consumption.

The representative agent framework has been challenged by more recent theoretical and empirical studies. The insensitive response of consumption to income in the representative agent new Keynesian (hereafter RANK) models is inconsistent with a large body of micro and macro empirical literature on excessive sensitivity. First, macro-econometric time-series analysis shows that consumption tracks current income for a large fraction of the US population. Using aggregate data, for example, Campbell and Mankiw (1989) and Mankiw (2000) found that 40-50% of the US population merely consumed their current income. Second, micro survey data on household portfolio shows that a small fraction of the US population holds assets. For example, Kaplan et al. (2014) using micro data shows that one third of the U.S. households hold close zero liquid assets and face borrowing constraints. The Survey of Consumer Finance also reports that about half of US households do not hold any equity. The European countries are no exception.

There is a large body of literature that have incorporated additional frictions into a standard new Keynesian model to address some stylized facts in macroeconomics. Galí, Lopez-Salido and Valles (2004, hereafter Galí et al.) and Galí, Lopez-Salido and Valles (2007, hereafter Galí et al.) set up a new Keynesian model with limited asset market participations (LAMP hereafter) to discuss some fiscal policy issues. Bilbiie (2008) has shown that the link between interest rates and aggregate demand can be reversed if the share of non-asset holders is larger than a threshold value. Bilbiie and Straub (2016) has gone one step further to suggest the possibility that the change in the fractions of non-asset holders in the U.S. over the late 1970s and early 1980s can explain the change of aggregate demand elasticity to interest rates. In theoretical perspective, Kaplan, Moll, and Violante (2016, hereafter Kaplan et al.) is noteworthy. To overcome the unrealistic implications of the RANK model where the intertemporal elasticity drives all aggregate demand, Kaplan et al. (2016) develops a heterogenous agent new Keynesian (HANK, hereafter) model. Kaplan et al. (2016) shows a HANK model that yields realistic distributions of assets and marginal propensity of consumption can successfully address the effect of monetary policy over business cycles as well as the excessive sensitivity of aggregate demand to transitory income variation. Nisticò (2016) sets up a two-agent model based on discontinuous asset market participations to discuss optimal monetary policy and financial stability, while Galí (2016) sets up a new Keynesian model featuring overlapping generations based on Yaari (1965) and Blanchard (1985)'s perpetual youth model to address the implications of monetary policy in economies with bubbly equilibria.

From the international finance perspective, Kollman (2012) set up an endowment economy where both asset holders and non-asset holders do not choose their labor hours. He showed that the limited asset market participation model helps to explain the consumption - real exchange rate anomaly. Gao, Hnatkovska, and Marmer (2014, hereafter Gao et al.) has also shown that the limited asset market participation plays an important role in explaining some stylized facts in international business cycles by employing a statistical framework of Vuong (1989).

Along the lines of Galí et al. (2004, 2007), Bilbiie (2008), Monacelli and Perotti (2011), we introduce simple heterogeneity features in households into otherwise a standard model by assuming that a fraction of households have zero assets and just consume their current disposable income, while other fraction of households have all assets to smooth their consumption profile over time. And then, we explore the role of the limited asset market participation in generating the divergence between the international relative price and relative consumption in the open economy new Keynesian model. In particular, we investigate the following questions. First, we explore whether the LAMP model can successfully address the real exchange rate - consumption puzzle when both real and nominal shocks exist in the model. Second, we explore whether this model can generate volatile exchange rates movements. Finally, we explore whether the comovements of exchange rates and other real variables simulated from the model match with those of the data.

The main findings of this paper can be summarized as follows. First, the real exchange rate and relative consumption do not move systematically to the real and nominal shock when some households cannot participate in the financial market to protect themselves from the exchange rate risk. Noticeably, the close relationship between the real exchange rate and relative consumption disappears even to the monetary shock if some households cannot have access to financial markets. Second, the correlation between the real exchange rate and relative consumption decreases as households are less willing to substitute home goods with foreign goods to the relative price change. Finally, the predetermined expenditure decisions as in Rotemberg and Woodford (1997), Bernanke et al. (1999) and Woodford (2003) are helpful in resolving the real exchange rate-relative consumption anomaly by disconnecting the close connection between the real exchange rate and relative consumption.

This paper is composed as follows. In section II, we specify a benchmark new Keynesian open economy model with non-asset holders and discuss the implications of the model, focusing on the relationship between exchange rates and real activities. In section III, we present the quantitative results of the model. Finally, we give concluding remarks in section IV.

II. The Model

Consider a world economy with two-countries, two goods, and a flexible exchange rate between the two moneys. The home (foreign) country is completely specialized in the production of its own goods, $Y_h(Y_f)$. Here h and f denote the home country and the foreign country, respectively. The goods production is subject to production shocks, A_h and A_f respectively. The economy consists of a continuum of identical infinite-lived households.

A share of $1-\lambda$ of the continuum of households - referred to as asset holders - have access to financial markets, while the remaining share λ of the households - referred to as non-asset holders - do not trade any assets and simply consume their current labor income.

2.1. Households

2.1.1. Asset Holder's Problem

Households who can have access to asset market, called asset holders own firms and choose their consumption, asset holdings, and labor supply to maximize their expected lifetime utility function subject to sequence of budget constraints:

$$E_t\left[\sum_{k=0}^{\infty}\beta^k u(C^o_{t+k}, N^o_{t+k})\right], \quad 0<\beta<1, \tag{2.1}$$

where $u(C^o_{t+k}, N^o_{t+k}) = \frac{(C^o_{t+k} - bH_{t+k-1})^{1-\sigma}}{1-\sigma} - \frac{N^{o1+\nu}_{t+k}}{1+\nu} (\sigma \neq 1)$, β is the household's discount factor, and $E_t \equiv \sum x_{t+1} f(x^{t+1} \mid x^t)$ denotes the mathematical expectation operator over all possible states of nature on history x^t. Here $x^t = \{x_0, \ldots x_t\}$ denotes the history of events up to period t and $0 \leq b < 1$ measures the degree of habit persistence. C^o_{t+k}, N^o_{t+k}, and H_{t+k} represent the asset holder's consumption, total working hours, and the time-varying habit level of consumption in period $t+k$, respectively. C^o_t is a composite consumption index defined by

$$C^o_t = \left[\theta^{\frac{1}{\psi}} C^{o\frac{\psi-1}{\psi}}_{ht} + (1-\theta)^{\frac{1}{\psi}} C^{o\frac{\psi-1}{\psi}}_{ft} \right]^{\frac{\psi}{\psi-1}}, \quad \psi > 0. \tag{2.2}$$

Here C^o_{ht} and C^o_{ft} are indices of domestic and foreign consumption goods of asset holders, and θ and $1-\theta$ represent the share of domestic consumption allocated to domestic goods and imported goods. The indices are given by the following CES aggregator of the quantities consumed of each variety of good:

$$C^o_{ht} = \left[\int_0^1 C^o_{ht}(j)^{\frac{\phi-1}{\phi}} dj \right]^{\frac{\phi}{\phi-1}}, \quad C^o_{ft} = \left[\int_0^1 C^o_{ft}(j)^{\frac{\phi-1}{\phi}} dj \right]^{\frac{\phi}{\phi-1}}, \quad \phi > 1. \tag{2.3}$$

Here ψ and ϕ measure the elasticity of substitution between domestic and foreign goods, and the elasticity of substitution among goods within each category, respectively.

For simplicity, H_t is specified as an external habit depending on only aggregate consumption as in Smets and Wouters (2007) and Jung (2015). That is,

$$H_t = \tilde{C}^o_{t-1}, \tag{2.4}$$

where $\tilde{C}^o_{t-1}$ is aggregate past consumption. In this specification of habit formation, habit depends on one lag of consumption. Since there is a representative asset holder, aggregate consumption of asset holder equals the asset holder's consumption in equilibrium.

$$H_t = C^o_{t-1}.$$

Assume that only asset holders can participate in the asset market. There is a domestic currency-denominated state-contingent bond market. Let B_t be the one-period nominal state contingent home-currency bond and $Q_{t,t+1}$ be the corresponding stochastic discount factor in period t. The riskless one-period nominal interest rate in period t is given by $R_t \equiv [E_t Q_{t,t+1}]^{-1}$. The asset holder receives lump-sum transfers from the government, and wages, rents for capital, and dividends from each firm. Then the asset holder's budget at the beginning of the period t is given by

$$P_t(C_t^o + I_t^o) + E_t[Q_{t,t+1}B_t^o] \le B_{t-1}^o + W_t N_t^o + V_t K_t^o + D_t^o + T_t^o , \tag{2.5}$$

where P_t is the home currency price of goods in period t. Here T_t^o, D_t^o, W_t, and V_t denote the domestic asset holder's lump-sum transfer or tax, nominal dividends and wages from domestic firms, and nominal rental rates for capital stock given to the home residents, respectively. When the incomplete asset market is assumed, the budget constraint is replaced by

$$P_t(C_t^o + I_t^o) + B_t^o / R_t + S_t B_{Ft}^o / R_t^* \le B_{t-1}^o + S_t B_{F,t-1}^o + W_t N_t^o + V_t K_t^o + \Pi_t^o + T_t^o . \tag{2.6}$$[1]

Here B_t^o and B_{Ft}^o denote the domestic and foreign one-period riskless bond in period t, and S_t is the nominal exchange rate in period t.

Suppose that household in each country owns only its own country's capital stock to rent to its country's firm and there is no firm specific capital stock. Since we do not empirically observe large discrete capital stock adjustments, it is reasonable to introduce an adjustment cost in capital stock installments. If there are costs of installing capital, the capital stock will move more sluggishly. To preserve the simple model structure as far as possible, the Christiano et al. (2005) type investment adjustment cost is adopted as follows:

$$K_{t+1}^o = (1-\delta_k)K_t^o + (1-\mathcal{F}(I_t^o / I_{t-1}^o))I_t^o , \tag{2.7}$$

where $\mathcal{F}(I_t^o / I_{t-1}^o)$ is a positive function of changes in investment as in Christiano et al. (2005). In particular, $\mathcal{F} = \mathcal{F}' = 0$ at the steady-state, and $\mathcal{F}'' > 0$. I_t^o is the composite investment of the home asset holder at period t, and K_t^o is the composite capital stock of the home asset holder at period t.

2.1.2. Non-Asset Holders

The non-asset holding households who cannot have access to the financial market just supply labor N_t^r and consume their whole wage income determined in each period:

$$P_t C_t^r = W_t N_t^r + T_t^r , \tag{2.8}$$

[1] To avoid the nonstationarity, we need to introduce some adjustment costs in bond holdings into the budget constraint.

where T_t^r is a lump-sum tax or transfer to the non-asset holder in period t.

2.1.3. Asset Holder's First Order Conditions

First order conditions for asset holders can be summarized as follows.

$$(C_t^o - bC_{t-1}^o)^{-\sigma} = \Lambda_t, \tag{2.9}$$

$$(N_t^o)^{\nu} = \Lambda_t w_t, \tag{2.10}$$

$$Q_{t,t+1} = \beta \frac{\Lambda_t P_{t+1}}{\Lambda_{t+1} P_t},^{2} \tag{2.11}$$

$$Q_{kt}\Lambda_t = \beta E_t[\Lambda_{t+1}(v_{t+1} + Q_{kt+1}(1-\delta))], \tag{2.12}$$

$$K_{t+1}^o = (1 - \mathcal{F}(I_t^o / I_{t-1}^o))I_t^o + (1-\delta_k)K_t^o, \tag{2.13}$$

$$Q_{kt}[\mathcal{F}(I_t^o / I_{t-1}^o) + \mathcal{F}'(I_t^o / I_{t-1}^o)I_t^o / I_{t-1}^o] - \beta E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t} Q_{kt+1}\mathcal{F}'(I_{t+1}^o / I_t^o)(I_{t+1}^o / I_t^o)^2\right] = 1. \tag{2.14}$$

and the budget constraint (2.5) or (2.6).[3] Here Λ_t is the Lagrange multiplier of the budget constraints and $v_t = \frac{V_t}{P_t}$, $w_t = \frac{W_t}{P_t}$. Equation (2.9) is the first order conditions for consumption goods, and (2.10) relates the marginal disutility of labor hours to the marginal utility of the real wage rate. Equation (2.11) and (2.12) refer to the intertemporal decision of the domestic asset holder, that is, the decision of bond holdings and capital stock holdings, respectively. Equation (2.14) represents the relationship between the rent paid to a unit of capital in $t+1$ and the expected return to holding a unit of capital from t to $t+1$ and thus the evolution of Tobin's q over time.

Under the assumption of complete asset markets, an optimal risk sharing condition implies that the marginal utility of consumption of foreign household is proportional to that of home asset holder multiplied by the real exchange rate, i.e.

$$\left(\frac{C_t^o - bC_{t-1}^o}{C_t^{*o} - bC_{t-1}^{*o}}\right)^{\sigma} = \mathbf{k}\mathcal{E}_t, \tag{2.15}$$

where $\mathcal{E}_t \equiv \frac{S_t P_t^*}{P_t}$ is the real exchange rate, and S_t is the nominal exchange rate in period t. Here $\mathbf{k}$ is a parameter capturing the initial cross-country distribution of

[2] The state of the economy, $x_t = [\log A_t, \log A_t^*, \xi_{rt}, \xi_{rt}^*, \log G_t, \log G_t^*]$ evolve according to a Marcov process described by the density funtion $f(x_{t+1}, x_t)$.

[3] In the case of incomplete market, (2.11) should be replaced by the efficiency conditions associated with the expected rate of returns.

wealth and foreign values of the corresponding domestic variables will be denoted by an asterisk (*). As in Galí and Monacelli (2005), we assume symmetric initial conditions without loss of generality, in which we have $\mathbf{k}=1$. The real exchange rate given by (2.15) says that the real value of one unit of domestic currency in domestic market, $\frac{(C_t^o - bC_{t-1}^o)^{-\sigma}}{P_t}$ should be equal to the real value of the corresponding unit in foreign currency in foreign market, $\frac{(C_t^{*o} - bC_{t-1}^{*o})^{-\sigma}}{S_t P_t^*}$. Notice that the real exchange rate depends only on consumption of the asset holder who participates in the financial market.

To generate the observed delay in the monetary policy effect on aggregate demand and to disconnect the close relationship between the real exchange rate and relative consumption, we will also consider an additional friction, i.e. predetermined expenditures à la Rotemberg and Woodford (1997), Bernanke et al. (1999), and Woodford (2003). This simple form has a feature of "time to build" in the real business cycle literature. When the asset holders decide their consumption in one period advance as in Woodford (2003), (2.9) is replace by

$$E_{t-1}[(C_t^o - bC_{t-1}^o)^{-\sigma}] = E_{t-1}\Lambda_t . \tag{2.16}$$

In the case of incomplete market, (2.11) and (2.15) are replaced by

$$\beta E_t\left[\frac{\Lambda_t}{\Lambda_{t+1}}\frac{R_t P_t}{P_{t+1}}\right] = 1, \tag{2.17}$$

$$\beta E_t\left[\frac{\Lambda_t}{\Lambda_{t+1}}\frac{R_t P_t}{P_{t+1}}\right] = \beta\Xi\left(\frac{S_t B_{F,t}^o}{P_t}\right)E_t\left[\frac{\Lambda_t^*}{\Lambda_{t+1}^*}\frac{R_t^* P_t^*}{P_{t+1}^*}\frac{S_t}{S_{t+1}}\right], \tag{2.18}$$

where the function $\Xi(\frac{S_t B_{F,t}^o}{P_t})$ denotes the cost from international borrowings, which avoids a nonstationarity of the equilibrium.

2.1.4. Non-Asset Holder's First Order Conditions

Non-asset holder's optimization conditions are given by

$$(C_t^r - bC_{t-1}^r)^{-\sigma} = \Lambda_t^r , \tag{2.19}$$

$$(N_t^r)^{\nu} = \Lambda_t^r w_t , \tag{2.20}$$

and the budget constraint (2.8). Λ_t^r is the Lagrange multiplier associated with the non-asset holder's budget constraint.

2.2. Aggregation

The aggregate level of any household-specific variable X_t^o is given by $X_t = \int_0^1 X_t(j)dj = (1-\lambda)X_t^o + \lambda X_t^r$. Hence, aggregate consumption and aggregate hours are given by

$$C_t = (1-\lambda)C_t^o + \lambda C_t^r \tag{2.21}$$

and

$$N_t = (1-\lambda)N_t^o + \lambda N_t^r . \tag{2.22}$$

Aggregate capital, investment, dividend, and bond holdings also satisfy

$$K_t = (1-\lambda)K_t^o , \tag{2.23}$$

$$I_t = (1-\lambda)I_t^o , \tag{2.24}$$

$$D_t = (1-\lambda)D_t^o , \tag{2.25}$$

$$B_t = (1-\lambda)B_t^o , \tag{2.26}$$

Finally, aggregate lump-sum taxes or transfers are also given by

$$T_t = (1-\lambda)T_t^o + \lambda T_t^r . \tag{2.27}$$

2.3. Firms

There are two type of firms in each country. A continuum of monopolistically competitive firms indexed by j, $0 \le j \le 1$, each of which produces its differentiated intermediates $Y_t(j)$, and a distinct set of perfectly competitive firms, which combine all the intermediate goods into a single final good Y_t.

2.3.1. Final-Good Firms

The final-good producing firms combine the differentiated domestic intermediate goods $Y_{ht}(j)$ using the CES aggregator

$$Y_{ht} = \left[\int_0^1 Y_{ht}(j)^{\frac{\phi-1}{\phi}} dj \right]^{\frac{\phi}{\phi-1}} , \quad \phi > 1 \tag{2.28}$$

to produce Y_{ht} and then combine a composite of foreign intermediate goods $Y_f(j)$ given by

$$Y_{ft} = \left[\int_0^1 Y_{ft}(j)^{\frac{\phi-1}{\phi}} dj \right]^{\frac{\phi}{\phi-1}} \tag{2.29}$$

to produce a composite good

$$Y_{ht} = \left[\theta^{\frac{1}{\psi}} Y_t^{\frac{\psi-1}{\psi}} + (1-\theta)^{\frac{1}{\psi}} Y_{ft}^{\frac{\psi-1}{\psi}} \right]^{\frac{\psi}{\psi-1}}, \quad \psi > 0 . \tag{2.30}$$

The optimal allocation for each differentiated good yields the demand functions:

$$Y_{ht}(j) = \left[\frac{P_{ht}(j)}{P_{ht}} \right]^{-\phi} Y_{ht}, \quad Y_{ft}(j) = \left[\frac{P_{ht}^*(j)}{P_{ht}^*} \right]^{-\phi} Y_{ft}, \tag{2.31}$$

for all $j \in [0,1]$, where $P_{ht} = (\int_0^1 P_{ht}(j)^{1-\phi} dj)^{\frac{1}{1-\phi}}$ and $P_{ht}^* = (\int_0^1 P_{ht}^*(j)^{1-\phi} dj)^{\frac{1}{1-\phi}}$ are the price indexes for domestic and foreign goods, both expressed in home currency.

The optimal allocation of expenditures between domestic and foreign goods implies:

$$Y_{ht} = \theta \left(\frac{P_{ht}}{P_t} \right)^{-\psi} Y_t, \quad Y_{ft} = (1-\theta) \left(\frac{P_{ht}^*}{P_t} \right)^{-\psi} Y_t, \tag{2.32}$$

Here P_t is the price index of the final good given by

$$P_t = [\theta P_{ht}^{1-\psi} + (1-\theta)(P_{ht}^*)^{1-\psi}]^{\frac{1}{1-\psi}} . \tag{2.33}$$

2.3.2. Intermediate-Good Firms

Each intermediate-goods firm j produces its differentiated output $Y_{ht}(j)$ with constant returns to scale, concave production technology.

$$Y_{ht}(j) = A_t K_t(j)^{\theta} N_t(j)^{1-\theta} - \Phi , \tag{2.34}$$

where A_t is a transitory technology process at period t, $N_t(j)$ is a labor used by the firm j, and Φ is a fixed cost. It is assumed that the technology shock follows an $AR(1)$ process:

$$\log A_t = \rho \log A_{t-1} + \xi_{At}, \quad -1 < \rho < 1,$$

where $E(\xi_{At})=0$ and ξ_{At} is i.i.d. over time.

Since the input markets are perfectly competitive, the firm $j's$ demand for labor and capital are determined by its cost minimization as follows:

$$V_t = MC_t(j)\frac{Y_{ht}(j)}{K_t(j)},\ \ W_t = MC_t(j)\frac{Y_{ht}(j)}{N_t(j)}, \tag{2.35}$$

where $MC_t(j)$ is firm $j's$ marginal cost. The marginal cost of each firm is equal, i.e. $MC_t(j)=MC_t$ for each j as the production function is CRS, implying that $\frac{N_t(j)}{K_t(j)}=\frac{N_t}{K_t}$ for all j.

2.3.3. Price Setting in Intermediate-Goods Sector

Intermediate good firms can segment their markets by country and set prices in the currency of the buyer in the segmented home and foreign markets to avoid the arbitrage opportunity that is implied by the Law of One Price. In each period, a fraction of $(1-\alpha)$ of the domestic goods producing firms is allowed to set a new price $P_{ht,t}$ to home consumers, and $P_{ft,t}$ to foreign consumers, while the other fraction of firms, α, set its price by multiplying the average inflation rate (ω) by its previous price level as in the Calvo-Yun model. Then the firm's maximization problem can be written as follows.

$$\max.E_t\left\{\sum_{k=0}^{\infty}(\alpha\beta)^k\frac{\Lambda_{t+k}P_t}{\Lambda_t P_{t+k}}[P_{ht,t+k}Y_{ht,t+k}+S_{t+k}P_{ft,t+k}Y_{ft,t+k}-MC_{t+k}(Y_{ht,t+k}+Y_{ft,t+k})]\right\}, \tag{2.36}$$

where $P_{ht,t+k}=\omega^k P_{ht,t}$ and $P_{ft,t+k}=\omega^k P_{ft,t}$.

The home firm's optimal price setting equations are given by

$$P_{ht,t}=\frac{\phi E_t[\sum_{k=0}^{\infty}(\alpha\beta)^k\frac{\Lambda_{t+k}}{P_{t+k}}Y_{ht,t+k}MC_{t+k}]}{(\phi-1)E_t[\sum_{k=0}^{\infty}(\alpha\beta\omega)^k\frac{\Lambda_{t+k}}{P_{t+k}}Y_{ht,t+k}]}, \text{ for home markets,} \tag{2.37}$$

$$P_{ft,t}=\frac{\phi E_t[\sum_{k=0}^{\infty}(\alpha\beta)^k\frac{\Lambda_{t+k}}{P_{t+k}}Y_{ft,t+k}MC_{t+k}]}{(\phi-1)E_t[\sum_{k=0}^{\infty}(\alpha\beta\omega)^k\frac{\Lambda_{t+k}}{P_{t+k}}S_{t+k}Y_{ft,t+k}]} \text{ for foreign markets.} \tag{2.38}$$

Next, the price level at period t under the Calvo-type staggered price-setting can be written as the recursive form:

$$P_{ht}^{1-\phi}=(1-\alpha)P_{ht,t}^{1-\phi}+\alpha\omega^{1-\phi}P_{ht-1}^{1-\phi}, \tag{3-14}$$

$$P_{ft}^{1-\phi} = (1-\alpha)P_{ft,t}^{1-\phi} + \alpha\omega^{1-\phi}P_{ft-1}^{1-\phi}. \tag{3-15}$$

If the price level is flexible, then the markup - the ratio of price to marginal cost - is constant at each period, while it responds to monetary and real shocks when prices are predetermined.

2.3.4. Government

There has been an extensive debate over the most appropriate way to model monetary policy in the U.S. and other countries. It concerns whether the money supply rule is more appropriate than the interest rule to evaluate the effect of monetary policy in the actual economy. Recently, many leading macroeconomists follow Taylor's recommendation of using a simple interest rule or a variant such as an interest smoothing policy to evaluate the effect of the monetary policy. In this paper, we employ the interest rate smoothing rule to evaluate the model.

The nominal interest rate r_t is assumed to be set according to a generalized Taylor rule as in Clarida, Gali, and Gertler (1999, hereafter Clarida et al.):

$$r_t = \rho_r r_{t-1} + (1-\rho)[b_y y_t + b_\pi E_t \pi_{t+1}] + \xi_{rt}, \tag{2.39}$$

where π_{t+1} is the inflation rate between $t+1$ and t, and $E(\xi_{rt}) = 0$ and ξ_{rt} is i.i.d. over time.

It is assumed that the fiscal authority in each country maintains a balanced budget, $P_t T_t = P_t G_t$, and the (log) government spending G_t follows an AR (1) process:

$$\log G_t = \rho_G \log G_{t-1} + \xi_{Gt}, \tag{2.40}$$

where $E(\xi_{Gt}) = 0$ and ξ_{Gt} is i.i.d. over time.

2.4. Equilibrium

The equilibrium conditions for domestic output is given by

$$Y_t = \left(\frac{P_{ht}}{P_t}\right)^{-\psi} [\theta(C_t + I_t + G_t) + (1-\theta)\mathcal{E}_t^{\psi}(C_t^* + I_t^* + G_t^*)]. \tag{2.41}$$

Because we focus on the symmetric equilibrium in which all agents in the same country make the same decisions, we need to define a symmetric equilibrium. The symmetric equilibrium conditions consist of (i) the efficiency conditions and the budget constraint of the home consumers and firms, (ii) the corresponding conditions of foreign country, (iii) the risk sharing condition, and (iv) market clearing conditions of each goods market, capital rental market, labor market, money, and bond market in each country. Specifically, a symmetric equilibrium is an allocation of home agents $\{C_t, C_t^*, N_t, N_t^*, K_{t+1}, K_{t+1}^*, I_t, I_t^*\}_{t=0}^{\infty}$, a sequence of prices and costate variables for the home country $\{P_{ht,t}, P_{ht}, P_{ft,t}, P_{ft}, P_{ht,t}^*, P_{ht}^*, P_{ft,t}^*, P_{ft}^*, P_t, P_t^*, \Lambda_t, W_t, V_t, q_t, MC_t, \Lambda_t^*, W_t^*, V_t^*, q_t^*, MC_t^*, r_t, r_t^*\}_{t=0}^{\infty}$ and a sequence of the real exchange rate $\{\mathcal{E}_t\}_{t=0}^{\infty}$ such that (1) the households decision rules solve their optimization problem given the states and the prices; (2) the demands for labor and capital solve each firm's cost minimization problem and price setting rules solve its present value maximization problem, given the states and the prices; (3) each goods market, labor market, bond market, and money market are cleared at the corresponding prices, given the initial conditions for the state variables and the exogenous stochastic processes $\{\xi_{rt}, \xi_{rt}^*, \xi_{At}, \xi_{At}^*, \xi_{Gt}, \xi_{Gt}^*\}_{t=0}^{\infty}$.

III. Quantitative Evaluation of the Model

3.1. Parameter Values

Because a two country world with identical features is set up, we will use the same parameter values of the US economy for the home country as well as for the foreign country. All parameter values used in this paper are reported in Table 1. Most of them are taken from Chari et al. (2002) and King and Watson (1996).

The baseline model of this paper takes the intertemporal elasticity of consumption equal to 2, and the Frisch elasticity of labor supply equal to 1. The serial correlation parameter for the technology shock, ρ is assumed to be 0.9. As an interest rate smoothing rule, Clarida, Gali, and Gertler (1999)'s estimate for the Fed's monetary reaction function during Volcker-Greenspan era, as shown in the simulation below, is utilized.

$$r_t = 0.66 r_{t-1} + 0.34(1.97 E_t \pi_{t+1} + 0.07 y_t) + \xi_{rt}. \tag{3.1}$$

The numbers are similar to those estimated by Chari, Kehoe, and McGrattan (2002).

Though we need not specify the functional form for the capital stock adjustment cost function $\mathcal{F}$, we should specify three parameters which describe the behavior around the steady state. First, we must specify the steady state value of Tobin's q and the share of investment in national product. Since the steady state value of Tobin's q is 1.0, we also set the value of this variable to 1.0 in the steady state. And we will take the same investment share in a steady state in the model as the one in the model without adjustment costs. Next, we have to specify the parameter which determines the elasticity of a marginal adjustment cost function. The value of an elasticity of i_t / i_{t-1} with respect to Tobin's q, η_q is the adjustment cost elasticity which reflects the volatility of investment. Though many studies have estimated this adjustment cost parameter, there is still a lot of uncertainty on the size about the adjustment cost. The parameter values concerning the investment adjustment cost are also taken from Smets and Wouters (2007). The investment adjustment cost function $\mathcal{F}$ is restricted to satisfy $\mathcal{F}(1) = \mathcal{F}'(1) = 0$ and $\mathcal{F}''(1) > 0$ as in CEE (2005) and Smets and Wouters (2007): The value of η_q is set to 4 in the baseline model as in Smets and Wouters (2007).

[Table 1] The Calibrated Parameters

Parameter	Values	Description and definitions
λ	0.4	Fraction of rule of thumb consumers
s_H	0.58	Steady state labor share
δ	0.025	Rate of depreciation of capital stock
r_h	0.016	Steady state rate of return
$\varepsilon_C(\sigma^{-1})$	1/2	Intertemporal elasticity of substitution
θ	0.5	Steady state share of domestic consumption goods
α	2/3	Fraction of firms that do not change their prices in a given period
ε	11	Elasticity of demand for a good with respect to its own price
ν	1	Inverse of elasticity of labor supply
η_q	4	Elasticity of i / k to Tobin's q
ρ_A, ρ_A^*	0.9	First-order serial correlation of technology shock
σ_A, σ_A^*	0.007	Standard deviation of technology shock
σ_r, σ_r^*	0.005	Standard deviation of monetary shock
σ_G, σ_G^*	0.01	Standard deviation of government expenditure shock

Note: Country subscripts (h, f) are suppressed. The same parameter values are used in the home country and the foreign country.

The nominal rigidity parameter value of α is also uncertain because the estimate of the parameter changes, depending on the period of interest and the estimation method. When a high degree of nominal price rigidities is taken, the volatilities of output and employment increase. In recent, Bils and Knelow (2005) using micro data reports a lower estimate of α, 0.5 than most literature assumes.[4]

[4] There is a lot of uncertainty in the degree of price rigidities. The range of empirical values for the

For this reason, we set α to 2/3. Next, we will choose 1.1 as the benchmark average size of markup (μ): Though this value is lower than the value that many sources of evidence suggest,[5] it is consistent with the average markup estimates in Fernald and Basu (1993).

Regarding to the intratemporal elasticity of domestic goods and foreign goods which plays a key role in the dynamic properties of the selected macroeconomic variables in the DSGE model, there is a considerable uncertainty about its value. Empirical studies using time series data have found estimates that range from 0.4 and 2 (See Obstfeld and Rogoff (2002)). For the U.S., Whalley (1985) estimates a value of 1.5, while Taylor (1993) finds it to be 0.39. For European countries most empirical studies find values below 1. However, the empirical studies in trade literature suggest a much higher value for ψ from 3 to 8. Correspondingly, the quantitative analysis takes different values for the elasticity. It is well known that the DSGE models need a low value for ψ to generate dynamics of the relevant variables that match to the corresponding ones in the data. For example, Backus et al. (1994) set it equal to 1.5, while Heathcote and Perri (2002) estimate it to be 0.9. Given the uncertainty about the appropriate value of the elasticity, we choose it to be 1 in the benchmark model whose value is commonly used in DSGE models and perform sensitivity analysis with a higher value equal to 1.5 and a lower value equal to 0.5.

Finally, we need to set the parameter value of LAMP (λ) in the region where aggregate demand responds negatively to the real interest rate changes, since there is a threshold value λ^* of the non-asset holder beyond which the relationship between aggregate demand and the real interest rate changes its sign. The parameter of the fraction of rule of thumb consumers is λ is set to 0.4 to be consistent with the estimate of Campbell and Mankiw (1989) and Bilbiie (2008).

3.2. Implications of the Benchmark Model

In this subsection, we review the main goal of this paper and see whether the sticky model embedded with limited asset market participation and predetermined expenditures can explain the real exchange rate - relative consumption puzzle. In particular, we compare the second moments calculated from the model with those of data drawn from major industrial economies.

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degree of price rigidities (α) are estimated around 0.5 or 0.85. Yun (1996) set $\alpha = 0.82$ in his endogenous money supply model. King and Watson (1996) use 0.9 as a benchmark parameter value, while King and Wolman (1997) use 0.75 to consider the optimal monetary policy in a Calvo-style sticky price model. Chari et al. (2002) set $\alpha = 0.75$ in the benchmark model.

[5] See Rotemberg and Woodford (1992) for more detailed discussion and references about markup.

3.2.1. Some Intuitions

To get an analytical insight on the exchange rate volatilities in the sticky price model with an external habit formation and LAMP, let us consider the risk sharing of the complete asset market which can be rewritten as follows:

$$\varepsilon_t = \mathbf{k}\left(\frac{C_t^o - bC_{t-1}^o}{C_t^{*o} - bC_{t-1}^{*o}}\right)^{\sigma}. \tag{3.2}$$

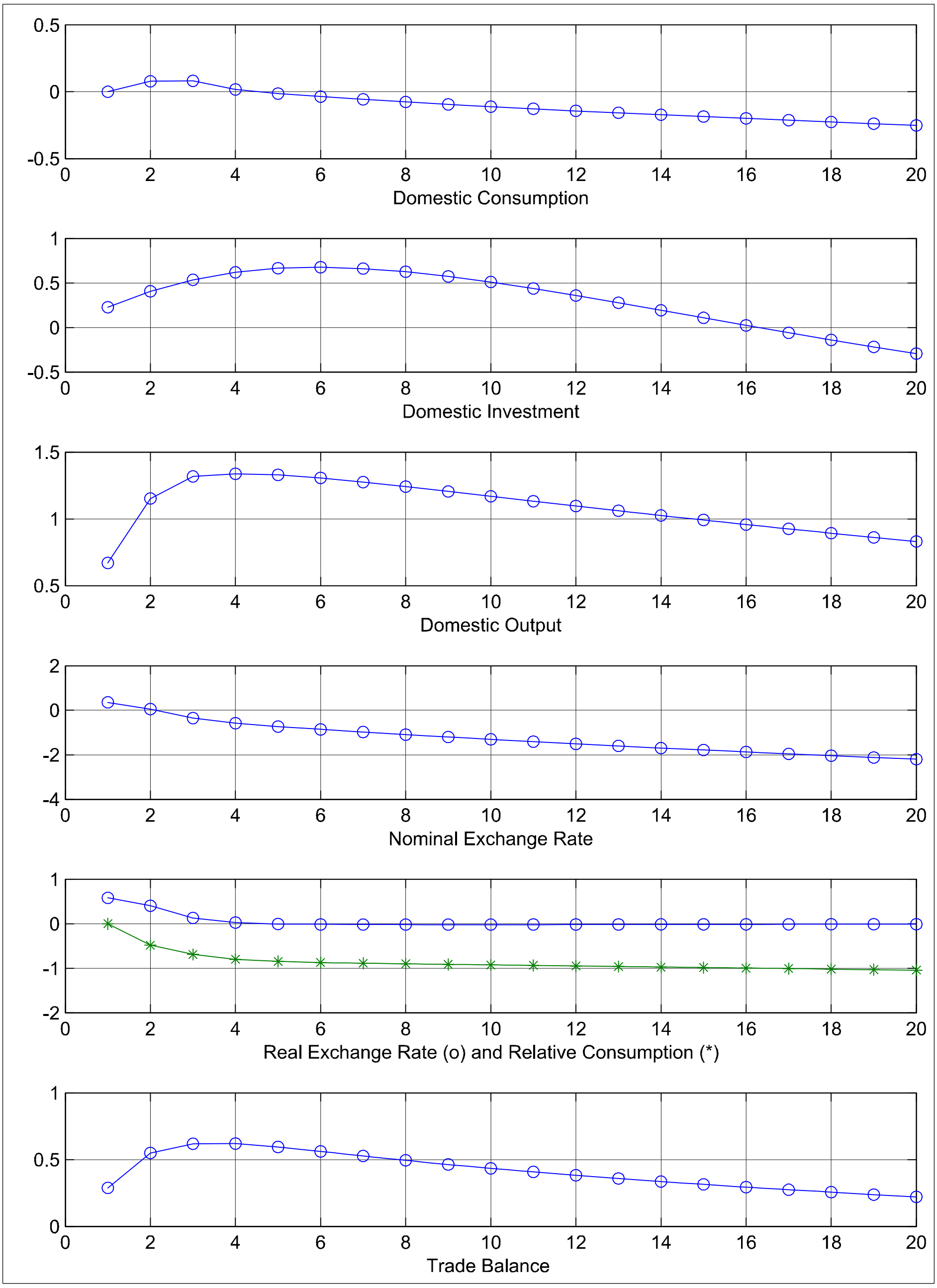
Since asset holder can perfectly share any risk by trading one period nominal state-contingent bond at the financial market, the real exchange rate moves one to one with the relative consumption of domestic asset holder and foreign asset holder. However, the real exchange rate and aggregate consumption do not perfectly comove to exogenous shocks when some households cannot participate in the financial market to protect themselves from the exchange rate risk. Consumption of asset holders is loosely linked to their current income, while consumption of non-asset holders is tightly linked their current income. This wedge plays a key role in breaking the close connection between aggregate consumption and the real exchange rate.

3.2.2. Dynamic Responses to Shocks

First, consider the response of the selected variables to a domestic technology shock.

Since the world demand for home goods is decreasing in its relative price, a positive domestic technology shock increases the demand for domestic goods by worsening the home country's terms of trade. A positive technology increases the supply of home goods relative to foreign goods, decreasing the relative price of home goods relative to foreign goods. This negative effect of productivity shocks on the real exchange rate is predicted by all standard models such as Lucas (1982), Backus et. al. (1994), and Chari et al. (2003). As Galí (1999) has shown, domestic households decrease their labor supply to the positive domestic productivity shock in a standard new Keynesian model as the monetary authority adjusts its policy rate to stabilize price and output. That is, since domestic output gap is still negative to the shock in the economy with nominal price rigidities, the monetary authority decreases its policy rate to boost the expenditure and to stabilize the economy. Hence, the deterioration of the terms of trade not only decreases the real wage, but also hurts the domestic household's purchasing power. Since consumption of non-asset holder whose current wage equals consumption decreases to the positive domestic productivity shock, the relative consumption falls to the shock as in Figure 1.

[Figure 1] Impluse Response Function to a Domestic Productivity Shock

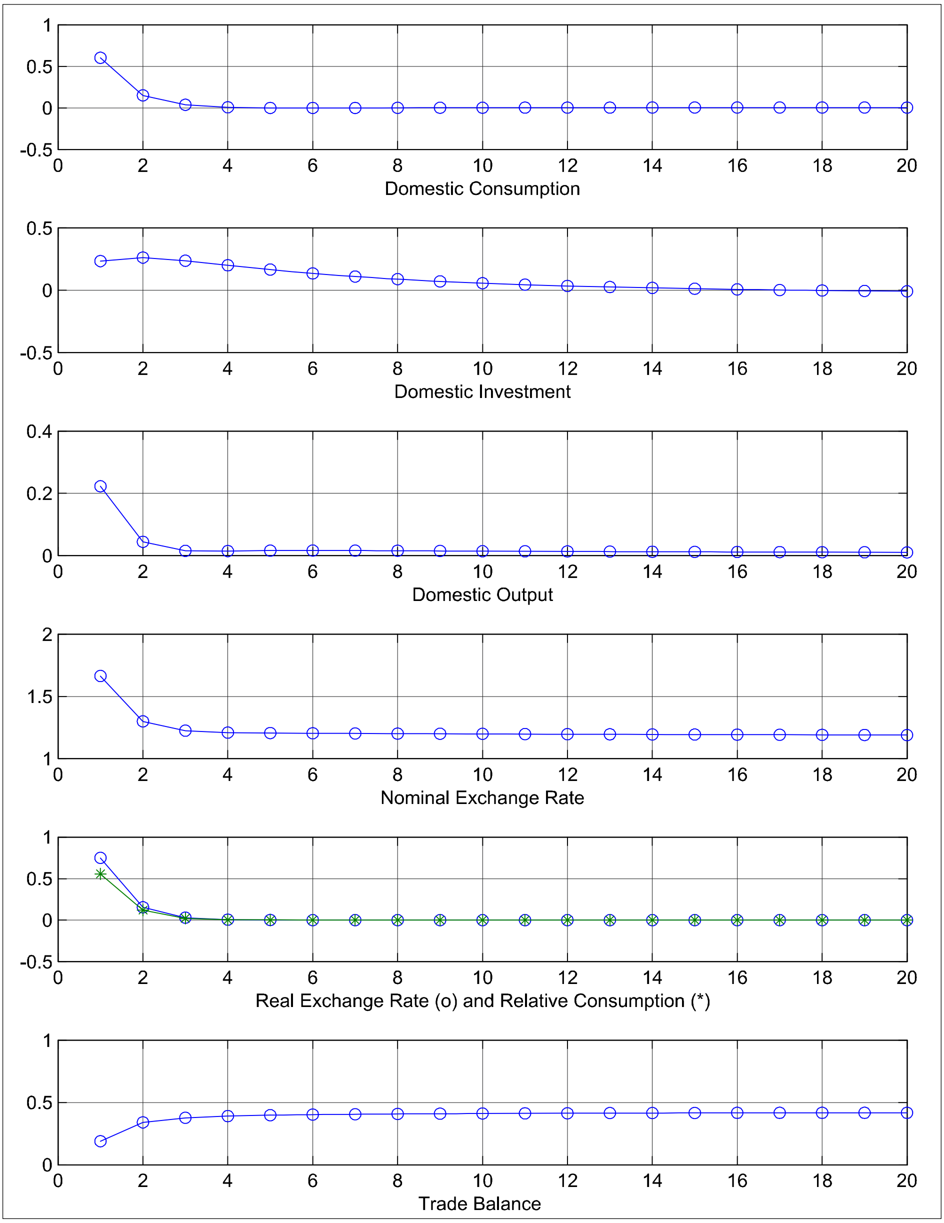


Next, consider the impulse response of some selected variables to a negative domestic policy rate shock.[6] Figure 2 presents the dynamics of the relevant variables

[6] It is well known that the persistence of exchange rates to a home monetary shock matches to the

to the shock.

[Figure 2] Impluse Response Function to a Domestic Interest Rate Shock



Since an expansion of domestic monetary supply associated with a decrease of the policy rate decreases a real marginal cost in the model with nominal price rigidities,

degree of the price stickiness in the sticky price model (Chari et al., 2002).

domestic firms produce more output, making the terms of trade to depreciate. Both investment and output increase as the marginal product of capital goes up along with an increase of labor demand. If households do not have any habit persistence and expenditure delays, then consumption responds monotonically to a monetary shock, leading to a monotonic response of trade balance. The expansionary monetary policy shock can initially deteriorate the trade balance.

Next, consider the sticky price model with habit persistence and expenditure delays. Households with habit persistence and expenditure delays adjust their consumption more gradually over time than households with habit persistence only. The response of consumption to a monetary shock is more muted in a sticky price model with habit persistence and expenditure delays than the one in a sticky price model without habit and expenditure delays. The trade balance improves to the shock as households substitute foreign goods with domestic goods to the increase of the international relative prices. Hence, the response of output is larger than the response of expenditures, leading to a trade surplus.

3.2.3. Variabilities and Serial Correlations

The foremost important issue that we address is whether the model can generate acyclical or mild negative correlation between relative consumption and the real exchange rate. In this subsection, we compare volatilities and serial correlations of the real variables calculated from the model with those of the data to examine the overall performance of the model. The column labelled 'Data' in Table 2 is reproduced from Chari et al. (2002) where moments are calculated for actual time series that have been Hodrick-Prescott filtered. This column reports composite data moments of six countries (Canada, France, Germany, Japan, United Kingdom, and United States).

First, consider the second moments of some selected variables calculated from the data. A prominent feature of the real exchange rate movement is its opposite movement with relative consumption and the excessive volatility relative to other real variables, as can be seen in Table 2. In the data, the standard deviation of the real exchange rate relative to GDP is 3.28, while its correlation with relative consumption is -0.45. Chari et al. (2002) using a subset of OECD economies from 1973 to 1994 reports a median value of -0.07 for the correlation between the real exchange rate and relative consumption. This acyclical or negative correlation between the real exchange rate and relative consumption is known as the real exchange rate - relative consumption puzzle or Backus-Smith puzzle. Table 3 also shows that there is no systematic correlation between the real exchange rate and relative consumption among the selected industrialized countries.

[Table 2] Data and Models - Baseline Model

	Data	Complete Market Model ($\lambda = 0$)	Baseline Model with Technology Shocks Only	Baseline Model with All Shocks	Baseline Model with predetermined C
Standard Deviations					
GDP	1.65	1.21	0.46	1.57	1.51
relative to GDP					
Real Exchange Rate	3.28	2.36	0.45	1.83	1.90
Terms of Trade	1.78	0.99	1.62	0.77	0.80
Consumption	0.92	0.30	1.19	0.80	0.76
Cross-correlations between home and foreign					
GDP	0.49	0.53	0.26	0.72	0.69
Consumption	0.32	0.40	-0.03	0.77	0.75
Trade Balance	-0.51	-0.19	-0.09	-0.09	-0.10
Cross-correlations between real exchange rate					
and relative consumption	-0.45	0.88	-0.87	0.26	0.09
and terms of trade	0.60	0.49	-0.55	0.34	0.35

[Table 3] Correlation between Real Exchange Rates and Relative Consumption

	France	Germany	Italy	UK
US	-0.06	-0.15	-0.35	-0.48
France		0.24		
Germany			-0.08	
Italy				0.14

Source: Chari, Kehoe, and McGrattan (2002).

Next, consider the second moments of the corresponding variables calculated from the model. First, we will look at the RANK model with complete asset markets. The second column in Table 2 presents the second moments associated with a model with nominal price rigidities and asset holders only. When there are only asset holders ($\lambda = 0$) in economies with nominal rigidities and complete financial markets, the correlation between the real exchange rate and relative consumption is 0.88, indicating a close link between home and foreign households via an optimal risk sharing condition.[7]

Next, we will look at the implications of the extended model. The third and fourth columns in Table 2 correspond to the baseline model with limited asset market participation and habit persistence. When there are some households who cannot participate in the asset market to protect themselves from the exchange rate

[7] If there is no external habit formation in consumption and the preference is separable, the correlation between the real exchange rate and relative consumption is unity.

risk, the existence of the complete financial market itself cannot guarantee the close relationship between aggregate consumption and the real exchange rate. Non-asset holders who do not have any asset to buffer their consumption against the shocks end up spending their wage income over the business cycles, while asset holders can use financial assets to smooth out their consumption profiles against the shocks. Hence, the real exchange rate does not closely comove with relative aggregate consumption. The third column in Table 2 shows the second moments calculated from the benchmark model with technology shocks only, which have been widely used to see the correlation between relative consumption and the real exchange rate (Benigno and Thoenissen, 2008 and Corsetti et al., 2008). The asymmetric response of asset holder and non-asset holder to the shock induces a negative correlation between the real exchange rate and relative consumption. The limited asset market participation model with nominal rigidities, habit persistence, and technology shocks only is successful in reversing the sign of correlation between the real exchange rate and relative consumption. However, when there are only technology shocks in the economy, the model generates a much higher negative correlation between the real exchange rate and relative consumption, -0.88, than the mild or acyclical correlation value in the data. The model with only technology shocks also has another problem. The volatilities of some selected endogenous variables are much lower than those of the data. Since it is well known that the monetary shock plays a key role in new Keynesian model to generate the cyclical movement of endogenous variables over business cycles, we need to disentangle the effect of nominal shocks on the relevant correlation from the effect of technology shock. For this reason, we report the second moments associated with the baseline model with all shocks. Note that both asset holders and non-asset holders respond symmetrically to the nominal shock. The correlation between the real exchange rate and relative consumption increases from -0.88 to 0.26, whose size is a little bit high compared to the data. But it is comparable to the value calculated from the data of European countries.

Finally, we will look at the second moments implied by the extended model à la Rotemberg and Woodford (1997), Bernanke et al. (1999), and Woodford (2003). To disconnect the close comovement between the real exchange rate and relative consumption, we have extended the model by incorporating consumption expenditure adjustment costs in the form of equation (2.16) into the benchmark model. The predetermined expenditures play a role of delaying the effect of shocks on the relevant variables. If asset holders decide their consumption expenditures in one period advance,[8] the correlation between relative consumption and the real exchange rate decreases further to 0.09, indicating that the systematic relationship between these variables almost disappears.

[8] This corresponds to a "time-to-build" investment decision in the real business cycle literature.

3.2.4. Sensitivity Analysis

In this subsection, some sensitivity analysis is performed by changing some important parameter values such as the intratemporal elasticity of substitution between home and foreign goods (ψ), and the degree of external habit persistence (b).

[Table 4] Data and Models - Sensitivity Analysis

	Data	High Degree of External Habit ($b = 0.75$)	Lower Elasticity between Home and Foreign Goods and predetermined C
Standard Deviations			
GDP	1.65	1.52	1.43
relative to GDP			
Real Exchange Rate	3.28	1.88	2.05
Terms of Trade	1.78	0.79	1.01
Consumption	0.92	0.78	0.81
Cross-correlations between home and foreign			
GDP	0.49	0.70	0.88
Consumption	0.32	0.76	0.69
Trade Balance	-0.51	-0.10	-0.10
Cross-correlations between real exchange rate			
and relative consumption	-0.45	0.16	-0.09
and terms of trade	0.60	0.35	0.22

Table 4 reports the results of sensitivity analysis conducted with respect to the supposedly critical parameter values. First, consider the implications of a change in the intratemporal elasticity of substitution between home and foreign goods. Notice that the correlation between the real exchange rate and relative consumption turns into a negative value, -0.09 when ψ equals 0.5. When the intratemporal elasticity between home and foreign goods is low, the household are less willing to substitute home goods for foreign goods to the decrease of an international relative price, making relative consumption move in the opposite direction. Moreover, domestic and foreign consumption move less closely than domestic and foreign output.

Next, consider the effect of external habit persistence on the corresponding variables. When households are more willing to catch up with the Joneses, i.e. when b increases, the role of financial market in sharing risk becomes less effective. As a result, the correlation between the real exchange rate and relative consumption decreases with an increase of b. Table 4 shows that the correlation between the real exchange rate and relative consumption decreases to 0.16 when b increases to 0.75.

Summing up, the limited asset market participation model embedded with nominal rigidities, habit persistence and expenditure delays is successful in replicating the correlation between the real exchange rate and relative consumption, even if there is a complete financial market.

IV. Concluding Remarks

This paper investigates whether a new Keynesian open economy model embedded with limited asset market participation and expenditure delays can explain the real exchange rate and relative consumption anomaly. The paper shows that when there are households who cannot participate in the financial market to protect themselves from the exchange rate risk, the relative aggregate consumption tends to move unsystematically, while the relative consumption of asset holders tends to move very closely to the real exchange rate. In particular, if the households with expenditure delays as in Rotemberg and Woodford (1997) are less willing to substitute home goods with foreign goods, relative consumption moves less closely with the real exchange rate.

In future research, it is desirable to extend the model in the following directions. First, it is desirable to incorporate the heterogeneous households with realistic distributions of portfolios into the model to uncover the real exchange rate and relative consumption puzzle. Second, it is necessary to incorporate the nontradables into the model and explore the role of nontradables in the real exchange rate - relative consumption puzzle. Finally, we need to redress the real exchange rate - relative consumption puzzle by using high values of the intratemporal elasticity between home and foreign goods widely used in international trade literature.

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