ESSAYS ON RISK PREMIA IN EMERGING MARKET CURRENCIES

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by

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Abstract

Emerging Market (EM) currencies have positive risk premia against the U.S. dollar. Although this fact has been well documented, current international economics literature does not provide adequate explanations of why these risk premia exist. This dissertation offers a theoretical model of currency risk premia, and reports empirical evidences to account for the stylized fact. In this dissertation, foreign exchange rate is viewed as an asset price, and currency risk premium is derived from a multi-country consumption-based asset-pricing framework. There are two main ideas. Firstly, long-run consumption growth risk is one component in EM currency risk premia; and asymmetric consumption growth risk between the US and EM countries determines the sign and magnitude of currency risk premia. Compared with the US, EM countries that have higher long-run consumption growth risk but lower long-run risk persistence often have substantial positive currency risk premia.

Secondly, macroeconomic models should treat EM and G10 currencies differently because the two groups of currencies face different risk profiles. Compared to G10 currencies, EM currencies are exposed more to Global Risk Factor. Additionally, short-term interest rate differential relative to the US is an important common risk factor for EM currencies, but not for G10 currencies.

The aim of this dissertation is to establish the validity of the two ideas mentioned above. This is the first study showing that a multi-country theoretical model of long-run consumption growth risk can be used to explain for risk premia in EM currencies. There are three main chapters. The first chapter provides empirical backgrounds and a literature survey on currency risk premia. The second chapter focuses on the first idea and shows that a model of long-run consumption growth risk can account for the risk premia in EM currencies. The third chapter focuses the second idea and reports new empirical evidences that G10 and EM currencies do not have common risk factors.

Dedication

To my beloved daughter – Vũ Minh Nhật

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Chapter 1: What Accounts for Currency Risk Premia? A Question Remains Unresolved

1.1. Introduction

My dissertation offers answers to a question: What accounts for positive risk premia in Emerging Market (EM) currencies? It contains three main chapters. The purpose of this first chapter is to provide empirical backgrounds and a literature survey that motivates my research project.

Arguments for the existence of risk premia in the foreign exchange market are associated with the rejection of the Uncovered Interest Parity (UIP) condition, and with a stylized fact that a forward exchange rate is a biased predictor of future spot exchange rate. According to the UIP condition, under the assumption of risk neutrality and rational expectation, when foreign interest rate is higher than the US's interest rate, foreign currency is expected to depreciate against the U.S. dollar by the same amount of interest rate differential. However, since an empirical work by Fama (1984), many empirical studies that replicate the Fama (1984)'s regression continue to reject the UIP condition, and reveal that high-interest-rate currencies tend to appreciate rather than depreciate as the UIP condition predicts. These results imply that an US investor can earn positive excess returns, on average, by buying a foreign currency in a forward contract and selling it in the spot market at maturity. These returns reflect currency risk premia. Researchers often refer the Fama (1984)'s empirical work as "Fama Regression" and the phenomenon as "Forward Premium Puzzle".

Conducting the Fama regression with an updated sample from January 2003 to December 2017 for 32 currencies, of which 10 currencies are considered as major currencies and 22 currencies are considered as EM currencies[1], I find empirical evidences of the UIP deviations mainly in EM currencies. A hypothesis test of the UIP condition is rejected in 10 out of 22 EM currencies. Additionally, 17 out of 22 EM currencies have the estimate of slope coefficient below 1, in which some EM currencies, such as the South African Rand (ZAR), have statistically significant and negative slope coefficient estimate.

Although the existence of currency risk premium is a natural explanation for the UIP deviations, the Fama Regression and many empirical studies themselves are not sufficient to provide insights into what economic reasons behind the risk premia. Economists seek for different economic models, but modelling currency risk premia is a challenge. To account for currency risk premia, those models require extreme restrictions on model parameters; and the link between macroeconomic fundamentals and currency risk premia continues to be questionable. More recently, asset-pricing models in Finance have gained significant developments toward resolving the (international) equity premium puzzles. Models of long-run risk or disaster risk start to become standard models in Finance. However, no study has successfully applied these asset-pricing models to account for the risk premia in the foreign exchange market. My attempt is to contribute to close this gap in the literature.

This chapter is organized into four main sections. After this first section of introduction, the second section provides details of the Fama Regression and reports

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[1] A list of 32 currencies is provided in Appendix 1A. To save space, throughout this dissertation, only currency notations are used. As a convention in the foreign exchange market, currency notation is often in the form of three-letter code. For example, JPY refers to the Japanese Yen, CHF refers to the Swiss Franc. Currency notations used in my research are similar to ones in Bloomberg Professional Terminal. Major currencies refer to ten most important currencies in the foreign exchange market, referred as G10 currencies throughout this dissertation.

estimation results for 32 currencies. The third section contains a literature survey. The last section presents the motivation of my research project.

1.2. Fama Regression Test

1.2.1. Covered and Uncovered Interest Parity Condition

Covered Interest Parity (CIP): The CIP condition is expressed as

$$1 + i_{t+1} = (1 + i^*_{t+1})\frac{S_t}{F_t}. \tag{1. 1}$$

Taking log of both sides[2] yields

$$f_t - s_t = i^*_t - i_t \,, \tag{1. 2}$$

in which s_t and f_t denote the natural logarithms of the nominal bilateral spot exchange rate (S_t) and forward exchange rate (F_t), respectively (in units of foreign currency per one domestic currency). $(f_t - s_t)$ is a forward premium. i_t and i^*_t denote nominal risk-free rate for domestic and foreign currency deposits, respectively.

The CIP condition implies that it is not possible for investors to exploit profitable market arbitrage opportunities by borrowing a domestic currency at a risk-free interest rate, converting the borrowed funds into a foreign currency, investing the funds at a risk-free rate in the foreign country, and locking in a forward contract to guarantee the rate of exchange back to the domestic currency.

Uncovered Interest Parity (UIP): The UIP condition is expressed as

$$E_t(s_{t+1}) - s_t = i^*_t - i_t, \tag{1. 3}$$

in which $E_t(.)$ is the rational expectations operator conditional on information set at time t. s_{t+1} and s_t are the natural logarithms of the nominal bilateral future spot exchange rates (S_{t+1}) and spot exchange rates (S_t), respectively. The UIP condition states that the expected change in the exchange rates should be equal to the risk-free interest rate differential. Accordingly, when the foreign interest rate is higher than the US's interest rate, risk-neutral and rational US investors should expect the foreign currency to depreciate against the dollar by the difference between the two interest rates. Thus, borrowing at home and lending abroad, or vice versa, would produce a zero return in excess of the US short-term interest rate.

From the CIP condition, given the assumption of risk neutrality and the assumption of rational expectation, the UIP condition can be derived as

$$E_t(s_{t+1}) = f_t \, . \tag{1. 4}$$

The relation implies that the forward foreign exchange rate should be equal to the future expected value of the spot exchange rate. If this condition does not hold, FX investors can earn positive profits by speculating currencies in a forward foreign exchange contract. In fact, deviations from the UIP condition are persistent in data.

1.2.2. Fama Regression Test

One way to test the UIP condition is to do a regression $s_{t+1} = \beta_0 + \beta_1 f_t + \varepsilon_{t+1}$. However, the regression will not provide a valid coefficient estimate because these two series are more likely not stationary. Fama (1984) suggested a different regression (hereafter referred as Fama regression), in which the empirical specification was written in terms of the forward premium ($f_t - s_t$).

$$s30_t - s_t = \beta_0 + \beta_1(f_t - s_t) + \varepsilon_t, \tag{1. 5}$$

---

[2] One advantage of the log specification is that it is independent of which country's currency is selected as a base currency.

in which $\mathrm{s30_t}$ is the spot exchange rate at time t+30 days. In the Fama regression, both series $(s30_t - s_t)$ and $(f_t - s_t)$ are stationary process. Under the market efficiency null hypothesis, $\beta_0 = 0$ and $\beta_1 = 1$, if the forward rate contains all information available at time t, then ε_t should be serially uncorrelated (See Hayashi (2000), Chapter 6 for detail discussions).

Empirical regularities find that forward rates are biased predictor of future spot exchange rates, in which empirical tests not only reject the null hypothesis but also find negative point estimates of β_1 coefficient. These results are so common that they are often referred as “Forward Bias”, or “Forward Premium Puzzle”, or “Forward Premium Anomaly”. It is a puzzle result because realized exchange rates tend to move in an opposite direction to one predicted by the forward premium. In other words, expected dollar depreciation is associated with actual dollar appreciation or higher-interest-rate currencies actually appreciate rather than depreciate as the UIP predicts, implying that investors can gain positive excess returns by trading currencies in forward contracts.

1.2.3. Estimation Results

This section reports estimation results of the Fama regression with an updated sample from January 2003 to December 2017.

Data:

Foreign exchange rates used in this chapter include spot exchange rates, one-month forward rates from Thomson Reuters Datastream for Office. All rates are daily closing mid rates against the U.S. dollar. Of 32 currencies, there are 22 EM currencies and 10 major currencies (hereafter referred as G10 currencies). Foreign exchange rates used for regression tests are the rates in the last business day of the month which are extracted from daily data series. Dates and value of future spot rates are realigned in order to minimize data misalignment between future spot rates ($S30_t$) and forward rates (F_t). For example, the maturity date for a one-month forward contract at time t is the date t+30. Suppose that agents sign the contract on October 1, 2015, so the maturity date will be on November 1, 2015 which is on Sunday. Because there will be no data available for spot rates on Sunday, the spot rate on the nearest working day, which is on Monday November 2, 2015, will be used as future spot rate ($S30_t$).

Estimation Results:

Rejection of the UIP Condition and Negative Point Estimate of β_1 in EM Currencies:

[Table 1.1 is about here]

Table 1.1 reports estimation results of the Fama Regression for both EM and G10 currencies. There are statistical evidences against the UIP condition. A null hypothesis test of the UIP condition (H_0: $\beta_0 = 0, \beta_1 = 1$) is rejected in 10 out of 22 EM currencies, while, for G10 currencies, the null hypothesis is rejected in only the New Zealand Dollar (NZD). Additionally, the point estimate of β_1 statistically significant less than 1 implies a statistical evidence of a positive average excess return or the existence of a positive risk premium. A substantial negative point estimate of β_1 suggests a sizable positive risk premium. In my estimation, four G10 currencies have negative point estimate of β_1, while 7 out of 22 EM currencies have this characteristic. Among 22 EM currencies, 10 currencies have the point estimate of β_1 between zero and one. Two currencies including the South Korean Won (KRW) and the South African Rand (ZAR) have substantial negative point estimate of β_1.

The Forward Premium Puzzle no longer exists in G10 currencies:

[Table 1.2 is about here]

Table 1.2 compares my estimates of the coefficient β_1 in G10 currencies with those in the existing literature. Empirical regularities have confirmed substantial negative point estimate of coefficient β_1 in G10 currencies. This phenomenon is well known as the forward premium puzzle, in which high-interest-rate currencies tend to appreciate rather than depreciate as the UIP condition predicts (see also the next section for a literature survey). However, different from the empirical regularities, my estimation of the Fama Regression over a period from January 2003 to December 2017 shows that the forward premium puzzle no longer exists in G10 currencies. While Lewis (1995), Frankel and Poonawala (2010), and Burnside (2014) reported that the point estimates of β_1 are negative for all of G10 currencies from 1975-2013, my estimation for a sample from 2003-2017 shows that only 4 currencies including the Canadian Dollar (CAD), the Danish Krone (DKK), the UK Pound (GBP), and the Euro (EUR) have negative point estimates of β_1. More importantly, in my estimation, the point estimates of β_1 for these four currencies are negative yet very close to zero, which is very different from previous studies. For example, the point estimate of β_1 for the EUR in my estimation is -0.047, while it was -1.98 in Burnside (2014) and -5.602 in Frankel and Poonawala (2010). Some G10 currencies such as the New Zealand Dollar (NZD), the Norwegian Krone (NOK), the Japanese Yen (JPY) and the Swiss Franc (CHF) have point estimate of β_1 larger than one in my estimation. However, Burnside (2014) and Frankel and Poonawala (2010) reported substantial negative point estimates of β_1 for those currencies.

Impacts of the Global Financial Crisis on the Estimate of the Fama Regression:

[Table 1.3 and Table 1.4 are about here]

Table 1.3 reports the estimate of Fama Regression for all currencies when the sample period exclude months pertaining to the Global Financial Crisis (GFC) from August 2008 to September 2009. Table 1.4 compares changes in the estimates of β_1 between the two samples which include and exclude the GFC months. Overall, there are two prominent differences. Firstly, for G10 currencies, removing months pertaining to the GFC makes the point estimates of β_1 for all G10 currencies turn out to be positive. For example, the point estimate of β_1 for the Canadian Dollar (CAD) changes from -0.453 in the sample including the GFC to 2.546 in the sample excluding the GFC. Secondly, for EM currencies, except the South African Rand (ZAR), the Mexican Peso (MXN), and the Singaporean Dollar (SGD), other currencies only have slightly changes in their point estimates of β_1. For example, the point estimate of β_1 for the Philippine Peso (PHP) slightly changes from -0.596 in the sample including the GFC to -0.334 in the sample excluding the GFC. Different from G10 currencies, the point estimates of β_1 for EM currencies do not change the sign between the two samples.

1.3. Literature Survey and Research Ideas

1.3.1. Rejections of the UIP Condition and the Forward Premium Puzzle

For 30 years, empirical regularities have replicated the Fama regression for different groups of currencies, with different samples, and with various econometric methodologies. A search with a keyword “UIP and Forward Premium Puzzle” in Scopus database shows more than 300 published papers containing either “forward premium” or “Uncovered Interest Parity” in their abstract and titles. Several studies confirm the forward premium puzzle. The estimate that the coefficient β_1 in the Fama Regression is significantly less than one is a common finding, especially for G10 currencies. For example, a recent empirical work by Burnside (2014) estimate 18 advanced currencies and 26 EM currencies. He reports that while 12 out 18 advanced currencies have large negative estimate of β_1, most EM currencies have the estimate of β_1 just below or close to one. For older literature on the forward premium puzzle, Lewis (1995) and Engel (1996) provide comprehensive surveys. More recently, Sarno and Taylor (2002) (Chapter 2), Sarno (2005), Evans (2012) (Chapter 1,2,3, and 11), and Engel (2014) conduct a survey on updated contributions to this literature.

For EM currencies, Bansal and Dahlquist (2000) and Frankel and Poonawala (2010) also document that the forward premium on EM currencies predicts their future depreciation rates in a maner that is consistent with the UIP condition. Bansal and Dahlquist (2000) conduct regression test for 28 developed and emerging economies using an unbalanced panel of weekly data from 1976–1998. They report that the forward premium puzzle is confined to developed currencies. They find that the coefficient β_1 increases towards one when countries characterized with lower per capita income, lower credit rating, higher average inflation and higher inflation volatility. Frankel and Poonawala (2010) conduct the regression test of the forward premium puzzle for a set of 21 developed and EM economies from December 1996 to April 2004. Both country-level regression and seemingly unrelated regression results indicate that the forward premium bias is less severe in EMs.

1.3.2. Currency Risk Premium

One direct explanation for the rejection of the UIP condition and the forward premium puzzle is the existence of a currency risk premium. If foreign exchange market participants are risk averse, the UIP condition may be distorted by a risk premium because investors demand a higher rate of return than the interest differential as a compensation for the risk of holding foreign currency. As a result, the ordinary least squares (OLS) estimation in the Fama regression can be invalid and common tests of the UIP condition become non-informative in the presence of the omitted risk premium in the regression.

A related question is how to specify and measure the risk premium in the foreign exchange market in connection with the forward premium puzzle. There are two possible ways to define the currency risk premium. The first way is to consider risk premium approximately equal to unconditional expectation of currency excess returns.

$$rp = E[E_t(er_{t+1})] = E(er_{t+1}), \tag{1. 6}$$

in which the currency excess return is defined as $er_{t+1} = f_t - s_{t+1}$ (the last equality holds because of law of iterated expectation). The currency risk premium calculated in the preceding formula is actually the mean of difference between forward rates and ex-post realized spot rates (given assumption of rational expectation). This definition of currency risk premium has been adopted in several recent studies. The core idea is that deviations from the UIP condition and the forward premium puzzle imply that investors can earn a positive average excess return if they borrow in low-interest rate currencies and lend to higher interest rate currencies and that excess returns are compensations for investors taking on risks. Gilmore and Hayashi (2011); Lustig, Roussanov, and Verdelhan (2011); Menkhoff, Sarno, Schmeling, and Schrimpf (2012a); Burnside (2014); Corte, Riddiough, and Sarno (2016); and Verdelhan (2018) are among those who contribute to this growing literature. Lustig et al. (2011) and Verdelhan (2018) calculate average excess returns of currency portfolios sorted by interest rates and report empirical evidences that excess returns from the foreign exchange market can be regarded as a reward for exposure to common risk factors. Carefully taking into account features of the foreign exchange market, Gilmore and Hayashi (2011) confirm that emerging market currencies have substantial positive risk premia. Menkhoff et al. (2012a) and Della Corte, Ramadorai, and Sarno (2016) also follow the currency-sorting approach and provide empirical evidences of correlation among foreign exchange rate volatilities, global imbalances, and currency risk premia.

The second way to define currency risk premium is to consider time series properties of spot exchange rates and the currency risk premium is a conditional mean of currency excess returns.

$$rp_t = E_t(f_t - s_{t+1}) = f_t - E_t(s_{t+1}) = (f_t - s_t) - E_t \Delta s_{t+1}, \qquad (1.7)$$

in which the excess return (er_{t+1}) is defined as $er_{t+1} = f_t - s_{t+1}$. Additionally, the excess return can be rewritten as $er_{t+1} = f_t - s_{t+1} = f_t - E_t(s_{t+1}) + E_t(s_{t+1}) - s_{t+1} = rp_t + (E_t s_{t+1} - s_{t+1})$. In other words, a currency excess return comprises a (conditional) currency risk premium (or predictable excess return) and a statistical forecast error. According to this definition of currency risk premium, under rational expectations, if f_t is equal to $E_t(s_{t+1})$, expected profits from forward market speculation is zero. If $f_t > E_t(s_{t+1})$, investors will pay a premium by buying the foreign currency forward at time t relative to its expected price on the spot market at time t+1. Regarding this definition of currency risk premium, Fama (1984) offered some insights into the relation between the currency risk premium and the sign of coefficient β_1. According to his decomposition (See Appendix 1.B for the derivation), a condition for the point estimate of β_1 to be smaller than $\frac{1}{2}$ is that the variance of expected rate of depreciation has to be smaller than the variance of currency risk premium. In other words, the currency risk premium must be more volatile than changes in future expected exchange rates. This condition provides a basis for a general equilibrium model of risk premia. Basing the condition, Sarno and Taylor (2002) (Chapter 2) review a two-country general model introduced by Lucas Jr (1982). Their derivations show that the model can explain for the risk premia in the foreign exchange market only if the coefficient of risk aversion is extremely high, or if there is a high correlation between consumption and foreign exchange rates. The two requirements create challenges for economic models of risk. However, recent developments in risk-based modelling in Macro-Finance provide potential resolutions for economic models of currency risk premia (See Cochrane (2005) and Cochrane (2017) for more discussions on developments in asset-pricing and macro-finance).

1.3.3. Risk-based Modelling and Currency Risk Premia

Some currencies have higher risk premium than others. These risk premia may reflect aggregate macroeconomic risks and the tendency of currencies to depreciate dramatically in bad times. A relevant question is what the nature of macroeconomic risk that drives risk premia in the foreign exchange market is. Empirical tests on currency risk premia are insufficient to answer this question and applying asset-pricing models in Finance into the foreign exchange rate market can provide answers.

In finance, risk-based approaches of asset returns begin from an idea that there is a Stochastic Discount Factor (SDF) that prices these returns. If the foreign exchange rate is viewed as an asset price, standard asset-pricing conditions in finance can be applied to explain currency risk premia. The asset-pricing condition is

$$\mathrm{p}_{\mathrm{t}}^{\mathrm{i}} = E_t(m_{t+1}x_{t+1}^i),$$
$$E_t\left(m_{t+1}\frac{x_{t+1}^i}{p_t^i}\right) = E_t(m_{t+1}R_{t+1}^i) = 1. \qquad (1.\,8)$$

in which $\mathrm{x}_{\mathrm{t+1}}^{\mathrm{i}}$ is a random payoff of a specific asset i, p_t^i is the price of asset i, and $\mathrm{m}_{\mathrm{t+1}}$ is stochastic discount factor. The condition implies that asset prices are determined by discounting future payoffs. If investors are risk-averse, they discount future payoffs not only because of the time value of money but also because of risks. The stochastic discount factor contains both discounts. With an excess return is defined as $R_{t+1}^{ex} = R_{t+1}^i - R_{t+1}^j$, the equation also implies that $E_t(m_{t+1}[R_{t+1}^i - R_{t+1}^j]) = E_t(m_{t+1}R_{t+1}^{ex}) = 0.$ Thus, the stochastic discount factor is orthogonal to excess returns. This condition holds for any portfolios as well as assets.

Applied to currency excess return in which investors taking short position in one currency and long position in another currency, using the definition of covariance and $1 = \mathrm{E}_{\mathrm{t}}(m_{t+1})R_t^f$ for a real risk-free rate, the condition can be rewritten as $\mathrm{E}_{\mathrm{t}}(R_{t+1}^{ex}) = -Cov_t(m_{t+1}, R_{t+1}^{ex},)$, implying that the expected excess return or risk premium is higher for currencies that have a large negative covariance with the stochastic discount factor. The condition suggests that more volatile currencies do not necessarily generate higher risk premium. In other words, the variance of the excess return does not measure risk or generate a risk premium. Covariance between the stochastic discount factor and the currency excess return is important.

Furthermore, the asset-pricing condition discussed above characterizes an equilibrium which describes a market after agents maximize their utility and optimize their portfolios. It is an equilibrium in which the return on an asset and its price are balanced. The equilibrium does not suggest that currencies with high predictable excess return are “good” currencies and investors should hold these currencies. “Good” currencies such as Japanese Yen (JPY) or Swiss Franc (CHF) are actually the one that do not depreciate much in bad times when investors want more wealth. Since investors tend to hold these currencies as a funding currency, those currencies should have lower average excess returns or lower risk premium in equilibrium.

The next question is what are fundamentals and economic determinants of the stochastic discount factor. In a consumption-based model, the stochastic discount factor $\mathrm{m}_{\mathrm{t+1}}$ can be expressed as intertemporal marginal rate of substitution

$$\mathrm{m}_{\mathrm{t+1}} = \frac{U'(C_{t+1})}{U'(C_t)}, \tag{1. 9}$$

in which $\mathrm{U}'(C)$ denotes marginal utility (at time t and t+1). The discount factor $\mathrm{m}_{\mathrm{t+1}}$ is high at time t+1 if investors want more utility at t+1 and would be willing to give up a lot of utility at time t. Thus, the risk premium is driven by the covariance between returns and the marginal utility of consumption. For the foreign exchange market, Lustig and Verdelhan (2007, 2011) provide empirical evidences to support this idea. They argue that aggregate consumption growth in the US is key to understanding the currency risk premia. In particular, they document that, on average, high interest currencies depreciate when consumption growth in the US is low, and US investors are compensated for taking on their own consumption risk. Lustig, Roussanov, Verdelhan (2011) also suggest two conditions needed for the stochastic discount factor (SDF) to match currency portfolio returns. Firstly, the SDF needs to have a large common or global component because this is the only source of cross-sectional variation in currency risk premium. Secondly, the SDF needs to have sufficient heterogeneity in exposure to the common component. Currencies with currently (on average) lower interest rates need to be temporarily more exposed to the common component. Currency risk premium are determined by a home risk premium that compensates for home country risk and a carry trade risk premium that compensates for global or common risk. However, Burnside (2011) discuss that basing on consumption growth in the US alone cannot explain currency risk premia and he casts doubt on the risk-based approach to account for the existence of risk premium in the currency market.

In general, economists and researchers have not reached an agreement on modelling the currency risk premium. I have not found a theoretical paper that successfully reproduces and accounts for the risk premia in the currency market. From asset-pricing perspective, the key lies on modelling the stochastic discount factor and its drivers. There are three ways to modify the model including modifying endowment process, modifying utility function, and modifying market structure.

An idea is to modify endowment process by adding disaster risks. This type of model shows its potential in applying into the foreign exchange market because it is related to a characteristic that some currencies can depreciate sharply when there is a rare yet disastrous economic shock hitting the economies (Gourio (2012); Farhi and Gabaix (2015)). Another option is to modify utility function by using a habit-based model (Campbell & Cochrane, 1999; Verdelhan, 2010). The basic idea of this model is that if there is a recession at home country that causes domestic consumption close to some threshold, or habit level, domestic investors become more risk aversion than foreign counterpart. A risk premium then reflects a close relation between foreign exchange rate and domestic consumption shocks.

Another idea that appears to be more attractive is arguments for the existence of a long-run risk component. As be shown in more details in Chapter 2, the long-run risk model (Bansal and Yaron, 2004) both modifies utility function and modifies endowment process of consumption growth, by using Epstein and Zin preference, which is non-separable across state of nature, and by allowing a persistent long-run risk component in consumption growth. In the Epstein and Zin preference, if the risk aversion coefficient is different from intertemporal substitution, expected returns depend on covariance of returns with news about the investor's utility future prospect, as well as on covariance of returns with consumption growth. News about future consumption as well as current consumption are components in the discount factor. Shocks to variables that predict future consumption growth will appear as additional risk factors even with current consumption growth.

1.4. Conclusions and Remarks

This chapter first reports estimation results of the Fama regression with an updated sample from January 2003 to December 2017 for 32 currencies, then provides a literature survey on currency risk premia, and explains major motivations behind my Ph.D. research project. Overall, there are statistical evidences of deviations from the UIP condition mainly in EM currencies. The existence of a risk premium is one direct explanation for the rejection of the UIP condition. A survey on literature shows that there are hundreds of empirical studies on the topic of currency risk premia. However, there are little research attention on EM currencies, and theoretical models have not successfully accounted for the currency risk premia yet. This dissertation will contribute to close the gap in the literature. The second chapter provides a theoretical model of long-run consumption risk, and suggests that this model can potentially account for the risk premia in EM currencies. The third chapter focuses on risk profiles of G10 and EM currencies from a practical perspective, and provides an empirical argument that future economic model of currency risk premium should treat G10 and EM currencies very differently.

Chapter 2: Long-run Consumption Risk and Emerging Market Currency Risk Premia

2.1. Introduction

This chapter provides empirical evidences of positive risk premia in EM currencies and shows that these risk premia can be explained by risk components of consumption growth in a multi-country asset pricing framework. Specifically, long-run consumption growth risk is one component in EM currency risk premia, and asymmetric consumption growth risk between the US and EM countries determines the sign and magnitude of currency risk premia. A version of calibrated model produces an implied risk premium of 1.01 percent in a portfolio of EM currencies, and the implied risk premium can account for a fair proportion of the risk premium calculated from actual data.

Regarding the empirical evidences, currency risk premium is defined as the mean of currency excess returns when US investors buy an EM currency via one-month forward contract and sell the currency in the spot market at maturity. A portfolio of EM currencies generally has positive and higher risk premia than that of G10 currencies. Additionally, the risk premium in a portfolio of EM currencies is statistically significant, even though the risk premium in a pair of one EM currency against the U.S. dollar may or may not be so. In a sample from January 2003 to December 2017, a portfolio of EM currencies has an inflation-adjusted risk premium of 3.54 percent with the annualized volatility of 6.93 percent. The t-value for EM currencies portfolio risk premium is 1.99, which is statistically significant at 5 percent.

Regarding the theoretical model, my model is an extension of the long-run risk model introduced by Bansal and Yaron (2004) and R. Colacito and Croce (2011). In their one-country setting, Bansal and Yaron (2004) show that long-run consumption growth risk is an additional state variable in asset price moments, and their model offers a solution to resolve equity premium puzzles. I make a departure from a two-country model introduced by Colacito and Croce (2011) by developing a multi-country model, and by allowing asymmetric parameters on the volatility and the persistence of short-run and long-run risk component of consumption growth between the US and EM countries. For each country pair, the currency risk premium is the mean difference in variance of stochastic discount factor between two countries. Accordingly, currency risk premium exists not only because of short-run risk component, but also because of long-run risk component and the persistence of long-run risk. Suppose that the US and EM countries receive the same long-run risk shock, and suppose that the long-run consumption growth risk in EM countries is higher than that of the US, the currency risk premium is positive from perspective of US investors, if the short-run consumption growth risk and the persistence of long-run risk component in the US are sufficiently higher than those of EM countries. Additionally, the model implies that the more US investors intend to resolve the uncertainty earlier, the higher the risk premium is. The magnitude of risk aversion coefficient, hence, also plays an important role in explaining for EM currencies risk premia.

Regarding parameter calibrations, the risk aversion coefficient is selected to be 10 and the inter-temporal elasticity of substitution is selected to be 1.5 for all countries, which are similar to parameter calibrations commonly found in the international economics literature. A robustness-check also shows that the risk aversion coefficient at 10 is the optimal value for the calibrated model. For parameters of the persistence and the volatility of long-run consumption growth, I use state-space methodology with annual consumption growths interpolated to monthly frequency. There are two noticeable points. Firstly, the short-run consumption growth risk and the persistence of long-run risk component in the US are higher than that of EM countries. Secondly, many EM countries have high long-run consumption growth risk but low persistence of long-run risk component.

The calibrated model shows that EM currencies such as the Argentinian Peso (ARS), the Hungarian Forint (HUF), and the Philippine Peso (PHP), which have high long-run consumption growth risk, but low long-run risk persistence relative to the US, often have sizable positive currency risk premium. The currency risk premium implied by the model for a basket of EM currencies is 1.01 percent, accounting for a fair proportion of the actual risk premium calculated from actual data.

My work is the first study that reproduces a positive risk premium in EM currencies in a long-run risk asset-pricing framework. Two countries model by Colacito and Croce (2011) do not contain the currency risk premium as their model assumes identical endowment parameters between two economies. Recently, R. Colacito and Croce (2013) and Colacito, Croce, Gavazzoni, and Ready (2018) extend their two-country model to a multi-country model, but they focus more on G10 currencies and on the persistent component of output growth and capital flows.

The rest of the chapter is organized as follows. Section 2.2 reports empirical evidences of positive risk premia in EM currencies. Section 2.3 outlines the long-run risk model and highlights its key implications for the currency risk premium. Section 2.4 provides calibrations of model parameters and a robustness check. Section 2.5 includes conclusions and remarks.

2.2. Emerging Market Currency Risk Premia

An US investor who buys an EM currency via a one-month forward contract and sells the currency in the spot market after one month can receive an excess return. The log excess return is defined as

$$\mathrm{er}_{\mathrm{t+1}} = f_t - s_{t+1}, \tag{2. 1}$$

in which $\mathrm{s}_{\mathrm{t+1}}$ denotes the log of the spot exchange rate at time t+1, in units of foreign currency per home currency; and f_{t} denotes log of the one-month forward exchange rate at time t, also in units of foreign currency per home currency. The U.S. dollar is selected as the home currency and the base currency, so an increase in the foreign exchange rate means an appreciation of the U.S. dollar.

Currency risk premium is then defined as the mean of the excess returns,

$$\mathrm{rp} = \mathrm{E}(\mathrm{er}_{\mathrm{t+1}}). \tag{2. 2}$$

From the perspective of US investors, a positive risk premium implies that they receive a reward because they are exposure to certain risks. It also implies that US investors gain positive returns from forward market speculations because they buy at low price and sell at high price[3].

Data: Currency excess returns are calculated from monthly foreign exchange rates. The spot and forward foreign exchange rates are the closing mid rates in the last

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[3] If the currency risk premium is positive, US investors are selling currency that has a forward premium and buying currency that has a forward discount. This strategy is equivalent to the "carry trade" strategy in which investors borrow in low-yield currencies and invest in high-yield currencies. Some manipulations of the risk premium equation (2. 2) can illustrate the strategy. Currency risk premium is defined as mean of excess returns in which $\mathrm{rp} = E(f_t - s_{t+1}) = E(f_t - s_t - \Delta s_{t+1})$. In normal condition when the cover interest parity hold, the forward premium on foreign currency is equal to the interest rate differential such that $\mathrm{f}_{\mathrm{t}} - s_t = i_t^* - i_t$ in which i_t^* and i_t denote foreign and home nominal risk-free rates over the maturity of the contract, respectively. The CIP often holds at daily frequency. It then follows that the log

business day of the month, extracted from their daily data. Data source is Thomson Reuters Datastream for Office. The U.S. dollar is the base currency. The sample period is from January 2003 to December 2017. The sample contains 31 currencies, of which 21 currencies are EM currencies, the remaining are G10 currencies.

The main criterion for selecting EM currencies in my study is that those currencies need to have sufficient historical data on spot and forward foreign exchange rates, reflecting that they are accessible and can be traded by international investors. EM currencies notations are based on FXTF code in Bloomberg Terminal Professional. Although the Chinese Renminbi (CNY) was pegged to the U.S. dollar and was maintained in a narrow bound until July 20, 2005, this currency is included in the sample because its forward contracts were still accessible for investors.

EM Currencies Risk Premium:

[Table 2.1 is about here]

Table 2.1 reports the risk premium and its annualized volatility for each currency. The risk premium is an annualized mean of monthly currency excess returns and the annualized volatility is an annualized standard deviation of monthly currency excess returns. For annualized moments, I multiply the mean of monthly data by 12, and the standard deviation by $\sqrt{12}$. The risk premium for all EM currencies in the sample is computed as $\mathrm{rp} = \frac{1}{\mathrm{T}} \sum_{t=1}^{T} \left[\frac{\sum_{i=1}^{N} er_{t+1}^{i}}{N} \right]_{\mathrm{i}}$ in which T is sample period, and N is the total of currencies at time t, representing the average of monthly excess returns of a basket of EM currencies.

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currency excess return equal the interest rate differential less the rate of depreciation $\mathrm{er}_{t+1} = i_t^* - i_t - \Delta s_{t+1}$ and the currency risk premium becomes $\mathrm{rp} = E(i_t^* - i_t - \Delta s_{t+1})$.

Table 2.1 reports the existence of a positive risk premium in the majority of EM currencies. Over the time period from January 2003 to December 2017, a positive risk premium exists in 18 out of 21 EM currencies, of which the Indonesian Rupiah (IDR) has highest risk premium, while the Taiwanese Dollar (TWD) has a negative risk premium[4]. Without adjustment for inflation, the risk premium in a basket of EM currencies is 431 basis points with annualized volatility of 6.8 percent. The t-value for EM currencies portfolio risk premium is 2.46, which is statistically significant at 5 percent. With adjustment for inflation, the risk premium in a basket of EM currencies is 354 basis points with annualized volatility of 6.93, which is also significant at 5 percent.

[Table 2.2 is about here]

Impact of the Global Financial Crisis (GFC) on EM Currency Risk Premium: Table 2.2 reports currency risk premia for a sample period excluding months pertaining to the GFC from Aug.2008 to Sep. 2009. Overall, there is an increase in the EM currency risk premium both with and without adjustment for inflation. For example, adjusted for inflation, the currency risk premium in EM currency portfolio increases from 354 basis points in the sample including the GFC to 425 basis points in the sample excluding the GFC. Increases in the EM currency risk premium after removing the GFC are consistent with economic intuitions. As the risk premium is a reward for taking risk, the risk premium in EM currencies will be high during normal times in compensation for their adverse future movements during economic downturns.

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[4] These results are another confirmation of positive risk premia in EM currencies with an updated sample to December 2017. Burnside, Eichenbaum, and Rebelo (2007), and Gilmore and Hayashi (2011) report economic evidences on EM currencies risk premium. For example, using a propriety dataset on foreign exchange rates, and carefully taking into account features of the foreign exchange market in calculation of currency excess returns, Gilmore and Hayashi (2011) confirm statistical evidences of positive risk premia in EM currencies.

2.3. Long-run Risk Model

2.3.1. Model Specification

The model presented in this section is an extension of the model developed by R. Colacito and Croce (2011). In their paper, Colacito and Croce (2011) develop a consumption-based, two-country, long-run risk equilibrium model to explain for foreign exchange rate volatility. Following the standard one-country long-run risk model introduced by Bansal and Yaron (2004), Colacito and Croce (2011) assume that consumers have Epstein-Zin recursive utility, and that there is an identical, small, and predictable component in the endowment process of consumption growth in each country. As in Backus, Foresi, and Telmer (2001), the two countries are connected by an exchange rate, and the change in foreign exchange rate is equal to the difference of the log stochastic discount factor between two countries. The model of Colacito and Croce (2011) successfully accounts for the link between common long-run consumption growth risk and exchange rate volatility. My model is a N-country model, in which the US is a home country, and EMs are foreign countries. My model adopts the economy setup similar to Colacito and Croce (2011), and then makes a departure from their model by allowing asymmetric parameters on the volatility and the persistence of risk component in the endowment processes of consumption growth in each country pair between the US and one EM country. As a result, a currency risk premium exists because of asymmetric short-run and long-run consumption growth risks.

Preference: For each country pair, there are a home (h) and a foreign (f) country. The US is always selected as the home country, while EM countries are the foreign countries. Markets are assumed to be complete. Representative agents are assumed to consume only the good endowed to their country, implying a complete home bias[5]. In each country $\mathrm{i} = [\mathrm{US}, \mathrm{EMs}]$, a representative agent has a Epstein-Zin Recursive Utility.

$$\mathrm{U}_{\mathrm{t}}^{\mathrm{i}} = \left\{(1-\delta)\left(C_t^i\right)^{\frac{1-\gamma}{\theta}} + \delta E_t\left[\left(U_{t+1}^i\right)^{1-\gamma}\right]^{\frac{1}{\theta}}\right\}^{\frac{\theta}{1-\psi}}. \tag{2. 3}$$

The parameter δ is time discount factor. $\mathrm{C}_t^{\mathrm{i}}$ denotes consumption at time t. The parameter $\theta = \frac{1-\gamma}{1-\frac{1}{\psi}}$ is determined by the risk aversion coefficient $(\gamma > 0)$ and the inter-temporal elasticity of substitution (IES) $(\psi > 0)$.

Dynamics of the Economy: Similar to Bansal and Yaron (2004), the dynamics of consumption growth, $\Delta \mathrm{c}_{t+1}^{\mathrm{i}}$, and dividends growth, $\Delta \mathrm{d}_{t+1}^{\mathrm{i}}$, incorporate a small but persistent component, $\mathrm{x}_{\mathrm{t}}^{\mathrm{i}}$, that captures long-run risks, in which *i*=[*US,EMs*].

$$\begin{gathered}\Delta c_{t+1}^i = \mu_c^i + x_t^i + \lambda_c^i \eta_{t+1}^i \\ \Delta d_{t+1}^i = \mu_d + \phi x_t^i + \lambda_d^i u_{t+1}^i \\ x_{t+1}^i = \rho^i x_t^i + \lambda_e^i e_{c,t+1}^i \\ \eta_{t+1}^i, u_{t+1}^i, e_{c,t+1}^i \sim N\ i.i.d.(0,1).\end{gathered} \tag{2. 4}$$

All shocks are assumed to be i.i.d normal and are mutually independent to each other. The shocks are allowed to correlated only between the US and an EM country, in which τ_{e} denotes the correlation of long-run risk shocks between $\mathrm{e}_{c,t+1}^{\mathrm{US}}$ and $\mathrm{e}_{\mathrm{c,t+1}}^{j}$ (*j* denotes one EM country); and τ_{η} denotes the correlation of short-run shocks between $\eta_{\mathrm{t+1}}^{\mathrm{US}}$ and $\eta_{\mathrm{t+1}}^{\mathrm{j}}$ (*j* denotes one EM country). Shocks correlation among EM countries are assumed to be zero.

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[5] Complete Home Biasness is a rather strong assumption. In their recent papers (R. Colacito & Croce, 2013; Ready, Croce, Gavazzoni, & Colacito, 2016), the assumption of complete home bias is relaxed by allowing trade and integrated output growth between two economies. The aim of my study is to start with the simple version of their model in 2011, and examine how well the model can account for the risk premia in EM currencies.

In a country *i*=[*US,EMs*], the parameter, ρ^i, captures the persistence of long-run risk; λ_c^i captures the short-run consumption growth risk, and is assumed to be constant ($\lambda_c^i = \overline{\sigma_c^i}$); λ_e^i captures the long-run consumption growth risk; thus, λ_e^i/λ_c^i represents the ratio between long-run and short-run consumption growth risk, and the ratio is also constant. Different from Colacito and Croce (2011), in my setting, not only three innovations η_{t+1}^i, u_{t+1}^i, $e_{c,t+1}^i$, but also the three parameters ρ^i, λ_c^i, λ_e^i are not identical in each country pair between the US and one EM country.

Dividends have a levered exposure to the persistent component in consumption, x_t^i, which is captured by the parameter ϕ. Although an exogenous process for the dividend growth is necessary to complete the model, the dividends growth process plays a less important role in my study, because the currency risk premium, in the end, contains only parameters from consumption growth, Δc_{t+1}^i, and long-run risk process, x_{t+1}^i. Thus, in the next section, the dividend process is not mentioned, although it is still in the model.

Equilibrium Condition:

In country *i*=[*US,EMs*], the return on a claim to aggregate consumption, $R_{c,t+1}^i$, and the return on the market portfolio, $R_{d,t+1}^i$, satisfy asset-pricing condition:

$$\begin{aligned} E_t\left[M_{t+1}^i R_{c,t+1}^i\right] &= 1; \\ E_t\left[M_{t+1}^i R_{d,t+1}^i\right] &= 1. \end{aligned} \tag{2. 5}$$

The log of Stochastic Discount Factor in country *i* (m_{t+1}^i) represents the intertemporal marginal rate of substitution, which is expressed as:

$$m_{t+1}^i = \log\left(M_{t+1}^i\right) = \theta \log\delta - \frac{\theta}{\psi}\Delta c_{t+1}^i + (\theta - 1) r_{c,t+1}^i. \tag{2. 6}$$

The return on a claim to aggregate consumption, $\mathrm{R}^{\mathrm{i}}_{\mathrm{c,t+1}}$, and the return on the market portfolio, $\mathrm{R}^{\mathrm{i}}_{d,t+1}$, are expressed as[6]

$$\mathrm{R}^{\mathrm{i}}_{\mathrm{c,t+1}} = \frac{(v^{i}_{c,t+1}+1)\exp(\Delta c^{i}_{t+1})}{v^{i}_{c,t}};\ \mathrm{R}^{\mathrm{i}}_{\mathrm{d,t+1}} = \frac{\left(v^{i}_{d,t+1}+1\right)\exp(\Delta d^{i}_{t+1})}{v^{i}_{d,t}};$$
$$\mathrm{r}^{\mathrm{i}}_{\mathrm{c,t+1}} = \log\left(R^{i}_{c,t+1}\right);\ \mathrm{r}^{\mathrm{i}}_{\mathrm{d,t+1}} = \log\left(R^{i}_{d,t+1}\right); \tag{2. 7}$$
$$\mathrm{v}^{\mathrm{i}}_{\mathrm{c,t}} = \frac{P^{i}_{c,t}}{C^{i}_{t}};\ \mathrm{v}^{\mathrm{i}}_{\mathrm{d,t}} = \frac{P^{i}_{d,t}}{D^{i}_{t}},$$

in which $\mathrm{r}^{\mathrm{i}}_{\mathrm{c,t+1}}$ represents the continuous return on aggregate consumption in country *i*, and $\mathrm{r}^{\mathrm{i}}_{\mathrm{d,t+1}}$ represents the continuous return on market portfolio in country *i*. $\mathrm{v}^{\mathrm{i}}_{\mathrm{c,t}}$ represents price-consumption ratio in country *i*, and $\mathrm{v}^{\mathrm{i}}_{\mathrm{d,t}}$ represents price-dividend ratio in country *i*.

Foreign Exchange Rate: As in the previous section, the spot exchange rate is defined as the foreign currency spot price of one unit of home currency. The U.S. dollar is the home currency. Under complete market assumption, there is an unique generalized stochastic discount factor, $\mathrm{m}^{\mathrm{i}}_{\mathrm{t+1}}$, in each country. As in Backus et al. (2001), the asset pricing condition in equation (2. 5) and the assumption of complete market imply that, for each currency pair between the US and one EM country, the change in foreign exchange rate is equal to the difference between the log stochastic discount factor in the two countries.

$$\Delta s_{t+1} = s_{t+1} - s_t = m^{US}_{t+1} - m^{EM}_{t+1}. \tag{2. 8}$$

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[6] The expression of return on a claim to aggregate consumption, $\mathrm{R}^{\mathrm{i}}_{\mathrm{c,t+1}}$, and the return on the market portfolio, $\mathrm{R}^{\mathrm{i}}_{d,t+1}$, are used for the purpose of solving the model numerically. To derive these returns, start with definition that $\mathrm{R}_{\mathrm{c,t+1}} = \frac{P_{c,t+1}+C_{t+1}}{P_{c,t}}$ and $\mathrm{R}_{d,t+1} = \frac{P_{d,t+1}+D_{t+1}}{P_{d,t}}$, in which $\mathrm{D}_{\mathrm{t+1}}$ is dividend at time t+1, $\mathrm{P}_{\mathrm{c,t}}$ is the price of consumption at time t, $\mathrm{P}_{\mathrm{d,t}}$ is the price of equity at time t. Another way of deriving $\mathrm{R}^{\mathrm{i}}_{\mathrm{c,t+1}}$ and $\mathrm{R}^{\mathrm{i}}_{d,t+1}$ is to use Campbel and Shiller approximation as shown in the Appendix 2.A.

2.3.2. Currency Risk Premium

Approximate analytical solutions of return on aggregate consumption ($\mathrm{r}_{\mathrm{c,t+1}}^{\mathrm{i}}$) and the stochastic discount factor ($\mathrm{m}_{\mathrm{t+1}}^{\mathrm{i}}$) are derived by the standard Campbell and Shiller (1988) approximation, and the methodology of solving the model is adopted from Bansal and Yaron (2004). These approximation analytical solutions are useful to analyze the sign and magnitude of currency risk premium. Details of derivations are shown in the Appendix 2.A. In the next section, the model can also be solved numerically, using polynomial-based projection method discussed in Judd and Judd (1998). The numerical algorithm is adopted from R. Colacito and Croce (2011). Both approximate analytical solutions and numerical solutions are quite close.

Stochastic Discount Factor:

$$\mathrm{m}_{\mathrm{t+1}}^{\mathrm{i}} - E_t\left(m_{t+1}^{i}\right) = -\lambda_{m,\eta}^{\mathrm{i}}\eta_{t+1}^{i} - \lambda_{m,e}^{\mathrm{i}}e_{t+1}^{i}. \tag{2. 9}$$

In a country i=[US,EMs], the parameters $\lambda_{m,\eta}^{\mathrm{i}} = \gamma\lambda_c^i$ represents the exposure of the stochastic discount factor to short-run consumption growth shocks ($\eta_{\mathrm{t+1}}^{\mathrm{i}}$), while the parameter $\lambda_{m,e}^{\mathrm{i}} = \left(\gamma - \frac{1}{\psi}\right)\frac{\kappa_1}{1-\kappa_1\rho^i}\lambda_e^i$ represents the exposure of the stochastic discount factor to long-run consumption growth shocks ($\mathrm{e}_{\mathrm{t+1}}^{\mathrm{i}}$). Alternatively, the two parameters can be interpreted as the price of short-run consumption growth risk ($\lambda_{m,\eta}^{\mathrm{i}}$), and the price of long-run consumption growth risk ($\lambda_{m,e}^{\mathrm{i}}$). Because the short-run consumption growth risk is constant ($\lambda_c^i = \overline{\sigma_c^i}$), all sources of risk have constant conditional variances. Equation (2. 9) implies that the exposure of the stochastic discount factor depends not only on short-run and long-run consumption growth risk, but also on the persistent of long-run risk component. In particular, the exposure of the stochastic discount factor to long-run consumption growth shocks ($\lambda^{i}_{m,e}$) will increase when the long-run consumption growth risk increases, and when the long-run risk is highly persistent.

Currency Risk Premium:

The currency risk premium is expressed as the mean of difference in the variance of stochastic discount factor between the US and an EM country,

$$\mathrm{rp} = \mathrm{E}(\mathrm{er}_{t+1}) = \mathrm{E}\left(\frac{1}{2}Var_t m^{US}_{t+1} - \frac{1}{2}Var_t m^{EM}_{t+1}\right). \qquad (2.\ 10)$$

The stochastic discount factor, $\mathrm{m}^{\mathrm{i}}_{t+1}$, represents the intertemporal marginal rate of substitution of representative agents in each country. When $(Var_t m^{US}_{t+1} - Var_t m^{EM}_{t+1})$ is positive, the currency risk premium will be positive from perspectives of US investors, as US investors get more on intertemporal marginal rate of substitution at the US relative to the EM country counterpart. In other words, when there is a common shock to the stochastic discount factor in both the US and EM country, the U.S. dollar offers a protection for investors as the U.S. dollar will appreciate against the EM currency ($m^{US}_{t+1} > m^{EM}_{t+1}$).

In Colacito and Croce (2011)'s model, because they assume the parameters of short-run and long-run consumption growth risk between home country (the US) and foreign country are identical, the implied currency risk premium in their model is always zero. Different from their model, my model allows the three parameters including the short-run consumption growth risk, λ^{i}_{c}, the long-run consumption growth risk, λ^{i}_{e}, and the persistence of long-run risk component, ρ^{i}, to be asymmetric in each country pair between the US and an EM country ($\rho^{US} \neq \rho^{EMs}$, $\lambda^{US}_{c} \neq \lambda^{EMs}_{c}$, and $\lambda^{US}_{e} \neq \lambda^{EMs}_{e}$), the implied currency risk premium can be expressed in terms of model parameters.

$$\text{rp} = \frac{1}{2}\gamma^2[(\lambda_c^{US})^2 - (\lambda_c^{EM})^2] + \frac{1}{2}\left(\gamma - \frac{1}{\psi}\right)^2\left[\left(\frac{\kappa_1}{1-\kappa_1\rho^{US}}\right)^2(\lambda_e^{US})^2 - \left(\frac{\kappa_1}{1-\kappa_1\rho^{EM}}\right)^2(\lambda_e^{EM})^2\right]. \quad (2.\ 11)$$

Given my extension by allowing asymmetric parameters on consumption growth risks between each country pair, the implied currency risk premium in Colacito and Croce (2011)'s model is actually a special case of equation (2. 11). The equation (2. 11) implies that short-run and long-run consumption risk are the two components that affect the currency risk premia. A currency risk premium arises because of two components: (i) the first term represents the difference in price of short-run consumption risk between the US and an EM country, and (ii) the second term represents the difference in price of long-run consumption risk between the US and an EM country. Whether the currency risk premium is positive or negative depends on relative dominant effect between the difference in short-run consumption risk and long-run consumption risk between the US and EM countries. In particular, when the long-run consumption risk in the US is less than that of an EM country, the term $(\lambda_e^{US})^2 - (\lambda_e^{EM})^2$ is negative, creating one force that reduces the currency risk premium. At the same time, if the short-run consumption risk in the US is higher than that of an EM country, the term $(\lambda_c^{US})^2 - (\lambda_c^{EM})^2$ is positive, creating another force that increases the currency risk premium. The sign of the currency risk premium then depends on which force dominates. For example, the currency risk premium will be positive, if the short-run consumption risk in the US is sufficiently large comparative to that of the EM country such that the US loads up more on the short-run consumption risk, even though the EM countries have higher long-run consumption risk.

Furthermore, the asymmetric persistence of long-run risk component (ρ^i) is an additional factor which affects the magnitude and the sign of the currency risk premia as it determines the relative price of long-run consumption growth risk between the two countries. For example, suppose that the short-run consumption risk in the US (λ_c^{US}) is larger than that of an EM country (λ_c^{EM}), and, at the same time, long-run consumption risk in the US (λ_e^{US}) is smaller than that of an EM country (λ_e^{EM}). If the persistence of long-run risk in the US (ρ^{US}) is sufficiently larger than that of an EM country (ρ^{EM}) so that the whole second term in equation (2. 11) has a positive sign, the currency risk premium will also be positive. Intuitively, from the perspective of US investors, a positive currency risk premium is a compensation for them for taking on the short-run consumption risk and the persistence of long-run risk component in the US relative to EM countries, even though EM countries may have higher long-run consumption growth risk.

Finally, an increase in either the risk aversion coefficient, γ, or in the IES, ψ, will magnify the currency risk premium. This is obvious that when the currency risk premium has a positive sign, given a value of the IES, higher risk aversion coefficient will inflate the currency risk premium. One advantage of the Epstein-Zin preference is that the IES, ψ, and the risk aversion coefficient, γ, can be both selected to be larger than 1, and $\gamma > \frac{1}{\psi}$. This inequality refers to the case in which people prefer early resolution of uncertainty. If so, the more people intends to resolve uncertainty earlier, the higher the currency risk premium is.

2.4. Model Implications

2.4.1. Data and Parameters Calibration

Preference Parameters: Decision interval of the agent is monthly. Preference parameters are identical in all countries. The time discount factor, δ, is set to be 0.993 to reflect a monthly decision problem. For baseline calibration, the coefficient of risk aversion, γ, is selected at 10, and the intertemporal elasticity of substitution, ψ, is selected at 1.5, which are consistent with the literature on long-run risk model[7].

Cross-country Correlation: As in Colacito and Croce (2011), I assume nearly perfect correlation of the long-run risk shocks (τ_e), implying a nearly perfect correlation of long-run consumption growth risk across economies. The correlation of short-run risk shocks (τ_η) is associated with the correlation of consumption growth between the US and an EM country.

Consumption Data: For all countries, annual consumption data are used for parameter calibrations. The consumption series are seasonally adjusted and in real term. The data source for consumption is national sources, which are all downloaded from Haver Analytics. Consumption data of expenditure on non-durable goods and services are used if they are available. The US consumption data is from National Income and Product Accounts (NIPA) tables, available in Bureau of Economic Analysis.

Consumption Growth Parameters: For parameters on consumption growth, the mean of consumption growth (μ_c^i) corresponds to the annualized real consumption growth in each country. Because parameters are in monthly terms, annual consumption growth is interpolated to monthly frequency. The parameters of the dynamic of consumption growth is estimated by state-space estimation for the set of two equations

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[7] Bansal and Yaron (2004), Beeler and Campbell (2009), Bansal, Kiku, and Yaron (2009) provide discussions on the selection of the risk aversion coefficient, γ, and the IES, ψ, parameters. While Bansal and Yaron's estimation of the IES suggests that it is approximately 1.5, Beeler and Campbel (2009) argue that the IES could exceed 1.5. While Bansal and Yaron (2004) mention that the upper bound for risk aversion is no more than 10, the literature on habit formation utility use extreme value of risk aversion coefficient to 250. In my study, I follow Bansal and Yaron (2004) and select the risk aversion coefficient at 10.

$$\Delta c_{t+1}^{i} = \mu_{c}^{i} + x_{t}^{i} + \lambda_{c}^{i}\eta_{t+1}^{i}$$
$$x_{t+1}^{i} = \rho^{i}x_{t}^{i} + \lambda_{e}^{i}e_{c,t+1}^{i}, \tag{2. 12}$$

in which Δc_{t+1}^{i} is the consumption growth in country i, and x_{t+1}^{i} is the unobserved factor. In the system (2. 12), the first equation is an observed equation, while the second equation is a state equation. The target is to estimate three parameters including the short-run consumption growth risk, λ_{c}^{i}, the long-run consumption growth risk, λ_{e}^{i}, and the persistence of long-run risk, ρ^{i}. Table 2.4 reports estimation results from the state-space estimation of the system (2. 12). There are two noticeable points. Firstly, the short-run consumption growth risk and the persistence of long-run risk component in the US are higher than those of EM countries. Secondly, many EM countries have low persistence of long-run risk component but high long-run consumption growth risk.

2.4.2. Implied Currency Risk Premium

From the parameter calibrations in Table 2.4, it can be seen that the short-run consumption risk in the US is higher than that of EM countries ($\lambda_{c}^{US} > \lambda_{c}^{EM}$), while the long-run consumption risk in the US is lower than that EM countries ($\lambda_{e}^{US} < \lambda_{e}^{EM}$). Additionally, the persistence of long-run risk component in the US is quite high relative to that of EM countries, magnifying the price of long-run risk component.

[Table 2.5 and Figure 2.1 is about here]

Figure 2.1 plots actual against implied currency risk premium. Each point represents an EM currency. The figure shows that data points move along the 45^{o} degree, suggesting that the long-run risk model can account fairly well for the risk premium in EM currencies. In Table 2.5, the first column reports the currency risk premia implied by the long-run risk model and the second column reports the currency risk premia calculated from actual data. The implied currency risk premium is calculated the same time period from January 2003 to December 2017 as in the actual data. Table 2.5 illustrates that the calibrated model can reproduce positive risk premia in several EM currencies. Particularly, except two currencies including the Chinese Renminbi (CNY) and the Mexican Peso (MXN), the sign of implied risk premium can match the sign of the actual one for all other currencies. Additionally, for some currencies such as the Hungarian Forint (HUF), the Czech Koruna (CZK), and the Philippine Peso (PHP), the magnitude of implied currency risk premium is close to the actual one. More importantly, the implied risk premium for a basket of EM currencies is positive at 1.01 percent, accounting for a fair proportion of the risk premium calculated from actual data.

2.4.3. Robustness Check

Changes in the Implied Risk Premia when the Risk Aversion Coefficient changes:

[Table 2.6 is about here]

Table 2.6 provides a robustness check on the coefficient of risk aversion. Three selected values for the risk aversion coefficient are 5, 7.5, and 10. These values are similar to values of risk aversion coefficient commonly found in the long-run risk literature. Colacito and Croce (2011) set 4.25, Colacito and Croce (2013) set 8, and Bansal and Yaron (2004) set 7.5 and 10 for the risk aversion coefficient. Overall, a gradual increase in the risk aversion coefficient leads to a gradual increase in the implied currency risk premium. For example, when the risk aversion coefficient increases from 5 to 7.5, and to 10, the risk premium on EM portfolio increases from 52 basis points to 76 basis points and to 101 basis points. Although Bansal and Yaron

(2004) argue that the upper bound for the risk aversion coefficient is 10, Table 2.6 reports one additional case when the coefficient increases from 10 to 12 in order to examine how high the coefficient should be to match the risk premia in the data. Table 2.6 suggests that the calibration of risk aversion coefficient is optimal at 10, because the risk premium on EM portfolio decreases to 73 basis points from 101 basis points when the risk aversion coefficient increases from 10 to 12. The reason is that, for currencies that have positive risk premium, an increase risk aversion coefficient from 10 to 12 leads to an increase in the risk premium of these currencies; however, for currencies that have negative risk premium, an increase risk aversion coefficient from 10 to 12 leads to a significantly decrease in the risk premium of these currencies.

Impact of the Global Financial Crisis on Implied Currency Risk Premia:

[Table 2.8 and Figure 2.2 are about here]

The exclusion of the GFC months from August 2008 to September 2009 in the sample results in changes in the parameter estimations (as reported in Table 2.7); thus, the implied currency risk premia also change. Table 2.8 reports changes in the implied and actual risk premium for the sample excluding the GFC months. Figure 2.2 plots the implied currency risk premia against the actual risk premium for the sample excluding the GFC months. In general, both the implied and actual risk premium in the sample excluding the GFC months increase compared with those in the sample including the GFC. More specifically, the implied currency risk premium in EM portfolio increases from 101 basis points in sample including the GFC months to 186 basis points in the sample excluding the GFC months. In a similar manner, the actual currency risk premium increases from 354 basis points in sample including the GFC months to 425 basis points in the sample excluding the GFC months. This characteristic suggests an intuition that EM currencies offer a high and positive risk premium during normal times as a reward for the investors who take risks of adverse long-run risk in EM countries.

2.5. Conclusions

In this chapter, I provide empirical evidences of positive risk premia in EM currencies and confirm the validity of an idea that the asymmetric consumption growth risk between the US and EM countries can determine currency risk premia. With the risk aversion coefficient at 10, the intertemporal elasticity of substitution at 1.5, and the state-space estimation of short-run and long-run consumption risk, the calibrated model can produce a positive risk premium in many EM currencies. Importantly, the calibrated model can produce a positive risk premium for a portfolio of EM currencies, which can account for a fair proportion of the risk premium calculated from actual data.

Chapter 3: Common Risk Factors in EM and G10 Currencies: New Empirical Evidences

3.1. Introduction

This chapter provides empirical evidences that Global Risk Factor and Interest Rate Differential relative to the US are the two common risk factors for EM currencies, but not for G10 currencies.

To estimate the price of risk factors, tests of Linear Factor Models, including Capital Asset Pricing Model (CAPM) and Three-Factor Model, are applied to currency portfolios. I first construct monthly portfolios of currencies, and then estimate the price of risk factors by applying two estimation approaches including Fama-French two-step OLS estimation and Generalized Method of Moments (GMM) estimation.

Regarding the currency portfolios, at the end of every month, all currencies are sorted simultaneously according to their interest rate differentials relatively to the US, and to their depreciation rates against the U.S. dollar. According to their interest rate differentials relatively to the US, currencies are allocated into three groups: "*B, M, S*" which correspond to currency portfolios that have "Big", "Medium", and "Small" interest rate differential relative to the US. According to their depreciation rates against the U.S. dollar, currencies are allocated to three groups: "*L, M, H*" which correspond to currency portfolios that have "Low", "Mid", and "High" depreciation rate against the U.S. dollar. A combination of all groups produces nine portfolios in total. Particularly, the first portfolio, referred as "Big-High" portfolio or BH, contains currencies that have biggest interest rate differential to the US, and highest depreciation rate against the U.S. dollar, while the last portfolio, referred as "Small-Low" portfolio or SL, contains currencies that have smallest interest rate differential to the US and lowest depreciation rate against the U.S. dollar. Portfolios are rebalanced every month. EM currencies and G10 currencies are examined separately. Compared with recent empirical works, the innovation of this study is to sort currencies simultaneously by their interest rate differentials (carry) and depreciation rates (momentum).

Three common risk factors identified from currency portfolios include Global Risk Factor denoted as RX_{t}, Interest Rate Differential Factor (or Carry Factor) denoted as $\mathrm{BMS}_{\mathrm{t}}$, and Depreciation Rate Factor (or Momentum Factor) denoted as LMH_{t}. The Global Risk Factor is the average excess returns of all portfolios at month t. The Interest Rate Differential Factor (or Carry Factor) is the average excess return spread between currencies portfolios that have biggest interest rate differential and currencies portfolios that have the smallest interest rate differential at month t. The Depreciation Rate Factor (or Momentum Factor) is the excess return spread between highest-deprecated currencies and lowest-depreciated currencies at month t.

The estimation results from both Fama-French two-step OLS regression and GMM regression reveal new empirical evidences about the common risk factors in EM and G10 currencies. Firstly, in both EM and G10 portfolios, currencies that have medium depreciation rate, rather than having high or low depreciation rate, are those having sizable positive risk premia. Additionally, currencies that have biggest interest rate differential to the US and medium depreciation rate are those having the highest risk premia. For example, a “Big-Mid” portfolio, which contain currencies that have biggest interest rate differential to the US and medium depreciation rate, has a risk premium of 743 basis points in EM currencies and 269 basis points in G10 currencies.

By contrast, a “Small-Mid” portfolio has a risk premium of 54 basis points in EM currencies and minus 95 in G10 currencies.

Secondly, linear factor model is more successful in explaining risk factors for EM currencies, than for G10 currencies. Particularly, the estimation test of three-factor model has small pricing errors in EM currencies, but having large pricing errors in G10 currencies. The R-squared in the estimation of EM currencies is 87% while it is 58% in G10 currencies.

Finally, the Global Risk Factor (RX_t) and the Interest Rate Differential (BMS_t) are the two factors for EM currencies, but not for G10 currencies. Particularly, estimation results show that while the factor risk price of both RX_t and BMS_t are positive and statistically different from zero in EM currencies, they are not statistically significant in G10 currencies.

Because only few studies have focused on common risk factors of EM currencies in comparison with G10 currencies. The contribution of this study is to close this gap in the literature by providing new empirical findings about the slope factor and price of risks for EM currencies in comparison with G10 currencies. These empirical evidences on the common risk factors in EM currencies would provide useful implications for future economic model of EM currency risk premia.

The rest of the chapter is organized as follows. Section 3.2 provides a literature review on common risk factors in the foreign exchange market. Section 3.3 presents the construction and calculation of monthly currency portfolios. Section 3.4 reports estimation results of factor risk prices by Fama-French two-stage estimation and GMM estimation. Section 3.5 contains conclusions and remarks.

3.2. Literature Review

Common Risk Factors in the Foreign Exchange Market:

This study is related to the literature on currency excess returns and common risk factors in the currency market. The core idea is that if the relation between average currency excess returns and systematic risk factors is statistically significant, the consideration of excess returns as risk premia can be justified. Furthermore, the reason for sorting currencies is to focus more on the aggregate risk component of currency excess returns rather than country-specific (or idiosyncratic) risks. This approach has been adopted by recent studies such as Asness, Moskowitz, and Pedersen (2013); Burnside, Eichenbaum, and Rebelo (2011); Lustig et al. (2011); Menkhoff et al. (2012a); Menkhoff et al. (2012b); and Verdelhan (2018).

Lustig and Verdelhan (2011) sort currencies into portfolios based on their current interest rates, and show that investors gain substantial average excess returns by taking long position in portfolios of high interest rate currencies and taking short positions in portfolios of currently low interest rate currencies. The average excess returns increase from the first portfolio, which contains currently low interest rate currencies, to the last portfolio which contains currently high interest rate currencies. They suggest two common risk factors including dollar risk factor which is the average excess returns on all foreign currency portfolios and carry risk factor which is returns on the carry trade strategy. Compared with their study, my study has a different conclusion that the carry risk factor is not a significant risk factor for G10 currencies.

Menkhoff et al. (2012a) show that global foreign exchange volatility is a main component of currency risk premia. High interest rate currencies are negatively correlated with global foreign exchange volatility and thus offer low excess returns in times of unexpected high volatility. Most recently, Verdelhan (2018) focuses more on the change in exchange rates rather than excess returns as risk factors. He shows that the change in exchange rates between high and low interest rate currencies and the average change in the exchange rate between the US dollar and all other currencies are the two common risk factors in currency market.

Asness et al. (2013) show evidences on the return premia to momentum strategies across several asset classes including the currency market. Burnside et al. (2011) examine empirical properties of the returns from the carry trade and momentum strategy. However, they conclude the returns from the carry trade and momentum are not compensations for risk because there is no statistically significant relationship between the returns from these two strategies and conventional risk factors.

***Studies on EM Currencies*:**

While there is a growing literature on estimating risk premium in G10 currencies, there are few studies focusing on explaining currency excess returns and common risk factors for EM currencies. Instead, studies tend to focus on country-specific risks of EM countries because the existence of risk premium in EMs is more likely to be justified by weak macroeconomic fundamentals, and highly volatile economic conditions.

Examining the forward premium puzzle and conducting single-factor asset pricing test for developed and EM currencies, Bansal and Dahlquist (2000) emphasize that country-specific risks rather than systematic risks are attributable to EM currency excess returns. They suggest that either the EM countries are segmented markets or the standard asset pricing models of systematic risk are misspecified. By contrast, incorporating size and value factors that may reflect financial risks and future growth opportunities, Francis, Hasan, and Hunter (2002) show that currency excess returns of nine EM currencies in the period 1980–2000 can be attributable to systematic risks. Also, capital market liberalizations significantly affect the systematic risk Latin American EM countries. Employing an international CAPM model, Tai (2003) also shows that systematic risk factors can account for excess currency returns for four East Asian countries during January 1986 to July 1998.

3.3. Currency Portfolios

In this section, I construct monthly portfolios of currencies and calculate the risk premium (the mean of currency excess returns) associated with each portfolio. Currencies are sorted simultaneously according to their interest rate differential relatively to the US and their depreciation rate against the US dollar. The way of sorting currencies replicates two common strategies in the foreign exchange market, which are carry trade and momentum strategy[8]. The carry trade refers to the strategy in which investors buy high-interest-rate currencies and sell low-interest-rate currencies because high interest rate currencies are more likely to appreciate against the US dollar. The momentum refers to the strategy in which investors follow trends in the currency market. One common way for investors is to take position in currency pairs that depreciate the least (or appreciate the most) against the US dollar.

One reason for sorting currencies this way is to create portfolios that truly reflect activities in the foreign exchange market. In chapter 2, the calculation of currency risk

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[8] Together with Carry Trade Strategy and Momentum Strategy, another common strategy in the foreign exchange market is Valuation Strategy. This strategy bases on an assumption that exchange rates will finally converge to an equilibrium level in the long-run. Investors will sort currencies by the magnitude of differences between the spot foreign exchange rates and its long-

premium in EM and G10 currency portfolios bases on assumptions that investors simply invest in all currencies that are available and accessible in the foreign exchange market. However, in practice, investors often use the two mentioned strategies[9] and rebalance their portfolios more frequently. The main motivation for investors is that if they keep holding a single position by buying and selling certain currency pairs, they will be more likely to exposed to risks associated with these currencies. Creating portfolios of currencies is one way to reduce and manage risks. Another more important reason is that sorting currencies into portfolios allows analyses to focus more on the aggregate risk component of currency excess returns rather than country-specific (or idiosyncratic) risks.

Similar to Chapter 2, the log excess return, er_{t+1}, of buying a foreign currency in the forward market and then selling it in the spot market after one month is defined as

$$\mathrm{er}_{t+1} = f_t - s_{t+1}, \tag{3. 1}$$

in which s_{t+1} denotes the log of the spot exchange rates at time t+1, in units of foreign currency per home currency. f_t denotes log of the one-month forward exchange rate at time t, also in units of foreign currency per home currency. The U.S dollar is selected as

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run equilibrium level. These differences are often referred as currency mis-valuation level. A strategy of buying undervalue currencies and selling overvalue currencies can be profitable.

[9] The portfolio sorting approach is similar to how these strategies are actually implemented in currency markets. Since 1996, a number of important banks in the foreign exchange market have developed their own indices that track the returns for different currency strategies. Some prominent banks are Citi Group, Deutsche Bank, UBS, and Nomura Security. For example, Deutsche Bank offers some indices for "DB Currency Returns" such as DBCR+USD (quoted as DBCRPLU in Bloomberg ticker) or DBCR Dynamic USD (quoted as DBCRDNU in Bloomberg ticker). Another common index is the Deutsche Bank G10 Carry Harvest Index consists of long future contracts on the three G10 currencies associated with the highest interest rates and of short future contracts on the three G10 currencies associated with the lowest interest rates.

the home currency or the base currency. An increase in foreign exchange rate means an appreciation of the US dollar.

Currency Portfolios:

At the end of each month, currencies are sorted according to their interest rate differentials to the US ($i_t^* - i_t$) and their depreciation rate against the US dollar observed at time t (Δs_t)[10]. Regarding interest rate differential to the US, there are three groups including Small, Medium, and Big. "Small" portfolio contains currencies which have the smallest interest rate differential relative to the US and "Big" portfolio contains currencies which have the biggest interest rate differential relatively to the US (or the largest forward premium). Regarding the depreciation rates, there are three groups including Low, Mid, and High. "Low" portfolio contains currencies which have the lowest depreciation rate against the U.S. dollars while "High" portfolio contains currencies which have the highest depreciation rate against the U.S. dollars. When currencies are sorted simultaneously by their interest rate differentials relative to the US and their depreciation rates against the US dollar, the first portfolio contains currencies that have biggest interest rate differential to the US and highest depreciation rate, while the last portfolio contains currencies that have smallest interest rate differential to the US and lowest depreciation rate.

Portfolios are rebalanced at the end of every month. The total number of currencies in portfolio varies over time. At the beginning of the sample in January 2003,

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[10] In normal condition when the CIP condition holds, forward premium ($f_t - s_t$) is equal to interest rate differential between a foreign country and the US ($i_t^* - i_t$). Thus, sorting currencies according to their interest rate differential is equivalent to sorting currencies according to their forward premium. Sarno and Taylor (2002) and Akram, Rime, and Sarno (2008) provide discussions and empirical test of the CIP condition. Overall, the CIP holds especially for low

the global portfolio contains 18 currencies and the maximum number of currencies is 29 currencies. The total number of portfolios is selected at nine portfolios because of two main reasons. Firstly, because there are ten currencies in the group of G10 currencies, it is necessary to keep the number of portfolios less than 10 to guarantee that there is at least one currency appeared in each portfolio in the G10 group. Secondly, keeping the number of portfolios as many as 9 portfolios is to avoid the mix up among currencies that have high depreciation rate and big interest rate differential with currencies that low depreciation rate and small interest rate differential.

Data: Together with global portfolios which include all 29 currencies, currencies are divided into two groups. G10 currencies include AUD, GBP, CAD, DKK, EUR, JPY, NZD, NOK, SEK, and CHF. Emerging currencies include CNY, INR, PHP, KRW, TWD, THB, CZK, HUF, ISK, PLN, RUB, ARS, BRL, CLP, COP, MXN, PEN, EGP, and ZAR[11]. The data source and sample period are similar to ones in Chapter 2. The spot and forward foreign exchange rates are the mid rates on the last business day of the month, extracted from their daily data. Data source is Thomson Reuters Datastream for Office. The US dollar is the base currency. The sample period is from January 2003 to December 2017.

Table 3.1, Table 3.2, and Table 3.3 report annualized mean and annualized standard deviation of average currency excess returns for three currency groups.

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frequency data such as monthly frequency. Also, forward premium ($f_t - s_t$) can be a negative number. In this case, it is a forward discount.

[11] To save space, only currencies notations are used. Appendix 1.A provides details of currencies names. Currencies including IDR, MYR, SGD, and HKD are excluded from the sample. SGD and HKD are considered as advanced economies in Asia. IDR and MYR have significant change in their institutions, causing large fluctuation in foreign exchange rates and creating outliers in the sample.

3.3.1. Portfolios Sorted by Momentum

[Table 3.1 is about here]

Table 3.1 reports the annualized mean and standard deviation of excess returns (or the risk premium) of currency portfolios sorted by their depreciation rate. Among all three groups, EM currencies have the highest average excess returns. For example, the average excess return of low-depreciated EM currencies is 3.57 percent, approximately 3 times higher than the average excess return of 0.14 percent in low-depreciated G10 currencies, and 2 times higher than the excess returns of 1.68 percent in low-depreciated Global portfolio.

Additionally, for EM group, currencies that have low depreciation rate offer the highest excess returns. By contrast, for Global and G10 group, currencies that have medium depreciation rate ("Mid" portfolio) offer highest excess returns. The Sharpe ratio in EM group (defined as the ratio of the mean of currency excess returns over its standard deviation) is relatively high, which is 49% for EM currencies that have low depreciation rate against the US dollar and 31% for EM currencies that have high depreciation rate against the US dollar.

3.3.2. Portfolios Sorted by Carry

[Table 3.2 is about here]

Table 3.2 reports the annualized mean and standard deviation of excess returns in currency portfolios sorted by their Interest Rate Differential relative to the US (Carry). Similar to portfolios sorted by depreciation rate, among three groups, EM currencies offer the highest average excess return (or the risk premium). Particularly, EM currencies that have big interest rate differential to the US ("Big" portfolio) have an average excess return of 7.04 percent, which is 3 times higher than the average excess return of 1.97 percent in “Big” portfolio of G10 currencies, and higher than the average excess return of 5.38 percent in “Big” Global portfolio. For EM currencies, the excess returns are especially large when measured per unit of risk. The Sharpe ratio on “Big” portfolio in EM currencies is 84 percent, while it is only 3 percent for the “Small” portfolio. Comparing currency portfolios sorted by Momentum (Table 3.1) and sorted by Carry (Table 3.2) shows that, for the same group of currencies, portfolios sorted by Carry have higher average excess returns than ones sorted by Momentum. For example, for EM currencies, the “Big” portfolio has a return of 7.04 percent while the “High” portfolio has a return of 2.71 percent.

3.3.3. Portfolios Sorted by Carry and Momentum

[Table 3.3 is about here]

Table 3.3 reports the annualized mean and standard deviation of excess returns in currency portfolios sorted by Interest Rate Differential (Carry) and by Depreciation Rate (Momentum). Different from Table 3.1 and Table 3.2, among three groups, EM currencies do not necessarily offer the highest average excess returns for all portfolios. For example, for G10 currencies, currencies which have small interest rate differential and high depreciation rate (“Small-High” portfolio) offer a positive excess return of 1.38 percent while the same portfolio for EM currencies have a negative excess return of -1.05 percent. Those G10 currencies are considered as safe-haven currencies. The Japanese Yen (JPY) and the Swish Franc (CHF) are the two currencies that appear the most in the “Small-High” portfolio.

Generally, from perspectives of US investors, low interest rate currencies have small or negative average excess returns, while high interest rate currencies have substantial positive excess return. Furthermore, in all three groups, taking position in currencies which have big interest rate differential and medium depreciation rate always has the largest average excess return. For example, for the 'Big-Mid' portfolio, the average excess returns on EM currencies is 7.43 percent, on Global currencies is 6.8 percent, and on G10 currencies is 2.69 percent.

3.4. Common Risk Factor

Risk factors can be broadly divided into two categories including idiosyncratic (country-specific) risk and systematic (broad market) risk. Idiosyncratic risk is associated with country-specific risk while systematic risk is associated with common risk factor such as a global economic shock that hit all currencies. As the foreign exchange rate is considered as asset prices, linear factor model can be applied to test the covariance of average currency excess returns against the systematic risk. The aim of this test is to answer whether the average excess returns reflect risk premia.

Constructing portfolios of currencies does not remove the impact of systematic risks. The currency excess return can be rewritten as $\mathrm{er}_{t+1} = f_t - s_{t+1} = f_t - s_t - \Delta s_{t+1} = i_t^* - i_t - \Delta s_{t+1}$, in which the last equality holds because of the CIP condition. This equation suggests that the currency excess return is not risk-free. The risk may come from foreign exchange rate risk (Δs_{t+1}) as foreign exchange rates are volatile. The risk may come from short-term interest rate adjustment ($i_t^* - i_t$) (even though the interest rate is risk-free). The risk may also come from a common risk factor that affects both foreign exchange rates and interest rates and affect all currencies in the market. For these reasons, from the currency portfolios above, three candidates for risk factors are included in this study.

The first factor is a Global Risk Factor (or Market Risk Factor) which is the average excess return of all portfolios at time t, denoted as RX_t. $\mathrm{RX_t} = \frac{1}{9}\sum_j er_t^j$, in which er_t^j denotes the excess return of portfolio j at time t. Portfolio j corresponds to 9 portfolios presented in previous section including BH, BM, BL, MH, MM, ML, SH, SM, SL.

The second risk factor is Interest Rate Differential (Carry) Factor which is the average excess return spread between portfolios of currencies that have biggest interest rate differential and currencies portfolios that have the smallest interest rate differential. This factor is equal to the difference in average excess return between “Big” and “Small” portfolio at time t, denoted as BMS_t (Big Minus Small). $\mathrm{BMS_t} = \frac{1}{3}\sum_{i=H,M,L}(er_t^{B,i} - er_t^{S,i})$.

The third factor is Momentum Factor which is the average excess return spread between highest-deprecated currencies and lowest-depreciated currencies. This factor is equal to the difference in average excess returns between “Low” and “High” portfolio at time t, denoted as LMH_t (Low Minus High). $\mathrm{LMH_t} = \frac{1}{3}\sum_{i=B,M,S}(er_t^{L,i} - er_t^{H,i})$.

$\mathrm{RX_t}$ is the average excess return for U.S. investors who buy all foreign currencies in the forward market and can be interpreted as broad market returns for the currency market with respect to the US Dollar. $\mathrm{BMS_t}$ is the average excess return denominated in the US Dollar on the carry strategy which takes long position in high interest rate currencies and short position in low interest rate currencies. LMH_t is the average excess return denominated in the US Dollar on the momentum strategy which takes long position in low-depreciated currencies and short position in high-depreciated currencies.

Linear Factor Model: A common way to test the covariance between excess returns and systematic risks is to test a linear factor model. The derivation of the linear factor model is shown in Yogo (2006) (see also in Cochrane (2009), Chapter 9). Let $\mathrm{er}_{\mathrm{t+1}}^{\mathrm{i}}$ denotes the excess return of currency portfolio *i* at time t+1 (take short position in one currency and long position in other currencies), which satisfies an asset-pricing condition:

$$E\left[M_{t+1} er_{t+1}^{i}\right] = 0, \tag{3. 2}$$

in which portfolio *i* corresponds to the 9 currency portfolios presented in the previous section including BH, BM, BL, MH, MM, ML, SH, SM, and SL.

Suppose that the stochastic discount factor, $\mathrm{M}_{\mathrm{t+1}}$, is linear in a vector of risk factors (f_{t}), in which the factor (f_{t}) can be either only one factor such as a broad market risk as in the Capital Asset Pricing Model (CAPM), or a vector of multiple factors ($\mathrm{F} \times 1$) such as the three-factor model,

$$\frac{-\mathrm{M}_{\mathrm{t+1}}}{E(M_{t+1})} = a + b' f_t \,. \tag{3. 3}$$

Denote the factor mean as $\mu_{\mathrm{f}} = E(f_t)$, the variance-covariance matrix of the factor as $\sum_{ff} = E[(f_t - \mu_t)(f_t - \mu_t)']$, and the covariance of factor and excess returns as $\sum_{fi} = E[(f_t - \mu_t) er_{t+1}^{i}]$. Combining equation (3. 2) and equation (3. 3), the linear factor model can be rewritten as[12]

$$E\left[er_{t+1}^{i}\right] = b' \, \Sigma_{\mathrm{fi}}. \tag{3. 4}$$

---

[12] To derive the linear factor model:
Firstly, taking the expectation of both sides of equation (3. 3) produces $\mathrm{b}'\mathrm{E}(\mathrm{f}_{\mathrm{t}}) = -(a+1)$.
Secondly, combining the definition of covariance with the asset-pricing condition $\mathrm{E}\left[\frac{\mathrm{M}_{\mathrm{t+1}}}{E(M_{t+1})} er_{t+1}^{i}\right] = 0$, then $\mathrm{E}\left[\frac{\mathrm{M}_{\mathrm{t+1}}}{E(M_{t+1})} er_{t+1}^{i}\right] = \mathrm{E}\left[\frac{\mathrm{M}_{\mathrm{t+1}}}{E(M_{t+1})}\right] E\left[er_{t+1}^{i}\right] + Cov\left(\frac{\mathrm{M}_{\mathrm{t+1}}}{E(M_{t+1})}, er_{t+1}^{i}\right) = 0$.
It then follows that $E\left[er_{t+1}^{i}\right] = b' Cov\left(\mathrm{f}_{\mathrm{t}}, er_{t+1}^{i}\right) = b' E\left[(f_t - \mu_t) er_{t+1}^{i}\right]$

This linear factor implies a beta pricing model, in which the expected excess return is equal to the factor price λ times the beta (β^{i}) of each portfolio:

$$\mathrm{E}\left(\mathrm{er}_{t+1}^{i}\right) = \lambda' \beta^{i}, \tag{3. 5}$$

in which $\beta^{i} = \Sigma_{ff}^{-1} \Sigma_{fi}$, which are the regression coefficients of the excess return (er_{t}^{i}) on the factors (f_{t}); and $\lambda = \Sigma_{ff} b$ which are price of risks or factors' risk premium[13].

Next sections provide the estimation results of testing linear factor models for currency portfolios by two estimation methods including the Fama-French two-stage estimation and Generalized Methods of Moments (GMM).

3.4.1. Fama-French Two-Stage Estimation

The two-stage estimation introduced by Fama and French (1993) (hereafter referred as FF estimation) is one common method to estimate factor prices (λ) and portfolio beta (β). Three main factors are Global Risk Factor (RX_t), Interest Rate Differential Factor (BMS_t), and Momentum Factor (LMH_t).

The first stage is to run a time-series regression of excess returns of each portfolio on the three factors.

$$\mathrm{er}_{t}^{i} = \alpha^{i} + \beta_{RX}^{i} RX_t + \beta_{LMH}^{i} LMH_t + \beta_{BMS}^{i} BMS_t + u_t^{i}. \tag{3. 6}$$

The second stage is to run a cross-sectional regression of average returns of each portfolio on the beta.

$$\mathrm{E}\left(\mathrm{er}^{i}\right) = \lambda_{RX} \beta_{RX}^{i} + \lambda_{LMH} \beta_{LMH}^{i} + \lambda_{BMS} \beta_{BMS}^{i}. \tag{3. 7}$$

Estimation Results:

[Table 3.4 is about here]

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[13] To derive the "beta" representation of the linear factor model, start with

$$E\left[er_{t+1}^{i}\right] = b' Cov\left(\mathrm{f}_{t}, er_{t+1}^{i}\right) = b'_{(1\times F)} Var(f_t)_{(F\times F)} Var(f_t)_{(F\times F)}^{-1} Cov\left(\mathrm{f}_{t}, er_{t+1}^{i}\right)_{(F\times 1)},$$

It then follows that $E\left[er_{t+1}^{i}\right] = \left(Var(f_t)_{(F\times F)} b_{F\times 1}\right)' Var(f_t)_{(F\times F)}^{-1} Cov\left(\mathrm{f}_{t}, er_{t+1}^{i}\right)_{(F\times 1)} = \lambda' \beta^{i}$

The First Stage: Time Series Regression

Table 3.4 reports the estimated factor loading (or beta factor) from three-factor model by the FF estimation for EM and G10 currencies. The coefficient beta in the first-stage regression provides the sensitivity of assets to risk factors. Generally, if the beta is very high, the asset is highly correlated with the risk factor. If beta is negative, the negative relation implies that the asset would lose value when the market rose.

Overall, currencies with higher excess returns should be more sensitive to broad market risks. This characteristic holds for both G10 and EM currencies. "Big-High" portfolio is the one that has highest excess returns. The "Big-High" portfolio from G10 currencies is more sensitive to the broad market risk than that of EM currencies. It is also not the case that all of the betas should be statistically different from zero.

The Second Stage: Cross-sectional Regression

Table 3.5 reports estimates of the factor prices (λ) and the R^2 from the second-stage regression for both EM and G10 currencies.

[Table 3.5 is about here]

The market price of the BMS risk factor is 673 basis points for EM currency portfolio, and 187 basis points for G10 currency portfolio. In all cases, the price of risk is highly statistically significant. Since the factors are returns, no-arbitrage implies that the risk prices of these factors should equal their average excess return. For example, for EM currencies, the risk factor RX, which is the average currency excess return, has an estimated risk price of 287 basis points, compared with its sample mean of 293 basis points.

The FF estimation also shows that while the Global Risk Factor and Interest Rate Differential help explain the cross-section of currency return of both EM and G10 currencies, the momentum factor does not. The Momentum Risk Factor ($\mathrm{LMH_t}$) is not statistically significant for both EM and G10 currencies.

Finally, the three-factor model can explain a large part of the return variance with the high R-squared in the regression. This is especially true for the EM currencies. The R-squared for EM currencies estimation is 87% while it is 57% for G10 currencies. This result implies that important cross-sectional information in the 9 portfolios is captured mainly by the three-factor portfolios for EM currencies.

3.4.2. Generalized Method of Moments Estimation

The main problem of the Fama-French two-stage estimation is that the coefficients ($\widehat{\beta^{\iota}}$) in the second step can contain errors. This error-in-variable problem is likely to cause two effects. Firstly, it causes a downwards bias of the estimate of λ. Secondly, standard statistics tests of λ become invalid. One way to handle this problem and to estimate the factor price (λ) is to combine the moment conditions of both time series and cross-sectional regression into a joint system and estimate the system by the Generalized Method of Moments (GMM). The estimation can be written either in covariance representation or in 'beta' representation. I base on covariance representation and GMM estimation presented in Yogo (2006) (The equivalent 'beta' representation can be seen in Appendix 3.A).

$$E\mathrm{g_t}\big(\mathrm{b}_{(\mathrm{F}\times 1)}, \mu_{(\mathrm{F}\times 1)}\big) = E\begin{bmatrix} \mathrm{ER_t} - ER_t\big(f_t - \mu_f\big)'b \\ f_t - \mu_f \end{bmatrix} = 0_{((N+F)\times 1)}, \qquad (3.\ 8)$$

in which $\mathrm{f_t}$ is the vector of factor that has a dimension of $(\mathrm{F} \times 1)$; F is the number of factors (F is equal to either one or three); $\mathrm{ER_t}$ is the vector of currency excess return that has a dimension of $(\mathrm{N} \times 1)$; and N is equal to the number of test portfolios (in this study N is equal to 9 portfolios including BH, BM, BL, MH, MM, ML, SH, SM, and SL).

Case 1: Testing Capital Asset Pricing Model (CAPM) by GMM

In the test of CAPM, the Global Risk Factor ($\mathrm{RX_t}$) is the only risk factor, representing a broad market risk. This test is to examine the relation (or the covariance) of the excess return of each portfolio with the broad market risk, and to estimate factor price ($\lambda_{RX} = \mu_{RX}$). The moment condition is

$$E\mathrm{g_t}(\mathrm{b_{RX}}, \mathrm{\mu_{RX}}) = E\begin{bmatrix} \mathrm{ER_t} - ER_t(RX_t - \mu_{RX})b_{RX} \\ RX_t - \mu_{RX} \end{bmatrix} = 0_{(10\times1)}, \tag{3. 9}$$

in which $\mathrm{ER_t} = [\mathrm{er_t^i}]$ (i = 9 portfolios including BH, BM, BL, MH, MM, ML, SH, SM, and SL).

Case 2: Testing Three-Factor Model by GMM

In this case, three factors include Global Risk Factor (RX_t), Interest Rate Differential Factor (BMS_t), and Momentum Factor (LMH_t).

$$E\mathrm{g_t}(\mathrm{b}, \mathrm{\mu}) = E\begin{bmatrix} \mathrm{ER_t} - ER_t(f_t - \mu_f)' b \\ f_t - \mu_f \end{bmatrix} = 0_{(12\times1)}, \tag{3. 10}$$

in which $\mathrm{b} = [\mathrm{b_{RX}}, \mathrm{b_{BMS}}, \mathrm{b_{LMH}}]$, $\mathrm{\mu} = [\mathrm{\mu_{RX}}, \mathrm{\mu_{BMS}}, \mathrm{\mu_{LMH}}]$, $\mathrm{f_t} = [RX_t, BMS_t, LMH_t]$, and $\mathrm{ER_t} = [\mathrm{er_t^i}]$ (i = 9 portfolios including BH, BM, BL, MH, MM, ML, SH, SM, and SL). Three estimated factor prices include $\lambda_{RX} = \mu_{RX}$, $\lambda_{BMS} = \mu_{BMS}$, and $\lambda_{LMH} = \mu_{LMH}$.

Estimation Results:

[Table 3.6 is about here]

The GMM estimation of the CAPM and three-factor model is a two-step GMM estimation presented in Yogo (2006) (See Appendix 3.B) (More details and treatments can be seen in Cochrane (2009), Chapter 11, 12). Table 3.6 reports estimates of factor risk prices.

While the risk price for market returns (RX) and the risk price for carry factor (BMS) are statistically significant in EM currencies, all factor risk prices are not statistically different from zero in G10 currencies. In particular, the risk price of the BMS factor in EM currencies is 641 basis points, statistically significant at 5%, and the risk price of the RX factor in EM currencies is 249 basis points, statistically significant at 15%.

The J-test of over-identifying restrictions do not reject the model for both the CAPM and the three-factor model for EM currencies. The Three-factor model is more successful than the CAPM as the pricing errors is smaller (See Figure 3.1). In particular, in EM currencies, the mean absolute pricing error is 2.43 percent for the CAPM and 1.09 percent for the three-factor model. The improvement of the three-factor model over the CAPM is mainly captured by the explanatory power of the BMS factor.

[Figure 3.1 is about here]

Figure 3.1 illustrates the success of the three-factor model for EM currencies, but not for G10 currencies. The vertical axis is the actual average excess return and the horizontal axis is the predicted average excess return implied from the model. The points represent the 9 portfolios. Compared with G10 currencies, the scatter plot of actual and predicted return for three-factor model in EM currencies shows the smaller pricing error with all points moving along closely to the 45o degree line. For G10 currencies, the SL, ML, and BM portfolios have relatively large pricing error. Figure 3.1 also visualizes the three-factor model outperforms the CAPM as there are large pricing errors of the CAPM for both EM and G10 currencies.

3.4.3 Key Results and Discussions

Estimation results of the linear factor model provide some key insights into the common risk factors of EM and G10 currencies.

Firstly, three-factor model is more successful in explaining common risk factors for EM currencies than for G10 currencies. Compared with the CAPM, adding two new factors including the BMS and LMH factor can explain a large part of the return variance in EM currencies. Estimation results show that the risk prices of the BMS and RX factor are statistically significant only in EM currencies.

Secondly, estimation results imply that EM currencies with big interest rate differential relative to the US have higher average excess return because they all move with common risk factors. The important common component to value EM currencies is captured by the BMS factor.

Thirdly, an implication for future model of currency risk premium is that, for EM currencies, the stochastic discount factor in an asset-pricing general equilibrium should contain at least two common shocks including the Global Common Risk and Interest Rate Differential, while the common risk factors for G10 currencies are different from those of EM currencies.

The Relation between the Long-run Risk Theoretical Model in Chapter 2 and the Factor Model in Chapter 3:

Chapter 3 provides empirical tests of the factor model for currency portfolios without providing any theoretical models behind it; thus, one possible option would be to utilize the long-run risk theoretical model presented in Chapter 2 to derive the factor model in Chapter 3. According to the factor model, the BMS factor represents the interest rate differential between EM countries and the US, and the LMH factor represents the depreciation rate of EM currencies against the US dollar. To derive these risk factors from the long-run risk model in Chapter 2, one can start from linearizing the expression of excess returns which indeed consist two main terms: interest rate differential and depreciation rate. Accordingly, the BMS factor of EM currencies will be the average of differences in expected consumption growth plus asymmetric short-run and long-run consumption volatilities between the US and other EM countries. The LMH factor of EM currencies will also contain the differences in expected consumption growth but only containing asymmetric short-run volatility between the US and other EM countries. Overall, the long-run risk theoretical model in Chapter 2 can provide better insights into what economic reasons behind the factor model. More specifically, those risk factors are not only due to asymmetric short-run consumption volatility but also due to the difference in expected consumption growth and asymmetric long-run consumption volatilities between the US and other EM countries. Additionally, the parameter of risk aversion will also affect the sign and magnitude of those risk factors. The derivation of the factor model from the long-run risk model also suggests the relation between consumption growths and interest rate differentials in which interest rates might adjust according to given asymmetric consumption growths, and, on average, high-interest-rate EM currencies might be more exposed to asymmetric consumption growth risk than low-interest-rate G10 currencies. For that reason, those EM currencies often offer substantial positive risk premia. There are two future potential works that can be extended from the derivation of the factor model by utilizing the model in Chapter 2. The first work is to generate currency risk premia for portfolios implied by the model, then calculate the risk factors from generated data and estimate the price of those risk factors. The second work is to map the calibrated long-run risk model to actual price of risks estimated from data.

3.5. Conclusions

This chapter provides tests of linear factor model on monthly sorted portfolios for both EM and G10 currencies. Estimation results show that the short-term interest rate differential, referred as BMS factor, is a statistically significant common risk factor for EM currencies, but not for G10 currencies. This chapter also discusses that the long-run risk theoretical model presented in Chapter 2 can be used to explain the risk factor on EM currency portfolios. One possible economic intuition is that the BMS factor of EM countries would come from asymmetric short-run and long-run volatility between the US and other EM countries.

Another future research is that the interest rate differential (BMS) factor would also reflect an inflation premium because EM countries are more likely to face events of high inflation that make the Central Bank of these countries have tendency to maintain a higher-than-usual short-term interest rates to curb potentially high inflation. Since the interest rate differential (BMS) is shown to be a significant factor for EM currencies, inflation premium would be one potential missing component in the EM currency risk premia that are needed to include into the theoretical model.

Conclusions

In conclusion, my dissertation emphasizes the validity of two main ideas that account for positive risk premia in Emerging Market currencies. Firstly, asymmetric consumption growth risk between the US and EM countries determines the sign and magnitude of currency risk premium; both short-run and long-run consumption growth risks are components of currency risk premia. Moreover, my study shows the potential of applying long-run risk consumption-based asset pricing model into the foreign exchange market. When parameters of the model are calibrated appropriately, the aggregate consumption growth risk can be a relevant measure of risk in the currency market. The long-run risk model, thus, has its potential in explaining not only (international) equity premium puzzles, but also puzzles in the foreign exchange market.

Secondly, Global Risk Factor and Interest Rate Differentials relative to the US are the two important common risk factor for EM currencies, but not for G10 currencies. Because EM and G10 currencies have different risk profiles, future theoretical model should treat the two groups differently. Furthermore, the empirical evidences of EM currencies' common risk factors are consistent with macroeconomic logic. Compared with G10 countries, EM countries are more likely to be characterized by events of high inflation and volatile macroeconomic fundamentals. The Central Banks of EM countries, hence, may have more tendency to maintain a high short-term interest rate. Thus, together with asymmetric consumption growth risk, inflation premium which reflect the tendency of maintaining high interest rate would be a potential component of EM currency risk premium. A future research would be to develop a model of currency risk premia that incorporate both long-run consumption risk component and inflation premium for EM currencies.

Intuitions and Implications from Main Results of This Dissertation:

Firstly, from Chapter 2, asymmetric consumption growth risk between the US and EM countries can account for EM currency risk premia. These asymmetric consumption growth risks may reflect global business cycles. During normal times, or boom periods, EM currencies offer positive risk premia in compensation for future reverse movement of these currencies during adverse economic downturns, or during burst periods. It is also crucial to understand that both short-run and long-run consumption growth risks are important components in currency risk premia, because only taking into account the short-run consumption risk is not enough to explain currency risk premia. Investors often concern about long-run risks in EM countries, so the long-run consumption risks should be priced as risk premia. The conclusions from Chapter 2 are all important for investors, economists, and policymakers. For investors, when setting up a portfolio of EM currencies, they need to examine carefully asymmetric consumption growth risks between the US and EM countries so that they can have better evaluation of the riskiness of EM currencies. For economists, many macroeconomic open-economy models often either assume out or set a flat currency risk premium. They do not contain the endogenity of currency risk premium as well as its drivers; thus, those models are ignoring important implications of asset-pricing moments of the model for the currency market. For policymakers, currency risk premia can be either the cause or the consequence of instability in the currency and financial market. Understanding the link between the currency risk premia and consumption growths can provide hints for policymakers to design and implement appropriate macroeconomic policies.

Secondly, empirical evidences in Chapter 3 show that even when EM currencies have a moderate depreciation rate against the U.S. dollar, these currencies can still be the ones offering the highest risk premia. That argument is true if those EM currencies have a larger than usual interest rate differential relative to the US. Moreover, the test of linear factor model shows that the interest rate differential is a significant common risk factor for EM currencies, but the depreciation rate is not. From Chapter 2, it might be the case in which the covariance between the depreciation rate of EM currencies and consumption growth risks among countries might not be as strong as the covariance between the interest rate differential and consumption growth risks among countries. Given a situation that the Central Bank in EM countries have tendency to maintain higher-than-usual short-term interest rate relative to the US, expected short-term and long-term consumption growth in these countries may follow and adjust, affecting the currency risk premia and foreign exchange rates.

Tables and Figures

Table 1.1: Fama Regression (Full Sample)

$$s30_t - s_t = \beta_0 + \beta_1(f_t - s_t) + \varepsilon_t$$

	β_0	β_1	Wald Test $\beta_0 = 0, \beta_1 = 1$		β_0	β_1	Wald Test $\beta_0 = 0, \beta_1 = 1$
AUD	-3.850	1.029	1.670	CNY	-1.146	0.557	4.824**
	(4.311)	(1.616)	(p-val = 0.43)		(0.848)	(0.206)	(p-val = 0.09)
CAD	-1.288	-0.453	0.881	INR	1.493	0.306	3.036
	(2.945)	(4.243)	(p-val = 0.64)		(3.498)	(0.515)	(p-val = 0.22)
CHF	-0.040	1.277	0.060	IDR	2.965	0.025	1350.716***
	(4.093)	(2.072)	(p-val = 0.97)		(3.095)	(0.035)	(p-val = 0.00)
DKK	-0.668	-0.724	1.254	KRW	2.031	-1.102	4.746**
	(2.675)	(1.586)	(p-val = 0.53)		(3.871)	(1.297)	(p-val = 0.09)
EUR	-0.395	-0.047	0.431	MYR	0.390	0.930	0.017
	(2.619)	(1.601)	(p-val = 0.81)		(3.324)	(0.766)	(p-val = 0.99)
GBP	2.587	-0.214	0.752	PHP	1.772	-0.596	8.044***
	(3.344)	(1.682)	(p-val = 0.69)		(3.072)	(0.834)	(p-val = 0.02)
JPY	2.079	1.893	0.328	THB	-1.284	-0.272	2.871
	(3.799)	(1.800)	(p-val = 0.85)		(2.101)	(1.263)	(p-val = 0.24)
NOK	-0.547	3.103	1.107	TWD	0.918	0.768	1.846
	(2.957)	(2.008)	(p-val = 0.57)		(1.873)	(0.494)	(p-val = 0.40)
NZD	-22.123	7.056	5.395**	SGD	-0.254	1.781	0.475
	(11.859)	(4.362)	(p-val = 0.07)		(1.392)	(1.218)	(p-val = 0.79)
SEK	0.031	0.824	0.015	HKD	-0.088	-0.447	84.024***
	(2.971)	(1.567)	(p-val = 0.99)		(0.099)	(0.172)	(p-val = 0.00)
ZAR	21.725	-2.939	3.811*	ARS	0.399	0.610	25.474***
	(11.763)	(2.018)	(p-val = 0.14)		(3.350)	(0.190)	(p-val = 0.00)
RUB	-5.724	1.476	15.190***	BRL	-2.058	0.555	1.784
	(2.574)	(0.233)	(p-val = 0.00)		(10.108)	(1.229)	(p-val = 0.41)
CZK	-1.122	1.751	0.669	CLP	-3.369	1.430	1.606
	(3.450)	(1.677)	(p-val = 0.72)		(2.886)	(0.884)	(p-val = 0.45)
HUF	4.783	-0.819	6.653***	COP	-2.473	1.117	0.377
	(4.890)	(0.830)	(p-val = 0.04)		(4.741)	(1.234)	(p-val = 0.83)
PLN	-1.698	0.590	0.632	MXN	6.928	-0.729	1.352
	(4.160)	(1.293)	(p-val = 0.73)		(5.991)	(1.675)	(p-val = 0.51)
ISK	-4.656	1.584	0.678	PEN	-1.077	0.134	388.6***
	(5.814)	(1.121)	(p-val = 0.71)		(1.937)	(0.044)	(p-val = 0.00)

Notes: Sample period is from January 2003 to December 2017, except MYR (Jan.2009-Dec.2017), and ARS, BRL, CLP, COP, and PEN (Mar.2004 – Dec.2017). Foreign exchange rates are spot and one-month forward exchange rates from Thomson Reuters Datastream. The standard errors are in parentheses calculated by using robust Heteroskedasticity-and-Autocorrelation (HAC). The asterisk *** represents statistical significant at 5%, ** statistical significant at 10%, and * statistical significant at 15%. Only currency notations are used in this table. Name of currencies can be found in the Appendix 1.A.

Table 1.2: Comparing the Estimates of β_1 for G10 Currencies

	My Estimate	Burnside (2014)	Frankel and Poonawala (2010)	Lewis (1995)	Fama (1984)
AUD	1.029	-1.94	-5.6437	NA	NA
	(1.616)	(0.690)	(2.167)		
CAD	-0.453	-1.77	-3.2183	NA	-1.64
	(4.243)	(0.600)	(1.893)		(0.980)
CHF	1.277	-2.25	-4.304	NA	-2.44
	(2.072)	(0.760)	(2.059)		(2.500)
DKK	-0.724	-1.72	-5.5150	NA	NA
	(1.586)	(0.460)	(2.032)		
EUR	-0.047	-1.98	-5.602	NA	NA
	(1.601)	(0.820)	(2.081)		
GBP	-0.214	-2.57	-3.999	-2.31	-2.83
	(1.682)	(0.740)	(2.872)	(0.790)	(1.120)
JPY	1.893	-2.76	-1.2805	-2.28	-1.84
	(1.800)	(0.740)	(2.047)	(0.830)	(1.460)
NOK	3.103	-1.42	-3.851	NA	NA
	(2.008)	(0.620)	(1.464)		
NZD	7.056	-2.04	-3.994	NA	NA
	(4.362)	(0.520)	(2.014)		
SEK	0.824	-0.07	-5.529	NA	NA
	(1.567)	(0.630)	(1.818)		

Notes: This table summarizes the estimate of coefficient β_1 in the Fama Regression, $s30_t - s_t = \beta_0 + \beta_1(f_t - s_t) + \varepsilon_t$, for G10 currencies. The sample in Burnside (2014) 1997-2013, in Frankel and Poonawala (2010) is Dec. 1996-Apr. 2004, in Lewis (1995) is 1975-1989, and in Fama (1984) is 5/5/1978-12/10/1982

Table 1.3: Fama Regression (Excluding the GFC Months - Aug.2008-Sep.2009)

$$s30_t - s_t = \beta_0 + \beta_1(f_t - s_t) + \varepsilon_t$$

	β_0	β_1	Wald Test $\beta_0 = 0, \beta_1 = 1$		β_0	β_1	Wald Test $\beta_0 = 0, \beta_1 = 1$
AUD	-3.811	1.098	2.717	CNY	-1.230	0.556	3.396
	(3.748)	(1.573)	(p-val = 0.26)		(0.962)	(0.245)	(p-val = 0.18)
CAD	-2.306	2.546	1.385	INR	-0.399	0.570	2.253
	(2.064)	(2.897)	(p-val = 0.50)		(2.240)	(0.436)	(p-val = 0.32)
CHF	-0.072	0.619	0.122	IDR	2.482	0.030	1340.543
	(4.193)	(1.840)	(p-val = 0.94)		(2.547)	(0.033)	(p-val = 0.00)
DKK	1.018	1.990	0.221	KRW	-0.363	-0.332	3.034
	(2.980)	(2.122)	(p-val = 0.90)		(2.440)	(1.003)	(p-val = 0.22)
EUR	0.740	1.658	0.111	MYR	0.390	0.930	0.017
	(2.845)	(2.060)	(p-val = 0.95)		(3.324)	(0.766)	(p-val = 0.99)
GBP	1.390	0.454	0.319	PHP	0.657	-0.334	6.660
	(2.472)	(1.935)	(p-val = 0.85)		(2.936)	(0.812)	(p-val = 0.04)
JPY	2.519	1.073	0.764	THB	-1.342	-0.380	2.939
	(3.937)	(1.500)	(p-val = 0.68)		(2.322)	(1.508)	(p-val = 0.23)
NOK	0.040	2.368	0.914	TWD	0.046	0.655	0.816
	(2.835)	(1.584)	(p-val = 0.63)		(1.512)	(0.487)	(p-val = 0.67)
NZD	-9.906	3.077	3.026	SGD	-0.304	2.262	2.293
	(7.499)	(2.495)	(p-val = 0.22)		(1.259)	(1.078)	(p-val = 0.32)
SEK	-0.507	0.466	0.121	HKD	-0.066	-0.498	115.195
	(2.783)	(1.634)	(p-val = 0.94)		(0.101)	(0.158)	(p-val = 0.00)
ZAR	28.032	-4.163	31.506	ARS	-2.363	0.770	29.960
	(7.815)	(1.060)	(p-val = 0.00)		(1.160)	(0.045)	(p-val = 0.00)
RUB	-5.304	1.665	3.797	BRL	1.800	0.037	3.123
	(2.999)	(1.041)	(p-val = 0.15)		(10.288)	(1.258)	(p-val = 0.21)
CZK	-0.846	1.874	0.703	CLP	-5.201	2.017	3.048
	(3.188)	(1.491)	(p-val = 0.70)		(3.083)	(1.039)	(p-val = 0.22)
HUF	2.474	-0.465	5.187	COP	-2.760	1.264	0.369
	(4.239)	(0.763)	(p-val = 0.07)		(4.740)	(0.994)	(p-val = 0.83)
PLN	-5.397	1.926	2.368	MXN	15.805	-3.458	22.745
	(3.663)	(1.588)	(p-val = 0.31)		(5.198)	(1.071)	(p-val = 0.00)
ISK	-6.451	1.517	1.768	PEN	-1.054	0.134	376.5
	(8.433)	(1.619)	(p-val = 0.41)		(1.505)	(0.045)	(p-val = 0.00)

Notes: Sample period is from January 2003 to December 2017, removing months of Global Financial Crisis from Aug.2008 to Sep. 2009, except MYR (Jan.2009-Dec.2017), and ARS, BRL, CLP, COP, and PEN (Mar.2004 – Dec.2017). Foreign exchange rates are spot and one-month forward exchange rates from Thomson Reuters Datastream. The standard errors are in parentheses calculated by using robust Heteroskedasticity-and-Autocorrelation (HAC). The asterisk *** represents statistical significant at 5%, ** statistical significant at 10%, and * statistical significant at 15%. Only currency notations are used in this table. Name of currencies can be found in the Appendix 1.A.

Table 1.4: Comparing the Estimates of β_1 between Two Samples

	Full Sample β_1	Remove GFC β_1		Full Sample β_1	Remove GFC β_1
AUD	1.029	1.098	CNY	0.557	0.556
	(1.616)	(1.573)		(0.206)	(0.245)
CAD	-0.453	2.546	INR	0.306	0.570
	(4.243)	(2.897)		(0.515)	(0.436)
CHF	1.277	0.619	IDR	0.025	0.030
	(2.072)	(1.840)		(0.035)	(0.033)
DKK	-0.724	1.990	KRW	-1.102	-0.332
	(1.586)	(2.122)		(1.297)	(1.003)
EUR	-0.047	1.658	MYR	0.930	0.930
	(1.601)	(2.060)		(0.766)	(0.766)
GBP	-0.214	0.454	PHP	-0.596	-0.334
	(1.682)	(1.935)		(0.834)	(0.812)
JPY	1.893	1.073	THB	-0.272	-0.380
	(1.800)	(1.500)		(1.263)	(1.508)
NOK	3.103	2.368	TWD	0.768	0.655
	(2.008)	(1.584)		(0.494)	(0.487)
NZD	7.056	3.077	SGD	1.781	2.262
	(4.362)	(2.495)		(1.218)	(1.078)
SEK	0.824	0.466	HKD	-0.447	-0.498
	(1.567)	(1.634)		(0.172)	(0.158)
ZAR	-2.939	-4.163	ARS	0.610	0.770
	(2.018)	(1.060)		(0.190)	(0.045)
RUB	1.476	1.665	BRL	0.555	0.037
	(0.233)	(1.041)		(1.229)	(1.258)
CZK	1.751	1.874	CLP	1.430	2.017
	(1.677)	(1.491)		(0.884)	(1.039)
HUF	-0.819	-0.465	COP	1.117	1.264
	(0.830)	(0.763)		(1.234)	(0.994)
PLN	2.005	1.926	MXN	-0.729	-3.458
	(1.818)	(1.588)		(1.675)	(1.071)
ISK	1.584	1.517	PEN	0.134	0.134
	(1.121)	(1.619)		(0.044)	(0.045)

Notes: This table compares the estimate of coefficient β_1 in two samples. "Full sample" represents a period from January 2003 to December 2017 including all months pertaining to the Global Financial Crisis. "Removing GFC" represents for a period from January 2003 to December 2017 excluding months pertaining to the Global Financial Crisis from Aug. 2008 to Sep. 2009.

Table 2.1**:** Currency Risk Premium (Full Sample)

Panel 1: No Inflation-Adjusted						**Panel 2: Inflation-Adjusted**					
EM Currencies (% p.a.)			*G10 Currencies (% p.a.)*			*EM Currencies (% p.a.)*			*G10 Currencies (% p.a.)*		
	RP	Std.		RP	Std.		RP	Std.		RP	Std.
CNY	0.98^{**}	2.25	AUD	3.77	12.48	CNY	0.93^{**}	2.24	AUD	3.36	12.44
INR	1.82	8.00	CAD	1.66	9.58	INR	1.43	8.06	CAD	1.69	9.59
IDR	24.89^{***}	16.71	CHF	0.43	10.49	IDR	24.55^{***}	16.75	CHF	0.58	10.47
KRW	-0.18	11.82	DKK	-0.01	9.68	KRW	-0.21	11.83	DKK	0.04	9.66
MYR	-0.26	8.57	EUR	-0.02	9.70	MYR	-0.33	8.58	EUR	0.02	9.69
PHP	2.23^{*}	5.77	GBP	-1.89	9.19	PHP	2.09^{*}	5.78	GBP	-1.90	9.20
THB	2.83^{**}	5.78	JPY	-0.63	9.55	THB	2.81^{**}	5.78	JPY	-0.48	9.54
TWD	-1.32	4.78	NOK	-1.06	11.45	TWD	-1.25	4.78	NOK	-1.04	11.47
CZK	1.54	11.69	NZD	3.75	13.32	CZK	1.55	11.70	NZD	3.74	13.28
HUF	2.09	14.02	SEK	-0.05	11.26	HUF	1.97	14.01	SEK	0.02	11.26
ISK	1.13	14.21				ISK	-1.77	14.31			
PLN	1.83	13.98				PLN	1.82	13.99			
RUB	2.61	13.79				RUB	2.07	13.79			
ARS	8.37^{***}	9.82				ARS	3.62	9.88			
BRL	6.81^{***}	15.27				BRL	6.51^{***}	15.29			
CLP	2.39	11.64				CLP	2.28	11.65			
COP	2.08	13.71				COP	1.90	13.70			
MXN	0.35	10.55				MXN	0.19	10.57			
PEN	3.73^{***}	5.95				PEN	3.66^{***}	5.95			
EGP	10.22^{***}	16.64				EGP	9.46^{***}	16.65			
ZAR	3.17	16.00				ZAR	2.95	16.01			
EM	**4.31^{***}**	**6.80**	**G10**	**0.59**	**8.30**	**EM**	**3.54^{***}**	**6.93**	**G10**	**0.60**	**8.34**

Notes: Data source is from Reuters Datastream for Office. Monthly spot exchange rates and forward exchange rates are closing mid rates on the last business day of the month. Sample period is from January 2003 to December 2017, except MYR (Jan.2009-Dec.2017), and ARS, BRL, CLP, COP, and PEN (Mar.2004 – Dec.2017). The US dollar is the base currency. All moments are annualized and reported in percentage points. Currency risk premium is defined as the mean of currency excess returns. The column "RP" represents annualized risk premium and the column "Std." represents the corresponding annualized standard deviation. Due to space limit, only currencies' codes are used, names of currencies can be found in Appendix 1.A. Panel 1 reports currency risk premium without adjustment for inflation. Panel 2 reports currency risk premium with adjustment for inflation, calculated as $\mathrm{E}(\mathrm{er}^{\mathrm{r}}_{\mathrm{t+1}}) = E[(f_t - s_{t+1}) - (\pi_t^f - \pi_t^{US})]$, in which π_t^f and π_t^{US} denote inflation rate in foreign country and in the US. Inflation rates in foreign countries and the US are monthly month-on-month percentage changes in CPI index. Data source for the CPI index is from International Financial Statistics, the International Monetary Funds. In the table, the asterisk *** represents statistical significant different from zero at 5%; the asterisk ** represents statistical significant different from zero at 10%; the asterisk * represents statistical significant different from zero at 15%.

Table 2.2**:** Currency Risk Premium (Excluding the GFC)
(Excluding Global Financial Crisis Period - Aug.2008-Sep.2009)

Panel 1: No Inflation-Adjusted						**Panel 2: Inflation-Adjusted**					
EM Currencies (% p.a.)			*G10 Currencies (% p.a.)*			*EM Currencies (% p.a.)*			*G10 Currencies (% p.a.)*		
	RP	Std.		RP	Std.		RP	Std.		RP	Std.
CNY	0.96**	2.32	AUD	3.55	11.39	CNY	0.91**	2.32	AUD	3.31	11.37
INR	2.49	7.51	CAD	1.87	1.87	INR	2.15	7.56	CAD	1.91	8.35
IDR	26.74***	16.21	CHF	-0.49	9.65	IDR	26.40***	16.25	CHF	-0.33	9.64
KRW	1.89	8.40	DKK	-0.51	8.82	KRW	1.89	8.40	DKK	-0.45	8.81
MYR	-0.26	8.57	EUR	-0.45	8.87	MYR	-0.33	8.58	EUR	-0.40	8.86
PHP	2.61**	5.58	GBP	-1.07	8.39	PHP	2.48**	5.60	GBP	-1.05	8.38
THB	2.83**	5.77	JPY	-2.40	9.05	THB	2.80**	5.77	JPY	-2.24	9.06
TWD	-0.63	4.53	NOK	-0.96	10.90	TWD	-0.55	4.54	NOK	-0.91	10.91
CZK	1.45	11.23	NZD	3.66	11.75	CZK	1.46	11.23	NZD	3.87	11.74
HUF	2.66	12.79	SEK	0.42	10.37	HUF	2.55	12.78	SEK	0.51	10.36
ISK	3.49	10.80				ISK	1.61	10.83			
PLN	3.45	12.90				PLN	3.49	12.90			
RUB	1.81	13.66				RUB	1.31	13.66			
ARS	7.12***	8.28				ARS	2.30	8.05			
BRL	7.67**	14.24				BRL	7.38**	14.25			
CLP	2.86	10.23				CLP	2.75	10.22			
COP	1.94	12.73				COP	1.78	12.72			
MXN	1.81	9.39				MXN	1.68	9.39			
PEN	3.65***	5.83				PEN	3.61***	5.82			
EGP	9.87**	17.35				EGP	9.14**	17.35			
ZAR	3.53	15.03				ZAR	3.34	15.04			
EM	**4.88*****	**5.99**	**G10**	**0.36**	**7.69**	**EM**	**4.25*****	**6.10**	**G10**	**0.42**	**7.68**

Notes: Data source is from Reuters Datastream for Office. Monthly spot exchange rates and forward exchange rates are closing mid rates on the last business day of the month. Sample period is from January 2003 to December 2017, except MYR (Jan.2009-Dec.2017), and ARS, BRL, CLP, COP, and PEN (Mar.2004 – Dec.2017). To see the impact of the Global Financial Crisis, months from August 2008 to September 2009 are excluded from the sample. The US dollar is the base currency. All moments are annualized and reported in percentage points. Currency risk premium is defined as the mean of currency excess returns. The column “RP” represents annualized risk premium and the column “Std.” represents the corresponding annualized standard deviation. Due to space limit, only currencies’ codes are used, names of currencies can be found in Appendix 1.A. Panel 1 reports currency risk premium without adjustment for inflation. Panel 2 reports currency risk premium with adjustment for inflation, calculated as $\mathrm{E}(\mathrm{er}^{\mathrm{r}}_{\mathrm{t+1}}) = E[(f_t - s_{t+1}) - (\pi^f_t - \pi^{US}_t)]$, in which π^f_t and π^{US}_t denote inflation rate in foreign country and in the US. Inflation rates in foreign countries and the US are monthly month-on-month percentage changes in CPI index. Data source for the CPI index is from International Financial Statistics, the International Monetary Funds. In the table, the asterisk *** represents statistical significant different from zero at 5%; the asterisk ** represents statistical significant different from zero at 10%; the asterisk * represents statistical significant different from zero at 15%.

Table 2.3: Parameter Calibration

Parameters		**Value**
Subjective Discount Factor	δ	0.993
Intertemporal Elasticity of Substitution	ψ	1.5
Risk Aversion Coefficient	γ	10
Correlation of Long-run Risk Shocks	τ_e	0.9999

Notes: Agents in all countries have identical preference parameters. The model describes a monthly decision problem. The risk aversion coefficient and the IES parameters are selected basing on the literature on long-run risks (Bansal et al., 2009; Beeler & Campbell, 2009). The correlation of long-run risk shock to consumption growth is selected to reflect perfect correlation, implying a common long-run risk shock to all countries.

Table 2.4: State-Space Estimation (Full Sample)

Country	μ_c	ρ	λ_e/λ_c	λ_c	λ_e
US Dollar (USD)	0.0025	0.9999	0.0100	0.0095	0.0001
Malaysian Ringgit (MYR)	0.0056	0.9998	0.0037	0.0031	0.0000
Chilean Peso (CLP)	0.0037	0.9970	0.0130	0.0085	0.0001
Colombian Peso (COP)	0.0034	0.9860	0.1000	0.0034	0.0003
Taiwanese Dollar (TWD)	0.0043	0.9700	0.1100	0.0057	0.0006
Chinese Renminbi (CNY)	0.0078	0.9440	0.3600	0.0030	0.0011
Hungarian Forint (HUF)	0.0016	0.9380	0.3600	0.0030	0.0011
Thai Baht (THB)	0.0027	0.9280	0.1000	0.0100	0.0010
Czech Koruna (CZK)	0.0019	0.8600	0.8600	0.0025	0.0022
Philippine Peso (PHP)	0.0041	0.7750	3.5000	0.0010	0.0035
South African Rand (ZAR)	0.0028	0.7736	0.6227	0.0045	0.0028
Brazilian Real (BRL)	0.0024	0.7540	3.1720	0.0016	0.0049
Mexican Peso (MXN)	0.0023	0.7468	3.8170	0.0011	0.0042
South Korean Won (KRW)	0.0044	0.6900	2.9000	0.0020	0.0059
Iceland Krona (ISK)	0.0025	0.6300	2.1000	0.0030	0.0063
Peruvian Sol (PEN)	0.0026	0.6000	6.0000	0.0011	0.0066
Argentinian Peso (ARS)	0.0034	0.5000	5.0000	0.0021	0.0107
Indian Rupee (INR)	0.0063	0.4000	2.7000	0.0037	0.0100

Notes: This table provides estimation results from the state-space estimation of the system of equation (2. 12), in which three estimated parameters include the short-run consumption growth risk, λ_c^i, the long-run consumption growth risk, λ_e^i, and the persistence of long-run risk, ρ^i.

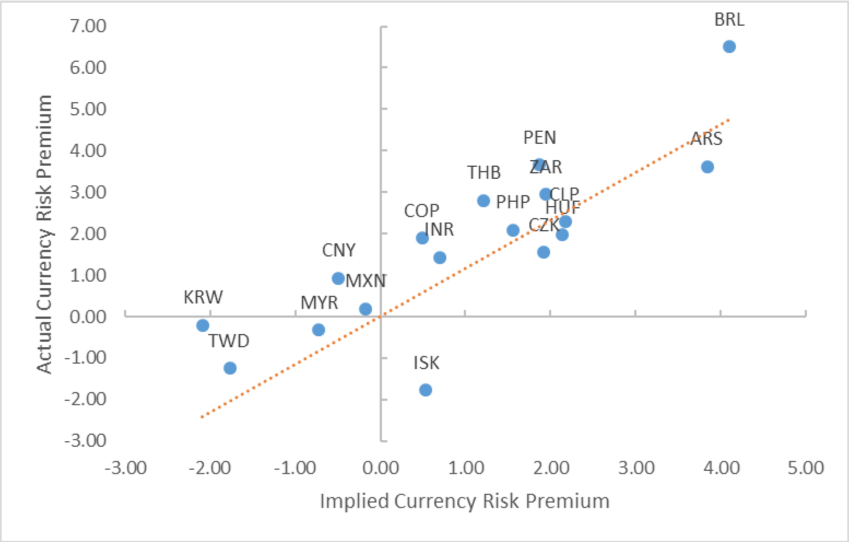


Figure 2.1: Actual and Implied EM Currency Risk Premium (Full Sample)

Notes: This figure plot the actual versus implied EM currency risk premium. The horizontal axis is the currency risk premium implied by the long-run risk model and the vertical axis is currency risk premium calculated from actual data from Jan. 2003 – Dec. 2017.

Table 2.5: Implied and Actual Currency Risk Premium (Full Sample)

Currency	**Implied Risk Premium**	**Actual Risk Premium**
Malaysian Ringgit (MYR)	-0.73	-0.33
Chilean Peso (CLP)	2.17	2.28
Colombian Peso (COP)	0.49	1.90
Taiwanese Dollar (TWD)	-1.77	-1.25
Chinese Renminbi (CNY)	-0.49	0.93
Hungarian Forint (HUF)	2.14	1.97
Thai Baht (THB)	1.21	2.81
Czech Koruna (CZK)	1.92	1.55
Philippine Peso (PHP)	1.56	2.09
South African Rand (ZAR)	1.95	2.95
Brazilian Real (BRL)	4.10	6.51
Mexican Peso (MXN)	-0.17	0.19
South Korean Won (KRW)	-2.09	-0.21
Iceland Krona (ISK)	0.53	-1.77
Peruvian Sol (PEN)	1.87	3.66
Argentinian Peso (ARS)	3.84	3.62
Indian Rupee (INR)	0.70	1.43
EM Portfolio	1.01	3.54

Notes: This table provides the currency risk premium implied by the long-run risk model (the first column) and the currency risk premium calculated from actual data from Jan. 2003 – Dec. 2017 (the second column).

Table 2.6: Robustness Check

	γ= 5	**γ = 7.5**	**γ =10**	**γ = 12**	
Currency	Implied Risk Premium	Implied Risk Premium	Implied Risk Premium	Implied Risk Premium	Actual Risk Premium
Malaysian Ringgit (MYR)	-0.10	-0.39	-0.73	-0.98	-0.33
Chilean Peso (CLP)	0.55	1.25	2.17	3.05	2.28
Colombian Peso (COP)	0.40	0.54	0.49	0.25	1.90
Taiwanese Dollar (TWD)	-0.12	-0.69	-1.77	-3.08	-1.25
Chinese Renminbi (CNY)	0.21	0.04	-0.49	-1.26	0.93
Hungarian Forint (HUF)	0.78	1.46	2.14	0.25	1.97
Thai Baht (THB)	0.61	0.82	1.21	1.43	2.81
Czech Koruna (CZK)	0.68	1.28	1.92	0.25	1.55
Philippine Peso (PHP)	0.61	1.09	1.56	1.88	2.09
South African Rand (ZAR)	0.65	1.26	1.95	2.50	2.95
Brazilian Real (BRL)	1.39	2.72	4.10	5.11	6.51
Mexican Peso (MXN)	0.23	0.16	-0.17	-0.67	0.19
South Korean Won (KRW)	-0.13	-0.80	-2.09	-3.63	-0.21
Iceland Krona (ISK)	0.43	0.60	0.53	0.24	-1.77
Peruvian Sol (PEN)	0.73	1.32	1.87	2.19	3.66
Argentinian Peso (ARS)	1.52	1.52	3.84	4.32	3.62
Indian Rupee (INR)	0.45	0.67	0.70	0.50	1.43
EM Portfolio	0.52	0.76	1.01	0.73	3.54

Notes: This table provides a robustness check of how implied currency risk premium changes when there are changes in the coefficient of risk aversion (γ) from 5, 7.5, 10, to 12.

Table 2.7: State-Space Estimation (Excluding the GFC)
(Excluding Global Financial Crisis Months - Aug.2008-Sep.2009)

Country	μ_c	ρ	λ_e/λ_c	λ_c	λ_e
US Dollar (USD)	0.0026	0.9940	0.1300	0.0017	0.0002
Malaysian Ringgit (MYR)	0.0056	0.9998	0.0040	0.0035	0.0000
Chilean Peso (CLP)	0.0038	0.9992	0.0180	0.0060	0.0001
Colombian Peso (COP)	0.0037	0.9985	0.0613	0.0027	0.0002
Taiwanese Dollar (TWD)	0.0044	0.9991	0.0506	0.0054	0.0003
Chinese Renminbi (CNY)	0.0079	0.9300	0.3300	0.0040	0.0013
Hungarian Forint (HUF)	0.0021	0.9830	0.3500	0.0011	0.0004
Thai Baht (THB)	0.0029	0.9684	0.0947	0.0072	0.0007
Czech Koruna (CZK)	0.0021	0.8570	0.6981	0.0031	0.0022
Philippine Peso (PHP)	0.0042	0.9999	0.0330	0.0040	0.0001
South African Rand (ZAR)	0.0029	0.7737	0.6227	0.0054	0.0033
Brazilian Real (BRL)	0.0026	0.7586	3.0000	0.0010	0.0030
Mexican Peso (MXN)	0.0026	0.7500	3.8000	0.0011	0.0042
South Korean Won (KRW)	0.0045	0.9100	0.1855	0.0074	0.0014
Iceland Krona (ISK)	0.0035	0.7856	1.5298	0.0073	0.0112
Peruvian Sol (PEN)	0.0028	0.6012	6.2000	0.0011	0.0068
Argentinian Peso (ARS)	0.0038	0.5762	4.8000	0.0011	0.0053
Indian Rupee (INR)	0.0051	0.9999	0.0020	0.0150	0.0001

Notes: This table provides estimation results from the state-space estimation of the system of equation (2. 12), in which three estimated parameters include the short-run consumption growth risk, λ_c^i, the long-run consumption growth risk, λ_e^i, and the persistence of long-run risk, ρ^i. To see the impact of the Global Financial Crisis, months from August 2008 to September 2009 are excluded from the time series of consumption growth in each country.

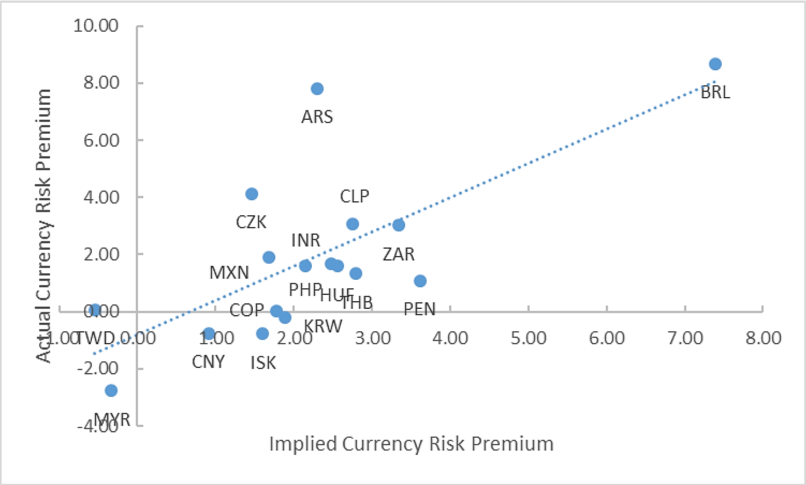


Figure 2.2: Actual and Implied EM Currency Risk Premium (Excluding the GFC)

Notes: This figure plot the actual versus implied EM currency risk premium. To see the impact of the Global Financial Crisis, months from August 2008 to September 2009 are excluded from the sample. The horizontal axis is the currency risk premium implied by the long-run risk model and the vertical axis is currency risk premium calculated from actual data from Jan. 2003 – Dec. 2017.

Table 2.8: Implied and Actual Currency Risk Premium (Excluding the GFC)
(Excluding Global Financial Crisis Months - Aug.2008-Sep.2009)

Currency	Implied RP (Remove GFC)	Implied RP (Full Sample)	Actual RP (Remove GFC)
Malaysian Ringgit (MYR)	-2.763	-0.73	-0.331
Chilean Peso (CLP)	3.073	2.17	2.752
Colombian Peso (COP)	0.035	0.49	1.779
Taiwanese Dollar (TWD)	0.070	-1.77	-0.547
Chinese Renminbi (CNY)	-0.748	-0.49	0.912
Hungarian Forint (HUF)	1.590	2.14	2.554
Thai Baht (THB)	1.338	1.21	2.798
Czech Koruna (CZK)	4.139	1.92	1.458
Philippine Peso (PHP)	1.699	1.56	2.483
South African Rand (ZAR)	3.022	1.95	3.342
Brazilian Real (BRL)	8.688	4.10	7.385
Mexican Peso (MXN)	1.919	-0.17	1.680
South Korean Won (KRW)	-0.195	-2.09	1.888
Iceland Krona (ISK)	-0.772	0.53	1.606
Peruvian Sol (PEN)	1.091	1.87	3.610
Argentinian Peso (ARS)	7.815	3.84	2.301
Indian Rupee (INR)	1.622	0.70	2.149
EM Portfolio	1.860	1.01	4.250

Notes: This table provides the currency risk premium implied by the long-run risk model (the first column) and the currency risk premium calculated from actual data from Jan. 2003 – Dec. 2017 (the second column). To see the impact of the Global Financial Crisis, months from August 2008 to September 2009 are excluded from the sample.

Table 3.1: Currency Portfolios Sorted by Momentum

	Global			**G10**			**EM**		
	High	Mid	Low	High	Mid	Low	High	Mid	Low
Mean	2.05	2.77	1.68	0.49	1.32	0.14	2.71	2.50	3.57
Std.	8.58	6.89	7.59	9.73	9.09	8.61	8.77	6.90	7.29
Sharpe Ratio	0.24	0.40	0.22	0.05	0.15	0.02	0.31	0.36	0.49

Notes: Sample period is from January 2003 to December 2017. “Global” refer to all 29 currencies; “G10” refers to 10 major currencies; “EM” refers to 19 EM currencies. Currencies are sorted by their depreciation rate against the US dollar, denoted as Momentum. “*Low, Mid, High*” correspond to portfolios of currencies that have “Low”, “Mid”, and “High” depreciation rate against the US dollar. Portfolios are rebalanced every month. All moments are annualized and reported in percentage points, in which the mean of monthly excess return is multiplied by 12 and the standard deviation is multiplied by $\sqrt{12}$. Sharpe Ratio is defined as the mean of currency excess returns over its standard deviation.

Table 3.2: Currency Portfolios Sorted by Carry

	Global			**G10**			**EM**		
	Big	Medium	Small	Big	Medium	Small	Big	Medium	Small
Mean	5.38	1.49	-0.50	1.97	-0.10	0.05	7.04	1.60	0.17
Std.	8.12	7.74	6.82	11.20	8.84	7.58	8.36	7.31	6.32
Sharpe Ratio	0.66	0.19	-0.07	0.18	-0.01	0.01	0.84	0.22	0.03

Notes: Sample period is from January 2003 to December 2017. “Global” refer to all 29 currencies; “G10” refers to 10 major currencies; “EM” refers to 19 EM currencies. Currencies are sorted by their interest rate differential relative to the US, denoted as Carry. “*Big, Medium, Small*” correspond to portfolios of currencies that have “Big”, “Medium”, and “Small” interest rate differential relative to the US. Portfolios are rebalanced every month. All moments are annualized and reported in percentage points, in which the mean of monthly excess return is multiplied by 12 and the standard deviation is multiplied by $\sqrt{12}$. Sharpe Ratio is defined as the mean of currency excess returns over its standard deviation.

Table 3.3: Currency Portfolios Sorted by Carry and Momentum

	Global			**G10**			**EM**		
	Big	Medium	Small	Big	Medium	Small	Big	Medium	Small
High	4.18	1.09	-1.26	1.40	0.57	1.38	6.83	0.91	-1.05
	(10.70)	(9.40)	(8.64)	(12.34)	(9.25)	(10.62)	(11.98)	(9.78)	(8.58)
Mid	6.80	2.22	0.82	2.69	0.24	-0.95	7.43	2.56	0.54
	(10.60)	(8.20)	(7.55)	(12.45)	(9.96)	(9.61)	(11.95)	(8.01)	(6.83)
Low	5.62	1.20	-0.89	1.81	-1.11	-0.01	6.68	1.33	1.16
	(8.81)	(8.11)	(7.15)	(12.29)	(11.36)	(8.25)	(10.10)	(8.24)	(7.11)

Notes: Sample period is from January 2003 to December 2017. “Global” refer to all 29 currencies; “G10” refers to 10 major currencies; “EM” refers to 19 EM currencies. Currencies are sorted by their interest rate differential relative to the US (Carry) and by their depreciation rate against the US dollar (Momentum). Portfolios are rebalanced every month. “*Big, Medium, Small*” correspond to portfolios of currencies that have “Big”, “Medium”, and “Small” interest rate differential relative to the US. “Low, Mid, High” correspond to portfolios of currencies that have “Low”, “Mid”, and “High” depreciation rate against the US dollar. All moments are annualized and reported in percentage points, in which the mean of monthly excess return is multiplied by 12 and the standard deviation presented in parentheses is multiplied by $\sqrt{12}$..

Table 3.4: Factor Betas (Two-Step Fama-French Regression)

G10 Currencies					EM Currencies			
Portfolio	β_{RX}	β_{BMS}	β_{LMH}		Portfolio	β_{RX}	β_{BMS}	β_{LMH}
BH	0.988	0.535	-0.402		BH	0.810	0.530	-0.830
	(0.048)	(0.055)	(0.064)			(0.067)	(0.071)	(0.058)
BM	0.997	0.565	-0.161		BM	1.083	0.729	0.206
	(0.051)	(0.059)	(0.068)			(0.088)	(0.093)	(0.076)
BL	1.021	0.508	0.483		BL	1.038	0.342	0.670
	(0.048)	(0.055)	(0.064)			(0.071)	(0.074)	(0.061)
MH	0.863	-0.019	-0.375		MH	1.080	-0.078	-0.494
	(0.049)	(0.056)	(0.065)			(0.055)	(0.058)	(0.048)
MM	1.025	-0.215	-0.021		MM	1.048	-0.123	-0.010
	(0.055)	(0.064)	(0.074)			(0.051)	(0.054)	(0.044)
ML	1.098	0.018	0.556		ML	1.011	-0.003	0.411
	(0.055)	(0.064)	(0.074)			(0.057)	(0.060)	(0.049)
SH	1.109	-0.461	-0.632		SH	1.105	-0.539	-0.285
	(0.048)	(0.055)	(0.063)			(0.046)	(0.049)	(0.040)
SM	1.058	-0.460	-0.001		SM	0.878	-0.434	0.021
	(0.051)	(0.058)	(0.067)			(0.048)	(0.050)	(0.041)
SL	0.841	-0.472	0.552		SL	0.947	0.947	0.310
	(0.043)	(0.049)	(0.057)			(0.044)	(0.044)	(0.038)

Notes: This table reports the estimated factor loading (or beta factor) from three-factor model for EM and G10 currencies. Estimation is the first-stage regression in the Fama-French two-stage OLS estimation. Standard errors are in parentheses The test portfolios are 9 portfolios sorted simultaneously by interest rate differential relative to the US and depreciation rate against the US dollar. "*B, M, S*" correspond to currency portfolios that have "Big", "Medium", and "Small" interest rate differential relative to the US. "L, M, H" correspond to currency portfolios that have "Low", "Mid", and "High" depreciation rate against the US dollar. Accordingly, for example, "BH" corresponds to "Big-High" currency portfolio.

Table 3.5: Factor Prices
(Fama-French Two-Stage Estimation)

	G10 Currencies	EM Currencies
λ_{RX}	0.65**	2.87****
	(0.32)	(0.45)
λ_{BMS}	1.87*	6.73****
	(0.77)	(1.07)
λ_{LMH}	-1.14	0.46
	(0.76)	(1.02)
R^2	0.58	0.87

Notes: This table reports the estimated factor risk prices from three-factor model for EM and G10 currencies. Estimation is the second-stage regression in the Fama-French two-stage OLS estimation. Standard errors are in parentheses. The test portfolios are 9 portfolios sorted simultaneously by interest rate differential and depreciation rate against the US dollar.

The asterisk **** represents Statistical Significant at 0.1%; The asterisk *** represents Statistical Significant at 1%; The asterisk ** represents Statistical Significant at 5%; and the asterisk * represents Statistical Significant at 10%.

Table 3.6: Factor Prices (GMM Estimation)

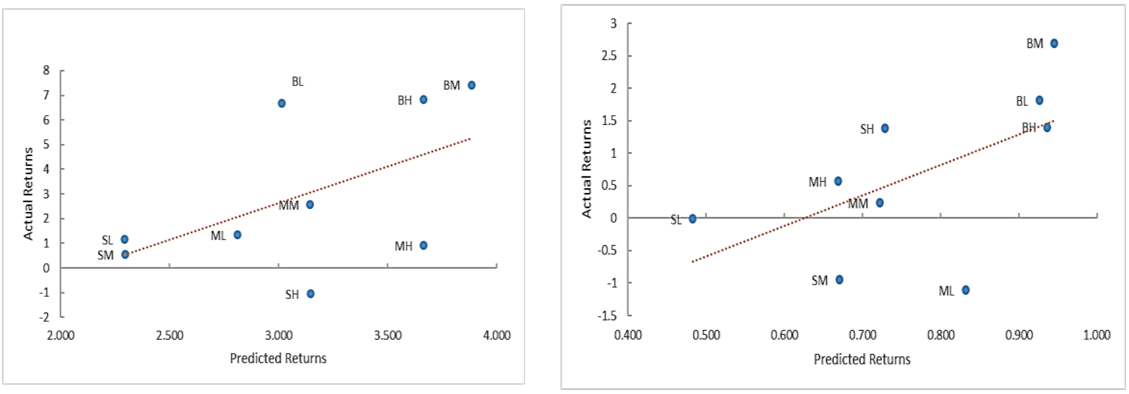
	EM Currencies		**G10 Currencies**	
Factor Price	CAPM	Three-Factor	CAPM	Three-Factor
λ_{RX}	2.329***	2.494*	-0.440	0.636
	(0.981)	(1.670)	(1.736)	(2.217)
λ_{BMS}		6.412***		1.944
		(1.349)		(1.874)
λ_{LMH}		1.479		-0.452
		(1.852)		(1.467)
Hansen's J-test χ^2	7.097	6.543	4.166	3.120
	(p-val = 0.53)	(p-val = 0.37)	(p-val = 0.84)	(p-val = 0.79)

Notes: This table reports the estimated factor risk prices for the CAPM and three-factor model for EM and G10 currencies. The test portfolios are 9 currency portfolios sorted simultaneously by interest rate differential and depreciation rate against the US dollar. Estimation is by two-step GMM. HAC standard errors are in parentheses. The p-value for the J-test of over-identifying restrictions are in parentheses.

The asterisk *** represents statistical significant at 5%; The asterisk ** represents statistical significant at 10%; The asterisk * represents statistical significant at 15%.

Panel 1: CAPM

(a) EM Currencies (b) G10 Currencies



Panel 2: Three-Factor Model

(a) EM Currencies (b) G10 Currencies

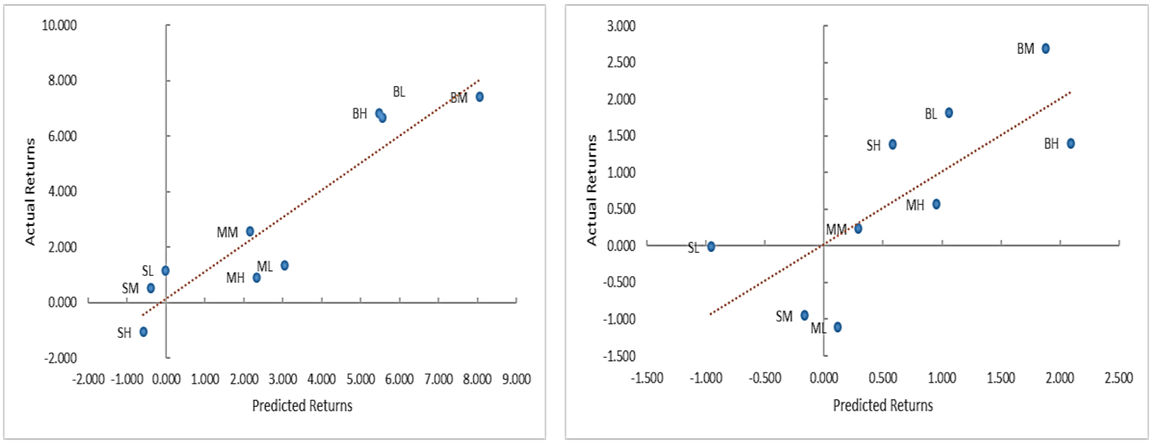


Figure 3.1: Actual and Predicted Returns for Currency Portfolios.

Notes: This figure plots actual against the predicted currency excess returns for 9 currency portfolios sorted simultaneously by interest rate differential and depreciation rate. There are two group of currencies including (a) EM and (b) G10 currencies. "*B, M, S*" correspond to currency portfolios that have "Big", "Medium", and "Small" interest rate differential relative to the US. "L, M, H" correspond to currency portfolios that have "Low", "Mid", and "High" depreciation rate against the US dollar. Accordingly, for example, "BH" corresponds to "Big-High" currency portfolio. Panel 1 includes figures for the CAPM which has RX_t as the only risk factor. Panel 2 includes figures for three-factor model which has RX_t, BMS_t, and LMH_t as the three risk factors.

Appendix

Appendix 1.A

Currency Notations

G10 Currencies	
AUD	Australian Dollar
CAD	Canadian Dollar
CHF	Swiss Franc
DKK	Danish Krone
EUR	Euro
GBP	United Kingdom Pound
JPY	Japanese Yen
NOK	Norwegian Krone
NZD	New Zealand Dollar
SEK	Swedish Krona
Emerging Market Currencies	
CNY	Chinese Renminbi
INR	Indian Rupee
IDR	Indonesian Rupiah
KRW	South Korean Won
MYR	Malaysian Ringgit
PHP	Philippine Peso
THB	Thai Baht
TWD	Taiwanese Dollar
HKD	Hong Kong Dollar
SGD	Singaporean Dollar
CZK	Czech Koruna
HUF	Hungarian Forint
ISK	Iceland Krona
PLN	Polish Zloty
RUB	Russian Rouble
ARS	Argentinian Peso
BRL	Brazilian Real
CLP	Chilean Peso
COP	Colombian Peso
MXN	Mexican Peso
PEN	Peruvian Sol
EGP	Egyptian Pound
ZAR	South African Rand

Appendix 1.B

The purpose of this appendix is to provide the decomposition of the Fama regression to show a condition for which currency risk premium can explain for the forward premium puzzle. Detailed derivations can be found in Wickens (2012), Chapter 12 or Evans (2012), Chapter 11. The Fama Regression regresses the change of exchange rate on the forward premium.

$$\mathrm{s}_{\mathrm{t+1}} - s_t = \beta_0 + \beta_1(f_t - s_t) + u_t, \tag{1.B. 1}$$

$$plim(\beta_1^{OLS}) = \frac{Cov(f_t - s_t, s_{t+1} - s_t)}{Var(f_t - s_t)}, \tag{1.B. 2}$$

Risk premium is defined as $rp_t = f_t - E_t(s_{t+1})$.

The definition of risk premium implies that

$$f_t - s_t = E_t(s_{t+1}) - s_t + rp_t, \tag{1.B. 3}$$

$$plim(\beta_1^{OLS}) = \frac{Cov(f_t - s_t, E_t(s_{t+1}) - s_t)}{Var(f_t - s_t)}. \tag{1.B. 4}$$

Substituting equation (1.B. 3) into equation (1.B. 4) produces

$$plim(\beta_1^{OLS}) = \frac{Var(E_t(s_{t+1}) - s_t) + Cov(E_t(s_{t+1}) - s_t, rp_t)}{Var(f_t - s_t)}. \tag{1.B. 5}$$

From the preceding equations, because variances are non-negative, the sign of $plim(\beta_1^{OLS})$ will depend on $Cov(E_t(s_{t+1}) - s_t, rp_t)$.

The condition $plim(\beta_1^{OLS}) < 0$ implies that $Cov(E_t(s_{t+1}) - s_t, rp_t) < -Var(E_t(s_{t+1}) - s_t)$.

Multiplying both sides of equation (1.B. 5) by $Var(f_t - s_t)$ and using again the equation (1.B. 3) yields

$$\begin{aligned} plim(\beta_1^{OLS})\{Var(E_t(s_{t+1}) - s_t) + 2Cov(E_t(s_{t+1}) - s_t, rp_t) + Var(rp_t)\} \\ = Var(E_t(s_{t+1}) - s_t) + Cov(E_t(s_{t+1}) - s_t, rp_t) \end{aligned} \tag{1.B. 6}$$

The condition $plim(\beta_1^{OLS}) < \frac{1}{2}$ implies that

$$\frac{1}{2}\{Var(E_t(s_{t+1}) - s_t) + Var(rp_t)\} > Var(E_t(s_{t+1}) - s_t) \qquad (1.B.\ 7)$$

$$\leftrightarrow Var(rp_t) > Var(E_t(s_{t+1}) - s_t) \qquad (1.B.\ 8)$$

The preceding inequality implies that, for $plim(\beta_1^{OLS}) < \frac{1}{2}$, the risk premium must be more volatile than changes in future expected exchange rates.

Appendix 2.A

This appendix provides approximate analytical solutions for the log return on the consumption claim ($\mathrm{r}^{\mathrm{i}}_{\mathrm{c,t+1}}$), the log stochastic discount factor ($\mathrm{m}^{\mathrm{i}}_{\mathrm{t+1}}$), and the currency risk premium (rp) in Section 2.3, Chapter 2.

The approximate analytical solutions of return on aggregate consumption ($\mathrm{r}^{\mathrm{i}}_{\mathrm{c,t+1}}$) and the stochastic discount factor ($\mathrm{m}^{\mathrm{i}}_{\mathrm{t+1}}$) are derived by the standard Campbel and Shiller approximation and the methodology in Bansal and Yaron (2004).

The law of motion for consumption and dividend growth are

$$\begin{gathered}\Delta c^i_{t+1} = \mu^i_c + x^i_t + \lambda^i_c \eta^i_{t+1} \\ \Delta d^i_{t+1} = \mu_d + \phi x^i_t + \lambda^i_d u^i_{t+1} \\ x^i_{t+1} = \rho^i x^i_t + \lambda^i_e e^i_{c,t+1} \\ \eta^i_{t+1}, u^i_{t+1}, e^i_{c,t+1} \sim N\ i.i.d. (0,1),\end{gathered} \tag{2.A. 1}$$

in which $i = [\text{the US (home country), and an EM (foreign country)}]$.

Asset-pricing Condition:

The asset pricing condition for any asset $R^i_{j,t+1}$, which is the return on asset j in country i, is that $\mathrm{E_t}\left[M^i_{t+1} R^i_{j,t+1}\right] = 1$, or $\mathrm{E_t}\left[\exp(\mathrm{m}^{\mathrm{i}}_{\mathrm{t+1}} + r^i_{j,t+1})\right] = 1$, in which, $\mathrm{m}^{\mathrm{i}}_{\mathrm{t+1}}$ is log stochastic discount factor, given as

$$\mathrm{m}^{\mathrm{i}}_{\mathrm{t+1}} = \log\left(M^i_{t+1}\right) = \theta ln\delta - \frac{\gamma}{\psi} \Delta c^i_{t+1} + (\theta - 1) r^i_{c,t+1}, \tag{2.A. 2}$$

and $r^i_{j,t+1} = \log(R^i_{j,t+1})$ is the log return on asset j in country i.

It then follows that

$$\mathrm{E_t}\left[\exp\left(\theta ln\delta - \frac{\gamma}{\psi} \Delta c^i_{t+1} + (\theta - 1) r^i_{c,t+1} + r^i_{j,t+1}\right)\right] = 1, \tag{2.A. 3}$$

Equation (2.A. 3) is the Euler equation which has two asset returns including the return on aggregate consumption claims ($\mathrm{R}^{\mathrm{i}}_{\mathrm{c,t+1}}$) and the return on the market portfolio ($\mathrm{R}^{\mathrm{i}}_{\mathrm{d,t+1}}$).

Return on Consumption Claim ($\mathbf{r}^{\mathbf{i}}_{\mathbf{c,t+1}}$):

Because the derivation of the approximation solutions for $\mathrm{R}^{i}_{\mathrm{c,t+1}}$ is similar in both countries $\mathrm{i} = [\mathrm{US\ (home\ country), and\ EM\ (foreign\ country)}]$, the superscript *i* is temporarily excluded in following equations. The approximation derivation starts from the definition of return on consumption claim as $\mathrm{R}_{\mathrm{c,t+1}} = \frac{P_{c,t+1}+C_{t+1}}{P_{c,t}}$, in which $P_{c,t}$ is the price of consumption. It then follows that

$$\mathrm{R}_{\mathrm{c,t+1}} = \frac{P_{c,t+1} + C_{t+1}}{P_{c,t}} = (1 + \frac{P_{c,t+1}}{C_{t+1}}) \times \frac{C_{t+1}}{C_t} \times \frac{1}{P_{c,t}/C_t}, \tag{2.A. 4}$$

$$\mathrm{R}_{\mathrm{c,t+1}} = \left[1 + \exp\left(log\left(\frac{P_{c,t+1}}{C_{t+1}}\right)\right)\right] \times \exp\left(log\left(\frac{C_{t+1}}{C_t}\right)\right) \times \frac{1}{\exp(\log(P_{c,t}/C_t))}; \tag{2.A. 5}$$

Let $\mathrm{v}_{\mathrm{c,t}} = \frac{\mathrm{P}_{\mathrm{c,t}}}{C_t}$, $\mathrm{v}_{\mathrm{c,t+1}} = \frac{\mathrm{P}_{\mathrm{c,t+1}}}{C_{t+1}}$, and $\Delta \mathrm{c}_{\mathrm{t+1}} = log\left(\frac{C_{t+1}}{C_t}\right)$, $\mathrm{R}_{\mathrm{c,t+1}}$ can be rewritten as

$$\mathrm{R}_{\mathrm{c,t+1}} = \frac{(1 + \mathrm{v}_{\mathrm{c,t+1}})e^{\Delta \mathrm{c}_{\mathrm{t+1}}}}{\mathrm{v}_{\mathrm{c,t}}}; \tag{2.A. 6}$$

Taking log both sides of the above equation yields

$$\log\mathrm{R}_{\mathrm{c,t+1}} = \log\left(\frac{(1 + \mathrm{v}_{\mathrm{c,t+1}})e^{\Delta \mathrm{c}_{\mathrm{t+1}}}}{\mathrm{v}_{\mathrm{c,t}}}\right), \tag{2.A. 7}$$

By the first-order Taylor expansion of the function, the return on consumption claim ($\mathrm{r}^{\mathrm{i}}_{\mathrm{c,t+1}}$) can be written as a linear combination of log price-consumption ratio and consumption growth as in Campbell and Shiller approximation (For detailed derivations of Campbell and Shiller log approximation, see Back (2010) Chapter 10).

$$\mathrm{r}^{\mathrm{i}}_{\mathrm{c,t+1}} = \kappa_0 + \kappa_1 z^i_{t+1} - z^i_t + \Delta c^i_{t+1}. \tag{2.A. 8}$$

The conjecture of log price-consumption ratio follows $\mathrm{z}_{\mathrm{t}}^{\mathrm{i}} = A_0 + A_1 x_t^i$, in which $\mathrm{z}_{\mathrm{t}}^{\mathrm{i}} = \log\left(\frac{P_t^i}{C_t^i}\right)$. In equation (2.A. 8), $\mathrm{r}_{\mathrm{c,t+1}}^{\mathrm{i}}$ is driven by $\mathrm{z}_{\mathrm{t}}^{\mathrm{i}}$; and $\mathrm{z}_{\mathrm{t}}^{\mathrm{i}}$, in turn, is driven by $\mathrm{C}_{\mathrm{t}}^{\mathrm{i}}$ and x_t^i. Because the dynamics of x_t^i is given in the equation (2.A. 1) as $x_{t+1}^i = \rho^i x_t^i + \lambda_e^i e_{c,t+1}^i$, $\mathrm{z}_{\mathrm{t}}^{\mathrm{i}}$ only depends on the x_t^i in country *i*.

The parameters κ's are log linearization constants, in which

$$\kappa_0 = \log(1 + \exp(\bar{z})) - \kappa_1 \bar{z}, \text{ and } \kappa_1 = \frac{\exp(\bar{z})}{1+\exp(\bar{z})}; \tag{2.A. 9}$$

The two parameter A_0 and A_1 can be found by the method of undetermined coefficients. There are two steps. The first step is to substitute the return on consumption claim ($\mathrm{r}_{\mathrm{c,t+1}}$) (equation (2.A. 8)), the law of motion of consumption growth (Δc_{t+1}^i) and the long-run risk component (x_{t+1}^i) (equation (2.A. 1)) into the Euler equation (2.A. 3). The second step is to pick up all terms involving constant terms and all terms involving x_{t}. It then follows that

$$\begin{gathered}\mathrm{A}_0 = \frac{log\delta + \mu_c\left(1 - \frac{1}{\psi}\right) + \kappa_0}{1 - \kappa_1}\ ; \\ \mathrm{A}_1 = \frac{1 - \frac{1}{\psi}}{1 - \kappa_1 \rho}\ ;\end{gathered} \tag{2.A. 10}$$

Given the solution for $\mathrm{z}_{\mathrm{t}}^{\mathrm{i}}$, the log return on consumption claim can be derived as

$$\mathrm{r}_{c,t+1}^{\mathrm{i}} - E_t\left(r_{c,t+1}^i\right) = \lambda_c^i \eta_{t+1}^i + \left(1 - \frac{1}{\psi}\right)\frac{\kappa_1}{1 - \kappa_1 \rho}\lambda_e^i e_{t+1}^i, \tag{2.A. 11}$$

in which $E_t\left(r_{c,t+1}^i\right) = constant + (1 + \kappa_1 A_1 \rho + A_1) x_t^i$.

Stochastic Discount Factor ($\mathbf{m}_{\mathbf{t+1}}^{\mathbf{i}}$):

To derive the log stochastic discount factor $\mathrm{m}_{\mathrm{t+1}}^{\mathrm{i}}$, substituting the approximation of returns on consumption claim ($\mathrm{r}_{\mathrm{c,t+1}}$) into the following expression:

$$\mathrm{m}^{\mathrm{i}}_{\mathrm{t+1}} = \log\left(M^{i}_{t+1}\right) = \theta ln\delta - \frac{\gamma}{\psi}\Delta c^{i}_{t+1} + (\theta - 1) r^{i}_{c,t+1}. \qquad (2.A.\ 12)$$

It then follows that

$$\mathrm{m}^{\mathrm{i}}_{\mathrm{t+1}} - E_t\left(m^{i}_{t+1}\right) = -\gamma\lambda^{i}_{c}\eta^{i}_{t+1} - \left(\gamma - \frac{1}{\psi}\right)\frac{\kappa_1}{1-\kappa_1\rho}\lambda^{i}_{e}e^{i}_{t+1}, \qquad (2.A.\ 13)$$

in which $E_t\left(m^{i}_{t+1}\right) = constant - \frac{x^{i}_{t}}{\psi}$.

Denote $\lambda^{\mathrm{i}}_{m,\eta} = \gamma\lambda^{i}_{c}$, representing the exposure of the SDF to short-run consumption shocks (η^{i}_{t+1}), or the price of short-run risk shock on consumption growth. Denote $\lambda^{\mathrm{i}}_{m,e} = \left(\gamma - \frac{1}{\psi}\right)\frac{(\kappa_1\lambda^{i}_{e})}{1-\kappa_1\rho^{i}}$, representing the exposure of the SDF to long-run consumption shocks ($\mathrm{e}^{\mathrm{i}}_{\mathrm{t+1}}$), or the price of long-run risk shock on consumption growth. The stochastic discount factor is then expressed as

$$\mathrm{m}^{\mathrm{i}}_{\mathrm{t+1}} - E_t\left(m^{i}_{t+1}\right) = -\lambda^{\mathrm{i}}_{m,\eta}\eta^{i}_{t+1} - \lambda^{\mathrm{i}}_{m,e}e^{i}_{t+1}. \qquad (2.A.\ 14)$$

Currency Risk Premium:

The derivation of currency risk premium starts from the risk-free rate which is given as

$$\mathrm{r}^{\mathrm{i}}_{\mathrm{t}} = E_t\left(M^{i}_{t+1}\right) = -E_t m^{i}_{t+1} - \tfrac{1}{2}Var_t(m^{i}_{t+1}). \qquad (2.A.\ 15)$$

Change in the foreign exchange rate ($\Delta\mathrm{s}_{\mathrm{t+1}}$) is given as

$$\Delta\mathrm{s}_{\mathrm{t+1}} = (s_{t+1} - s_t) = E_t m^{h}_{t+1} - \mathrm{E}_{\mathrm{t}} m^{f}_{t+1}. \qquad (2.A.\ 16)$$

The currency excess return is given as

$$\mathrm{er}_{\mathrm{t+1}} = \left(r^{f}_{t} - r^{h}_{t}\right) - \Delta\mathrm{s}_{\mathrm{t+1}}. \qquad (2.A.\ 17)$$

From equation (2.A. 16) and (2.A. 17), currency risk premium is then expressed as

$$\mathrm{rp} = \mathrm{E}(\mathrm{er}_{\mathrm{t+1}}) = \mathrm{E}\left(\frac{1}{2}\mathrm{Var}_{\mathrm{t}}\mathrm{m}^{\mathrm{h}}_{\mathrm{t+1}} - \frac{1}{2}\mathrm{Var}_{\mathrm{t}}\mathrm{m}^{\mathrm{f}}_{\mathrm{t+1}}\right). \qquad (2.A.\ 18)$$

Substituting equation (2.A. 13) into equation (2.A. 18), when the short-run consumption volatility, λ_c^i, the long-run consumption volatility, λ_e^i, and the persistence of long-run risk, ρ^i, are not identical in home and foreign country, the implied currency risk premium is expressed as

$$\mathrm{rp} = \frac{1}{2}\gamma^2[(\lambda_c^{US})^2 - (\lambda_c^{EM})^2] + \frac{1}{2}\left(\gamma - \frac{1}{\psi}\right)^2\left[\left(\frac{\kappa_1}{1-\kappa_1\rho^{US}}\right)^2(\lambda_e^{US})^2 - \left(\frac{\kappa_1}{1-\kappa_1\rho^{EM}}\right)^2(\lambda_e^{EM})^2\right]. \qquad (2.A.\ 19)$$

Appendix 3.A

The purpose of this appendix is to provide the ‘beta’ representation for GMM estimation of the Linear Factor Model presented in Chapter 3. Details on the treatment of the GMM estimation of the Linear Factor Model are provided in Chapter 11-12 in Cochrane (2009). As mentioned in Section 3.4.2 in Chapter 3, the estimation can be either in covariance representation or in ‘beta’ representation. For a ‘beta’ representation, the moment conditions can be written as

$$\mathrm{g_t}(\alpha,\beta,\lambda) = \begin{bmatrix} \mathrm{ER_t} - \alpha - \beta f_t \\ f_t(\mathrm{ER_t} - \alpha - \beta f_t) \\ \mathrm{ER_t} - \beta\lambda \end{bmatrix}. \tag{3.A. 1}$$

Case 1: Testing Capital Asset Pricing Model by GMM

In this case, a Global Risk Factor is the only risk factor. The aim of this test is to test the relation (or the covariance) between excess returns with the broad market risk (RX).

$$\mathrm{ER_t} = \alpha_{\mathrm{RX}} + \beta_{RX} RX_t + u_t, \tag{3.A. 2}$$

in which α and β_{RX} are $\mathrm{n} \times 1$ vertor $(\mathrm{n} = 9)$.

The GMM moment conditions are that, at the true values of α and β

$$E\mathrm{g_t}(\alpha_{\mathrm{RX}}, \beta_{\mathrm{RX}}, \lambda_{\mathrm{RX}}) = 0_{\mathrm{n(1+K+1)\times 1}}, \tag{3.A. 3}$$

in which

$$E\mathrm{g_t}(\alpha_{\mathrm{RX}}, \beta_{\mathrm{RX}}, \lambda_{\mathrm{RX}}) = E\begin{bmatrix} \mathrm{ER_t} - \alpha_{\mathrm{RX}} - \beta_{RX} RX_t \\ RX_t(\mathrm{ER_t} - \alpha_{\mathrm{RX}} - \beta_{RX} RX_t) \\ \mathrm{ER_t} - \beta_{RX}\lambda_{\mathrm{RX}} \end{bmatrix} = 0_{27\times 1}, \tag{3.A. 4}$$

in which $\mathrm{ER_t} = [\mathrm{er_t^i}]$ (i = 9 portfolios including BH, BM, BL, MH, MM, ML, SH, SM, SL). In this case, there are one risk factor (RX), nine portfolios of currencies, the moment conditions are $9(1 + 1 + 1) = 27$. There are $\mathrm{n}(1 + \mathrm{F}) + 1 = 9(1 + 1) + 1 = 19$ parameters, in which there are n estimates of α, nF estimates of β, and K estimates of λ. Thus, there are $\mathrm{n} - \mathrm{F} = 9 - 1 = 8$ (also equal to $27 - 19$) over-identifying restrictions.

Case 2: Testing Three-Factor Model by GMM

In this case, three factors include Global Risk Factor (RX_t), Interest Rate Differential Factor (BMS_t), and Momentum Factor (LMH_t).

$$E\mathrm{g_t}(\alpha, \beta, \lambda) = E\begin{bmatrix} \mathrm{ER_t} - \alpha - \beta f_t \\ f_t(\mathrm{ER_t} - \alpha - \beta f_t) \\ \mathrm{ER_t} - \beta\lambda \end{bmatrix} = 0_{(\mathrm{n}(1+\mathrm{K}+1)\times 1)}, \qquad (3.\mathrm{A}.\ 5)$$

in which $\mathrm{ER_t} = [\mathrm{er_t^i}]$, $\beta = [\beta^{\mathrm{i}}]$ (i = 9 portfolios including BH, BM, BL, MH, MM, ML, SH, SM, SL); $\mathrm{f_t} = [RX_t, BMS_t, LMH_t]$, and $\lambda = [\lambda_{\mathrm{RX}}, \lambda_{\mathrm{BMS}}, \lambda_{\mathrm{LMH}}]$.

There are $\mathrm{n}(1 + \mathrm{K} + 1)$ moment conditions, in which for each asset, there is one moment condition for the constant, F moment conditions for F factors, and one moment condition corresponding to the restriction on the linear factor model. Accordingly, in the case of three factors, nine portfolios of currencies, the moment conditions are $9(1 + 3 + 1) = 45$. There are $\mathrm{n}(1 + \mathrm{F}) + \mathrm{F} = 9(1 + 3) + 3 = 39$ parameters, in which there are n estimates of α, nF estimates of β, and K estimates of λ. Thus, there are $\mathrm{n} - \mathrm{K} = 6$ over-identifying restrictions.

The system can be estimated by two-step GMM estimation with the weighting for the third moment condition is $\theta = \beta'\hat{\Sigma}^{-1}$, in which Σ is the covariance matrix of the residuals from time-series estimations. The parameter vector is $\mathrm{b}' = [\alpha'\ \beta'\ \lambda]$.

Appendix 3.B

The purpose of this chapter is to provide the GMM estimation for the covariance representation of the linear factor model in Chapter 3.

The moment functions satisfy zero-mean conditions.

$$E\mathrm{g}_{\mathrm{t}}\big(\mathrm{b}_{(\mathrm{F}\times 1)}, \mu_{(\mathrm{F}\times 1)}\big) = E\begin{bmatrix} \mathrm{ER}_{\mathrm{t}} - ER_t\big(f_t - \mu_f\big)'b \\ f_t - \mu_f \end{bmatrix} = 0_{((N+F)\times 1)}, \qquad (3.\mathrm{B}.\ 1)$$

in which f_{t} is the vector of factor that has a dimension of $(\mathrm{F} \times 1)$; F is the number of factors (F is equal to either one or three); ER_{t} is the vector of currency excess return that has a dimension of $(\mathrm{N} \times 1)$; and N is equal to the number of test portfolios (in this study N is equal to 9 portfolios including BH, BM, BL, MH, MM, ML, SH, SM, SL).

Case 1: Testing Capital Asset Pricing Model (CAPM) by GMM

In the test of CAPM, the Global Risk Factor $(\mathrm{RX}_{\mathrm{t}})$ is the only risk factor, representing a broad market risk.

$$E\mathrm{g}_{\mathrm{t}}(\mathrm{b}_{\mathrm{RX}}, \mu_{\mathrm{RX}}) = E\begin{bmatrix} \mathrm{ER}_{\mathrm{t}} - ER_t(RX_t - \mu_{RX})b_{RX} \\ RX_t - \mu_{RX} \end{bmatrix} = 0_{(10\times 1)}, \qquad (3.\mathrm{B}.\ 2)$$

in which $\mathrm{ER}_{\mathrm{t}} = \big[\mathrm{er}_{\mathrm{t}}^{\mathrm{i}}\big]$ (i = 9 portfolios including BH, BM, BL, MH, MM, ML, SH, SM, SL). In this case, there are 10 moment conditions and 6 parameters to be estimated, so the over-identifying restriction is 4.

Case 2: Testing Three-Factor Model by GMM

In this case, three factors include Global Risk Factor (RX_t), Interest Rate Differential Factor (BMS_t), and Momentum Factor (LMH_t).

$$E\mathrm{g}_{\mathrm{t}}(\mathrm{b}, \mu) = E\begin{bmatrix} \mathrm{ER}_{\mathrm{t}} - ER_t\big(f_t - \mu_f\big)'b \\ f_t - \mu_f \end{bmatrix} = 0_{(12\times 1)}, \qquad (3.\mathrm{B}.\ 3)$$

in which $\mathrm{b} = [\mathrm{b}_{\mathrm{RX}}, \mathrm{b}_{\mathrm{BMS}}, \mathrm{b}_{\mathrm{LMH}}]$, $\mu = [\mu_{\mathrm{RX}}, \mu_{\mathrm{BMS}}, \mu_{\mathrm{LMH}}]$, $\mathrm{f}_{\mathrm{t}} = [RX_t, BMS_t, LMH_t]$, and $\mathrm{ER}_{\mathrm{t}} = \big[\mathrm{er}_{\mathrm{t}}^{\mathrm{i}}\big]$ (i = 9 portfolios including BH, BM, BL, MH, MM, ML, SH, SM, SL).

Three estimated factor prices include $\lambda_{RX} = \mu_{RX}$, $\lambda_{BMS} = \mu_{BMS}$, and $\lambda_{LMH} = \mu_{LMH}$. In this case, there are 12 moment conditions and 6 parameters to be estimated, so the over-identifying restriction is 6.

In two-step GMM estimation, the weighting matrix for the first moment condition $\mathrm{ER_t} - ER_t\left(f_t - \mu_f\right)' b$ is $a\mathbf{I_N}$, in which $\mathbf{I_N}$ is an identity matrix; the second moment condition $(f_t - \mu_f)$ is $\widehat{\Sigma_{\mathrm{ff}}^{-1}}$, in which the $\widehat{\Sigma_{\mathrm{ff}}}$ is a consistent estimator of Σ_{ff}.

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