Intermediary Leverage and Currency Risk Premium∗

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Abstract

This paper proposes an intermediary-based explanation of the risk premium of currency carry trade in a model with a cross-section of small open economies. In the model, bankers in each country lever up and hold interest-free cash as liquid assets against funding shocks. Countries set different nominal interest rates while low interest rates encourage bankers to take high leverage. Consequently, bankers’ wealth drops sharply with a negative shock. This reduces foreign asset demand and leads to a domestic appreciation, which in turn makes low-interest-rate currencies good hedges. The model implies covered interest rate parity deviations when safe assets differ in liquidity. Empirical evidence is consistent with main model implications: (i) Low-interest-rate countries have high bank leverage and low currency returns; (ii) The carry trade return is procyclical with positive exposure to bank stock return; (iii) Comovement of the carry trade return and the stock return increases with the stock market volatility.

Key Words: Bank leverage, Carry trade, Currency risk premium, Exchange rate, Liquidity premium, Nominal interest rate

JEL Classification: E40, F31, G15, G21

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1 Introduction

Investors earn sizable excess returns on average by borrowing low-interest-rate currencies (such as Japanese yen) and investing in high-interest-rate currencies (such as Australian dollar). This investment strategy is famously known as “carry trade”. One widely-used approach to explain the phenomenon is based on risk (Lustig and Verdelhan, 2007; Lustig, Roussanov, and Verdelhan, 2011), which argues low-interest-rate currencies are less risky than high-interest-rate ones. In other words, low-interest-rate currencies appreciate relative to high-interest-rate ones in bad times. There is, however, not yet a consensus on the sources of currency risks. In this paper, we propose a liquidity-leverage mechanism on how nominal interest rates affect currency risk premia through financial intermediaries. We build a dynamic model in which low-interest-rate currencies appreciate in bad times relative to high-interest-rate ones. As a result, investors require a positive risk premium to conduct carry trades.

Our model features a cross-section of small open endowment economies that differ in their nominal interest rates as exogenous policy choices. These economies are separate from each other and face a common foreign security whose foreign currency denominated return is exogenously given. In each economy, there are two types of agents $h$ and $b$ with heterogeneous preferences: The type-$h$ agent has higher risk aversion and lower IES than the type-$b$ agent. Throughout the paper, the type-$b$ agent is referred to as “banker” and the type-$h$ as “household”. In equilibrium, the type-$b$ agent borrows from the type-$h$ by issuing riskless deposit, and thus play the role of banks in the economy. While taking leverage, bankers face a liquidity shock (Drechsler, Savov, and Schnabl, 2018). When the shock arrives, depositors request to withdraw a portion of their deposits. Since the risky assets held by the bankers are illiquid and liquidating them incurs a large firesale loss, bankers voluntarily hold interest-free cash as liquid assets to avoid firesale loss. Consequently, interest rate represents the opportunity cost of leverage and bankers in low-interest-rate countries take high leverage.

When a negative endowment shock hits a low-interest-rate country, bankers’ wealth share sharply decreases in that country due to high leverage. Since bankers have higher IES than households, the wealth-weighted consumption-wealth ratio of the country increases and the demand for foreign asset decreases. As a result, the domestic currency appreciates, making it a good hedge against adverse shocks. We call this channel the liquidity-leverage channel throughout the paper. When the same negative shock hits the high-interest-rate country with low bank leverage, the exchange rate movement is small. Therefore, investors require a positive premium to borrow low-interest-rate currencies and invest in high-interest-rate ones.

Our model has rich implications on the factor structure of asset returns. Lustig et al. (2011) empirically show that the cross-section of currency portfolio returns can be priced by the “carry risk factor”, defined as the spread between returns of investing in high- and low-interest-rate currencies.

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1Empirical evidence shows that investors that hold more risky assets have higher IES (Vissing-Jørgensen, 2002). Guvenen (2009) proposes a model with high-IES stock-holders and match both asset prices and macro dynamics quantitatively.
In our model, the “carry risk factor” measures the magnitude of the common endowment shock faced by all countries. When the shock is positive, the carry risk factor becomes large. Consequently, low-interest-rate currencies depreciate when the “carry risk factor” is large, consistent with the empirical finding.

Furthermore, our model delivers a factor structure of stock valuations, as shown by Colacito, Croce, Gavazzoni, and Ready (2018) that low interest rate countries’ stock prices load more on the global risk. In our model, when the same shock hits all the economies, stock valuations of low interest rate countries rise more because of high bank leverage.

We derive a new factor structure of currency returns and the average bankers’ wealth portfolio in the model. When a common positive shock hits all the countries, bankers’ wealth increases in every country, while low-interest-rate currencies depreciate relative to high-interest-rate ones and the carry trade delivers a positive return. As a result, carry trade is procyclical and exposures of currency carry trade return to bankers’ wealth portfolio increase with interest rate. In the empirical section, we verify this implication by measuring bankers’ wealth portfolio dynamics with banking sector stock return in each country.

Dynamically, the factor structure of exchange rate and stock return is time-varying. The time variation is first noted by Lustig, Roussanov, and Verdelhan (2008) that the currency carry trade beta with stock return is particularly high in crisis. Since our model does not have a clearcut definition of crisis, we examine the correlation between currency carry trade beta and the stock market volatility. In the model, beta increases with the stock market volatility. The reason is simple: Exchange rates comove with stock returns when the amplification effect brought by leverage is strong. This is exactly when the endogenous volatility of stock return is high. We document this feature in the data in the empirical section. The implication of the dynamic property of beta distinguishes our model from most of the existing literature.

After exploring the cross-sectional implications on interest rates, bank leverage, exchange rates, and stock prices, we analyze the time-series relationship between interest rates and currency risk premia by introducing stochastic interest rates into the model. If a country experiences an unexpected rise in interest rate, bankers in that country take less leverage and the required risk premium to invest abroad decreases. This result is in line with the empirical finding of Mueller, Tahbaz-Salehi, and Vedolin (2017) that the subsequent return of investing abroad after FOMC interest rate rise (cut) is lower (higher). Moreover, our model implied regression coefficient of foreign excess return on interest rate differential between foreign and domestic currency is positive, consistent with the long-standing literature on the “forward premium puzzle”.

Our model delivers two additional results that are consistent with the recent empirical literature. Du, Tepper, and Verdelhan (2018b) document the large and persistent deviations from covered interest rate parity (CIP) after the financial crisis, while Jiang, Krishnamurthy, and Lustig (2018) and Du, Im, and Schreger (2018a) show that dollar safe assets have privilege over foreign ones. In our model, the return to CIP arbitrage with a long dollar position is negative if dollar safe assets
are more liquid. Jiang et al. (2018) take a further step and find that the “liquidity premium” of the dollar has a positive correlation with the risk premium of investing in dollar assets. In a slightly extended version of our model when domestic and dollar assets are imperfectly substitutable liquid assets, a rise in dollar liquidity premium reduces the total cost of holding liquid assets for foreign investors. This is effectively similar to a drop in nominal interest rate, so that the risk premium to invest in the dollar increases.

Despite the parsimony of the liquidity friction that only cash is held as the liquid asset, our model captures a wide range of regulation and market discipline practices concerning liquidity. Regulations include reserve requirement ratio for depository institutions, and more recent liquidity coverage ratio required by the Basel III framework. Apart from regulations, financial institutions also voluntarily hold liquid assets. In our model, we have interest-free cash as the single type of liquid assets available. However, the model can be easily extended to incorporate other near-money safe assets that provide liquidity, such as government treasuries. The different liquidity properties of these assets lead to different liquidity premia. Nagel (2016) shows detailed empirical evidence that liquidity premia of near-money assets are tightly linked to the nominal interest rate.

Our liquidity-leverage mechanism is different from other models of cross-sectional currency risk premia. Existing studies (For example, Hassan, 2013; Richmond, 2018; Ready, Roussanov, and Ward, 2017) propose some source of fundamental heterogeneity (e.g., country size, trade network centrality, and composition of trade, respectively) across countries that simultaneously drive interest rates and currency risk premia. While most advanced economies use nominal interest rates as their monetary policy tools, the literature is largely silent on how nominal interest rates are translated into exchange rate properties. In our paper, nominal interest rates are taken as exogenous policy choices and real exchange rate properties are determined by the leverage of bankers in these economies, which in turn depends on nominal interest rates. We consider our liquidity-leverage channel as a complement to the literature.

The empirical exercise of the paper is centered around three main model implications: (i) Low-interest-rate countries have high bank leverage and low currency returns; (ii) The carry trade return is procyclical with positive exposure to bank stock return; (iii) Comovement of the carry trade return and the stock return increases with the stock market volatility.

As the first-pass validation of implication (i), Figure 1 plots the cross-sectional relation of bank capital ratio (the inverse of bank leverage, in percent) with average forward discounts (interest rate differentials) and currency returns vis-a-vis dollar for ten most liquid currencies. A positive slope stands out in both graphs: Countries with lower bank capital ratio (higher leverage) tend to have lower interest rates and currency returns. The typical carry trade funding country (Japan) has substantially lower capital ratio than the typical investment country (Australia). Later in the empirical section, we show the same relationship for 22 advanced economies through panel regressions. The relationship is robust after controlling for inflation and GDP of the country. Following standard asset pricing practice, we sort currencies into portfolios based on bank leverage
and find currency returns monotonically increase from high leverage portfolios to low leverage portfolios. The spread between the lowest and highest leverage portfolios, the “Lev-factor”, is 2.0 percent per annum. Heterogenous exposures to the “Lev-factor” accounts for the different expected returns of currency portfolios and the “Lev-factor” has a significantly positive risk price, which is consistent with our model implication.

To validate implication (ii), we construct a measure of the common endowment shock by averaging the banking sector stock returns across countries in the sample. The use of banking sector return is to highlight the role of banks in driving exchange rates, while we show the same results hold if we replace bank stock returns with country-level stock return index in the appendix. Exposures of currency returns to the bank stock return factor are in line with countries’ average interest rate: low-interest-rate currencies have lower (more negative) exposures than high-interest-rate ones. In other words, carry trade is highly procyclical.

Lastly, we examine implication (iii), the time variation of currency return’s comovement (beta) with the stock market return. We construct the stock return risk factor by averaging the MSCI country index and calculate the carry trade betas based on five-year rolling windows. Carry trade betas are increasing in the average stock return volatility, computed as the realized volatility of monthly average stock returns in the same five-year window.

This paper makes three contributions to the literature. First, we provide a new explanation of the currency risk premium featuring the liquidity-leverage channel, with nominal interest rates as exogenous monetary policy choices. Our model can accommodate many empirical findings in the literature, including the factor structure of currency and stock returns, CIP deviation, and the positive relationship between the liquidity premium and the risk premium of dollar. Second, our model can simultaneously explain the time series relationship between interest rates and risk premia. Third, we show the empirical evidence in line with our model implications, especially the novel relation between interest rate, bank leverage, and currency returns in the cross-section.

Related Literature

Our paper is closest to three papers in the literature. Backus, Gavazzoni, Telmer, and Zin (2013) link currency risk premium to monetary policy heterogeneity across countries but the real side of the economy is not affected by monetary policy. In our model, monetary policy affects currency risk premium in real terms. Maggiori (2017) shows that currencies of countries with more developed financial system (such as US) appreciate in bad times, while Malamud and Schrimpf (2018) derive exchange rate dynamics from a model with monopolistic intermediaries. Neither of these two papers links currency risk premia to countries’ interest rate levels. Moreover, our paper provides empirical evidence in support of the key mechanism of our model, while both Maggiori (2017) and Malamud and Schrimpf (2018) are theoretical studies.

Lustig and Verdelhan (2007) and Lustig et al. (2011) document the systemic variation of currency returns for cross-sectional interest rate sorted portfolios and construct pricing factors. These papers are silent on how economic fundamentals determine exchange rates. Economic explanations
to sources of currency risk premium highlight the fundamental heterogeneity across countries, including monetary policy (Backus et al., 2013), country size (Hassan, 2013), trade network centrality (Richmond, 2018), composition of international trade (Ready et al., 2017), long run risk exposure (Colacito et al., 2018), fiscal cyclicality (Jiang, 2018), and dollar external debt (Wiriadinata, 2018).

Our paper takes a different perspective by taking nominal interest rates as exogenous policy choices and proposes the liquidity-leverage channel that link nominal interest rate and currency risk premium.

On the other hand, the literature on time series violation of uncovered interest rate parity (the “forward premium puzzle”) is vast since Fama (1984). The robust positive comovement between currency returns and interest rate differentials poses challenges to exchange rate modeling. Early studies with the asset pricing approach include Bekaert (1996), Bansal (1997), Backus, Foresi, and Telmer (2001), and Brennan and Xia (2006). Structural macro-finance models explain the forward premium puzzle under frictionless financial market, including habit formation (Verdelhan, 2010; Stathopoulos, 2016), long run risk (Bansal and Shaliastovich, 2013; Colacito and Croce, 2013), rare disaster (Farhi and Gabaix, 2015). Models with frictions include market segmentation (Alvarez, Atkeson, and Kehoe, 2009), financial market incompleteness (Favilukis and Garlappi, 2017), leverage constraint (Gabaix and Maggiori, 2015; Fang and Liu, 2018), etc.

A recent literature starts to focus on the role of intermediaries in exchange rate determination. Empirical asset pricing literature shows the pricing power of intermediary variables on currency returns (Adrian, Etula, and Shin, 2015; Adrian, Etula, and Muir, 2014; He, Kelly, and Manela, 2017; Haddad and Muir, 2017). Sandulescu, Trojani, and Vedolin (2017) derive model-free international SDFs and show they are highly correlated with intermediary variables. Theoretical models of intermediation and exchange rates include Gabaix and Maggiori (2015), Maggiori (2017), Fang and Liu (2018), and Malamud and Schrimpf (2018). Our model highlights the liquidity frictions faced by intermediaries, while the effect of the friction depends on nominal interest rates. Moreover, our model explains the relationship between interest rates and currency risk premia in both cross-sectional and time-series dimensions.

Lastly, our paper is related to the literature of the risk taking channel of monetary policy. The model framework and the liquidity-leverage channel is similar to Drechsler et al. (2018), while we extend the model into the open economy. Bruno and Shin (2015) and Dell’Ariccia, Laeven, and Suarez (2017) show that banks play important roles in the risk taking channel of monetary policy. Rey (2016) and Miranda-Agrippino and Rey (2018) demonstrate that intermediary credit and leverage are important in monetary transmission across the border. Our liquidity-leverage channel bridges the literatures on risk taking channel of monetary policy and currency risk premium.

The rest of the paper is organized as follows. Section 2 lays out the structure of the model and derives equilibrium conditions. Section 3 shows the solutions and simulation results of the model. Section 4 provides empirical evidence on the main model implications. Section 5 concludes the paper.
2 The Model

The world consists of a cross-section of $N + 1$ small open economies. Each economy is populated with two types of agents. Both agents consume two goods: a country specific nontraded good and a common traded good. Country 1 is labeled as the provider of a global riskless asset denominated in its local nontraded good that agents in all economies have access to. We abstract away the optimization behavior of country 1’s agents and assume exogenously the relative price of country 1’s nontraded good in the traded good. The remaining $N$ countries are symmetric, except that they have different nominal interest rates. In the next section, we describe the economic environment of a typical small open economy.

2.1 Environment

Consider a representative small open endowment economy. There are two types of goods in the economy: nontraded goods (X) and traded goods (Y). Traded goods can be exported to or imported from other countries. Time is continuous and infinite. Uncertainty is characterized by a standard filtered probability space $(\Omega, \mathcal{F}, \mathbb{P}, \{\mathcal{F}_t\})$, to which all stochastic processes are adapted. The structure of the model is closely to Drechsler et al. (2018) except for its open economy features.

2.1.1 Endowment

The economy is endowed with a tree that pays dividends in both nontraded and traded goods. The dividend process of the nontraded good $X$ follows a geometric Brownian motion:

$$\frac{dX}{X} = \mu_x dt + \sigma_x dB_x$$ (1)

$\mu_x, \sigma_x$ are positive constants. The traded good endowment $Y$ is given by:

$$Y = \bar{\tau}X$$ (2)

with $\bar{\tau}$ being a constant.

2.1.2 Agents

The economy is populated with two types of agents, $h$ and $b$. Both agents have recursive utility as in Duffie and Epstein (1992). Denote $\psi_j$ and $\gamma_j$ agent $j$’s intertemporal elasticity of substitution (IES) and risk aversion. All parameters without subscript $j$ are common to both agents. The time $t$ lifetime utility of agent $j$, $V_t^j$ is given by:

$$V_t^j = \int_t^\infty f^j(C_t^j, V_t^j) d\tau$$ (3)
where:

\[
f^j(C^j,V^j) = \frac{1 - \gamma^j}{1 - \psi^j} \left\{ \frac{C^j}{[(1 - \gamma^j) V^j]^{1/(1-\gamma^j)}} \right\}^{1 - \frac{1}{\psi^j}} - \rho \tag{4}
\]

\(\rho\) is the time discount factor. \(C^j\) is agent \(j\)'s consumption basket, a CES aggregation of nontraded and traded consumption:

\[
C^j = \left[ \alpha (C^j_x)^{\frac{\theta - 1}{\theta}} + (1 - \alpha) (C^j_y)^{\frac{\theta - 1}{\theta}} \right]^{\frac{1}{\theta}} \tag{5}
\]

\(\alpha\) measures the relative preference of nontraded good over traded good. \(\theta\) is the elasticity of substitution between the two goods.

The two agents differ in both risk aversion and IES. Type-\(b\) agents have smaller risk aversion and larger IES than type-\(h\) agents: \(\gamma_h > \gamma_b\) and \(\psi_h < \psi_b\). The assumption implies that it is more desirable for type-\(h\) agents to have a smooth consumption profile across states of the world as well as across time. This assumption is consistent with the empirical evidence that investors with more risky asset holding have higher IES (Vissing-Jørgensen, 2002). Moreover, it is consistent with the assumption made by Guvenen (2009) that stock-holders have higher IES. In equilibrium, type-\(b\) agents borrow from type-\(h\) agents in the form of riskless deposits (denominated in local nontraded good) and essentially play the role of banks in the economy. In the rest of the paper, I will call type-\(h\) agents as “Households”, and type-\(b\) agents as “Bankers”.

We assume that \(\kappa\) fraction of agents exit the market with the same measure of agents newly born in every period. The wealth of exiting agents are transferred to the newly borns on an equal per capital basis. This assumption is standard in the two-agent dynamic models to prevent one type of agent from dominating the other.

### 2.1.3 Assets

Each agent has four assets to choose from: a riskless asset denominated in local nontraded good (deposit), a claim to the local tree (local stock), a foreign security that is risk free in country 1’s nontraded good (foreign bond), and the country specific cash that pays zero nominal interest rate (cash). The return characteristics of these assets are as follows.

Deposit is risk free in terms of the local nontraded good, with an instantaneous real risk free rate \(r_t\), which is endogenously determined by the intertemporal choices of the agents.

\(^2\)In Guvenen (2009), the two types of agents are homogenous in risk aversion but one type is excluded from holding stocks. In our model, heterogeneity in risk aversion endogenously generates the heterogenous holdings of the risky asset across the two types.

\(^3\)In our model, bankers represent broadly defined commercial banks, investment banks, hedge funds, broker dealers, and other leveraged financial institutions.
The return process of the local stock is:

\[
dR_s = \frac{X + QY}{P} dt + \frac{dP}{P} \equiv \mu_s dt + \sigma_s' dB
\]  

(6)

where \( P \) is the price of the local stock denominated in nontraded good, \( \frac{1}{Q} \) is the relative price of local nontraded good in traded good. \( \mu_s \) and \( \sigma_s \) are the endogenous drift and diffusion of the local stock return process. We group all the Browian shocks into the vector \( B \), to be specified toward the end of this section.

The instantaneous return to foreign bond in country 1’s nontraded good is \( r^* \). The price of country 1’s nontraded good \( \frac{1}{Q^*} \) follows the following exogenous process\(^4\):

\[
\frac{dQ^*}{Q^*} = \sigma_q^* dB_q^* \equiv \sigma^* dB
\]  

(7)

With a postulated endogenous \( Q \) process:

\[
\frac{dQ}{Q} = \mu_q dt + \sigma_q dB
\]  

(8)

We can express the foreign bond return process in local nontraded good as:

\[
dR^*_f = (r^* + \mu_q + \sigma_q' \sigma^*) dt + (\sigma_q + \sigma^*) dB \equiv \mu_f dt + \sigma_f' dB
\]  

(9)

\( \mu_f, \sigma_f \) are the endogenous drift and diffusion of the foreign bond return in local nontraded good.

Agents can hold cash that does not pay interest. We introduce a friction so that there will an incentive to hold cash despite its zero interest: When an agent borrows to buy illiquid assets, she holds cash as the liquid asset to be insulated from the funding shock. The details are laid out in section 2.2.

2.1.4 Nominal Interest Rates as Policy Choices

We consider two versions of the model. The baseline version features constant nominal interest rates, while in the second version we introduce nominal interest rate shocks. Central banks use nominal interest rates as policy tools. When stochastic, nominal interest rates follow Orstein-Uhlenbeck processes:

\[
di = \zeta(i_0 - i) dt + \sigma_i dB_i
\]  

(10)

Different countries have different means of nominal interest rates, \( i_0 \). \( \zeta > 0 \) governs the persistence of nominal interest rates, and \( \sigma_i \) controls their volatility.

To sum up, there are two Brownian shocks in this economy if nominal interest rates are fixed,\(^4\) Any drift in the \( Q^* \) process can be absorbed in \( r^* \).
Thus the vector \( \mathbf{B} \) is defined as a column vector:

\[
\mathbf{B} = [B_x, B_q^*]' \tag{11}
\]

If nominal interests are stochastic, we have an additional interest rate shock \( B_i \).

Our model features incomplete financial market in two aspects. First, agents in different countries are segmented: they do not have access to the trees in other countries. Second, cash holding impedes risk sharing across agents in one economy.

Without loss of generality, throughout the paper, we define “real exchange rate” as the reciprocal of country-specific nontraded good price in traded good, \( Q \).

### 2.2 The Liquidity Friction

This section analyzes in detail the main friction in the economy, the liquidity friction. In every period, a Poisson funding shock hits the economy at rate \( \eta \). Once hit, all lenders (both domestic and foreign) will request for a withdrawal of \( \frac{\lambda}{1+\lambda} \) fraction of their assets.

The borrowers can hold four assets, while each asset differs in their liquidity. “Liquidity” is defined as how much proportion of an asset that can be liquidated to meet withdrawal needs costlessly when the funding shock hits the economy. The liquidity of each asset is as follows:

\( \frac{\lambda}{1+\lambda} \) fraction of deposit or foreign bond can be liquidated without additional costs. If an agent wants to sell more, she has to pay a firesale loss \( \phi \) for each unit. Local stocks can be sold only at a fire sale price with loss \( \phi \) per unit, while all cash can be used to meet the withdrawal needs costlessly.

To summarize, the assets are ranked according to liquidity as:

Cash > Deposit = Foreign bond > Local stock

We define \( L_D^j \) as the liquidity need of agent \( j \) when the funding shock hits, and \( L_H^j \) the available assets owned by agent \( j \) that can be liquidated costlessly.

Denote \( w_h^j, w_f^j, w_c^j \) agent \( j \)'s portfolio share in local stock, foreign bond, and cash, so that \( 1 - w_h^j - w_f^j - w_c^j \) is her portfolio share in deposit. The liquidity need (in portfolio share) when the funding shock hits is:

\[
L_D^j = \frac{\lambda}{1+\lambda} \left[ \max\{w_h^j + w_f^j + w_c^j - 1, 0\} + \max\{-w_f^j, 0\} \right] \tag{12}
\]

The first term is the liquidity need from domestic lenders, while the second term is the liquidity need from foreign lenders. Meanwhile, the available share of liquid assets agent \( j \) holds is:

\[
L_H^j = \frac{\lambda}{1+\lambda} \left[ \max\{1 - w_h^j - w_f^j - w_c^j, 0\} + \max\{w_f^j, 0\} \right] + w_c^j \tag{13}
\]
The term in the bracket is the amount of deposit and foreign bond that can be used to repay without cost. All cash \( w_c^j \) can be used to meet the liquidity need.

If an agent holds more liquid assets than needed \( (L_H^j < L_D^j) \), she can fully protect herself from the funding shock. Otherwise, she has to fire sell \( L_D^j - L_H^j \) of illiquid assets and incur a loss.

The function of cash in the economy is to provide liquidity to insulate borrowers from the funding shock. If agent \( j \) holds one unit of cash, an additional liquidity of \( \frac{λ}{1 + λ} \) is provided. In fact, our model can incorporate a wide range of safe assets that differ in their liquidity properties. The yields of these safe assets are determined by how much liquidity they can provide. Consider another safe asset (for example, treasury bill) that \( \frac{λ}{1 + λ} \) fraction can be liquidated costlessly. The nominal yield to treasury bill \( x \) satisfies:

\[
\frac{i}{1 - \frac{λ}{1 + λ}} = \frac{i - x}{\frac{λ - \frac{λ}{1 + λ}}{1 + λ}}
\]

The left hand side is the price of liquidity for cash, while the right hand side is the price of liquidity for treasury bills. Suppose borrowers are indifferent in holding the two assets, the price of liquidity should be identical across the two assets. Therefore, we can solve for:

\[
x = (1 - \frac{λ}{1 + λ})i
\]

If \( \frac{λ}{1 + λ} > λ \), treasury bills are more liquid than deposits, thus the treasury yield is smaller than the nominal interest rate. All forgone proceeds are rebated to borrowers in a lump-sum fashion.

We abstract from modeling the different liquidity properties between the foreign bond and deposit, so that the excess return to the foreign bond only consists of a risk premium component. This assumption also simplifies analysis by ensuring all policy functions are smooth.

### 2.3 Agents’ Optimization Problem

In this section, we characterize the optimization problem for agent \( j \) \( (j = h, b) \). The nominal price of nontraded good (numeraire) is assumed to be locally deterministic. Agent \( j \) solves the following optimization problem:

\[
V_0^j = \max_{c^j, c^j_y, w_h^j, w_f^j, w_c^j} E \int_0^\infty f^j(C_t^j, V_t^j) \, dt
\]

s.t.: \[
\frac{dW^j}{W^j} = \left[ r - c^j_x - Qc^j_y + w_h^j(\mu_s - r) + w_f^j(\mu_f - r) + w_c^j(-\lambda) \right] \, dt + \left( w_h^j\sigma_s + w_f^j\sigma_f \right) \, d\mathbf{B} \\
+ \Pi^j \, dt - \frac{\phi}{1 - \phi} \max(L_D^j - L_H^j, 0) \, dN
\]

\[
c^j = \left[ \alpha(c^j_x) + (1 - \alpha)(c^j_y) \right] \frac{\sigma_f}{\sigma_s}
\]
Agent $j$ chooses optimal consumption of both nontraded good $c^j_x$ and traded good $c^j_y$, as well as portfolio shares $w^j_h, w^j_f$, and $w^j_i$, taking return processes as given. $c^j_x, c^j_y$ are consumption $C^j_x, C^j_y$ scaled by $W^j$. $N$ is a non-decreasing count process with arrival rate $\eta$ which represents the funding shock. $\Pi^j$ is the lump-sum wealth transfer to agent $j$, which will be specified later.

$L^j_D$ is the liquidity demand for withdrawal when the funding shock hits and $L^j_H$ is agent $j$'s available liquid assets, defined in equations (12) and (13). If agent $j$ is hit by the funding shock, she has to fire sell $L^j_D - L^j_H$ of illiquid assets and incurs a loss of $\frac{\phi}{1-\phi}$ per unit of fire sale.

The following proposition characterizes the HJB equation for agent $j$:

**Proposition 1** The value function of agent $j$ can be written as:

$$V^j(W^j; \Omega) = \frac{(W^j)^{1-\gamma_j}}{1-\gamma_j} \left[ G^j(\Omega) \right]^{\frac{1-\gamma_j}{1-\gamma_j}}$$  \hspace{1cm} (19)

$G^j(\Omega)$ satisfies the following Partial Differential Equations (PDE):

$$0 = \max_{c^j_x, c^j_y, w^j_h, w^j_f, w^j_i} \left\{ \frac{1}{1-\psi_j} \left( \frac{c^j}{G^j} \right)^{1-\psi_j} G^j - (\rho + \kappa) \right\} + \mu^j_w - \frac{1}{2} \gamma_j (\sigma^j)^\prime \sigma^j_w + \frac{1}{1-\psi_j} \nabla G^j \mu \Omega$$

$$+ \frac{1}{2 \psi_j - \gamma_j} tr(\Sigma^j_\Omega \Sigma^j \mathcal{H} G^j) + \frac{1}{1-\psi_j} \nabla G^j \Sigma^j_\Omega \nabla G^j - \frac{1}{2 \psi_j} \nabla G^j \Sigma^j_\Omega \sigma^j_w + \eta(V^j_+ - V^j)$$ \hspace{1cm} (20)

where $c^j$ is defined in equation (18), and:

$$\mu^j_w = r - c^j_x - Q c^j_y + w^j_h (\mu_s - r) + w^j_f (\mu_f - r) - w^j_i + \Pi^j$$ \hspace{1cm} (21)

$$\sigma^j_w = w^j_h \sigma_s + w^j_f \sigma_f$$ \hspace{1cm} (22)

$\Omega$ represents the vector of aggregate state variables. $\Pi^j$ is the lump-sum wealth transfer. $\nabla G^j$ is the gradient (row) vector of function $G^j$, $\mathcal{H} G^j$ is the Hessian matrix of $G^j$. $\mu \Omega$ is the column vector for state variable drift, $\Sigma^j_\Omega$ is the matrix for state variables' diffusions, with each column representing one state variable’s exposures to various Brownian shocks. $V^j_+ = V^j(W^j_+; \Omega)$, and $W^j_+$ is the wealth of agent $j$ following a funding shock.

Note that agent $j$ has $\kappa$ probability to exit the market. It is equivalent to changing agent $j$’s time discount rate from $\rho$ to $\rho + \kappa$. A complete, term-by-term exhibition of the HJB equation can be found in Appendix B, equation (83).

We assume that the nominal price of nontraded good is locally deterministic. This assumption serves as an equilibrium selection criterion and abstracts away the inflation risk.\footnote{Hollifield and Yaron (2003) show currency risk premium is mainly compensation for real risks instead of inflation risks.}

We proceed in two steps: First, we derive agents’ optimal cash holding. Second, we solve for optimal consumption and portfolio choice decisions.
2.3.1 Optimal Cash Holding

The incentive to hold cash as liquid assets depend on the tradeoff between its benefit of avoiding fire sale loss and nominal interest rate, the opportunity cost of holding cash. We impose the following restriction on parameters $\eta, \lambda, \phi, i$ in this economy.

**Assumption 1** Parameters of $\eta, \phi, \lambda$ satisfy\(^6\):

\[ \frac{\phi}{1 - \phi} \frac{1}{1 + \lambda} > i \]  
\[ (23) \]

The left hand side is the expected fire sale loss if the borrower marginally reduces one unit of cash holding and incurs fire sale loss. The right hand side, nominal interest rate, measures the opportunity cost of holding cash. Under Assumption 1, the benefit of holding cash overweighs the cost. Therefore, fire sale will never happen in equilibrium, as shown in Proposition 2:

**Proposition 2** Agent $j$ chooses to insulate herself from the funding shock:

\[ \max(L_j^j - L_H^j, 0) = 0 \]  
\[ (24) \]

A formal proof is provided in Appendix A.1. The intuition for full insurance is the benefit of avoiding fire sale overweighs the cost of holding cash.

The next proposition derives the optimal portfolio share on cash holding.

**Proposition 3** Agent $j$’s optimal cash holding depends on her local stock holding

\[ w_c^j = \max\{\lambda(w_h^j - 1), 0\} \]  
\[ (25) \]

The proof of the proposition is shown in Appendix A.2. The intuition here is that if agent $j$’s portfolio constitutes liquidity transformation, she is exposed to the funding shock and needs to hold cash for liquidity service. The only liquidity transformation occurs when the agent borrows (either from home or abroad) to buy the local stock. Therefore, only the portfolio share on local stocks matters for cash holding. If $w_h^j < 1$, there is no liquidity transformation so that no cash holding is needed. If $w_h^j > 1$, agent $j$ transforms $w_h^j - 1$ units of liquid liabilities to the illiquid local stock and voluntarily holds cash proportionally.

Meanwhile, borrowing from home and investing in the foreign does not require additional cash holding, since the deposit and the foreign bond have the same liquidity. We make this simplifying assumption so that the excess return of foreign investment purely comes from the risk premium component.

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\(^6\)This is a sufficient assumption (not necessary) to ensure agents to hold enough cash to protect themselves from being exposed to the funding shock.
2.3.2 Optimal Consumption and Portfolio Choice

The following two corollaries derive agents’ optimal consumption and portfolio choice decisions.

**Corollary 1** Agent $j$’s optimality conditions for (20) is given by:

$$\alpha \left( \frac{c^j}{G^j} \right) \left( \frac{1}{\psi_j} \frac{1}{\psi_j} \right) = 1$$

(26)

$$\left( 1 - \alpha \right) \left( \frac{c^j}{G^j} \right) \left( \frac{1}{\psi_j} \right) = Q$$

(27)

If $w^j_h \geq 1$:

$$\begin{bmatrix} w^j_h \\ w^j_f \end{bmatrix} = \frac{1}{\gamma_j} (\Sigma')^{-1} \begin{bmatrix} \mu_s - r - \lambda_i \\ \mu_f - r \end{bmatrix} + \frac{1 - \gamma_j}{1 - \psi_j} \frac{1}{\gamma_j} \Sigma' \Sigma (\nabla G^j)'$$

$$w^j_c = \lambda (w^j_h - 1)$$

(28)

If $w^j_h < 1$:

$$\begin{bmatrix} w^j_h \\ w^j_f \end{bmatrix} = \frac{1}{\gamma_j} (\Sigma')^{-1} \begin{bmatrix} \mu_s - r \\ \mu_f - r \end{bmatrix} + \frac{1 - \gamma_j}{1 - \psi_j} \frac{1}{\gamma_j} \Sigma' \Sigma (\nabla G^j)'$$

$$w^j_c = 0$$

(30)

where: $\Sigma = \begin{bmatrix} \sigma_s & \sigma_f \end{bmatrix}$, $\nabla G^j$ is the (row) vector of the gradient of $G^j$, and $\Sigma_\Omega$ is the matrix for state variables’ diffusions, with each column representing one state variable’s exposure to various Brownina shocks. $\Sigma'_\Omega \Sigma$ is the covariance matrix between asset returns and state variables.

This corollary is a standard result, except for the risk premium term is augmented with $-\lambda i$ if $w^j_h > 1$. We can see how nominal interest rate affects portfolio decisions from equation (28).

Throughout the model section, I define $w^j_h$ as leverage choice if it exceeds 1. We can see how nominal interest rate affects portfolio decisions from equation (28).

The households are more risk averse and insured by the bankers. As a result, $w^b_h > 1$, $w^b_h < 1$. Bankers borrow to buy the local stock. As we analyze in section 2.2, bankers conduct liquidity transformation in their portfolio and hold cash for liquidity purposes. Nominal interest rate represents the cost of leverage taking. When the nominal interest rate is lower, bankers will demand more of the local stock.

Corollary 2 shows the Euler equation for asset $i$ and agent $j$:

A more precise definition of leverage is $w^j_h + w^j_c + w^j_f I(w^j_f > 0)$, where $I$ is an indicator function. For the ease of illustration, we ignore the third term. We will choose the proper exogenous foreign asset return process so that both investors’ portfolio share on foreign asset is small relative to portfolio share on the local stock. This is consistent with the observation that a majority of wealth in a country is in its local assets, or the “home bias” literature (Lewis, 1999). The second term $w^j_c$ is proportional to $w^j_h - 1$ if it is positive.

In the numerical section, we solve the model with the conjecture that bankers taking leverage, and verify our conjecture after we obtain the solutions.
Corollary 2 The risk premium required by agent $j$ for any asset return process $dR_i$ is given by:

$$RP^j_i = -\frac{d}{dt} \text{cov} \left( \frac{1 - \gamma_j}{1 - \psi_j} d(\hat{P}c^j) - \gamma_j \frac{dW^j}{W^j} - (1 - \gamma_j) \frac{d\hat{P}}{P}, dR_i \right)$$

(32)

where $W^j$ is the wealth of agent $j$ denominated in nontraded goods. $\hat{P}$ is the price of the consumption basket, with:

$$\hat{P}^{1-\theta} = \alpha \theta + (1 - \alpha) \theta Q^{1-\theta}$$

(33)

$\hat{P}c^j \equiv \frac{\hat{P}c^j}{W^j}$, represents the consumption wealth ratio of agent $j$.

Proof is provided in Appendix A.3.

Corollary 2 is a standard result. The state price densities of agents with recursive preferences not only rely on instantaneous consumption growth, but also on the return to their wealth portfolios. Having multiple goods complicates the problem slightly by introducing $\hat{P}$, the price of consumption basket into the state price density.

Note that for the local stock, $\mu_s - r = RP^h_h$ for households. But for bankers, the excess return of domestic stocks have two components: liquidity premium $\lambda i$ and risk premium $RP^h_h = \mu_s - r - \lambda i$. The risk premium component satisfies equation (32) for bankers. The excess return to foreign bond satisfies equation (32) for both agents as it does not include a liquidity premium component. Particularly, for $j = h, b$:

$$RP^j_j = \mu + r^* - r + \sigma_q' \sigma^* = -\text{cov} \left( \frac{1 - \gamma_j}{1 - \psi_j} d(\hat{P}c^j) - \gamma_j \frac{dW^j}{W^j} - (1 - \gamma_j) \frac{d\hat{P}}{P}, \frac{dQ}{Q} \right)$$

(34)

2.4 Market Clearing

The nontraded goods market and the local stock market should clear:

$$C^h_x + C^b_x = X$$

(35)

$$P = W^h w^h_h + W^b w^b_h$$

(36)

Moreover, we define the total net foreign asset of the country $NFA$ as:

$$NFA = W^h w^h_f + W^b w^b_f$$

(37)

The total wealth of the economy equals value of the local stock plus value of the net foreign asset:

$$W = W^h + W^b = P + NFA$$

(38)

By Walras’ law, the market clearing condition for deposit is automatically satisfied.
2.5 State Variable Dynamics

There are two endogenous state variables, the wealth share of households ($\omega$), and scaled net foreign asset position of the economy ($\chi$). We define $\chi$ in traded goods, so that the two state variables are expressed as:

$$\omega = \frac{W^h}{W^h + W^b}, \chi = \frac{NFA}{Q}$$

(39)

The dynamics of $\omega$ can easily obtained by using Ito’s lemma:

$$d\omega = \omega(1-\omega) \left[ c^h_x - c^b_x + Q(c^h_y - c^b_y) + (w^h_h - w^b_h)(\mu_s - r) + w^h_i + (w^b_i - w^b_f) + \Pi^h - \Pi^b \right] dt$$

$$+ \kappa(t_\omega - \omega)dt + \omega(1-\omega) \left[ (w^h_h - w^b_h)\sigma_s + (w^b_f - w^b_f)\sigma_f \right] dB$$

(40)

All the forgone interest are rebated back to the bankers, so that the liquidity friction distorts the portfolio choice of bankers without resource loss.

We can write out the dynamics of $\frac{NFA}{Q}$ from the balance sheet equation:

$$d\left( \frac{NFA}{Q} \right) = (Y - C^h_y - C^b_y)dt + \frac{NFA}{Q}r^*dt + \frac{NFA}{Q}(\sigma^*)'dB - \Pi^{NFA}dt$$

(41)

Equation (41) describes the three components of net foreign asset change: current account adjustment, valuation change, and the lump-sum transfer $\Pi^{NFA} = \eta\frac{NFA}{Q}$. The lump-sum transfer is from (to) the outside world to keep the scaled net foreign asset stationary, following Schmitt-Grohé and Uribe (2003). Then we can derive dynamics of $\chi$ easily using Ito’s lemma:

$$d\chi = \left( \tau - \frac{C^h_y + C^b_y}{X} + \chi r^* \right) dt + \chi(\sigma^*)'dB - \eta\chi dt$$

(42)

When we introduce stochastic interest rates, there is another state variable, the nominal interest rate, which follows equation (10).

3 Numerical Solution and Model Analysis

In this section, we solve the model numerically. After discussing the parameters in section 3.1, we study a cross-section of six economies with different fixed nominal interest rates from 0 to 5 percent in section 3.2 and section 3.3. In section 3.4, we introduce stochastic interest rates and examine the time series relation between nominal interest rate and currency risk premium. Lastly, in section 3.5 we discuss two additional results of our model that are consistent with the recent empirical literature on exchange rates and currency returns, including the deviation of covered interest rate parity (Du et al., 2018b) and the positive relationship between the liquidity premium of dollar assets and the risk premium of investing in dollar (Jiang et al., 2018).
We solve the model using Chebyshev polynomial approximation with collocation method. Tensor products are used to deal with multiple state variables. A detailed description of the solution procedure is provided in Appendix B.

3.1 Parameter Values

Table 1 presents the parameters for numerical solutions. All parameters are at the annual frequency.

The parameters are grouped into five sets. Panel A contains parameters of preferences. One key ingredient of this model is preference heterogeneity between households and bankers. Households have higher risk aversion and lower IES than bankers. Heterogeneity in risk aversion determines risk allocation and leverage, while heterogeneity in IES drives changes in intertemporal choice and exchange rate dynamics when wealth is redistributed between the two agents. We require a substantial heterogeneity in both parameters, so that we choose $\gamma_h = 30$ and $\gamma_b = 5$ to target at a risk premium of 3 percent when $i = 0$. The risk aversion coefficients are high compared with most of the literature, since we do not embed additional features that enable us to have a sizable risk premium. Most asset pricing studies calibrate and estimate IES being greater than 1 (For example, Schorfheide, Song, and Yaron (2018) estimate IES=2). In our model, since we require a substantial heterogeneity in IES across agents, we choose $\psi_h = 1$ and $\psi_b = 3$.

The effective time discount rates of both agents are $\rho + \kappa = 0.025$. The relative preference over nontraded goods $\alpha > \frac{1}{2}$ captures a bias of preference towards local nontraded goods. $\alpha = 0.975$ captures a substantial consumption home bias. The elasticity of substitution across goods $\theta$ takes a small number of 0.5. It is consistent with a number of studies in the international macroeconomics literature, such as Stockman and Tesar (1995) and Corsetti, Dedola, and Leduc (2008).

Panel B lists the parameters for endowment processes. The dividend of nontraded good follows a geometric Brownian motion with an average growth rate of 2.5 percent and a volatility of 2.5 percent. The ratio of traded good over nontraded good is a constant, being $(\frac{1-\alpha}{\alpha})^\theta = 0.160$, so that $Q = 1$ under autarky.

Panel C shows the parameters on the foreign bond return process. The instantaneous return $r^*$ is equal to 2.36 percent, equal to the real risk free rate implied by a closed economy with households only.

Panel D reports the crucial parameter that links nominal interest rate to the cost of leverage, $\lambda$. $\lambda$ determines how much cash is needed for each unit of borrowing. We set $\lambda$ as a common parameter across all countries and calibrate it to the average ratio of liquid assets over total assets in major G10 countries’ banking system. With the parameter choice $\lambda = 0.2$, countries with different nominal interest rates have substantial differences in their costs of leverage, while bankers still have incentives to lever up.

When we introduce stochastic interest rates, we set its persistence $1 - \zeta = 0.9$. Nominal interest rates are very persistent in the data, while we choose a relatively mild number. The unconditional means of nominal interest rates change from 0.01 to 0.04, with an incremental step of 0.01.
Lastly in Panel E, we report the parameters that keep the economy stationary. We set $\bar{\omega} = 0.95$ so that the redistribution of wealth favors households. $\eta = 0.2$ ensures a stationary distribution of $\chi$ in the simulation.

### 3.2 Bank Leverage, Stock Return, and Real Exchange Rate

In this section, we illustrate the liquidity-leverage mechanism by analyzing the solutions of bank leverage, local stock returns, exchange rates, and currency risk premia as functions of the endogenous state variables. We also show impulse responses of various variables to a positive endowment shock in different economies. We study a cross-section of economies that differ only in nominal interest rates, ranging from $i = 0$ to $i = 0.05$ with an incremental step of $0.01$. For the sake of space, we only report results for the two economies with $i = 0$ and $i = 0.05$.

When solving and simulating the model, we introduce a country-specific lump-sum redistribution of wealth between households and bankers that make the ergodic mean of $\omega$ being relatively similar across countries. Details about simulation are provided in Appendix C. In Appendix D.2, we show the same set of results without the redistribution. The results are qualitatively similar, but with a smaller spread of currency risk premium between $i = 0$ and $i = 0.05$.

#### 3.2.1 Bank Leverage and Stock Return

Nominal interest rates affect bank leverage since they represent the cost of taking leverage. Equation (28) indicates that higher nominal rates reduce risk taking and lead to lower leverage for bankers, as the Panel A of Figure 2 shows. Compare the two economies, for every given $\omega$ and $\chi$, bank leverage is higher when $i = 0$.

The higher leverage in the $i = 0$ economy makes bankers’ wealth more exposed to the endowment shock due to the following amplification mechanism: A positive endowment shock increases bankers’ wealth share, which pushes up the local stock price and further increases bankers’ wealth share. The magnitude of amplification increases with bankers’ leverage choice. Therefore, as shown in Panel B of Figure 2, the low-interest-rate economy’s ($i = 0$) local stock price exposure to the endowment shock $\sigma_{sx}$ is larger.

We note that $\sigma_{sx}$ displays a hump shape with respect to households’ wealth share $\omega$, since the amplification is strong when bankers have enough wealth to affect the local stock price while take a high enough leverage. Panel C of Figure 2 shows that the local stock risk premium is an asymmetric hump shape along $\omega$: when the endogenous volatility $\sigma_{sx}$ spikes, risk premium also spikes. When endogenous volatility $\sigma_{sx}$ is close to the endowment volatility $\sigma_x$, risk premium is higher when wealth is accumulated in more risk-averse households, or $\omega$ being close to 1.

The impulse response functions in the two upper panels of Figure 4 show the different responses of local stock returns and household wealth shares to the same positive endowment shock in the two economies. The blue solid line shows the response of local stock return and households’ wealth...
share in the $i = 0$ economy, while the red dashed line shows the responses in the $i = 0.05$ economy. Local stock return rises by 8 percent in the $i = 0$ economy on impact while the increase of 3 percent in the $i = 0.05$ economy is much milder. Consequently, household wealth share $\omega$ drops by 3 percent in the $i = 0$ economy, larger than the 0.5 percent drop in the $i = 0.05$ economy.

### 3.2.2 Exchange Rate and Currency Risk Premium

This section discusses the exchange rate responses to the endowment shock, and the associated currency risk premium in the two economies with $i = 0$ and $i = 0.05$. As we show in section 3.2.1, bankers' wealth share increases in response to a positive endowment shock. Since bankers' have higher IES than households, the low-interest-rate economy is more desired to save with a higher bankers’ wealth share in good times. Therefore, the demand for foreign asset increases sharply and the foreign currency strongly appreciates. On the contrary, the magnitude of foreign appreciation for the high-interest-rate economy is much milder.

Panel A of Figure 3 shows the exchange rate response to a positive endowment shock, $\sigma_{qX}$. Foreign exchange rate appreciates with a positive endowment shock, and the magnitude of appreciation is a hump-shape along households’wealth share $\omega$. The exchange rate response mirrors the response of local stock returns. Compare the $i = 0$ and $i = 0.05$ economies, foreign appreciation is larger in the low-interest-rate economy, since wealth redistribution between households and bankers is stronger. The lower panel in Figure 4 shows the impulse response of foreign appreciation in response to a positive endowment shock. The appreciation is larger with $i = 0$ (the blue solid line) than with $i = 0.05$ (the red dashed line).

From the Euler equation (34), currency risk premium depends on the covariance of exchange rate movement with the state price densities for both investors, which are largely driven by $\sigma_{sx}$. Because the low-interest-rate countries have higher stock returns and sharply depreciated exchange rates in good times, investors require a higher return to borrow low-interest-rate currencies to invest abroad. In other words, low-interest-rate currencies are good hedges to endowment shocks. Panel B in Figure 3 shows the currency risk premium of investing in the common foreign bond in the two economies. Currency risk premium also displays a hump shape along $\omega$, while it is larger in the low-interest-rate country with $i = 0$. In Panel C of Figure 3, we report the ergodic distribution of the two endogenous state variables.

### 3.3 Simulation

We simulate a cross-section of six small open economies with fixed but different levels of nominal interest rates, ranging from 0 to 0.05 with an incremental step of 0.01. We report the ergodic mean of different variables for each economy in Panels A to C of Table 2 and confirm the implications discussed above.

Nominal interest rates affect bankers’ leverage choices as they essentially represent the cost of
taking leverage. Average bankers’ leverage $w_{bh}$ decreases with nominal interest rates, from 1.946 to 1.373. We are not able to replicate the high bank leverage in the data quantitatively. From the market clearing condition for the local stock:

$$w_{bh} = \frac{1 - \frac{NFA}{W} - \omega w_{bh}}{1 - \omega} < \frac{1 - \frac{NFA}{W}}{1 - \omega} \quad (43)$$

As $\frac{NFA}{W}$ is very close to 0, the largest possible bank leverage can be no higher than $\frac{1}{1-\omega}$. Suppose $\omega$ ranges from 0.4 to 0.7, the maximum possible bank leverage can be no more than 3.3. Despite the quantitative discrepancy, the model still captures the qualitative heterogeneity in bank leverage across economies with different levels of nominal interest rates.

Due to the high bankers’ leverage $w_{bh}$ and strong amplification, low-interest-rate economies have large local stock return exposure $\sigma_{sx}$ endogenously and thus high risk premia $\mu_s - r$. In the simulation, the risk premium for the local stock is as large as 3.140 percent when $i = 0$, and declines to 1.791 percent when $i = 0.05$. Due to higher leverage and higher risk premium for the local stock, the $i = 0$ economy has a smaller ergodic mean of $\omega$ than the $i = 0.05$ economy.

The real interest rates $r$ are mainly determined by the wealth distribution across households and bankers in these economies. If households’ wealth share is high, the real interest rate is high because households have lower IES. Countries with lower nominal interest rates have lower households’ wealth share on average, so they tend to have low real interest rates as well. The average real interest rate ranges from 0.756 percent when $i = 0$ to 2.392 percent when $i = 0.05$. This is consistent with the data that low-nominal-rate economies also tend to have low real rates.

As for the exchange rates and currency risk premia, the exchange rate exposure to endowment shock $\sigma_{qx}$ is 5.425 percent for the $i = 0$ economy and 1.215 percent when $i = 0.05$. A positive exposure means a foreign depreciation and domestic appreciation in bad times. A large appreciation of the low-interest-rate currency in bad times makes it a good hedge, thus investors require higher risk premium to borrow it to invest abroad. The currency risk premium is 2.061 percent in the $i = 0$ economy and 0.457 percent in the $i = 0.05$ economy. The spread is 1.604 percent on average, which is close to its empirical counterpart of 2.161 percent shown in Table 5.

### 3.3.1 Factor Structures of Asset Returns

After examining the unconditional moments of the key variables, we explore the rich factor structure of asset returns implied by our model. In the simulation, all countries are experiencing common endowment shocks. Asset return factor structures in our simulated data are reported in Panel D of Table 2.

We first look at the factor structure of currency returns. Lustig et al. (2011) find that the differences in expected returns of currency portfolios can be explained by their heterogenous exposures to a “carry risk factor”. The “carry risk factor” is defined as the spread between returns in the highest interest rate currencies and the lowest interest rate currencies. Low interest rate currencies
(long position) are less (more negatively) exposed to the “carry risk factor”.

We compute the analog of the “carry risk factor” in our model as $dR_f|_{i=0} - dR_f|_{i=0.05}$. It essentially measure the magnitude of the endowment shock: Low-interest-rate currencies depreciate in good times while high-interestrate currencies appreciate. Therefore, the “carry risk factor” is larger when the positive endowment shock is larger. The return exposure, $\beta_{FX}$, is computed as the regression coefficient of $dR_f$ on the risk factor for each economy. $dR_f$ is the return to borrowing domestic currency and investing in the common foreign asset. A larger $\beta_{FX}$ for currency $i$ means the currency depreciates more in response to a positive endowment shock. The first row in Panel D shows that $\beta_{FX}$ is monotonically decreasing in the nominal interest rate of the short position, consistent with the empirical finding of Lustig et al. (2011).

Second, we examine the factor structure of stock returns. In a recent paper, Colacito et al. (2018) identify a factor structure of stock valuations across countries. They find that low interest rate countries’ stocks have higher exposures to the cross-sectional average. We calculate the exposure of stock return $dR_s$ to the cross-sectional average $\overline{dR_s}$ and find $\beta_s$’s are monotonically decreasing in nominal interest rates. The intuition is straightforward: when the same shock hits low interest rate countries, their local stock returns increase more due to higher bank leverage. Therefore, our model can also replicate Colacito et al. (2018)’s empirical finding.

Finally, we compute the exposure of currency returns $dR_f$ to average stock return $\overline{dR_s}$ and bank wealth portfolio return $\overline{w_b dR_s}$ across countries, $\beta_{FX,s}$ and $\beta_{FX,b}$ respectively. Both the average stock return $\overline{dR_s}$ and the average bank wealth portfolio return $\overline{w_b dR_s}$ are measures of the magnitude of the common endowment shock. Therefore, both $\beta_{FX,s}$ and $\beta_{FX,b}$ decrease with interest rate. In section 4.3, we empirically test this implication by measuring bankers’ wealth portfolio return with the banking sector stock return of each country.

### 3.3.2 Time-varying Carry Trade Beta

In this section, we discuss a distinct feature of the model on the time variation of currency carry trade exposures (betas) to the average stock returns $\beta_{FX,s}$. The dynamics of carry trade beta is first noted by Lustig et al. (2008) that they are particularly high in crisis. As we do not have well-defined notion of “crisis” in our model, we explore the dynamic property of the carry trade portfolio’s $\beta_{FX,s}$ (the portfolio return is computed as $dR_f|_{i=0} - dR_f|_{i=0.05}$), particularly, its correlation with the volatility of the average stock return.

In our model, $\beta_{FX,s}$ is positively related to the average stock return volatility. The intuition is simple: exchange rate movement tracks stock return only when the amplification mechanism is strong. This is also when the endogenous stock return volatility is high. In the simulated data, we calculate the correlation between $\beta_{FX,s}$ and the average stock return volatility as 0.705. We empirically test this implication in section 4.4.

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9We ignore the return on the foreign asset since it is very small.
3.4 Interest Rates and Currency Risk Premia in the Time Series

In previous sections, we compare bank leverage and currency risk premia across countries with heterogenous but fixed nominal interest rates. In this section, we examine our model implications on the time series relationship between interest rates and currency risk premia. To study the time series relationship, we introduce stochastic nominal interest rate following equation (10) into a cross-section of four economies with $i_0 = 0.01, 0.02, 0.03,$ and $0.04$ respectively.

We first study the time-series correlation of nominal interest rate and currency risk premium. There has been a large literature documenting and explaining the positive regression coefficient of currency returns on interest rate differentials $\beta_{FP}$, or the so-called “forward premium puzzle”. In Panel A to C of Figure 5, we plot the solutions of bank leverage $w_h$, exchange rate exposure $\sigma_{qx}$, and currency risk premium $\mu_f - r$ as functions of households’ wealth share $\omega$ and nominal interest rate $i$ for the $i_0 = 0.01$ economy\(^{10}\). Since there are three state variables with stochastic interest rates, we fix $\chi = 0$ when plotting the solutions. From the three panels, we see that the risk premium of investing abroad declines with $i$ because when $i$ increases, its exchange rate becomes less of a hedge due to the decreased leverage choices of bankers.

We run the following regressions with simulated data in each economy:

$$rx_{r,t+1} = \alpha - \gamma_r i_t + \epsilon_{t+1}$$

(44)

$$rx_{i,t+1} = \alpha - \gamma_i i_t + \epsilon_{t+1}$$

(45)

We assume the foreign interest rate is an exogeneous constant, so that $i_t^*$ is abstracted from the right hand side of both regressions. The left hand side of equation (44) is the return of investing abroad in excess of the real interest rate, while the left hand side of equation (45) is the return of investing abroad in excess of the nominal interest rate.

Panel E of Table 3 show $\gamma_r$ and $\gamma_i$ for the four economies. $\gamma_r(\gamma_i)$ represents the correlation of nominal interest rate with currency risk premium in real (nominal) terms. Both coefficients in the four economies are positive, consistent with the empirical findings of the large literature on the “forward premium puzzle”. Quantitatively, $\gamma_r$ is small while $\gamma_i$ is about the same magnitude as in the data. In our model, there is no stickiness in price setting and real interest rate is determined by the intertemporal choice of households and bankers. A nominal rate rise is mostly reflected in an increase in inflation while the real interest rate responds only by a small magnitude induced by the decline of bankers’ wealth share.

Panel A to D of the table are analogous to Table 2 and all results hold in the cross-section of economies with stochastic nominal interest rates: Low-interest-rate countries have high bank leverage and their currencies appreciate the most in bad times. Therefore, investors require a positive premium to borrow these currencies and invest abroad.

Next, we study the impulse response of the currency risk premium of investing abroad to an

\(^{10}\)For other values of $i_0$, the solutions are very similar.
unexpected rise in nominal interest rate in each economy. Mueller et al. (2017) find that after
the Fed unexpectedly raises the Federal Funds Rate, the subsequent return of foreign currency
investment declines. Panel D of Figure 5 display the impulse responses of currency risk premia (in
real terms) for the four economies of $i_0 = 0.01, 0.02, 0.03,$ and $0.04$ to the same shock to nominal
interest rate. The size of the shock is equal to $\sigma_t = 17.4$ basis points. In all four economies, currency
risk premia decrease after an unexpected increase in nominal interest rate. Currency risk premia
for the four economies decline by about 3-4 basis points on impact and gradually reverts back.

The literature on the currency risk premium change in response to monetary shocks such as
Mueller et al. (2017) mainly uses high-frequency data and looks at daily or even intraday change.
It is hard to map our model implication to the data quantitatively. Therefore, we only make
qualitative claims in terms of the currency risk premium response to unexpected nominal interest
rate shocks.

3.5 Additional Results

3.5.1 Liquidity Premium and CIP Deviation

In this subsection, we show that our model can naturally generate deviations from covered interest
rate parity (CIP). Covered interest rate parity is a no-arbitrage condition stating that if an investor
borrows dollar and invest in a foreign currency while hedging away the exchange rate risk using
forward contract, the return should be 0.

We define $i_t^*, i_t^s$ the interest rate in foreign currency and dollar, $q_t$ the spot exchange rate of
foreign currency in dollars, and $f_t$ the forward rate. The return to the arbitrage $-x_t$ ($x_t$ is called
“basis”) can be expressed as:

$$-x_t = -i_t^s + q_t + i_t^* - f_t$$  \hspace{1cm} (46)

Under CIP, $x_t = 0$. Du et al. (2018b) document that after the recent financial crisis in 2008, the
basis $x_t$ has persistently been negative. Our model sheds light on the liquidity friction that could
potentially lead to what we observe in the data\footnote{In Du et al. (2018b), they explain CIP deviations with changes in regulations after the financial crisis, such as the leverage ratio requirement and other regulations including liquidity}.

Suppose only the bankers have access to CIP arbitrage. Each unit of safe dollar liabilities is
subject to a withdrawal need of $\frac{\lambda}{1+\lambda}$, while $\frac{\tilde{\lambda}}{1+\lambda}$ fraction of the foreign asset can be liquidated
costlessly. The foreign asset payoff is $i_t^s - x_t$, so that according to equation (15), we have:

$$x_t = (\tilde{\lambda} - \lambda)i_t^s$$  \hspace{1cm} (47)

Equation (47) shows that if $\tilde{\lambda} < \lambda$, $x_t < 0$. Intuitively, if dollar assets are more liquid than the
foreign asset, investors require a positive premium to conduct the CIP arbitrage above.

Next we explore into the quantitative implication of CIP deviation on the relative liquidity of
dollar and foreign safe assets. Du et al. (2018b) document an average currency basis $x_t$ of -25 basis points, while one third of the basis can be possibly attributed to be caused by liquidity concerns\footnote{See Table VI of Du et al. (2018b). Another major reason that leads to CIP deviation is the change in non-risk-weighted leverage ratio requirement.}. Plug in $x = -8bp$, $\lambda = 0.2$, and $i^s = 50bp$, which is equal to the time series average of US LIBOR rate between 2010 to 2016, we obtain $\hat{\lambda} = 0.04$. It implies a substantial difference in liquidity between dollar and foreign assets even though they only lead to 8 basis points of the return spread. The main reason is the low interest rates in the US during the period, so that the cost of holding liquid assets is very low.

### 3.5.2 Liquidity Premium and Currency Risk Premium

In this subsection, we discuss a distinct feature of this model, the interaction between the liquidity premium and currency risk premium. In a recent paper, Jiang et al. (2018) uncover a positive correlation between the liquidity premium of dollar liquid assets and its currency premium component in the VAR decomposition of exchange rate.

A slightly extended version of our model can account for this empirical observation. Take the stand of a foreign investor, who holds both domestic and dollar liquid assets that are imperfect substitutes with the aggregator:

$$
L = \left( L^d \epsilon^{-1} + L^s \epsilon^s \right)^{\epsilon^{-1}}
$$

$L$ is the total liquid asset holding. $L_d$ is holding of domestic liquid asset, and $L_s$ is the holding of dollar liquid asset.

The banker chooses the optimal amount of local and dollar liquid asset by minimizing the cost of liquidity:

$$
\min_{L_d, L_s} L_d lp + L_s lp_s
$$

s.t. : $L = \left( L_d \epsilon^{-1} + L_s \epsilon^s \right)^{\epsilon^{-1}}$

$l_p, l_p$ are liquidity premium of local and dollar liquid asset, respectively. With cash, the liquidity premium $l_p$ is equal to the nominal interest rate $i$. We assume $L_s$ is supplied with perfect elasticity, and the domestic monetary authority and government control the supply of $L_d$, and dollar liquidity premium $l_p$ is exogenously given. The optimal holdings of dollar liquidity is given by:

$$
L_s = L_d \left( \frac{l_p}{l_p} \right)^{\epsilon}
$$

A rise in $l_p$ implies less of dollar asset holding $L_s$. The total cost of liquidity is given by:

$$
L_d lp + L_s lp_s = L_d lp + L_d lp_s l_p^{-\epsilon}
$$
With $\epsilon > 1$ when the two liquid assets are substantially substitutable, a rise in dollar asset liquidity premium is associated with a drop in the total cost of liquidity. For the bankers, it is equivalent to a drop in the nominal interest rate, so that the risk premium to invest in dollar rises.

### 3.6 Model Implications

We conclude this section by summarizing the three major model implications, around which our subsequent empirical analysis is centered.

The first implication is straightforward: countries with lower nominal interest rates tend to have higher bank leverage and lower currency returns.

The second implication states the cyclicality of exchange rates: Low-interest-rate currencies depreciate in good times relative to high-interest-rate ones. To highlight the role of intermediaries, we measure “good times” with average bank stock returns in all countries.

Third, our model implies a time-varying carry trade return comovement average stock returns that increases in the stock market volatility.

### 4 Empirical Analysis

#### 4.1 Data

We mainly use three sets of data in our empirical analysis: spot and forward exchange rates, country level banking sector balance sheet, and country level stock return index of the banking sector. The data cover 22 advanced countries: Australia, Austria, Belgium, Canada, Denmark, Finland, Euro, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, South Korea, Spain, Switzerland, Sweden, and UK.

The spot and 1-month forward exchange rate data from standard sources of Datastream at monthly frequency from November 1983 to December 2016, following Lustig et al. (2011). We take the mid price of forward and spot quotes on the last day of each month.

We calculate each country’s banking sector capital ratio (the inverse of leverage, in percentage) using the aggregate banking data from SNL Financial, originally provided by Economist Intelligence Unit (EIU). Capital ratio is calculated as the ratio of total equity capital over assets. The bank balance sheet data are at annual frequency from 1990 to 2015. Total assets and equity capital are simple sum of those collected from reporting banks. After 1999, all countries using euros are replaced with a single time series of euro spot and forward rate and bank capital ratio for the euro area is the average across these countries.

Country level banking sector stock total return indices are from Datastream from January 1983 to December 2016 at monthly frequency. The dataset includes an index for Euro area bank stock returns, which are used after 1999 for the euro area.
We also use each country’s GDP and inflation as control variables. Both variables are obtained from the World Bank website at annual frequency.

4.2 Interest Rate, Bank Leverage, and Currency Return

4.2.1 Panel Regression

We first show with panel regressions that countries with lower interest rates have lower bank capital ratio (higher leverage) and lower currency returns. Since we do not attempt to make causal statement from our regression results, it does not matter whether we use interest rate as a regressor or a regressant. We regress interest rates\textsuperscript{13} and currency returns on the bank capital ratios.

The panel regression is conducted in the two-step Fama-MacBeth procedure: First we run a cross-sectional regression of forward discount and currency return on bank capital ratio and get a regression coefficient for each month. The Fama-MacBeth estimator is the simple average of regression coefficients across time and standard errors are calculated after adjusting for possible serial correlations.

The regression results are shown in Table 4. The left panel reports regression coefficients of average forward discount on bank capital ratio, while the right panel reports regression coefficients of currency returns. In column (1) of the left panel, the coefficient of forward discount on bank capital ratio is 0.463, being significantly positive. In the cross section, a one percent increase of bank capital ratio is associated with a 46.3 basis point increase in average forward discount per annum. The same is true for currency returns: a one percent increase of bank capital ratio is associated with a 27.9 basis point increase in average currency returns. In the data, average bank capital ratio varies from about 3 percent to 10 percent, which translates into a 3.24 percent difference in average forward discount and 1.95 percent difference in currency returns.

In column (2) of both panels, we control for the inflation (percentage change of consumer price index) in each country. The coefficient for forward discount is smaller in magnitude but still significant. It is not surprising that inflation accounts for a big fraction of cross-sectional difference in nominal interest rate across countries ($R^2$ increases from 0.134 to 0.394). However, the coefficient of currency returns stays stable at 0.204 while being statistically significant, and the $R^2$ increase is mild from 0.124 to 0.265.

In column (3) we control for each country’s log GDP (country size), which is considered by Hassan (2013) as an important determinant of interest rate and currency return. In column (4) we control for both inflation and country size. Our results are robust to these controls.

The regressions in Table 4 include 22 advanced economies. A natural question is whether the relationship also holds for the emerging economies. We show the regression results for both advanced and emerging economies in Appendix E.2. After including the emerging economies, the relationship

\textsuperscript{13}Under the covered interest rate parity, forward discount is equal to the difference between country specific interest rate and US interest rate. Even though CIP is deviated after the crisis, the deviation is small in magnitude relative to interest rate differentials. In this section, “forward discount” and “interest rate differential” are used interchangably.
between interest rate and bank capital ratio is positive, similar to the advanced economies. The regression coefficient of currency return on bank capital ratio is also positive without controlling for inflation. However, after controlling for inflation, the regression coefficient becomes insignificant and sometimes even negative. The result suggests that inflation plays a more important role in emerging economies than in advanced economies. In the rest of the empirical analysis, we restrict our attention to the set of 22 advanced economies.

4.2.2 Portfolio Sorting

In this section, we show the relevance of bank leverage in currency pricing by sorting currencies based on each country’s bank leverage. We sort all available currencies into three portfolios with annual rebalance, as our banking sector balance sheet variables are only available at the annual frequency.

Panel A in Table 5 shows the characteristics of leverage sorted currency portfolio returns. Portfolio 1 contains currencies with highest banking sector leverage (such as Japan) and Portfolio 3 contains those with lowest banking sector leverage (such as Australia). The mean average forward discount increases from 0.05 percent to 1.669 percent per annum. The bank capital ratio rises from 4.476 percent in portfolio 1 to 7.612 percent in portfolio 3. Average currency return monotonically increases from -0.687 percent in portfolio 1 to 1.465 percent in portfolio 3. The spread between the lowest leverage countries and the highest leverage countries is 2.152 percent on average, with a Sharpe ratio of 0.389.

In Panel B, we sort currencies based on their unconditional average forward discount, measured by the full sample average of each country. Portfolio rebalancing is also at the annual frequency. The lowest interest rate currencies has -0.734 percent average forward discount while the highest ones have an average of 2.540 percent. The forward discount differential between Portfolio 3 and Portfolio 1 is 3.274 percent, about 2 times as large as what we get in Panel A. Bank capital ratio increases from low interest countries to high interest rate countries with the spread of 1.224 percent, about one third of what we obtain when sorting on bank leverage. The return spread between Portfolio 3 and 1 is 2.161 percent per annum with a Sharpe ratio of 0.343. The average return spread and Sharpe ratio is similar to those in Panel A.

In Panel C, we sort the currency portfolios based on the previous year’s average forward discount. The pattern of forward discount, bank capital ratio, and excess returns are similar to Panel B while the return spread is larger but capital ratio spread is smaller. The return spread is smaller than in Lustig et al. (2011), as we rebalance the portfolio at annual frequency. Return characteristics of leverage sorted portfolios in Panel A are closer to unconditional forward discount sorted portfolios in Panel B. It indicates that cross-sectional variation in bank leverage largely captures the unconditional interest rate heterogeneity, while not completely reflects the time-series variations.

Two other reasons make sorting on bank leverage a less profitable investment strategy than sorting on forward discount. First, as our model suggests, bank leverage increases with bankers’ wealth
share while the relation between currency risk premium and bankers’ wealth share is nonmonotonic. Second, the bank balance sheet variables are hard to measure accurately, which also adds noise to our portfolio sorting. Despite these disadvantages, we still find similarities in currency portfolios sorted on bank leverage and forward discount, validating our hypothesis that bank leverage is an important driver of currency returns.

4.2.3 Asset Pricing Test

In this subsection, we show the pricing power of the risk factor constructed from portfolios sorted on bank leverage. The risk factor (Lev-factor) is the spread between Portfolio 3 and Portfolio 1 in Table 5. We first examine the correlation of Lev-factor with conventional “carry risk factor” in the literature, defined as the spread between Portfolio 3 and Portfolio 1 in Panel B and C of Table 5. We call these two factors “unconditional carry-factor” and “conditional carry-factor” respectively. In Table 6, we regress the unconditional and conditional carry-factor on the Lev-factor. In the first column, the sensitivity of unconditional carry-factor to Lev-factor is 0.655 with the unexplained residual of 0.752 percent and an $R^2$ of 0.332. The two are highly correlated and the unexplained residual is statistically insignificant. The second column reports regression coefficients for the conditional carry-factor, $\beta$ is still significantly positive but smaller in magnitude (0.444). The unexplained residual is 2.460 percent and statistically significant. The $R^2$ is 0.119, much smaller than the that with the unconditional carry-factor. The comparison further verifies that the Lev-factor better captures the variations of the unconditional forward discount sorted portfolios than the conditional forward discount sorted ones.

Next we conduct an asset pricing test by using the six portfolios sorted on bank leverage and forward discount (unconditionally) as test assets. Panel A of Table 7 reports the first step Fama-MacBeth estimation results for the six portfolios. For the leverage sorted portfolios, the exposure to the Lev-factor monotonically increases from -0.444 for portfolio 1 to 0.556 for portfolio 3. For the forward discount sorted portfolios, the exposure to the Lev-factor also monotonically increases, from -0.228 for the portfolio with lowest interest rates, to 0.427 for the portfolio with highest interest rates. Heterogenous exposures to the Lev-factor accounts for the cross-sectional variations in expected returns of these portfolios.

In Panel B of Table 7, we report the estimates of the risk price using both Fama-MacBeth method and GMM method. When using GMM, the pricing kernel is written as a linear factor model following Lustig et al. (2011):

$$m = 1 - bf$$ (53)

where $f$ is the factor, and $b$ is the price of risk. We use Hansen and Jagannathan (1997)’s scale-invariant weight matrix in GMM estimation. We get similar positive estimates of price of risk using two methods. They are close to the unconditional mean of the Lev-factor. The risk price is statistically significant with both methods.
4.3 Currency Returns and Bank Stock Returns

In this section, we test the second implication of the model that low-interest-rate currencies are less (more negatively) exposed to average bank stock returns. The cross-sectional average is to measure the common “good times” for all countries instead of idiosyncratic ones. We use bank stock return to highlight the role of intermediaries in driving exchange rate dynamics. In Appendix E.3, we show similar results with average country MSCI stock return indices.

4.3.1 Procyclical Carry Trade

First, we calculate the sensitivities of exchange rates to the average bank stock return ($\beta_{bank}$) for the G10 currencies and plot them against their average forward discounts in the upper panel of Figure 6. The two variables are highly correlated. Countries such as Japan and Switzerland have low forward discounts and their exchange rates are countercyclical. On the other hand, countries like Australia and New Zealand have high forward discounts and procyclical exchange rates.

In the lower panel of Figure 6, we replace average forward discount with average bank capital ratio. The result is very similar that $\beta_{bank}$ increases with average bank capital ratio across countries.

To see the procyclicality of carry trade returns more clearly, we regress returns to three “carry trade” strategies on average bank stock returns. The first strategy borrows Japanese yen and invests in Australian dollar, “AUD-JPY”. The second strategy borrows Swiss Franc and invests in New Zealand dollar, “NZD-CHF”. These are the typical currency pairs involved in currency carry trades. The third strategy borrows currencies with unconditionally low forward discounts and invests in those with high forward discounts, “unconditional carry”. All the three slope coefficients are significantly positive: A one percent increase in average bank stock return is associated with a 30 basis point increase in “AUD-JPY” strategy, 25.1 basis point increase in “NZD-CHF” strategy, and 15.5 basis point increase in the unconditional carry strategy.

4.3.2 Asset Pricing Test

In this section, we test whether heterogenous exposures to average bank stock returns account for the cross-sectional variation in expected returns of currency portfolios. Again, we focus on the portfolios sorted on unconditional forward discounts.

In the top row of Table 9, we report the average returns to the three currency portfolios, from 0.780 percent for the currencies with the lowest interest rates to 2.877 percent for the currencies with the highest interest rate. Panel A shows the first-step Fama-MacBeth regression results. Exposures to the average bank stock return monotonically increase from -0.005 to 0.15. In panel B, we estimate the price of risk using Fama-MacBeth method and GMM method and get similar estimates. Our asset pricing test indicates that bank stock return is one candidate risk factor that can explain the cross-sectional variation in currency expected returns. However, the $\alpha$’s are large so that a single factor of bank stock return is not enough to price these currency portfolios.
4.4 Time-varying Carry Trade Beta

In this section, we examine the last implication on the relationship of carry trade beta with average stock returns $\beta_{FX,s}$ and the stock market volatility. We average the country level MSCI stock return indices with equal weights and obtain a risk factor of average stock returns, in the similar way as in section 4.3. We compute $\beta_{FX,s}$ in every five-year rolling window for the long-short portfolio sorted on unconditional forward discounts. The stock market volatility is measured as the realized volatility of the average stock return. Figure 7 plots the relationship between the stock return volatility (on the horizontal axis) and $\beta_{FX,s}$ (on the vertical axis). It is clear that $\beta_{FX,s}$ increases with the stock return volatility, with a statistically significant regression coefficient of 6.64. It implies a one percent increase in the stock market volatility is associated with an increase of 0.0664 in $\beta_{FX,s}$ for the long-short portfolio on average. The correlation between currency beta and stock market volatility in the data is 0.645, while the correlation in the model simulation is 0.705.

5 Conclusion

This paper provides an intermediary-based explanation of the currency risk premium associated with carry trade with a liquidity-leverage channel. Countries differ in nominal interest rates. Bankers in low-interest-rate countries take high leverage for the low cost of holding liquid assets, which translates into a large drop in bankers’ wealth with a negative shock. Due to the higher IES of bankers than households, the total demand of foreign asset declines in bad times and the domestic currency appreciates. Therefore, low interest rate countries’ investors requires a higher risk premium to invest in foreign currencies. With the same liquidity-leverage mechanism, our model can account for the decline (rise) of currency risk premium of investing abroad in response to an unexpected interest rate rise (cut), as well as the time series positive correlation of interest rate differential and subsequent currency return to invest abroad. Our model implies deviations from covered interest rate parity when safe assets differ in liquidity, and delivers the positive relation between liquidity premium and currency risk premium of dollar assets. Empirically we show evidence that is consistent with the major model implications. First, low-interest-rate countries tend to have high bank leverage and low currency returns. This is the key mechanism of the model. Second, carry trade is procyclical with respect to average bank stock returns. Finally, comovement of carry trade return and average stock return increases with the stock market volatility.
References


J. Favilukis and L. Garlappi. The carry trade and uncovered interest parity when markets are incomplete. 2017.


Table 1: Parameter Values

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<thead>
<tr>
<th>Variable</th>
<th>Notation</th>
<th>Value</th>
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<td>Panel A: Preference Parameters</td>
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<tr>
<td>Households’ risk aversion</td>
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<td>Bankers’ risk aversion</td>
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<td>Households’ IES</td>
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<td>Bankers’ IES</td>
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<td>Preference over nontrade goods</td>
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<td>Elasticity of substitution across goods</td>
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<td>Exit rate</td>
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<td>Drift of dividend process</td>
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<tr>
<td>Diffusion of dividend process</td>
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<td>Foreign interest rate</td>
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<td>Diffusion of US nontraded good price</td>
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<td>Panel D: Monetary Policy Parameters</td>
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<td>Size of funding shock</td>
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<td>Persistence of nominal interest rate</td>
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<td>Diffusion of nominal interest rate</td>
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<td>Panel E: Other Parameters</td>
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<td>Wealth redistribution share</td>
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<td>Net foreign asset redistribution</td>
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Table 2: Simulation Results for A Cross-section of Economies with Fixed Interest Rates

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<td>i</td>
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<td>(i)</td>
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<td>0.03</td>
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<td>(\mu_s)</td>
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<td>3.872</td>
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<td>(r)</td>
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Panel A: Asset Prices (in percent)

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<th>w_h^b</th>
<th>1.899</th>
<th>1.872</th>
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<td>w_f^b</td>
<td>-0.035</td>
<td>0.063</td>
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<td>w_f^h</td>
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Panel B: Portfolio Choices

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<th>(\omega)</th>
<th>0.531</th>
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<td>-0.212</td>
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Panel C: State Variables

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Panel D: Return Exposures
Table 3: Simulation Results for A Cross-section of Economies with Fixed Interest Rates

<table>
<thead>
<tr>
<th>( i_0 )</th>
<th>0.01</th>
<th>0.02</th>
<th>0.03</th>
<th>0.04</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel A: Asset Prices (in percent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \mu_s )</td>
<td>3.873</td>
<td>3.867</td>
<td>3.959</td>
<td>3.972</td>
</tr>
<tr>
<td>( r )</td>
<td>1.411</td>
<td>1.534</td>
<td>1.722</td>
<td>2.034</td>
</tr>
<tr>
<td>( \mu_s - r )</td>
<td>2.462</td>
<td>2.333</td>
<td>2.237</td>
<td>1.938</td>
</tr>
<tr>
<td>( \sigma_{sx} )</td>
<td>5.955</td>
<td>5.245</td>
<td>4.517</td>
<td>4.092</td>
</tr>
<tr>
<td>( \sigma_{qx} )</td>
<td>3.774</td>
<td>3.366</td>
<td>2.815</td>
<td>2.374</td>
</tr>
<tr>
<td>( \mu_f - r )</td>
<td>1.487</td>
<td>1.352</td>
<td>1.147</td>
<td>0.779</td>
</tr>
<tr>
<td>Panel B: Portfolio Choices</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( w^b_h )</td>
<td>1.803</td>
<td>1.622</td>
<td>1.553</td>
<td>1.559</td>
</tr>
<tr>
<td>( w^b_f )</td>
<td>0.076</td>
<td>0.138</td>
<td>0.196</td>
<td>0.281</td>
</tr>
<tr>
<td>( w^h_f )</td>
<td>0.402</td>
<td>0.491</td>
<td>0.603</td>
<td>0.673</td>
</tr>
<tr>
<td>( w^b_f )</td>
<td>-0.060</td>
<td>-0.116</td>
<td>-0.145</td>
<td>-0.172</td>
</tr>
<tr>
<td>Panel C: State Variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \omega )</td>
<td>0.561</td>
<td>0.542</td>
<td>0.574</td>
<td>0.621</td>
</tr>
<tr>
<td>( \chi )</td>
<td>-0.137</td>
<td>-0.146</td>
<td>-0.196</td>
<td>-0.312</td>
</tr>
<tr>
<td>Panel D: Return Exposures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \beta_{FX} )</td>
<td>1.370</td>
<td>1.063</td>
<td>0.649</td>
<td>0.370</td>
</tr>
<tr>
<td>( \beta_s )</td>
<td>1.195</td>
<td>1.058</td>
<td>0.916</td>
<td>0.832</td>
</tr>
<tr>
<td>( \beta_{FX,s} )</td>
<td>0.802</td>
<td>0.729</td>
<td>0.627</td>
<td>0.544</td>
</tr>
<tr>
<td>( \beta_{FX,b} )</td>
<td>0.473</td>
<td>0.431</td>
<td>0.365</td>
<td>0.313</td>
</tr>
<tr>
<td>Panel E: Time Series Coefficients</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \gamma_r )</td>
<td>0.165</td>
<td>0.199</td>
<td>0.277</td>
<td>0.298</td>
</tr>
<tr>
<td>( \gamma_i )</td>
<td>1.401</td>
<td>1.446</td>
<td>1.508</td>
<td>1.482</td>
</tr>
</tbody>
</table>
Table 4: Bank capital ratio, forward discount, and currency return

<table>
<thead>
<tr>
<th></th>
<th>Forward discount</th>
<th></th>
<th></th>
<th>Currency return</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>Capital ratio</td>
<td>0.463**</td>
<td>0.170**</td>
<td>0.366**</td>
<td>0.113**</td>
</tr>
<tr>
<td></td>
<td>(0.071)</td>
<td>(0.011)</td>
<td>(0.063)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.971**</td>
<td>0.948**</td>
<td>0.435</td>
<td>0.374</td>
</tr>
<tr>
<td></td>
<td>(0.117)</td>
<td>(0.098)</td>
<td>(0.557)</td>
<td>(0.570)</td>
</tr>
<tr>
<td>GDP</td>
<td>-0.483**</td>
<td>-0.429**</td>
<td>-0.629**</td>
<td>-0.587**</td>
</tr>
<tr>
<td></td>
<td>(0.031)</td>
<td>(0.031)</td>
<td>(0.111)</td>
<td>(0.025)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.134</td>
<td>0.394</td>
<td>0.225</td>
<td>0.468</td>
</tr>
</tbody>
</table>

Note: Fama-Macbeth regression results of forward discount (left panel) and currency return (right panel) on bank capital ratio (the inverse of leverage, in percentage). In both panels, column (1) report the univariate regression coefficients. Column (2) controls for inflation, column (3) controls for the log GDP (size) of each country, and column (4) controls both inflation and log GDP. Data are monthly including 22 countries, from Jan 1990 to Dec 2016. Annual measures of bank capital ratio and GDP share are used repetitively for months within a year. Standard errors are Newey-West adjusted with 120 lags. ** indicates statistical significance at 5% level. * indicates statistical significance at 10% level.
Table 5: Currency portfolios

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(3)-(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A: Leverage sorted portfolios</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward discount</td>
<td>0.050</td>
<td>1.068</td>
<td>1.669</td>
<td>1.619</td>
</tr>
<tr>
<td>Bank capital ratio</td>
<td>4.476</td>
<td>5.738</td>
<td>7.612</td>
<td>3.135</td>
</tr>
<tr>
<td>Excess return</td>
<td>-0.687</td>
<td>0.182</td>
<td>1.465</td>
<td>2.152</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>8.513</td>
<td>9.165</td>
<td>8.711</td>
<td>5.550</td>
</tr>
<tr>
<td>Sharpe ratio</td>
<td>-0.081</td>
<td>0.020</td>
<td>0.168</td>
<td>0.388</td>
</tr>
<tr>
<td><strong>Panel B: Forward discount sorted portfolios (unconditional)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward discount</td>
<td>-0.734</td>
<td>1.128</td>
<td>2.540</td>
<td>3.274</td>
</tr>
<tr>
<td>Bank capital ratio</td>
<td>5.324</td>
<td>5.738</td>
<td>6.548</td>
<td>1.224</td>
</tr>
<tr>
<td>Excess return</td>
<td>-0.526</td>
<td>-0.226</td>
<td>1.635</td>
<td>2.161</td>
</tr>
<tr>
<td>Sharpe ratio</td>
<td>-0.069</td>
<td>-0.023</td>
<td>0.177</td>
<td>0.343</td>
</tr>
<tr>
<td><strong>Panel C: Forward discount sorted portfolios (conditional)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward discount</td>
<td>-1.054</td>
<td>0.868</td>
<td>3.250</td>
<td>4.303</td>
</tr>
<tr>
<td>Bank capital ratio</td>
<td>5.348</td>
<td>6.035</td>
<td>6.199</td>
<td>0.851</td>
</tr>
<tr>
<td>Excess return</td>
<td>-0.952</td>
<td>-0.221</td>
<td>2.462</td>
<td>3.414</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>8.271</td>
<td>8.575</td>
<td>10.107</td>
<td>7.141</td>
</tr>
<tr>
<td>Sharpe ratio</td>
<td>-0.115</td>
<td>-0.026</td>
<td>0.244</td>
<td>0.478</td>
</tr>
</tbody>
</table>

Note: Panel A reports statistics to the three portfolios sorted on bank leverage. Portfolio 1 includes countries with the highest bank leverage while portfolio 3 includes countries with the lowest bank leverage. Rebalancing is annual. Panel B reports the statistics to the three portfolios sorted on full sample average forward discount. Panel C reports the statistics to the three portfolios sorted on average forward discount in the previous year with annual rebalancing. All numbers are annualized.

Table 6: Correlation of Lev-factor with (un)conditional carry-factor

<table>
<thead>
<tr>
<th></th>
<th>Unconditional</th>
<th>Conditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>α</td>
<td>0.752</td>
<td>2.460**</td>
</tr>
<tr>
<td>(1.019)</td>
<td>(1.325)</td>
<td></td>
</tr>
<tr>
<td>β</td>
<td>0.655**</td>
<td>0.444**</td>
</tr>
<tr>
<td>(0.053)</td>
<td>(0.069)</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.332</td>
<td>0.119</td>
</tr>
</tbody>
</table>

Note: This table shows the regression coefficients of conditional and unconditional Carry-factors on the Lev-factor. Lev-factor is constructed from portfolios in Panel A of Table 5 while conditional and unconditional Carry-factors are constructed from portfolios in Panel B and C of Table 5, respectively. All numbers are annualized. ** indicates statistical significance at 5% level. * indicates statistically significance at 10% level.
### Table 7: Estimation of the factor model: Lev-factor

#### Panel A: Risk Factor Exposure

<table>
<thead>
<tr>
<th></th>
<th>Lev-1</th>
<th>Lev-2</th>
<th>Lev-3</th>
<th>Fd-1</th>
<th>Fd-2</th>
<th>Fd-3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>α</strong></td>
<td>0.269</td>
<td>0.060</td>
<td>0.269</td>
<td>-0.036</td>
<td>-0.127</td>
<td>0.716</td>
</tr>
<tr>
<td></td>
<td>(1.613)</td>
<td>(1.813)</td>
<td>(1.613)</td>
<td>(1.484)</td>
<td>(1.927)</td>
<td>(1.769)</td>
</tr>
<tr>
<td><strong>β</strong></td>
<td>-0.444**</td>
<td>0.056</td>
<td>0.556**</td>
<td>-0.228**</td>
<td>-0.046</td>
<td>0.427**</td>
</tr>
<tr>
<td></td>
<td>(0.084)</td>
<td>(0.094)</td>
<td>(0.084)</td>
<td>(0.077)</td>
<td>(0.100)</td>
<td>(0.092)</td>
</tr>
<tr>
<td>R²</td>
<td>0.084</td>
<td>0.001</td>
<td>0.125</td>
<td>0.028</td>
<td>0.001</td>
<td>0.066</td>
</tr>
<tr>
<td>Obs</td>
<td>312</td>
<td>312</td>
<td>312</td>
<td>312</td>
<td>312</td>
<td>312</td>
</tr>
</tbody>
</table>

#### Panel B: Price of Risk

<table>
<thead>
<tr>
<th></th>
<th>Fama-MacBeth</th>
<th>GMM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.552**</td>
<td>2.134**</td>
</tr>
<tr>
<td></td>
<td>(0.342)</td>
<td>(0.925)</td>
</tr>
</tbody>
</table>

Note: Panel A in this table shows the exposure to Lev-factor across the three currency portfolios sorted on unconditional average forward discount. Panel B reports the estimated price of Lev-factor risk using Fama-MacBeth and GMM methods. Hansen and Jagannathan (1997)'s scale-invariant weight matrix is used in GMM estimation. Standard errors are Newey-West adjusted with 120 lags. All estimates of price of risk are annualized. ** indicates statistical significance at 5% level. * indicates statistically significance at 10% level.

### Table 8: Procyclical Carry Trade Returns

<table>
<thead>
<tr>
<th></th>
<th>“AUD-JPY”</th>
<th>“NZD-CHF”</th>
<th>unconditional carry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>α</strong></td>
<td>-0.092</td>
<td>1.709</td>
<td>0.607</td>
</tr>
<tr>
<td></td>
<td>(2.580)</td>
<td>(2.161)</td>
<td>(1.163)</td>
</tr>
<tr>
<td><strong>β</strong></td>
<td>0.300**</td>
<td>0.251**</td>
<td>0.155**</td>
</tr>
<tr>
<td></td>
<td>(0.041)</td>
<td>(0.035)</td>
<td>(0.019)</td>
</tr>
<tr>
<td>R²</td>
<td>0.121</td>
<td>0.121</td>
<td>0.148</td>
</tr>
</tbody>
</table>

Note: This table shows the regression coefficients of three carry trade strategies on average bank stock returns. The first column shows the result for “AUD-JPY” strategy, the second column for “NZD-CHF” strategy, and the third column for the unconditional carry strategy. All numbers are annualized. ** indicates statistically significance at 5% level. * indicates statistically significance at 10% level.
Table 9: Average Bank Stock Return as the Pricing Factor

<table>
<thead>
<tr>
<th>Portfolio</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average return</td>
<td>0.780</td>
<td>0.927</td>
<td>2.877</td>
</tr>
</tbody>
</table>

Panel A: Risk Factor Exposure

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>α</td>
<td>0.826</td>
<td>0.115</td>
<td>1.432</td>
</tr>
<tr>
<td></td>
<td>(1.613)</td>
<td>(1.553)</td>
<td>(1.663)</td>
</tr>
<tr>
<td>β</td>
<td>-0.005</td>
<td>0.084**</td>
<td>0.150**</td>
</tr>
<tr>
<td></td>
<td>(0.026)</td>
<td>(0.025)</td>
<td>(0.027)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.000</td>
<td>0.028</td>
<td>0.074</td>
</tr>
<tr>
<td>Obs</td>
<td>398</td>
<td>398</td>
<td>398</td>
</tr>
</tbody>
</table>

Panel B: Price of Risk

<table>
<thead>
<tr>
<th>Method</th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fama-MacBeth</td>
<td>12.852*</td>
<td>11.180*</td>
</tr>
<tr>
<td>GMM</td>
<td>(7.840)</td>
<td>(6.673)</td>
</tr>
</tbody>
</table>

Note: The top row reports the average return to the three currency portfolios sorted on unconditional average forward discount. Panel A shows the exposure to average bank stock returns across the three currency portfolios. Panel B reports the estimated price of risk using Fama-MacBeth and GMM methods. Hansen and Jagannathan (1997)'s scale-invariant weight matrix is used in GMM estimation. Standard errors are Newey-West adjusted with 120 lags. All estimates of price of risk are annualized. ** indicates statistical significance at 5% level. * indicates statistically significance at 10% level.
Figure 1: Bank Capital Ratio, Interest Rate, and Currency Returns

Note: Observations span from 1990 to 2016, with currency data at monthly frequency and bank balance sheet data at annual frequency. We select the most liquid G10 countries with relatively long sample for comparability. We use German currency data before 1999 and euro currency data after 1999.
Figure 2: Leverage, Local Stock Return Exposure, and Excess Stock Return

Panel A: Bank Leverage

Panel B: Local Stock Return Exposure

Panel C: Excess Local Stock Return

Note: This figure shows the solutions of bank leverage, excess local stock return, and local stock return exposure for economies with fixed nominal interest rate $i = 0$ and $i = 0.05$ in each panel, respectively. The graphs are on the same scale. $\omega$ represents the households’ wealth share, and $\chi$ represents the scaled net foreign asset position.

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Figure 3: Exchange Rate Exposure, Currency Risk Premium, and Ergodic Distribution

Panel A: Exchange Rate Exposure

Panel B: Currency Risk Premium

Panel C: Ergodic Distribution

Note: This figure shows the solutions of exchange rate exposure and currency risk premium for economies with fixed nominal interest rate \( i = 0 \) and \( i = 0.05 \) in Panel A and B. Panel C shows the ergodic distribution of the two state variables. The graphs are on the same scale. \( \omega \) represents the households’ wealth share, and \( \chi \) represents the scaled net foreign asset position.
Figure 4: Impulse Responses to a Positive Endowment Shock

Note: This figure shows impulse responses of various variables to a one standard deviation positive endowment shock in the two economies with $i = 0$ and $i = 0.05$. The solid blue line represents the $i = 0$ (low interest rate) economy and the dashed red line represents the $i = 0.05$ (high interest rate) economy. Impulse responses are obtained by simulation of $N = 2,000$ parallel economies and taking their average.
Figure 5: Solutions for the Stochastic Interest Rates

Panel A: Bank Leverage

Panel B: Exchange Rate Exposure

Panel C: Currency Risk Premium

Panel D: Currency risk premium responses

Note: Panel A to C show the solutions of bank leverage $w_n^b$, exchange rate exposure $\sigma_{q^e}$, and currency risk premium $\mu_f - r$ as functions of households’ wealth share $\omega$ and nominal interest rate $i$, while fixing $\chi = 0$. Panel A to C are solutions to the economy with $i_0 = 0.01$. Panel D shows the impulse responses of currency risk premium (in percentage) to a positive nominal interest rate shock for four economies. Impulse responses are obtained by simulation of $N = 1,000$ parallel economies and taking their average.
Figure 6: Currency Beta on Average Bank Stock Returns and Average Forward Discount

Note: This figure plots the relationship of a country’s average forward discount (the upper panel) and average bank capital ratio (the lower panel) with exchange rate beta with respect to average bank stock return (the upper panel) for G10 currencies (vis-a-vis dollar). Data range from November 1983 to December 2016. Euro exchange rate is used for “DEM” after 1999.
Figure 7: Currency Beta and Stock Market Volatility

Note: This figure plots the relationship of time-varying currency beta of the carry trade portfolio to world average stock return (using five-year rolling window) and stock market volatility (monthly realized volatility of the average stock return across countries). Each dot represents an observation, and the solid blue line is the empirical fitted line.
Appendix A  Proofs

A.1 Proof of Proposition 2

Using the definition in (12) and (13):

\[
L_D^j - L_H^j = \frac{\lambda}{1+\lambda} \left[ \max(w_h^j + w_c^j + w_f^j - 1, 0) + \max(-w_f^j, 0) \right] \\
- \frac{\lambda}{1+\lambda} \left[ \max(1 - w_h^j - w_f^j - w_c^j, 0) + \max(w_f^j, 0) \right] - w_c^j
\] (54)

There are three cases in which the funding shock is relevant.

Case 1: \(-w_h^j - w_f^j - w_c^j + 1 < 0, w_f^j < 0\). Under this case:

\[
L_D^j - L_H^j = -w_c^j + \frac{\lambda}{1+\lambda}(w_h^j + w_c^j - 1) = -\frac{1}{1+\lambda}[w_c^j - \lambda(w_h^j - 1)]
\]

Case 2: \(-w_h^j - w_f^j - w_c^j + 1 < 0, w_f^j > 0\). Under this case:

\[
L_D^j - L_H^j = \frac{\lambda}{1+\lambda}(w_h^j + w_c^j + w_f^j - 1) - \frac{\lambda}{1+\lambda}w_f^j + w_c^j = -\frac{1}{1+\lambda}[w_c^j - \lambda(w_h^j - 1)]
\]

Case 3: \(-w_h^j - w_f^j - w_c^j + 1 > 0, w_f^j < 0\). Under this case:

\[
L_D^j - L_H^j = -\frac{\lambda}{1+\lambda}w_f^j - \frac{\lambda}{1+\lambda}(1 - w_h^j - w_c^j - w_f) - w_c^j = -\frac{1}{1+\lambda}[w_c^j - \lambda(w_h^j - 1)]
\]

We see that in three cases, the HJB equation shown in proposition 1 has the same form. Take the first order condition with \(w_c^j\), we always have:

\[
V_W W^j(-i) + V_{W+} \eta \frac{\phi}{1+\lambda} > 0
\] (55)

First, marginal utility of wealth decreases with \(W\), so \(V_W < V_{W+}\) for \(W+ > W\). Under Assumption 1, equation (55) always holds. Therefore, agent \(j\) chooses to hold enough liquid assets to protect herself from being exposed to the funding shock in all three cases, i.e.: \(\max(L_D^j - L_H^j, 0) = 0\).

A.2 Proof of Proposition 3

There are four possible cases: \(w_f^j > (<)0, w_f^j + w_h^j + w_c^j - 1 > (<)0\).

Case 1: \(w_f^j < 0, w_f^j + w_h^j + w_c^j - 1 > 0\)

\[
L_D^j = \frac{\lambda}{1+\lambda}(w_h^j + w_c^j - 1), L_H^j = w_c^j
\]
From $L^j_H \geq L^j_D$, we solve for:

$$w^j_c \geq \lambda (w^j_h - 1)$$

**Case 2:** $w^j_f > 0, w^j_f + w^j_h + w^j_c - 1 > 0$

$$L^j_D = \frac{\lambda}{1 + \lambda} (w^j_h + w^j_c - 1), L^j_H = \frac{\lambda}{1 + \lambda} w^j_f + w^j_c$$

From $L^j_H \geq L^j_D$, again we solve for:

$$w^j_c \geq \lambda (w^j_h - 1)$$

**Case 3:** $w^j_f < 0, w^j_f + w^j_h + w^j_c - 1 < 0$

$$L^j_D = -\frac{\lambda}{1 + \lambda} w^j_f, L^j_H = w^j_c + \frac{\lambda}{1 + \lambda} (1 - w^j_h - w^j_c - w^j_f)$$

From $L^j_H \geq L^j_D$, again we solve for:

$$w^j_c \geq \lambda (w^j_h - 1)$$

**Case 4:** $w^j_f > 0, w^j_f + w^j_h + w^j_c - 1 < 0$

Under this case, the agent does not borrow from either domestic agents or foreign agents, so optimal cash holding must be 0.

Combine the four cases together with $w^j_c \geq 0$, we can conclude that:

$$w^j_c = \max\{\lambda (w^j_h - 1), 0\}$$  \hspace{1cm} (56)

### A.3 Proof of Corollary 2

The proof starts from the equation (28) and (30). For simplicity, we only consider that for households. The same procedure applies for bankers, except for that $\mu_s - r$ should be replaced by $\mu_s - r - \lambda i$.

As in the main text, we denote portfolio share as $w$, the diffusion of asset return as $\Sigma = \begin{bmatrix} \sigma_s & \sigma_f \end{bmatrix}$, and the diffusion of state variable $\Sigma_\Omega$, with each column representing one state variables’ exposure to various Brownian shocks. We suppress $j$ in the following proof. Equation (30) can be inverted into:

$$\mu - r = \gamma \Sigma' \Sigma w - \frac{1 - \gamma}{1 - \psi} \Sigma_\Omega \Sigma \frac{\nabla G}{G}$$  \hspace{1cm} (57)

$$= \gamma \frac{d}{dt} \text{cov}(dR, \frac{dW}{W}) - \frac{1 - \gamma}{1 - \psi} \frac{d}{dt} \text{cov}(dR, \frac{dG}{G})$$  \hspace{1cm} (58)

For given price of consumption basket $\tilde{P}$, we can write out the first order condition with respect
to consumption basket (though redundant given equations (26) and (27):

\[ G = (\hat{P}_c) \hat{P}^{\psi - 1} \]  

(59)

Therefore, equation (58) can be rewritten as:

\[
\mu - r = -\frac{d}{dt} \text{cov} \left( \frac{1 - \gamma}{1 - \psi} \frac{d(\hat{P}_c)}{\hat{P}_c} - \frac{\gamma}{W} \frac{dW}{W} - (1 - \gamma) \frac{d\hat{P}}{\hat{P}} + dR \right)
\]

(60)

**Appendix B  Solution Details**

In this section, we describe the details of how to solve the model numerically. We rely on Chebyshev approximations to the unknown functions. We start with a set of conjectured functions: value functions \( G^h, G^b \), exchange rate \( Q \), dividend yield of local stock \( F \), and household portfolio share \( w^h, w^f \). We only show the details for the case of fixed nominal interest rates, while extending the model to incorporate stochastic interest rate is straightforward with an additional state variable \( i \).

The optimality conditions for consumption of traded and nontraded goods are shown in Corollary 1, equations (26) and (27). Combined with the CES aggregation equation (18), we can obtain:

\[
c^j_x = G^j \alpha^\theta \left[ \alpha^\theta + (1 - \alpha)^\theta Q^{1-\theta} \right]^{\psi_j - \theta} \frac{\theta - 1}{\theta - \theta}
\]

(61)

\[
c^j_y = c^j_h \left( \frac{1 - \alpha}{\alpha Q} \right)^\theta
\]

(62)

The market clearing condition of nontraded good implies:

\[
\omega c^h_x + (1 - \omega)c^b_x = \frac{X}{W}
\]

(63)

Define the dividend of local stock \( Z = X + QY \), then:

\[
\frac{dZ}{Z} = \left[ \mu_x + \frac{Q \tau}{1 + Q \tau} (\mu_q + \sigma_q^x \sigma_x) \right] dt + \left[ \sigma_x + \frac{Q \tau}{1 + Q \tau} \left( \frac{Q \omega}{Q} \sigma_w + \frac{Q \chi}{Q} \sigma_x \right) \right] dB \equiv \mu_z dt + \sigma_z dB
\]

(64)

As \( F = \frac{Z}{P} \), the return process for local stock is:

\[
dR = (F + \mu_P) dt + \sigma_P dB
\]

(65)

where:

\[
\sigma_P = \sigma_z - \frac{F \omega}{F} \sigma_x - \frac{F \chi}{F} \sigma_x
\]

(66)

\( \mu_P \) will be specified later. The diffusion of the state variables, from equations (40) and (42), are
given by:

$$
\sigma_\omega = (w_h^h - w_h^b)(\sigma_z - \frac{F_c}{F} \sigma_\omega - \frac{F_x}{F} \sigma_\chi) + (w_f^h - w_f^b)(\sigma^* + \frac{Q_\omega}{Q} \sigma_\omega + \frac{Q_\chi}{Q} \sigma_\chi)
$$  \(67\)

$$
\sigma_\chi = \chi \sigma^*
$$  \(68\)

Thus, we can solve for \(\sigma_\omega\) from equations (64), (67), and (68):

$$
\sigma_\omega = \frac{(w_h^h - w_h^b) \left[ \sigma_x + \frac{Q_\tau}{1+Q_\tau} \frac{Q_\omega}{Q_\omega} \sigma^* - \frac{F_c}{F} \chi \sigma^* \right] + (w_f^h - w_f^b)(\sigma^* + \frac{Q_\omega}{Q} \sigma_\omega + \frac{Q_\chi}{Q} \sigma_\chi)}{1 - (w_h^h - w_h^b) \left( \frac{Q_\tau}{1+Q_\tau} \frac{Q_\omega}{Q_\omega} - \frac{F_c}{F} \right) - (w_f^h - w_f^b) \frac{Q_\omega}{Q}}
$$  \(69\)

Now that we can solve for all other diffusions, \(\sigma_q, \sigma_f, \sigma_z, \) and \(\sigma_P\).

Next we derive the expected excess return of the two assets from the portfolio holding of households from Corollary 1:

$$
\mu_s - r = \gamma_h \sigma_s' \sigma_s + \gamma_h \sigma_f' \sigma_f - 1 - \frac{\gamma_h}{\psi_h} \left( \frac{G_h^h}{G_h^h} \sigma_s' \sigma_s + \frac{G_h^h}{G_h^h} \sigma_\chi' \sigma_s \right)
$$  \(70\)

$$
\mu_f - r = \gamma_h \sigma_f' \sigma_f + \gamma_h \sigma_s' \sigma_f - 1 - \frac{\gamma_h}{\psi_h} \left( \frac{G_h^h}{G_h^h} \sigma_f' \sigma_f + \frac{G_h^h}{G_h^h} \sigma_\chi' \sigma_f \right)
$$  \(71\)

According to market clearing condition, the portfolio holding of bankers are:

$$
w_b^h = \frac{1 - \chi \frac{X}{W}}{1 - \omega} w_h^h, w_f^b = \frac{\chi \frac{X}{W} - \omega w_f^h}{1 - \omega}
$$  \(72\)

where \(\frac{X}{W}\) is given by equation (63).

Then we can derive the drift of state variables:

$$
\mu_\omega = \omega (1 - \omega) \left[ c_z^h - c_z^b + Q(c_y^h - c_y^b) + (w_h^h - w_h^b)(\mu_s - r) + (w_f^h - w_f^b)(\mu_f - r) \right] + \kappa(\bar{\omega} - \omega)
$$  \(73\)

$$
\mu_\chi = \tau - \left( \frac{1 - \alpha}{\alpha Q} \right)^\theta + \chi \sigma^*
$$  \(74\)

Thus we can derive the drift of exchange rate \(\mu_q\), dividend \(\mu_z\), and the drift of local stock price change \(\mu_P\):

$$
\mu_q = \frac{Q_\omega}{Q} \mu_\omega + \frac{Q_\chi}{Q} \mu_\chi + \frac{1}{2} \left( \frac{Q_{\omega \omega}}{Q} \sigma_s' \sigma_\omega + \frac{Q_{\chi \chi}}{Q} \sigma_\chi' \sigma_\chi \right) + \frac{Q_{\omega x}}{Q} \sigma_s' \sigma_x
$$  \(75\)

$$
\mu_z = \mu_x + \frac{Q_\tau}{1 + Q_\tau} (\mu_q + \sigma_q' \sigma_x)
$$  \(76\)

$$
\mu_P = \mu_z + \sigma_P' \sigma_P - \sigma_z' \sigma_P - \mu_F
$$  \(77\)
In total, we have six unknown functions and six equilibrium conditions to solve for them.

The expected return to local stock is \( \mu_s = F + \mu_p \), and real risk free rate is \( r = \mu_s - (\mu_s - r) \).

Finally, we check whether the following conditions from (79) to (83) are satisfied.

The definition of dividend yield:

\[
F = \frac{X(1 + Q\tau)}{P} = \frac{X}{W(1 + Q\tau)} \frac{1}{1 - \chi Q\frac{X}{W}}
\]  

(79)

Consistency of foreign asset return:

\[
\mu_f - r = r^* + \mu_q + \sigma_q^* - r
\]  

(80)

Portfolio holding for bankers:

\[
\mu_s - r - \lambda i = \gamma_0 \sigma_q^* \sigma_s + \gamma_0 \sigma_q^* \sigma_f - \frac{1 - \gamma_b}{1 - \psi_b} \left( \frac{G^b_\omega}{G^b} \sigma_q^* \sigma_s + \frac{G^b_\chi}{G^b} \sigma_q^* \sigma_s \right)
\]  

(81)

\[
\mu_f - r = \gamma_0 \sigma_q^* \sigma_f + \gamma_0 \sigma_q^* \sigma_f - \frac{1 - \gamma_b}{1 - \psi_b} \left( \frac{G^b_\omega}{G^b} \sigma_q^* \sigma_f + \frac{G^b_\chi}{G^b} \sigma_q^* \sigma_f \right)
\]  

(82)

HJB equations for both agents:

\[
0 = \frac{1}{1 - \psi_j} \left[ \frac{(c^j)^{1 - \frac{1}{\sigma_j}}}{(G^j)^{1 - \frac{1}{\psi_j}}} - (\rho + \kappa) \right] + \mu^j_w - \frac{1}{2} \gamma_j \left( \sigma^j_w \right)^{1 - \frac{1}{\sigma_j}} \sigma^j_w + \frac{1}{1 - \psi_j} \left( \frac{G^j_\omega}{G^j} \mu_w + \frac{G^j_\chi}{G^j} \mu_x \right)
\]

\[
+ \frac{1}{2(1 - \psi_j)} \left[ \psi_j - \frac{\gamma_j}{G^j} G^j_\omega G^j_\chi \right] \sigma^j_w \sigma_x + \frac{1}{2(1 - \psi_j)} \left[ \psi_j - \frac{\gamma_j}{G^j} G^j_\omega G^j_\chi \right] \sigma^j_x \sigma_w
\]

\[
+ \frac{1}{1 - \psi_j} \left[ \psi_j - \frac{\gamma_j}{G^j} G^j_\omega G^j_\chi \right] \sigma^j_w \sigma_x + \frac{1}{1 - \psi_j} \left[ \psi_j - \frac{\gamma_j}{G^j} G^j_\omega G^j_\chi \right] \sigma^j_x \sigma_w
\]  

(83)

where:

\[
\mu^j_w = r - c^j_x - Qc^j_y + w^j_h(\mu_s - r) + w^j_f(\mu_f - r), \sigma^j_w = w^j_h \sigma_P + w^j_f \sigma_f
\]  

(84)

\[
c^j = \left[ \alpha(c^j_x)^{\theta - 1 - \sigma} + (1 - \alpha)(c^j_y)^{\theta - 1 - \sigma} \right]^{\theta - 1 - \sigma}
\]  

(85)

In total, we have six unknown functions and six equilibrium conditions to solve for them.
Appendix C Simulation Details

In our model, the low interest rate countries have higher bank leverage, so that bankers in these countries accumulate wealth faster than households and the ergodic distribution of \( \omega \) will be highly tilted toward bankers compared to high interest rate countries. To make the ergodic mean of \( \omega \) relatively equal, we impose a wealth redistribution between bankers and households and keep the ergodic distribution of \( \omega \) concentrating in the region of interest with a substantial currency risk premium. In the simulation, we specify \( \Pi^h \) and \( \Pi^b \) as:

\[
\Pi^h = -\delta + \frac{\delta \bar{\omega}}{\omega}, \quad \Pi^b = -\delta + \frac{\delta(1 - \bar{\omega})}{1 - \omega} + w^{b,i}_c
\]

(86)

In every period, \( \delta \) fraction of each agent’s wealth is taxed and redistributed. \( \bar{\omega} \) fraction is redistributed to households and \( 1 - \bar{\omega} \) is redistributed to bankers. We set \( \delta \) to be larger in low interest rate countries, so that the ergodic mean of \( \omega \) across countries are closer.

In our simulation in section 3.3, \( \delta \) for each economy is set as 0.02, 0.014, 0.012, 0.008, 0.004, and 0 respectively.

We report the results without the introduction of the lump-sum redistribution in Appendix D.2, and find they do not affect the qualitative feature of policy functions. The spread of currency risk premium is smaller without the lump-sum redistribution.

The model is simulated using the solutions obtained in section 3.2. We use a two-point approximation of the standard Brownian motions: \( dB = 1 \) or \( -1 \) with equal probability \( \frac{1}{2} \). We simulate 1000 periods for each economy and discard the first 100 periods for computation of ergodic mean.

C.1 Impulse Response Functions

Since we solve the model globally, there is no deterministic steady state. To obtain the impulse response functions, we simulate \( N = 2,000 \) parallel economies. In each economy, we first simulate \( T_1 = 120 \) periods with randomly drawn Brownian shocks. For the period \( T_1 + 1 \), we set the domestic endowment shock to be 1 (a positive endowment shock) for all economies. Then each economy evolves freely for \( T_2 = 20 \) periods. We take the average of each variable across the 2,000 parallel economies for the \( T_2 \) periods, and subtract their values in period \( T_1 \), the ergodic mean.
Appendix D  Additional Results with the Model

D.1  Current Account Cyclicality

In this section, we look at the impulse response of current account surplus (in terms of traded good) scaled by $X$ in the model with fixed interest rates, as in section 3.2. In our model, the current account surplus is equal to $\overline{CA} = Y - C_y^h - C_y^b$. It is a monotonic function of exchange rate $Q$:

$$CA = \frac{\overline{CA}}{X} = \bar{\tau} - \left(\frac{1 - \alpha}{\alpha Q}\right)^\theta$$  \hspace{1cm} (87)

Therefore, the impulse responses of $CA$ mirrors the responses of $Q$. The current account surplus increases when there is a positive endowment shock to the economy.

In the international business cycle literature, it has been widely known that current account is countercyclical, while our model predicts a procyclical current account surplus. The driving force of current account countercyclical is investment, which is abstracted away from our model. If we redefine output as the sum of nondurable good and service consumption plus net export, the correlation between net export and output is positive for most advanced economies. The correlation between consumption, net export, and the sum of the two (defined as output) are shown in Table E.1\textsuperscript{14}.

D.2  Fixed Interest Rates without Redistribution

In this appendix, we repeat the numerical solution to the model with $\Pi^h = 0, P_t^b = w^b_i$. The purpose is to show that the change in redistribution does not change the policy functions or impulse responses, while making the currency return spread between $i = 0$ and $i = 0.05$ economy smaller. All qualitative results remain.

We show the counterpart of Figure 2 and Figure 3 in Figure D.1 and Figure D.2, the counterpart of Figure 4 in Figure D.3, and the counterpart of Table 2 in Table D.1.

\textsuperscript{14}I thank Yang Liu for sharing the data.
Figure D.1: Leverage, Local Stock Return Exposure, and Excess Stock Return

Panel B: Local Stock Return Exposure

Panel C: Excess Local Stock Return

Note: This figure shows the solutions of bank leverage, excess local stock return, and local stock return exposure for economies with fixed nominal interest rate $i = 0$ and $i = 0.05$ in each panel, respectively. The graphs are on the same scale. $\omega$ represents the households’ wealth share, and $\chi$ represents the scaled net foreign asset position.
Figure D.2: Exchange Rate Exposure and Currency Risk Premium

Panel A: Exchange Rate Exposure

Panel B: Currency Risk Premium

Panel C: Ergodic Distribution

Note: This figure shows the solutions of exchange rate exposure and currency risk premium for economies with fixed nominal interest rate $i = 0$ and $i = 0.05$ in Panel A and B. Panel C shows the ergodic distribution of the two state variables. The graphs are on the same scale. $\omega$ represents the households’ wealth share, and $\chi$ represents the scaled net foreign asset position.
Figure D.3: Impulse Responses to a Positive Endowment Shock

Note: This figure shows impulse responses of various variables to a one standard deviation positive endowment shock in the two economies with $i = 0$ and $i = 0.05$. The solid blue line represents the $i = 0$ (low interest rate) economy and the dashed red line represents the $i = 0.05$ (high interest rate) economy. Impulse responses are obtained by simulation of $N = 2,000$ parallel economies and taking their average.
Table D.1: Simulation Results for A Cross-Section of Economies with Fixed Interest Rates

<table>
<thead>
<tr>
<th>i</th>
<th>0</th>
<th>0.01</th>
<th>0.02</th>
<th>0.03</th>
<th>0.04</th>
<th>0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Panel A: Asset Prices (in percent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu_s$</td>
<td>3.538</td>
<td>3.617</td>
<td>3.675</td>
<td>3.766</td>
<td>3.986</td>
<td>4.183</td>
</tr>
<tr>
<td>$r$</td>
<td>1.695</td>
<td>2.023</td>
<td>2.201</td>
<td>2.327</td>
<td>2.134</td>
<td>2.392</td>
</tr>
<tr>
<td>$\mu_s - r$</td>
<td>1.843</td>
<td>1.594</td>
<td>1.474</td>
<td>1.438</td>
<td>1.852</td>
<td>1.791</td>
</tr>
<tr>
<td>$\sigma_{sx}$</td>
<td>6.327</td>
<td>5.274</td>
<td>4.634</td>
<td>4.105</td>
<td>3.674</td>
<td>3.161</td>
</tr>
<tr>
<td>$\sigma_{qx}$</td>
<td>3.782</td>
<td>2.891</td>
<td>2.496</td>
<td>2.222</td>
<td>1.897</td>
<td>1.225</td>
</tr>
<tr>
<td>$\mu_f - r$</td>
<td>1.109</td>
<td>0.789</td>
<td>0.620</td>
<td>0.502</td>
<td>0.708</td>
<td>0.457</td>
</tr>
<tr>
<td></td>
<td>Panel B: Portfolio Choices</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$w_b^h$</td>
<td>1.557</td>
<td>1.527</td>
<td>1.484</td>
<td>1.421</td>
<td>1.385</td>
<td>1.367</td>
</tr>
<tr>
<td>$w_f^b$</td>
<td>-0.008</td>
<td>0.050</td>
<td>0.101</td>
<td>0.144</td>
<td>0.197</td>
<td>0.228</td>
</tr>
<tr>
<td>$w_h^b$</td>
<td>0.272</td>
<td>0.388</td>
<td>0.491</td>
<td>0.581</td>
<td>0.667</td>
<td>0.785</td>
</tr>
<tr>
<td>$w_f^h$</td>
<td>0.007</td>
<td>-0.060</td>
<td>-0.108</td>
<td>-0.146</td>
<td>-0.174</td>
<td>-0.139</td>
</tr>
<tr>
<td></td>
<td>Panel C: State Variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\omega$</td>
<td>0.425</td>
<td>0.457</td>
<td>0.483</td>
<td>0.498</td>
<td>0.534</td>
<td>0.626</td>
</tr>
<tr>
<td>$\chi$</td>
<td>-0.073</td>
<td>-0.084</td>
<td>-0.111</td>
<td>-0.120</td>
<td>-0.161</td>
<td>-0.221</td>
</tr>
<tr>
<td></td>
<td>Panel D: Return Exposures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta_{FX}$</td>
<td>1.178</td>
<td>0.809</td>
<td>0.645</td>
<td>0.529</td>
<td>0.390</td>
<td>0.178</td>
</tr>
<tr>
<td>$\beta_s$</td>
<td>1.400</td>
<td>1.166</td>
<td>1.024</td>
<td>0.906</td>
<td>0.810</td>
<td>0.695</td>
</tr>
<tr>
<td>$\beta_{FX,s}$</td>
<td>0.865</td>
<td>0.666</td>
<td>0.581</td>
<td>0.522</td>
<td>0.452</td>
<td>0.302</td>
</tr>
<tr>
<td>$\beta_{FX,b}$</td>
<td>0.581</td>
<td>0.445</td>
<td>0.386</td>
<td>0.346</td>
<td>0.299</td>
<td>0.199</td>
</tr>
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</table>
Appendix E  Additional Empirical Results

E.1 Consumption, Net Export, and Output

Table E.1 shows the correlation between growth rates of nondurable good and service consumption \( c \), net export \( nx \), and the sum of the two, \( y \).

Table E.1: Correlation of Consumption, Net Export, and Output

<table>
<thead>
<tr>
<th></th>
<th>( corr(c, y) )</th>
<th>( corr(c, nx) )</th>
<th>( corr(nx, y) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>0.95</td>
<td>-0.29</td>
<td>0.26</td>
</tr>
<tr>
<td>Canada</td>
<td>0.43</td>
<td>-0.24</td>
<td>0.77</td>
</tr>
<tr>
<td>France</td>
<td>0.68</td>
<td>-0.18</td>
<td>0.59</td>
</tr>
<tr>
<td>Germany</td>
<td>0.63</td>
<td>-0.15</td>
<td>0.67</td>
</tr>
<tr>
<td>Italy</td>
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<td>-0.31</td>
<td>0.66</td>
</tr>
<tr>
<td>Japan</td>
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<td>0.54</td>
</tr>
<tr>
<td>UK</td>
<td>0.74</td>
<td>-0.08</td>
<td>0.61</td>
</tr>
<tr>
<td>Australia</td>
<td>0.42</td>
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<td>0.79</td>
</tr>
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<td>Belgium</td>
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<td>-0.24</td>
<td>0.94</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.72</td>
<td>-0.12</td>
<td>0.61</td>
</tr>
<tr>
<td>Netherlands</td>
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<td>-0.10</td>
<td>0.77</td>
</tr>
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<td>New Zealand</td>
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<td>0.75</td>
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<tr>
<td>Portugal</td>
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<tr>
<td>Spain</td>
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<td>-0.74</td>
<td>0.36</td>
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<tr>
<td>Sweden</td>
<td>0.49</td>
<td>-0.11</td>
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<tr>
<td>Switzerland</td>
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<td>G7</td>
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<td>-0.18</td>
<td>0.59</td>
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<td>G10</td>
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<tr>
<td>Mean</td>
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</tbody>
</table>

Note: This table shows the correlations of consumption, output, and net export growth rate for 17 countries, as well as the average of the correlations for G7, G10, and G17. Consumption only consists of nondurable goods and services, and output is equal to the consumption of nondurable goods and services plus net exports. Data span 1970 to 2014 at quarterly frequency.

E.2 Panel Regressions with Emerging Economies

Table E.2 in this subsection shows the results analogous to Table 4 with 44 countries including emerging economies of Bulgaria, Chile, Czech Republic, Egypt, Hong Kong, Hungary, India, Indonesia, Israel, Malaysia, Mexico, Philippines, Poland, Russia, Saudi Arabia, Singapore, Slovakia, South Africa, Taiwan, Thailand, Turkey, and Ukraine.
Table E.2: Bank capital ratio, forward discount, and currency return with emerging economies

<table>
<thead>
<tr>
<th></th>
<th>Forward discount</th>
<th>Currency return</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Capital ratio</td>
<td>0.385**</td>
<td>0.330**</td>
</tr>
<tr>
<td></td>
<td>(0.033)</td>
<td>(0.057)</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.534**</td>
<td>0.541**</td>
</tr>
<tr>
<td></td>
<td>(0.065)</td>
<td>(0.031)</td>
</tr>
<tr>
<td>GDP</td>
<td>-0.388*</td>
<td>-0.323**</td>
</tr>
<tr>
<td></td>
<td>(0.235)</td>
<td>(0.032)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.079</td>
<td>0.428</td>
</tr>
</tbody>
</table>

Note: Fama-Macbeth regression results of forward discount (left panel) and currency return (right panel) on bank capital ratio (the inverse of leverage, in percentage). In both panels, column (1) report the univariate regression coefficients. Column (2) controls for inflation, column (3) controls for the log GDP (size) of each country, and column (4) controls both inflation and log GDP. Data are monthly including 44 countries, from Jan 1990 to Dec 2016. Both advanced economies and emerging economies are included. Annual measures of bank capital ratio and GDP share are used repetitively for months within a year. Standard errors are Newey-West adjusted with 120 lags. ** indicates statistical significance at 5% level. * indicates statistical significance at 10% level.

### E.3 Average Stock Return as a Risk Factor

Figure E.1 and Table E.3 in this section show results analogous to Figure 6 and Table 9, while replacing the average bank stock returns with average country MSCI indices in the cross section. The results are similar to using average bank stock returns.
Figure E.1: Currency Beta on Global Stock Returns and Average Forward Discount

Note: This figure plots the relationship of a country's average forward discount (the upper panel) and average bank capital ratio (the lower panel) with exchange rate beta with respect to average stock return (the upper panel) for G10 currencies (vis-a-vis dollar). Data range from November 1983 to December 2016. Euro exchange rate is used for "DEM" after 1999.
Table E.3: Average Stock Return as the Pricing Factor

<table>
<thead>
<tr>
<th>Portfolio</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average return</td>
<td>0.780</td>
<td>0.927</td>
<td>2.877</td>
</tr>
</tbody>
</table>

Panel A: Risk Factor Exposure

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>-1.014</td>
<td>-1.570</td>
<td>-0.391</td>
</tr>
<tr>
<td></td>
<td>(1.521)</td>
<td>(1.383)</td>
<td>(1.418)</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.184**</td>
<td>0.257**</td>
<td>0.336**</td>
</tr>
<tr>
<td></td>
<td>(0.026)</td>
<td>(0.024)</td>
<td>(0.024)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.114</td>
<td>0.231</td>
<td>0.329</td>
</tr>
<tr>
<td>Obs</td>
<td>398</td>
<td>398</td>
<td>398</td>
</tr>
</tbody>
</table>

Panel B: Price of Risk

<table>
<thead>
<tr>
<th></th>
<th>Fama-MacBeth</th>
<th>GMM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14.019**</td>
<td>8.018</td>
</tr>
<tr>
<td></td>
<td>(6.499)</td>
<td>(5.053)</td>
</tr>
</tbody>
</table>

Note: The top row reports the average return to the three currency portfolios sorted on unconditional average forward discount. Panel A shows the exposure to average stock returns across the three currency portfolios. Panel B reports the estimated price of risk using Fama-MacBeth and GMM methods. Hansen and Jagannathan (1997)'s scale-invariant weight matrix is used in GMM estimation. Standard errors are Newey-West adjusted with 120 lags. All estimates of price of risk are annualized. ** indicates statistical significance at 5% level. * indicates statistically significance at 10% level.