An Investment-Based Explanation of Currency Excess Returns*

Ibrahim Jamali [a]
Associate Professor of Finance, American University of Beirut

Ehab Yamani [b]
Associate Professor of Finance, Chicago State University

Aaron D. Smallwood [c]
Associate Professor of Economics, University of Texas-Arlington

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a) Department of Finance, Accounting and Managerial Economics, Suliman S. Olayan School of Business, American University of Beirut. Email: ij08@aub.edu.lb
b) Accounting and Finance Department, College of Business - BHS 411. 9501 South King Drive, Chicago State University, Chicago, Illinois 60628. Email: ehabyamani@csu.edu
c) Department of Economics, University of Texas-Arlington. Email: smallwood@uta.edu

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Abstract

This paper offers an investment-based explanation for currency excess returns using fundamental macroeconomic drivers emanating from physical investment across countries. We propose an international investment-based asset-pricing model where representative firms in two countries choose structure and equipment capital to maximize profits. The model generates stochastic discount factors on bonds in two countries related to their marginal rates of transformation between both types of capital. The stochastic discount factors are, in turn, connected to the carry trade risk premium. We empirically test a production model with factors constructed by sorting currencies based on differences in gross fixed capital formation, and investment in equipment and structures. Our findings show the investment risk factors are priced in the cross-section of currency excess returns. The prices of risk associated with investment are negative and significant. This indicates that the currencies of countries with a higher sensitivity to investment risk earn lower excess returns. Furthermore, we show that this investment effect is not systematically related to the forward premium effect.

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1. Introduction

The evidence emerging from the existing research overwhelmingly rejects the predictions of Uncovered Interest Parity (UIP), which implies that the exchange rate changes do not offset interest rate differentials between countries (Fama, 1984). As a result, the currency carry trade, which is a simple strategy in which an investor borrows in low interest rate currencies and invests in high interest rate currencies, provides positive returns on average. The violation of UIP and the ensuing abnormal profits from the carry trade have garnered considerable attention, resulting in a flurry of research attempting to provide a suitable explanation.

In a typical asset-pricing framework that relies on the standard approach to risk adjustment, the positive excess returns should reflect compensation for a possibly time varying risk premium. Several competing risk-based explanations have been proposed in the literature to rationalize the existence of positive currency excess returns (See Burnside, 2012). An incomplete list includes risk factors related to equity (Burnside, Eichenbaum, and Rebelo, 2011), consumption (Lustig and Verdelhan, 2007), global foreign exchange volatility (Menkhoff *et al.*, 2012), liquidity (Mancini, Ranaldo, and Wrampelmeyer, 2013), credit default (Coudert and Mignon, 2013), and currencies (Lustig, Roussanov, and Verdelhan, 2011). The evidence from the existing studies suggest that the canonical equity and consumption risk factors' success is modest in pricing the cross-section of currency excess returns (Burnside, 2011; Burnside, Eichenbaum, and Rebelo, 2011).

A related line of research underscores the role of low-probability events associated with periods of extreme risk aversion (e.g., rare events, crashes and crises). This strand of literature examines whether currency excess returns are a compensation for crash risk (Farhi and Gabaix, 2016; Farhi *et al.* 2015; Brunnermeier, Nagel, and Pedersen, 2009; Daniel, Hodrick, and Lu, 2017), uncertainty (Husted, Rogers, and Sun 2018; Berg and Mark, 2018; Ismailov and Rossi, 2018), downside risk (Lettau, Maggiori, and Weber, 2014; Atanasov and Nitschka, 2014; Dobrynskaya, 2014; Jurek, 2014; Jurek and Stafford, 2015), and 'Peso problems' (Burnside *et al.*, 2011). A critical review of this literature reveals that the degree of covariance between equities and currencies during episodes of market distress has not been sufficiently high to attribute the profitability of the carry trade to crash risk (Burnside, 2012).

In this paper, we take a different approach and propose an investment-based explanation to pricing currency excess returns. For asset pricing in general, the production-based approach has enjoyed particular success in equity pricing, since the seminal work of Cochrane (1991) who reinterprets the *q*-theory of investment as a production-based model to show that investment returns and stock returns are equal. On the empirical side, several studies have implemented an investment-based approach in pricing US stock returns (Cochrane, 1996; Liu, Whited, and Zhang, 2009; Li and Zhang, 2010; Hou *et al.*, 2019 and 2021), value premium (Zhang, 2005), equity premium (Jermann, 2010), term premium (Jermann, 2013), firms' external financing constraints (Li, Livdan, and Zhang, 2009), and international stock returns (Watanabe *et al.*, 2013).

Although it has gained a foothold in pricing equities, the role of production has surprisingly yet to be extended to puzzles in international finance. To the best of our knowledge, this paper is the first to address this gap. A major challenge appears to result from deriving appropriate stochastic discount factors that rely on the constituent elements of the carry trade, namely both exchange rate returns between two countries and relative differences in interest rates. To this end, we capitalize on the modeling framework in Jermann (2010, 2013) to propose pricing equations for nominal bonds in two countries, which are then linked to the risk premium on currency carry trades. The pricing equations naturally relate to the production decisions of firms, which, following Jermann (2010, 2013), includes optimal choices for capital investment in equipment and structures.

Given the dearth in the literature, our analysis is largely exploratory and empirical in nature. Our theoretical design provides preliminary findings that allow us to develop a two-sector model, where we construct two investment-based risk factors for equipment and structure investment differences for countries relative to the US dollar. The first investment factor is an "equipment" factor, which we call the equipment low-minus-high risk factor *(EQLMH)*. The second factor is the "structure" factor, which we call the structure low-minus-high risk factor *(STLMH)*. Both factors are constructed as the difference between the returns on the low and high quintile portfolios sorted on the difference in lagged investment in equipment and structures between each country and the United States (US), meaning that the beta estimates measure the sensitivity of currency excess returns to changes in the investment gap with the US. For completeness, we also consider a more conventional single-factor model in the spirit of Cochrane's (1991) original production-based approach, which is built on the gross private domestic investment gap relative to the US. These factors are interpreted as the return on a zero-cost trading strategy that consists of a long position in countries with low investment and a short position in countries with high investment.

We find that our investment factors are priced in the cross-section of currency excess returns, with prices of risk that are negative and significant. Intuitively, higher returns are observed for currencies with excess returns that co-vary negatively with investment. Conversely, lower risk premia may be expected when excess returns are positively correlated with investment, which results in lower returns. Further, the time-series regressions show that our investment-based factors are negatively correlated with the currency excess returns, particularly for the equipment factor. We find that there is a striking near monotone increase in the estimated betas for the *EQLMH* factor as we go from low to high interest rate portfolios, showing that the equipment risk factor is at work in currency markets. More specifically, estimates of equipment betas are insignificantly negative for portfolios with the smallest forward premium, but they are large and significantly negative for portfolios with the largest forward premium. We also look at the one-factor model using the Cochrane-based risk factor and confirm the same pattern in excess returns. We further take our investment-based model to individual currency-level data and we find that this investment effect continues to hold at the country level. In comparing our investment factors with the other standard determinants of the cross-section of currency returns, we augment our models with the high-minus-low *(HML)* risk factor developed by Lustig, Roussanov, and Verdelhan (2011), henceforth LRV, and we find that the investment effect remains strong.

In a nutshell, the evidence provided in this paper is straightforward: countries that increase their investment expenditures the most (relative to the US) tend to realize lower currency excess returns. Our results suggest promise in explaining puzzles in international finance using factors based on production variables. While it is important not to portray the production-based approach in an overly positive light, the merits of using the production approach could be justified given our evidence that the investment-based stochastic discount factor is correlated with the currency excess returns, suggesting that production variables are potentially missing elements for researchers interested in studying the dynamics of international asset pricing models.

The remainder of the paper proceeds as follows. In section 2, we review the related literature and outline a theoretical approach that can be used to justify suitable production-based factors for currency excess returns. Section 3 discusses the construction of our factors. We describe our data in section 4 and present our results in section 5. Section 6 concludes.

2. Theoretical Motivation

In this section, we sketch a theoretical model to generate risk premia that can be used to justify production-based factors for excess currency returns. Expected excess returns at time *t* for an asset maturing in one period are given by $i_t^* - i_t + E_t s_{t+1} - s_t$, where i_t and i_t^* denote interest rates in the domestic and foreign economies, respectively, and where s_t refers to the logarithm of the domestic spot price of the foreign currency, S_t. In an asset-pricing framework that relies on the standard approach to risk adjustment, positive excess returns should reflect compensation for a possibly time varying risk premium. The literature typically analyzes pricing kernels arising from consumption decisions, based on marginal rates of substitution. Regrettably, the empirical failure of the consumption-based models in explaining abnormal currency returns is now well documented within the literature, as emphasized by Burnside (2011). It seems that a fresh approach based on production factors is merited.

Consider, the case of a single bond in the US and the foreign country, which yield returns $\exp(i_t)$ and $\exp(i_t^*)$. For the carry trade, the risk premium associated with holding foreign bonds is

$$RP_t = i_t^* + E_t \log(S_{t+1}) - \log(S_t) - i_t. \tag{1}$$

In each country, the state-contingent pricing kernels would satisfy the normal Euler conditions,

$$E_t \widetilde{M}_{t+1} R_{t+1} = 1, E_t \widetilde{M}_{t+1}^* R_{t+1}^* = 1, \tag{2}$$

where R^*_{t+1} denotes returns in the foreign country. As such, it is easily seen that i_t=-log($E_t\widetilde{M}_{t+1}$) and similarly for the foreign bond. As in Alvarez, Atkeson, and Kehoe (2009) assuming complete asset markets, the foreign pricing kernel will satisfy $\widetilde{M}^*_{t+1} = \widetilde{M}_{t+1}S_{t+1}/S_t$. As such, the risk premium can easily be re-written in terms of the stochastic discount factors (SDF) as,

$$RP_t = E_t \log\left(\widetilde{M}^*_{t+1}\right) - E_t \log\left(\widetilde{M}_{t+1}\right) + \log\left(E_t\widetilde{M}_{t+1}\right) - \log\left(E_t\widetilde{M}^*_{t+1}\right). \qquad (3)$$

In proposing the needed SDFs, we borrow heavily on Jermann (2013) who constructs pricing equations for bonds. Jermann assumes that a country's output is produced by a representative firm that has access to J technologies, with which it can transfer some of the consumption good forward through time regardless of consumer preferences. The simplest case involves two types of capital, structures and equipment, and two states of the world. In each country,

$$E_t\left(\widetilde{M}_{t+1}R_{j,t+1}\right) = 1, \quad E_t\left(\widetilde{M}^*_{t+1}R^*_{j,t+1}\right) = 1 \qquad j = 1,2. \qquad (4)$$

In Jermann's model, the representative US firm's output, $Y_t(\mathfrak{s}^t)$, is produced using capital stock $K_j(\mathfrak{s}^{t+1})$ accumulated during period $\mathfrak{s}^t$, in addition to other costless inputs. An analogous representation is assumed for the foreign country. With $A_j(\mathfrak{s}^t)$ denoting factors impacting the marginal product of capital, such as productivity shocks, revenue is given by

$$\Pi_t(\mathfrak{s}^t) = \sum_{j=1}^{2} A_j(\mathfrak{s}^t)\left(K_j(\mathfrak{s}^{t-1})\right). \qquad (5)$$

The model assumes convex adjustment costs denoted $\emptyset_j\left(I_j(\mathfrak{s}^t), K_j(\mathfrak{s}^{t-1})\right)$.[1]

[1] The firm's total costs of investment, $\left[\emptyset\left(I_j(\mathfrak{s}^t), K_j(\mathfrak{s}^{t-1})\right)\right]$, equals the actual cost of purchasing the new capital goods $\left(I_j(\mathfrak{s}^t)\right)$ plus a deadweight adjustment cost that represents the firms' foregone operating profit since they have to reduce sales to increase investment. In reality, capital cannot be installed without incurring frictional costs. Therefore, the total costs of investment is given by $\emptyset(I_t, K_{t-1}) = I_t + \left(\frac{a}{2}\left(\frac{I_j(\mathfrak{s}^t)}{K_j(\mathfrak{s}^{t-1})}\right)^2 K_j(\mathfrak{s}^{t-1})\right)$, where a > 0 is a constant parameter and captures the curvature of the adjustment cost (Li, Livdan, and Zhang, 2009; and Liu, Whited, and Zhang, 2009).

With state prices, $P(\mathfrak{s}^t)$, taken as given, the firm chooses overall investment and future capital stock in structures and equipment subject to the standard capital accumulation equation, $K_j(\mathfrak{s}^t) = K_j(\mathfrak{s}^{t-1})(1-\delta_j) + I_j(\mathfrak{s}^t)$. With $\mathrm{q_j}(\mathfrak{s}^t)$ denoting the marginal investment cost, which is equivalent to the average Tobin's q, first order conditions yield the following Euler condition

$$1 = \sum_{\mathfrak{s}_{t+1}} \mathrm{P}\,(\mathfrak{s}_{t+1}|\mathfrak{s}^t) \left\{ \frac{\frac{\partial \Pi\left(\mathrm{K_j}(\mathfrak{s}^{t-1})\right)}{\partial \mathrm{K_j}(\mathfrak{s}^{t-1})} - \frac{\partial \emptyset\left(\mathrm{I_j}(\mathfrak{s}^t), \mathrm{K_j}(\mathfrak{s}^{t-1})\right)}{\partial \mathrm{K_j}(\mathfrak{s}^{t-1})} + (1-\delta_j)\mathrm{q_j}(\mathfrak{s}^t, \mathfrak{s}_{t+1})}{\mathrm{q_j}(\mathfrak{s}^t)} \right\} = \sum_{\mathfrak{s}_{t+1}} \mathrm{P}\,(\mathfrak{s}_{t+1}|\mathfrak{s}^t) R_j^I(\mathfrak{s}^t, \mathfrak{s}_{t+1}), \quad (6)$$

where, $R_j^I(\mathfrak{s}^t, \mathfrak{s}_{t+1})$ denotes investment return on the j-th capital type. This equation yields the standard investment returns derived from production-based models (e.g., Cochrane, 1991 and 1996; Li, Vassalou, and Xing, 2006; Gomes, Yaron, and Zhang, 2006; and Liu, Whited, and Zhang, 2009). These returns measure the stochastic rate of return from trading more investment today for less in the future. A critical feature of Equation (6) is its implication that the desired capital stock is independent of domestic consumption preferences.[2]

The relationship between state prices and returns can be represented in matrix form as

$$\begin{bmatrix} \mathrm{R}_1^\mathrm{I}(\mathfrak{s}^t, \mathfrak{s}_1) & \mathrm{R}_1^\mathrm{I}(\mathfrak{s}^t, \mathfrak{s}_2) \\ \mathrm{R}_2^\mathrm{I}(\mathfrak{s}^t, \mathfrak{s}_1) & \mathrm{R}_2^\mathrm{I}(\mathfrak{s}^t, \mathfrak{s}_1) \end{bmatrix} \begin{bmatrix} \mathrm{P}(\mathfrak{s}_1|\mathfrak{s}^t) \\ \mathrm{P}(\mathfrak{s}_2|\mathfrak{s}^t) \end{bmatrix} = \mathbf{1}. \quad (7)$$

From this equation, state prices can be retrieved and hence any contingent claim can be priced. To price nominal bonds, Jermann (2013) introduces inflation, which is not a priced factor by

[2] According to the q-theory, the firm's investment return rises with its q, defined as the ratio of market value of new additional investment goods to their replacement cost. The present value version of the theory states that the marginal cost of investment equals its marginal benefit, defined as the present value of the expected future profit (Abel and Blanchard, 1986; Shapiro, 1986; Gilchrist and Himmelberg, 1995; and Love and Zicchino, 2006). The Tobin's q-theory emphasizes the importance of both financial factors (such as debt leverage and dividend payments) and investment factors, as determinants of the optimal investment. The discount rate channel controls for expected cash flows, and predicts that the lower the discount rate, the higher the current investment (Cochrane, 1996; Li, Vassalou, and Xing, 2006; and Liu, Whited, and Zhang, 2009), while the cash flow channel says that, controlling for the discount rates, the higher the future marginal productivity, the higher the current investment (Li, Livdan, and Zhang, 2009).

assumption. Let inflation in the home country have two possible realizations $(\mathfrak{z}_1, \mathfrak{z}_2)$. Combined with two states of nature $(\mathfrak{s}_1, \mathfrak{s}_2)$ in the original model, this gives rise to four different states $(\mathfrak{s}_1, \mathfrak{z}_1), (\mathfrak{s}_1, \mathfrak{z}_2), (\mathfrak{s}_2, \mathfrak{z}_1)$, and $(\mathfrak{s}_2, \mathfrak{z}_2)$. Thus, the price to a contingent claim equals the sum of the four state prices, as follows:

$$P(s_{t+1}|s^t, z^t) = \sum_{k=1}^{2}[P(s_{t+1}, s_k|s^t, z^t) + P(s_{t+1}, \mathfrak{z}_k|s^t, z^t)]. \quad (8)$$

Given this setup, with *Pr* denoting the probability and $\lambda^P(\mathfrak{z}_j)$ denoting the state *j* inflation rate, Jermann (2013) derives the price of a one period bond that pays one dollar at time $t+1$, denoted as $V_t^{\$(1)}(s^t, z^t)$, as follows:

$$V_t^{\$(1)}(s^t, z^t) = E_t(m_{t+1}|s^t, z^t) = \left(\frac{Pr(\mathfrak{s}_1, \mathfrak{z}_1|s^t, z^t)}{Pr(\mathfrak{s}_1, \mathfrak{z}_1|s^t, z^t) + Pr(\mathfrak{s}_1, \mathfrak{z}_2|s^t, z^t)}\right)\frac{P(\mathfrak{s}_1|s^t)}{\lambda^P(\mathfrak{z}_1)} + \left(1 - \frac{Pr(\mathfrak{s}_1, \mathfrak{z}_1|s^t, z^t)}{Pr(\mathfrak{s}_1, \mathfrak{z}_1|s^t, z^t) + Pr(\mathfrak{s}_1, \mathfrak{z}_2|s^t, z^t)}\right)\frac{P(\mathfrak{s}_1|s^t)}{\lambda^P(\mathfrak{z}_2)} + \left(\frac{Pr(\mathfrak{s}_2, \mathfrak{z}_1|s^t, z^t)}{Pr(\mathfrak{s}_2, \mathfrak{z}_1|s^t, z^t) + Pr(\mathfrak{s}_2, \mathfrak{z}_2|s^t, z^t)}\right)\frac{P(\mathfrak{s}_2|s^t)}{\lambda^P(\mathfrak{z}_1)} + \left(1 - \frac{Pr(\mathfrak{s}_2, \mathfrak{z}_1|s^t, z^t)}{Pr(\mathfrak{s}_2, \mathfrak{z}_1|s^t, z^t) + Pr(\mathfrak{s}_2, \mathfrak{z}_2|s^t, z^t)}\right)\frac{P(\mathfrak{s}_2|s^t)}{\lambda^P(\mathfrak{z}_2)}. \quad (9)$$

Let $m(\mathfrak{s}_{t+1}|\mathfrak{s}^t) = Pr(\mathfrak{s}_{t+1}|\mathfrak{s}^t)\widetilde{M}_{t+1}$, and similarly for $m^*(\mathfrak{s}_{t+1}|\mathfrak{s}^t)$. Since i_t is the continuously compounded interest rate in the home country, it can be stated as the logarithm of the bond price:

$$i_t = -\log V_t^{\$(1)}(s^t, z^t) = -log\ E_t(m_{t+1}|s^t, z^t). \quad (10)$$

Under analogous conditions for the foreign country, the price of a one period bond that pays one foreign currency unit at time $t+1$, denoted as $V_t^{FCU(1)}(s^{t^*}, z^{t^*})$, is given as follows:

$$V_t^{FCU(1)}(s^{t^*}, z^{t^*}) = E_t(m_{t+1}^*|s^{t^*}, z^{t^*}). \quad (11)$$

The continuously compounded interest rate in the foreign country, i_t^*, can be stated as:

$$i_t^* = -\log V_t^{FCU(1)}\left(s^{t^*}, z^{t^*}\right) = -log\ E_t\left(m_{t+1}^* \middle| s^{t^*}, z^{t^*}\right). \qquad (12)$$

The conclusion is that, through respective returns, the state prices can ultimately be expressed as a function of the firms' marginal products of capital, here for equipment and structures. Of course, these state prices yield resulting stochastic discount factors and the interest rates as depicted above. In turn, these quantities can be related to the risk premium on currency excess returns.

Having established that the risk-premium on excess currency returns can be written as a function of the stochastic discount factors associated with investment in equipment and structures between two countries, we turn to the question of asset pricing. For a cross-section of currency returns, Rx_{t+1}, we investigate the question of whether the investment returns from two production technologies (equipment and structure) span currency excess returns. In particular, we conjecture that there exists a stochastic discount factor of the following form,

$$E_t(M_{t+1} Rx_{t+1}) = 0. \qquad (13)$$

The main proposition of any production-based model is that asset riskiness can be measured by the covariance of the asset's returns with the investment returns. In general, an asset will earn a positive risk premium if its return is negatively correlated with M_{t+1}. Ultimately, expected returns can be expressed, as follows:

$$E_t(Rx_{t+1}) = -\frac{cov(M_{t+1}, Rx_{t+1})}{E(M_{t+1})}. \qquad (14)$$

This equation implies that the explanation for the positive average currency excess returns is that these payoffs compensate currency traders for the risk resulting from negative covariance between M_{t+1} and Rx_{t+1}. Below, we test the cross-sectional implications of the equipment and structure investment model by approximating it as a linear factor model. Modeling the stochastic discount factor directly as a function of investment returns is similar to the implementation used by Cochrane (1996), Lamont (2000), and Li, Vassalou, and Xing (2006).

In fact, we acknowledge that there are caveats in our analysis, given that the underlying theory discussed above should be viewed as generating a reduced-form mechanism for linking production variables to currency excess returns. It does not provide a solution that yields a structural interpretation to our factors studied below, although it does yield guidance in selecting the specific factors we use. Ultimately, our recourse to more definitively understand the relationship between our resulting investment variables and currency returns will be a more complete empirical exploration. Bearing in mind these caveats, we focus on proposing an empirical model that delivers important insights on the relationship between investment and expected currency returns. As such, we posit that the stochastic discount factor that prices investment returns in Equation (13) can be approximated as a linear function of two underlying factors: The returns to long-short equipment investment portfolios, $R_{t+1}^{Equipment}$, as well as long-short structure investment portfolios, $R_{t+1}^{Structue}$, as:

$$M_{t+1} = a + b_1 R_{t+1}^{Equipment} + b_2 R_{t+1}^{Structure}. \tag{15}$$

The implications are that expected excess returns are governed by the covariance with differences in equipment investment and structure investment between countries,

$$E[Rx_{t+1}] = b_1 cov\left(R_{t+1}^{Equipment}, Rx_{t+1}\right) + b_2 cov(R_{t+1}^{Structure}, Rx_{t+1}). \tag{16}$$

This factor model can also be restated as a two-factor beta pricing model for the expected excess returns where the excess return on each foreign currency is equal to the price of risk (λ) multiplied by each portfolio or asset's beta (β). Hence, the beta representation of our proposed model is:

$$\begin{aligned} E[Rx] &= \frac{cov(R^{Equipment}, Rx)}{var\ (R^{Equipment})} b_1 var\ (R^{Equipment}) + \frac{cov\left(R^{Structure}, Rx\right)}{var\left(R^{Structure}\right)}\ b_2 var\ (R^{Structure}) \\ &= \beta_1 \lambda^{Equipment} + \beta_2 \lambda^{Structure}. \end{aligned} \tag{17}$$

In Equation (17), β_1 and β_2 measure, respectively, the covariance between currency excess returns and investment differences in equipment and structures.

3. Testable Predictions and the Empirical Framework: Investment-based Model

To better align our analysis with previous literature studying the implications of production models for standard problems in finance such as the value effect (see, Xing, 2008), we consider two hypotheses in this section that are potentially analogous extensions to excess currency returns.

3.1. Hypothesis 1. Physical investment is negatively correlated with future currency returns.

Hypothesis 1 corresponds to a testable hypothesis common to the investment-based literature that has yet to be applied to excess currency returns. To be specific, we investigate whether the well-known "investment effect" common to equity markets, where high-investment countries earn lower average returns than low investment countries, extends to currency markets. We now address this question using a two-factor model based on differences between equipment and structure investment relative to the United States.

Two-factor EQLMH and STHML model: In spite of the voluminous literature on production-based models, there do not appear to be any studies attempting to examine the investment-effect in the context of currency excess returns. Here, drawing on the theory introduced above, we introduce two risk factors related to production to develop a two-sector investment-based model. Our equipment factor, *EQLMH*, is constructed by sorting currencies in our sample into five portfolios based on lagged differences for equipment investment relative to the US. We rebalance portfolios every quarter and rank them from small to large differences in equipment investment (between each country and the US) to form quintile portfolios, which are denoted EQ1, EQ2, EQ3, EQ4 and EQ5. That is, the 20% of countries with the lowest investment in equipment are assigned to portfolio EQ1, the next 20% to portfolio EQ2 and so on. The fifth portfolio EQ5, contains the 20% of countries with the highest investment in equipment vis-à-vis the US. Next, we compute the excess currency returns for each portfolio by averaging the excess currency returns within the portfolio. The *EQLMH* factor is given by the return difference between portfolios EQ1 and EQ5.

We construct a second factor based on investment in structures in a similar fashion. Namely, the structure low-minus high-risk factor *STLMH* is constructed by sorting the currencies in our sample into quintile portfolios based on the lagged differences in structure investment between country k and the US, where excess returns are then averaged within each portfolio. The $STLMH$ factor is given by the return difference between the portfolio with the smallest investment in structures vis-à-vis the US, denoted as ST1, and the one with the largest investment in structures vis-à-vis the US, denoted as ST5. It is important to note that two factors that we construct are returns. However, these factors are not tradable due to data revisions in macroeconomic data and to the fact that the investment variables are available with a time lag.[3]

To test our factor model, we first use the traditional two-pass regression methodology of Black, Jensen, and Scholes (1972) and Fama and MacBeth (1973) to examine whether the factors are priced in the cross section of excess currency returns. In the first pass, we run a time series regression of currency excess returns in levels, denoted as $Rx_{k,t}$, on the two risk factors:

$$Rx_{k,t+1} = c_k + \beta_{k,EQHML} EQLMH_{t+1} + \beta_{k,STHML} STLMH_{t+1} + \varepsilon_{k,t+1}. \tag{18}$$

In the second pass, we run a cross sectional regression of average excess returns on the estimated betas from the first stage to estimate the prices of risk:

$$\overline{Rx_t} = \hat{\beta}_{1i} \lambda_{EQLMH} + \hat{\beta}_{2i} \lambda_{STLMH} + \xi_t, \tag{19}$$

where λ_{EQLMH} and λ_{STLMH} are the prices of risk. Equations (18) and (19) thus imply that the expected currency returns can be explained by their exposure to systematic risk factors that are related to investment differences in 'equipment' and 'structures'. We do not include a constant in the second pass regression to impose discipline on the model. In line with the prescriptions of Lewellen, Nagel and Shanken (2010), we estimate the two-pass regressions using Generalized Least Squares (GLS) and report the GLS R^2 for the cross-sectional regression.[4]

[3] Gospodinov, Kan, and Robotti (2019) discuss the caveats involved in estimating asset-pricing models with macroeconomic factors. Namely, they highlight the perils of overlooking potential model misspecification and lack of identification when the model includes macroeconomic factors and they find that models with tradable factors are not prone to the same identification issues.

[4] Gospodinov and Robotti (2021) provide a discussion of the importance of using GLS estimation in the context of the two-pass methodology.

One-factor INVLMH model: While the common wisdom for using a two-sector model is that both sectors may receive different productivity shocks, the intuition of using a one-sector model is usually that heterogeneous economic agents vary their consumption and investment decisions in response to macroeconomic shocks.[5] For completeness, we thus examine whether gross private domestic investment is priced in the cross-section of currency excess returns. To do so, we construct a low-minus-high factor based on the growth rate in total gross capital formation, denoted as $INVLMH$, analogously to the way we construct the $EQLMH$ and $STLMH$ factors. More specifically, the $INVLMH$ factor is the return difference between a quintile portfolio that goes long in the currencies of the countries with the smallest gross private fixed investment vis-à-vis the US (INV1) and goes short in the currencies of the countries with the highest gross private fixed investment relative to the US (INV5). Our one-factor *INVLMH* model can be specified as follows:

$$Rx_{k,t+1} = a_k + \beta_{k,INLMH} INVLMH_{t+1} + \epsilon_{k,t+1}, \tag{20}$$

In sum, our investment-based models imply that currency excess returns compensate investors for taking on more investment risk. More specifically, currencies whose excess returns co-vary negatively with investment must earn investors higher expected returns to induce them to hold them. Our low-minus-high investment risk factors ($EQLMH$, $STLMH$ and $INVLMH$), which go long in low investment currencies and short in high investment currencies are similar to the investment risk factor of Xing (2008) and have a natural interpretation as the return on a zero-cost portfolio that captures the difference between countries with different levels of investment.

[5] On one hand, previous research has used disaggregated investment data to examine whether sector investment can be used to improve the performance of explaining equity returns. For example, Cochrane (1996) uses residential and nonresidential investment growth; Li, Vassalou, and Xing (2006) use a four-sector model (household and nonprofit organizations, nonfarm nonfinancial corporate business, nonfarm non-corporate business, and financial business); and Jermann (2010, 2013) focus on equipment and structures. On the other hand, several studies have achieved relative success in taking a one-sector investment-based approach in pricing US stock returns (Cochrane, 1991; Lamont, 2000; Gomes, Yaron, and Zhang, 2006; Belo, 2010).

3.2. Hypothesis 2. The investment variables contain information relevant to future currency excess returns, after controlling for the forward premium.

Hypothesis 2 builds on the work of Fama and Bliss (1987), and Hassan, Mertens, and Zhang (2016, 2020). Fama and Bliss (1987) point out that the spread between the forward and spot rate for bonds displays a cyclical pattern, which is highly correlated with production variables.[6] More recently, Hassan, Mertens, and Zhang (2016, 2020) document that countries with low interest rates have lower marginal products of capital. They consider a model with non-tradeable goods and show that countries with a large share of world output gain value when the price of tradeable goods is high. The currencies of these countries, which tend to serve as better hedges during financial stress, tend to gain value during bad times. Because of a low interest rate and an appreciating currency, these countries are able to accumulate capital at a lower cost. Note that the discount rate channel of the standard q-theory predicts that the lower the discount rate, the higher the current investment (Cochrane, 1996; Li, Vassalou, and Xing, 2006; and Liu, Whited, and Zhang, 2009). If a low interest rate implies higher investment, therefore, the forward premium (or equivalently interest rate differential) and investment variables are expected to contain information for future currency returns. That is, if low interest rate currencies (i.e., currencies with a low forward premium in the carry trade portfolio) earn low average currency excess returns (the forward premium effect), then high capital investment countries should also earn low average currency excess returns (the investment effect).

We test hypothesis 2 using two empirical procedures. First, we subject our baseline one-factor and two-factor models to a more stringent test by including the *HML* factor of LRV (2011). If our investment factors contain information that is similar to the HML factor, the investment effect should disappear when we augment our models in Equations (18) and (20) with the HML risk factor.[7] We first augment the two-factor (*EQLMH* and *STLMH*) model with *HML*:

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[6] Koijen *et al.* (2018) construct the "carry" of an asset as the spread between the futures (or forward) and the spot rates. The bond spread of Fama and Bliss (1987) and the currency forward premium, which measure the carry in bond and foreign exchange markets, respectively, may therefore exhibit a similar cyclical pattern.

[7] The *HML* risk factor is analogous to the high-minus-low book-to-market risk factor in the popular Fama and French (1993) three-factor model. In the standard q-theory literature, the book-to-market ratio is used to proxy for the inverse

$$Rx_{k,t+1} = c_k + \beta_{k,HML}HML_{t+1} + \beta_{k,EQLMH}EQLMH_{t+1} + \beta_{k,STLMH}STLMH_{t+1} + \varepsilon_{k,t+1}. \quad (21)$$

Similarly, we augment the one-factor (*INVLMH*) with *HML*:

$$Rx_{k,t+1} = a_k + \beta_{k,HML}\, HML_{t+1} + \beta_{k,INLMH}INVLMH_{t+1} + v_{k,t+1}. \quad (22)$$

In another empirical test of whether the investment effect is robust to accounting for the forward premium, we resort to double sorts based on forward premium and capital investment. If the forward premium and capital investment contain similar information, the two effects should weaken after an independent double sort.

The asset pricing models are estimated with the excess returns in level, as follows:[8]

$$Rx_{k,t+1} = \frac{F_{k,t} - S_{k,t}}{S_{k,t}} \quad (23)$$

3.3. Contrasting our model with LRV

As a benchmark, our analysis below is contrasted with the findings of LRV (2011). In their influential contribution, LRV (2011) uncover two currency-based risk factors, the dollar and carry trade factors that are largely successful in pricing the cross-section of excess currency returns.[9] LRV (2011) construct two factors, the dollar (*DOL*) risk factor, measured as the average of currency returns, and the high-minus-low (*HML*) carry trade risk factor, which is calculated as the return differential between the portfolio with the largest forward discount and the one with the smallest forward discount. The *DOL* and *HML* risk factors are analogous to the market risk and high-minus-low book-to-market risk factors, respectively, in the popular Fama and French (1993)

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of the average *q*. Along the same lines, prior research finds the value effect is interpreted by the investment effect. Compared to firms with low book-to-market ratios, firms with high book-to-market ratios will invest less and earn higher average returns (Xing, 2008; Li, Livdan, and Zhang, 2009).

[8] As noted in LRV (2011) and Menkhoff *et al.* (2012), the Euler equation is satisfied for excess returns in levels.

[9] LRV (2011) pioneered the literature examining the cross-sectional pricing of currency-based risk factors, which was extended by Menkhoff *et al.* (2012) to also include a global currency volatility risk factor.

three-factor model. The LRV (2011) model is empirically motivated, and it is not clear whether *HML* is related to fundamental economic risk. Hence, interpreting the *HML* factor continues to attract attention. Instead of focusing on empirically motivated risk factors, as LRV (2011) do, we attempt to explain currency returns using investment variables.

In order to scrutinize the performance of our models, we run horse races between our investment-based models and the two-factor model developed by LRV (2011) as a benchmark model to assess the relative power of our models in pricing currency excess returns. To run such horse race test, we follow Hou *et al.* (2019) and compare our two-factor model comprising *EQLMH* and *STLMH* to the LRV (2011) using spanning regressions. In an important contribution to the literature, Hou, Xue, and Zhang (2015) propose a four-factor investment-based model for equity returns and provide empirical evidence that their factor model explains nearly half of the anomalies discussed in the literature. The authors also show that their investment-based model performs as well as the three and four-factor models of Fama and French (1993) and Carhart (1997), respectively. Hou *et al.* (2021) augment Hou, Xue, and Zhang (2015)'s four-factor model with an expected growth factor and provide compelling evidence that the proposed model exhibits strong explanatory power for the cross-section of equity returns. Using spanning regressions, Hou *et al.* (2019) provide evidence that the *q*-factor models' cross-sectional performance is at least as good as the Fama and French (2015, 2018) five and six factor models, the Stambaugh and Yuan (2017) four-factor model, as well as the Barillas and Shanken (2018) six-factor model. Zhang (2017) develops an investment consumption asset-pricing model based on the *q*-theory of investment and argues that it is more tractable than the consumption CAPM.

4. Data Description

Investment data: We assemble quarterly observations on total gross capital formation and its subcomponents for the period 1996Q1 to 2019Q1 from Datastream. The starting date of our data is dictated by the availability of the subcomponents of gross capital formation, discussed next, for some of the Eurozone countries.[10] The data on gross capital formation and its subcomponents are collected and disseminated by the Organization for Economic Cooperation and Development (OECD). The data are obtained for a cross-section of twenty-five countries: Australia, Canada, Japan, New Zealand, Norway, Sweden, Switzerland, United Kingdom, United States, Austria, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Portugal, Slovak Republic, Republic of Slovenia and Spain. More specifically, we collect data on total gross capital formation, in nominal and real terms, as well as more granular investment data on dwellings, other buildings and structures, cultivated biological resources, intellectual property products and machinery, equipment and weapons systems in nominal terms.[11] We deflate the nominal investment data using a common price deflator, which we compute as the ratio of nominal to real gross capital formation.

Our definitions of investment in structures and equipment are broadly consistent with the OECD's classification of investment in equipment and structures[12], as well as with the NBER's definition of these variables.[13] In our empirical analysis, investment in structures is defined as the sum of dwellings, other buildings and structures and cultivated biological resources, whereas investment in equipment is the sum of intellectual property products and machinery, equipment and weapons systems.

The data on the Eurozone's investment in equipment and structures is computed as the sum of the (real) investment in equipment and structure for the sixteen Eurozone countries in our sample

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[10] To be precise, the data for Austria, Italy and the Netherlands are not available prior to 1996Q1.

[11] The granular investment data are collected in nominal terms because, perhaps surprisingly, the data on the subcomponents of total gross capital formation are not available prior to 2002 in real terms for the US.

[12] The OECD glossary of statistical terms is available here: https://stats.oecd.org/glossary/.

[13] The NBER glossary is available here: https://www.bea.gov/glossary/glossary_n.htm. According to the NBER, investment in nonresidential structures consists of new construction (including own-account production), improvements to existing structures, expenditures on new mobile structures, brokers' commissions on sales of structures, and net purchases of used structures by private businesses and by nonprofit institutions from government agencies. New construction includes hotels and motels and mining exploration, shafts, and wells. Nonresidential structures also include equipment considered to be an integral part of a structure, such as plumbing, heating, and electrical systems. On the other hand, equipment and software investment in equipment and software consists of capital account purchases of new machinery, equipment, furniture, vehicles, and computer software; dealers' margins on sales of used equipment; and net purchases of used equipment from government agencies, persons, and the rest of the world. Own-account production of computer software is also included.

for which we can collect granular investment data.[14] The investment data are seasonally adjusted for all the countries. We should acknowledge and discuss several data limitations that we face. For Canada and the US, the data on cultivated biological resources are not available. Given that the cultivated biological resources are a small fraction of total gross capital formation, the unavailability of these data does not significantly affect the investment in structures for the latter two countries. For Japan, the intellectual property products data are not available after 2017Q1. In addition, neither the cultivated biological resources nor the machinery, equipment and weapons systems data are available. We substitute for the machinery, equipment and weapons systems subcomponent of total gross capital formation with transport equipment when constructing investment in equipment for Japan. Furthermore, none of the granular investment data are available for Switzerland after 2015, while total gross capital formation data are. Finally, no granular investment data are available for the following countries: Belgium, Cyprus and Malta. Therefore, the latter countries are omitted from the Eurozone's investment in equipment and structure computations. We also omit Switzerland from the cross-section when we compute the investment in equipment and structures but include it when we use total investment data.[15]

Spot and forward data: We collect daily observations on the spot and three-month forward rates of the G10 currencies and Danish Krone (DKK), against the United States dollar (USD), from Thomson Reuters database of Datastream.[16] All exchange rates are expressed in foreign currency units per USD, given that we carry out our analysis from the perspective of a US investor. We sample the quarter's observation as the last observation of the quarter.

[14] It is important to note that the real total gross capital formation for each of the Eurozone countries is expressed in terms of 2015 prices. In fact, real total gross capital formation for every country is in terms of 2015 prices. Therefore, our investment deflator is defined in a consistent manner across all the Eurozone countries. As discussed next, the granular investment data for Belgium are not available. Therefore, Belgium is excluded from the computations of the investment in equipment and structures but included in the computation of total investment for the Eurozone.

[15] We always maintain the returns on the Swiss Franc in the analysis so as not to shrink the cross-section of currencies that we employ.

[16] The G10 currencies are the world's ten most liquid and traded currencies. These are Australian dollar (AUD), British pound (GBP), Canadian dollar (CAD), Swiss franc (CHF), Euro (EUR), Japanese yen (JPY), New Zealand dollar (NZD), Swedish krona (SEK), Norwegian krone (NOK). The data are available starting May 25, 1990.

5. Empirical Results

5.1. Common Investment-Based Factors in Currency Returns – Hypothesis 1

To set the stage, Table 1 provides the summary statistics of the currency excess returns on various portfolios. In Panel A, we employ the returns on the quintile carry trade portfolios, P1 to P5, constructed by sorting currencies based on their lagged forward premium. P1 comprises the currencies with the smallest forward premium while P5 contains the currencies with the largest forward premium. Panels B, C and D provide the returns on the quintile portfolios constructed by sorting currencies on the basis of the lagged difference between country *k* and the US's investment in equipment (EQ1, EQ2, EQ3, EQ4 and EQ5), investment in structures (ST1, ST2, ST3, ST4 and ST5) and total investment (INV1, INV2, INV3, INV4 and INV5). The *INVLMH*, *STLMH* and *EQLMH* factors are, in turn, constructed as the return difference between portfolios with the smallest total investment, investment in structures and equipment (EQ1, ST1 and INV1) and the portfolios with the largest total investment, investment in structures and equipment (EQ5, ST5 and INV5). The returns on the *DOL* portfolio are negative and insignificant. In line with LRV (2011), the *HML* portfolio, constructed as the difference between the returns on portfolios P5 and P1, earns, on average, a positive and statistically significant return. The time series dynamics of the returns of our and LRV (2011)'s factors are provided in Figure 1. Figure 1 suggests that our factors exhibit little persistence. This is confirmed by the low autocorrelation coefficients for our factors. The autocorrelation in the *INVLMH*, *EQLMH*, and *STLMH* factors are, respectively, 0.12, 0.13, and -0.14.

Our goal is to examine whether sorting countries by capital investment leads to significant variation in portfolio currency returns. In Panels B, C and D, therefore, we sort currencies based on their lagged equipment, structure and total investment, respectively, relative to the US. We find that countries with the lowest past capital investment relative to the US (quintile 1) have higher returns compared to countries with the highest past capital investment relative to the US (quintile 5). We also find that the return differentials between the low and high quintiles are 0.17%, 0.22% and 0.30% per quarter for the equipment, structure, and total investment portfolios, respectively. Hence, the *EQLMH*, *STLMH* and *INVLMH* portfolios appear to earn investors a positive return.

Turning now to examining the central idea in our analysis, we report the asset pricing results from estimating the *INVLMH* one-factor and the *EQLMH* and *STLMH* two-factor models. Hypothesis 1 predicts that return-based factors, constructed only from information on capital investment, can help in predicting currency excess returns. For comparison purposes, we report the results from estimating our one and two-factor investment models alongside those of the LRV (2011) two-factor benchmark model, which includes the *DOL* and *HML* factors. Our goal is to present a comparative assessment of whether there is an improvement in explaining currency excess returns. To be in line with the literature, our test assets comprise the returns on five carry trade portfolios (Table 2) as well as the individual currency excess returns (Table 3).

Table 2 presents the estimation results for currency portfolios. Panel A of Table 2 provides the results from the cross-sectional regressions. That is, we report the prices of risk, the Fama and MacBeth (1973) standard errors with the Heteroskedasticity and Autocorrelation (HAC) adjustment of Newey and West (1987) (with optimal lag selection) and the Shanken (1992) standard errors under general distributional assumptions, which are adjusted for errors in variables. We also account for potential model misspecification by employing the misspecification-robust standard errors of Kan, Robotti, and Shanken (2013).[17] Gospodinov and Robotti (2021) note that, when the model is estimated using GLS, statistical inference can be conducted using misspecification-robust standard errors even if the model is misspecified or not identified. The results in Panel A suggest that, in line with our theoretical expectations, the *INVLMH*, *EQLMH* and *STLMH* are priced risk factors. More specifically, the prices of risk associated with the *INVLMH*, *EQLMH* and *STLMH* are negative and significant when the Fama and MacBeth (1973) standard errors are employed. The *INVLMH* risk factor commands a significant risk premium when the Shanken (1992) and misspecification-robust standard errors are employed but the price of risk of the *EQLMH* and *STLMH* factors are insignificant when inference is conducted using the misspecification-robust standard errors. The price of risk of the *EQLMH* factor is significant when the Shanken (1992) standard errors are employed. The negative prices of risk translate into higher

[17] In fact, the Hansen and Jagannathan (1997) distance, which we report as a model diagnostic, indicates that all of the models, including LRV (2011), are misspecified.

(lower) risk premia for portfolios whose returns co-move negatively (positively) with investment. Thus, the portfolios whose sensitivity to investment risk is negative earn a positive risk premium, which induces investors to hold them. In contrast, portfolios whose returns co-vary positively with investment risk earn investors a low return because they tend to serve as investment hedges. We also find that our investment factor exhibits a good cross-sectional fit. The R^2 of the second pass cross-sectional regression exceeds 70% for the one and two-factor investment models.

Panel B reports the time series betas and the HAC standard errors with a Bartlett kernel and the parametric, data dependent, bandwidth selection of Andrews (1991). Any risk-based explanation of the cross-section of returns relies on a significant spread, across portfolios, in the covariance between the returns and the stochastic discount factor. There is a strikingly monotone decline in *INVLMH* and *EQLMH* betas when moving from P1 to P5. It is notable that the investment effect gets stronger as we go from P1 to P5. While portfolio P1 exhibits no significant sensitivity to both factors, portfolios P2 to P5 exhibit a negative and highly statistically significant sensitivity to *INVLMH* and *EQLMH* factors, suggesting that countries with high forward premium tend to co-move more negatively with their investment gap relative to the US. Note also that the constant is insignificant for any of the portfolios except P1. This evidence implies that high interest rate currencies (i.e., currencies with a high forward premium in the carry trade portfolio) co-move negatively with both *INVLMH* and *EQLMH* factors, suggesting that they perform poorly on average in periods of investment risk. In contrast, the sensitivity of the returns of portfolios P3 and P5 to the *STLMH* factor is positive albeit the significance of the response is lower than for the *EQLMH* factor. Again, the constant is significant only for the P1 portfolio. Turning to the LRV (2011) model, portfolios P1 to P5 exhibit a positive and highly statistically significant exposure to the *DOL* factor whereas only portfolios' P1 and P5 sensitivities to the *HML* are significant. Interestingly, the constant is significant for the P1 and P5 portfolios.

Table 3 provides the results from estimating our one and two-factor investment models as well as the LRV (2011) model for individual currencies. The cross-sectional asset pricing results, in Panel A, suggest that, in line with our results for the portfolios, the prices of risk associated with the *INVLMH, EQLMH* and *STLMH* factors continue to be negative and significant when the Fama and MacBeth (1973) standard errors are used. When we conduct statistical inference using the Shanken (1992) standard errors, the prices of risk of the *INVLMH* and *STLMH* factors continue to be significant but none of our factors are priced when the misspecification-robust standard errors are employed. The results in Panel B indicate that, except for GBP and NZD, all currencies' exposure to the *INVLMH* factor is negative and highly statistically significant. Similarly, the betas associated with the *EQLMH* factor are highly significant and negative for all the currencies except GBP and NZD for which they are positive and significant. In general, the significance of the betas associated with the *STLMH* factor are lower than those associated with the *EQLMH* factor. The results from estimating the model of LRV (2011) for individual currencies show that the betas associated with the *DOL* factor are highly significant and positive, except for GBP and NZD. The sensitivity of the individual currency excess returns to the *HML* factor is less pronounced in that the betas associated with DKK, EUR and GBP are not significant. The betas associated with the *HML* factor are positive and highly significant for AUD, CAD and NOK whereas they are negative and highly significant for CHF, JPY and NZD. Again, this shows that the sensitivities of the individual currencies to the *HML* factor exhibit some heterogeneity.

5.2. Controlling for the forward premium effect – Hypothesis 2

Augmented Investment Model Results: In hypothesis 2, we investigate whether the investment effect (reported in Tables 2 and 3) weakens after controlling for the forward premium impact. Given that the factor-mimicking portfolios, P1 to P5, are constructed by sorting the currencies based on their forward premium, it is natural to examine whether the carry trade (*HML*) risk factor proposed by LRV (2011) diminishes the significance of the investment factors. To do so, we subject our baseline one-factor and two-factor models to a more stringent test by including the *HML* factor, as defined in Equations (21) and (22), as a control variable. Our goal is to examine whether the carry trade risk factor can explain our results. Finding that statistical significance of our investment-based risk factors disappear when we use such expanded specification of our models would imply that systematic risk (proxied by the carry risk factor) drives the performance of our results.

Table 4 provides the results from estimating the augmented version of our two benchmark models using the carry trade portfolios. The overall results are in line with those reported in Table 2 and show that the investment effect continues to hold in the presence of the *HML* risk factor. Panel A demonstrates that each of our three investment-based factors is priced in the cross-section currency excess returns and that the prices of risk continue to be negative. Interestingly, the *INVLMH* and *EQLMH* are priced even when the misspecification-robust standard errors are employed. In contrast, the price of risk associated with the *STLMH* factor is significant only when statistical inference is conducted using the Fama and MacBeth (1973) standard errors. We interpret our results as suggestive that the significant prices of risk of the investment factors cannot be ascribed to the omission of the *HML* factor from earlier specifications and view these findings as supportive of our second hypothesis. Furthermore, Panel B shows that betas associated with the *INVLMH* factor continue to be negative and highly significant in the presence of the *HML* factor. The R^2 of the time series regressions are noticeably larger than those of the models that exclude *HML*. The constant is significant at the 1% level for portfolios P1 and P5. In a similar vein, the significance of the *EQLMH* factor is maintained at the 5% level or higher for all portfolios except P4 albeit the introduction of *HML* renders the *STLMH* factor insignificant. The constant is significant for the P1 portfolio and marginally significant for the P3 portfolio.

For completeness, Table 5 provides the results from estimating the one-factor *INVLMH* and two-factor *EQLMH* and *STLMH* models that are augmented with *HML* using individual currency excess returns. The results in Table 5 are again in line with those reported in Table 3. In Panel A, the prices of risk of the *INVLMH* and *STLMH* factors are significant at the 5% level or lower when the Fama and MacBeth (1973) and Shanken (1992) standard errors are employed. In Panel B, it is clear again that the significance of the *INVLMH* factor is maintained when the *HML* factor is added to the model. In fact, the beta associated with the *INVLMH* factor is negative for all the currencies except GBP and NZD, for which it is positive and significant. The same observation applies to the *EQLMH* factor given that the beta associated with it is negative and highly significant for all the currencies, except GBP and NZD, for which it is positive and significant. The significance of the betas associated with the *STLMH* factor is generally lower than that of the *EQLMH*. Indeed, the beta associated with the *STLMH* is negative and highly significant for GBP and JPY whereas it is positive and significant at the 10% level or higher for CAD, DKK, EUR, NOK and SEK.

Following Gospodinov and Robotti (2021), we test the identification of all of our models using the rank test.[18] More specifically, let the matrix β denote the covariance between the returns and the factors. If the matrix β is of full column rank, the risk premia are identifiable. The null hypothesis of the rank test is that the matrix β is of deficient rank. A rejection of the null hypothesis therefore implies that β is of full rank and that the model is identified. The results of the rank test in Table 2 indicate that the LRV (2011) and investment models are not identified when the returns on portfolios P1 to P5 are used as test assets. Similarly, the results of the rank test in Table 4 suggest that the *HML* and *INVLMH* as well as the *HML*, *EQLMH* and *STLMH* models are not identified when the returns on portfolios P1 to P5 are used as test assets. All of the remaining models pass the rank test for identification.

Double Sorting Results: To further examine hypothesis 2, we resort to double sorts based on the forward premium, total investment, as well as investment in structures and equipment. The summary statistics of these double-sorted portfolios are reported in Table 6. As can be gleaned from Table 6, the forward premium effect remains strong after controlling for capital investment. We construct a long-short portfolio, which we refer to as Δ_{FP}, by assuming that the investor goes long in the high forward premium and goes short in the low forward premium portfolio. The average return on the latter long-short portfolio is positive and statistically significant in all panels whether investment is high or low (at the 10% level or higher). Put differently, the 'difference' portfolios, which long the high forward premium and high/low equipment (or structure) portfolios and short the low forward premium and high/low equipment (or structure) portfolios, generate positive and statistically significant returns. Interestingly, the forward premium effect is stronger in the low investment countries. It is notable that the Δ_{FP} portfolio generates average positive returns of 1.030%, 1.507% and 1.332% for the low investment countries (compared to 0.820%,

[18] See also Burnside (2016) for a discussion of the rank test and the identification of asset pricing models.

1.073% and 0.827% for the high investment countries) for the total investment, equipment investment, and structure investment, respectively.

We also consider portfolios in which the forward premium is held constant and the difference in returns are computed based on changes in total investment, equipment and structure, referred to as $\Delta_{INV,}$ Δ_{EQ} and $\Delta_{ST,}$ respectively, by assuming that the investor goes long in the low investment portfolio and goes short in the high investment portfolio. We find that the investment effect is concentrated in the high forward premium portfolios only. For example, it is seen in Panel A that the Δ_{INV} portfolio generates average positive returns of 0.004% for the high forward premium countries (compared to average negative returns of -0.205% for the low forward premium countries). Similar observations can be gleaned from Panel B of Table 6, given that the Δ_{EQ} portfolio generates average positive (negative) returns of 0.141% (-0.431%) for the high (low) forward premium countries. None of the returns on these portfolios, however, are significant.

The main finding in Table 6 is that the forward premium effect is the strongest among countries with low investment, while the investment effect seems the strongest among countries with high forward premium. In support, we find in all panels that the low investment and high forward premium portfolio generates a higher return than the high investment and low forward premium portfolio. Motivated by this evidence, we construct another long-short portfolio, which assumes that the investor goes long in the high forward premium and low investment portfolio and short the low forward premium and high investment portfolio. Our results, available on request, indicate that the average return on the latter portfolio is positive and statistically significant.

5.3. Spanning Regressions Results – Contrasting our Results with LRV

To contrast our results with LRV, we follow Hou *et al.* (2019) and compare our two-factor model comprising *EQLMH* and *STLMH* to the LRV (2011) model using spanning regressions. Barillas and Shanken (2017, 2018) argue that, for models with traded factors, which is the case for both our two-factor investment and the LRV (2011) models, a direct comparison of the models can be undertaken by examining whether a model is able to explain the returns of the factor-mimicking portfolios of the other model. Part of the above analysis in performed in Panel B of

Table 2 for the factor-mimicking portfolios, P1 to P5, constructed from sorting on the forward premium. That is, the results in Panel B of Table 2 shed light on whether our one-factor, *INVLMH*, and two-factor, *EQLMH* and *STLMH* models, can explain the returns on the portfolios P1 to P5. Our results suggest that the constant for P1 is highly significant for the one and two-factor investment models, while it is significant for the portfolios P1 and P5 when the LRV (2011) model is employed. Our findings thus far suggest that the one and two-factor investment models appear to be as good as the LRV (2011) model in explaining the returns on the P1 to P5 portfolios.

However, we turn to a more formal assessment using the Gibbons, Ross, and Shanken (1989), henceforth GRS, test. The GRS statistic tests that all the alphas (i.e., constants) in the time series regressions are jointly equal to zero. Under an assumption of joint normality of the regressions' residuals, the test follows an F distribution. When the two-factor investment model is estimated using the returns on the P1 to P5 portfolio, the GRS statistic is equal to 2.811, with a significance level of 0.021. The heteroscedasticity-robust version of the GRS test is 15.343 with a significance level of 0.008. The two versions of the test statistic lead us to conclude that the null that the alphas are jointly equal to zero should be rejected. When we estimate the LRV (2011) model using the returns on the P1 to P5 portfolios, the standard and heteroscedasticity-robust versions of the GRS tests are, respectively, 0.824 (with a significance level of 0.535) and 4.397 (with a significance level of 0.493). The two versions of the test statistic yield the same conclusion. The null that the alphas are jointly equal to zero is not rejected for the LRV (2011) model, which, therefore, appears to better explain the returns on the P1 to P5 portfolios than our two-factor investment model.

Table 7 provides the results from estimating our two-factor investment and LRV (2011) models using the EQ1 to EQ5 as well as the ST1 to ST5 factor-mimicking portfolios. The results in Table 7 show that only one constant is significant for the two models. Namely, the constant associated with the portfolio EQ2 is negative and significant at the 5% level when the two-factor investment model is estimated, while the constant associated with the EQ5 portfolio is positive and significant at the 10% level for the LRV (2011) model. Again, the results are broadly similar across the two models so we turn next to the GRS test. When the returns on the EQ1 to EQ5 and ST1 to ST5 portfolios are employed as dependent variables to estimate our two-factor investment model, the

GRS statistic and its heteroscedasticity-robust version are, respectively, 0.470 (with a significance level of 0.904) and 5.285 (with a significance level of 0.871). The two versions of the test statistic suggest that the joint null that alphas are equal to zero cannot be rejected. Thus, our model is able to explain the returns on the EQ1 to EQ5 and ST1 to ST5 portfolios. When we estimate the LRV (2011) model with the returns on the EQ1 to EQ5 and ST1 to ST5 portfolios as dependent variables, the standard and heteroscedasticity-robust versions of the GRS test are 0.5871 (with a significance level of 0.820) and 5.899 (with a significance level of 0.823), respectively. In sum, the LRV (2011) model is better able to explain the returns on the forward premium as well as the equipment and structure portfolios than our two-factor investment model.

6. Conclusion

The historical advantage that has been enjoyed by consumption in asset pricing models has recently been challenged with the emergence of methods that emphasize a role for production. In contrast to their consumption-based counterparts, producers have a well-defined objective function specifically connected to the desire to maximize profits. It is perhaps not surprising, therefore, that production-based methods have emerged to link physical investment decisions in capital to asset prices. The production-based approach appears to have enjoyed particular success in equity pricing, as emphasized by the findings of Jermann (2010) as it relates to the equity premium puzzle.

Although production has clearly gained a foothold in pricing equities and to a lesser extent bonds, the role of production has not generally been extended to puzzles in international finance. Most notably, the violation of uncovered interest rate parity and the ensuing abnormal profits from the carry trade have garnered considerable attention elsewhere, resulting in a flurry of research attempting to provide a suitable explanation as discussed in the introduction. To date, however, the role of production has not been considered. A major challenge appears to result from deriving appropriate stochastic discount factors that rely on the constituent elements of the carry trade, namely both exchange rate returns between two countries and relative differences in interest rates. To this end, we propose factors emanating from analyzing the risk premium on the carry trade that involve stochastic discount factors on nominal bonds in two countries using the analysis of

Jermann (2013). The model of Jermann (2013) is based on production decisions using capital in equipment and structures, and therefore provides an interesting avenue for exploring how production potentially impacts the relationships governing excess currency returns.

Given the dearth in the literature using production-based models to explore deviations from uncovered interest parity, our analysis is largely exploratory and empirical in nature. Specifically, we construct portfolio-based factors for equipment and structure investment differences for countries relative to the US. Our finding suggest that the investment factors are priced in the cross-section of currency excess returns and that the prices of risk are negative and significant. The findings are robust to the inclusion of the carry trade risk factor proposed by LRV (2011). Overall, the findings suggest promise for the use of factors based on production variables.

There are of course caveats. For example, baseline findings do suggest that the one and two-factor investment models provide comparable results relative to the model of LRV (2011), who use dollar and carry trade factors to capture movement in excess currency returns. However, more careful scrutiny based on spanning regression and the use of the test of Gibbons, Ross, and Shanken (1989) reveal that the model of LRV (2011) is better able to explain the returns on portfolios sorted by the forward premium. Additionally, there is likely room to consider additional variables related to production and investment. A more careful theoretical exposition would likely yield additional insight into other production-based factors that are suitable. This could include, for example, the use of factors based on the volatility of investment and other types of capital. Nonetheless, our findings suggest that production variables are potentially missing elements for researchers interested in studying the dynamics of international asset models.

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Figure 1: Time Series Dynamics of the Factor Returns

This figure provides the time series dynamics of the investment and Lustig, Rousanov and Verdelhan (2011) factors for the period 1996:Q1 to 2019:Q1

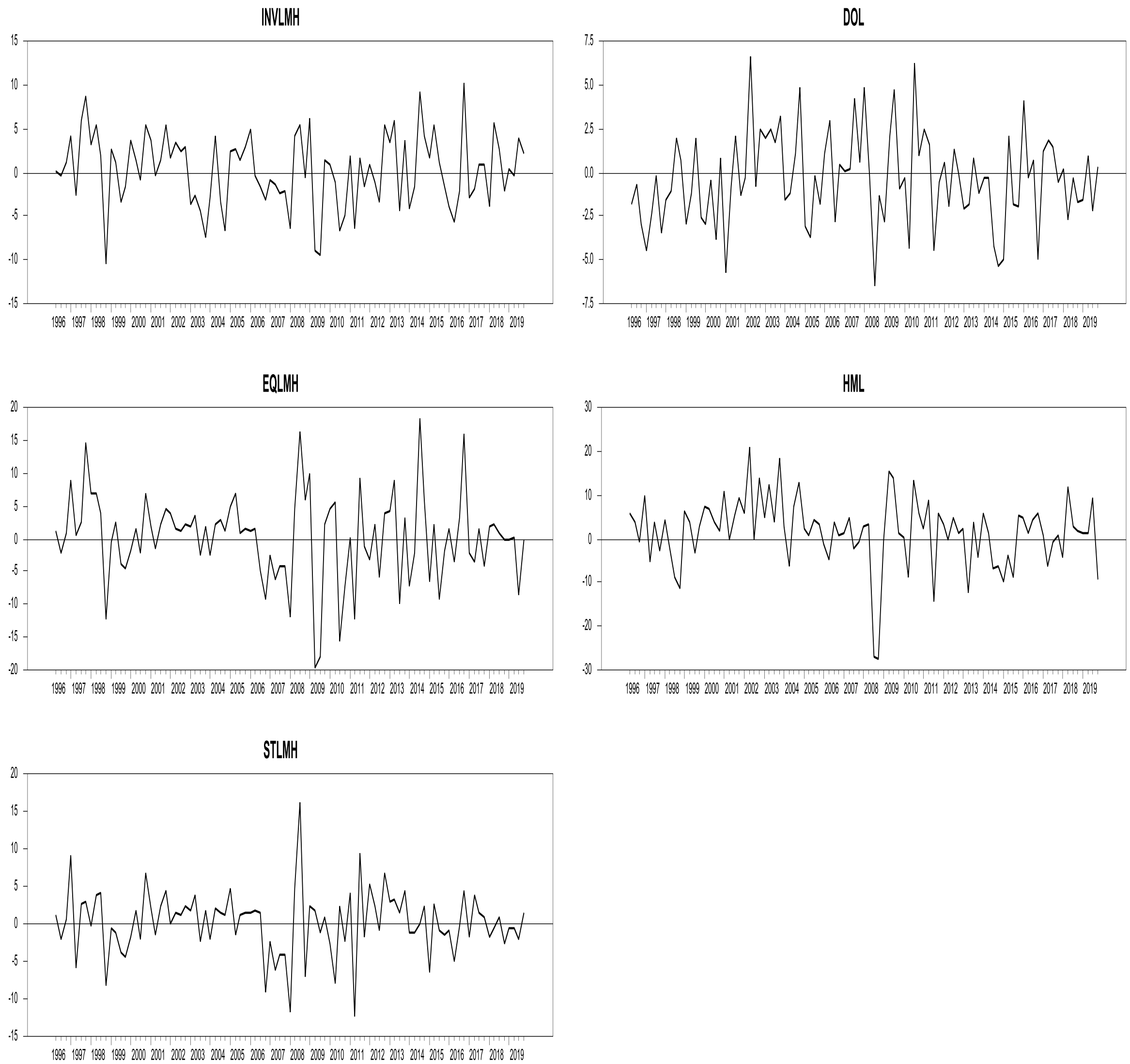

Table 1: Descriptive Statistics for Currency Portfolios

The table provides the average quarterly excess returns, *t*-statistic for testing that the mean return is equal to zero, standard deviation, skewness, excess kurtosis and Sharpe ratios of the quintile forward premium portfolios constructed by sorting currencies on the lagged forward premium (P1, P2, P2, P3, P4 and P5), equipment portfolios constructed by sorting currencies based on the lagged difference between country *k* and the US's equipment investment (EQ1, EQ2, EQ3, EQ4, EQ5), structure portfolios constructed by sorting currencies on the lagged difference between country *k* and the US's investment in structures (ST1, ST2, ST3, ST4, ST5) and investment portfolios constructed by sorting currencies on the lagged difference between country *k* and the US's total investment (INV1, INV2, INV3, INV4, INV5). The *EQAVE* (*STAVE*) is the average return of the five equipment (structure) portfolios. The *INVLMH* factor is the return difference between a quintile portfolio that goes long in the currencies of the countries with the smallest gross private fixed investment vis-à-vis the US (INV1) and goes short in the currencies of the countries with the highest gross private fixed investment relative to the US (INV5). Similarly, the *EQLMH* factor is given by the return difference between portfolio EQ1 and portfolio EQ5, which are quintile portfolios formed by sorting currencies on the lagged difference of investment in equipment vis-à-vis the US. The *STLMH* factor is given by the return difference between portfolio ST1 and portfolio ST5, which are quintile portfolios, constructed by sorting currencies on the difference of investment in structures vis-à-vis the US. The *INVAVE* is the average return on the five total investment portfolios. The dollar factor (*DOL*) is the average excess return of all the currencies in our cross-section. The *HML* factors are constructed as the difference between the returns of portfolios P5 and P1. *, ** and *** denote, respectively, statistical significance at the 10%, 5% and 1% levels.

Panel A. Carry Portfolios - Single sorting on lagged forward premium							
Portfolio	P1	P2	P3	P4	P5	DOL	HML
Mean	-1.44***	-0.25	-0.35	-0.06	0.23	-0.37	1.67**
t-statistic	-3.45	-0.61	-0.89	-0.14	0.44	-1.39	2.07
Std, Dev.	4.06	4.01	3.90	4.30	5.03	2.63	7.84
Skewness	0.60	-0.10	0.07	-0.06	-0.64	0.19	-0.89
Excess Kurtosis	1.27	0.89	-0.39	0.68	1.61	0.12	2.95
Sharpe Ratio	-0.35	-0.06	-0.08	-0.01	0.04	-0.14	0.21
Panel B. Equipment Portfolios- Single sorting on the lagged difference between country *k* and the US's equipment investment							
Portfolio	EQ1	EQ2	EQ3	EQ4	EQ5	EQAVE	EQLMH
Mean	-0.29	-0.61	-0.17	-0.17	-0.52	-0.35	0.22
t-statistic	-0.51	-1.46	-0.45	-0.44	-1.16	-1.46	0.33
Std, Dev.	5.63	4.08	3.83	3.75	4.39	2.38	-6.65
Skewness	-0.12	-0.32	-0.07	-0.72	0.08	0.24	-0.26
Excess Kurtosis	-0.03	0.57	1.74	1.89	-0.18	0.40	-1.35
Sharpe Ratio	-0.05	-0.14	-0.04	-0.04	-0.11	-0.14	0.03
Panel C. Structure Portfolios - Single sorting on the lagged difference between country *k* and the US's structure investment							
Portfolio	ST1	ST2	ST3	ST4	ST5	STAVE	STLMH
Mean	-0.45	-0.49	-0.20	-0.14	-0.62	-0.38	0.17
t-statistic	-0.88	-1.49	-0.59	-0.34	-1.41	-1.44	0.39
Std, Dev.	4.97	3.20	3.33	4.01	4.32	2.58	-4.25
Skewness	0.09	-0.67	0.03	-0.41	0.12	0.24	-0.02
Excess Kurtosis	-0.01	2.18	1.86	1.67	-0.06	0.29	-2.48
Sharpe Ratio	-0.09	-0.15	-0.06	-0.03	-0.14	-0.14	0.04
Panel D. Investment Portfolios - Single sorting on the lagged difference between country *k* and the US's total investment							
Portfolio	INV1	INV2	INV3	INV4	INV5	INVAVE	INVLMH
Mean	-0.31	-0.48	-0.36	-0.08	-0.62	-0.37	0.30
t-statistic	-0.95	-0.99	-1.26	-0.18	-1.41	-1.39	0.71
Std, Dev.	3.27	4.74	2.84	4.23	4.32	2.63	-4.16
Skewness	1.23	0.19	-0.90	-0.40	0.12	0.19	-0.20
Excess Kurtosis	3.54	0.32	5.39	1.07	-0.06	0.12	0.10
Sharpe Ratio	-0.09	-0.10	-0.12	-0.01	-0.14	-0.14	0.07

Table 2: Asset Pricing Results for the One-Factor and Two-Factor Investment Models using Currency Portfolios as Test Assets

The table provides the asset pricing results for: a one-factor total investment (*INVLMH*) model, a two-factor investment model in equipment *EQLMH*) and structures (*STLMH*), and the LRV (2011) model. We estimate the models using the two-pass approach of Fama and MacBeth (1973). The two-pass regressions are estimated using Generalized Least Squares (GLS), and we report the GLS R^2 for the cross-sectional regressions. The *INVLMH* factor is the return difference between a quintile portfolio that goes long in the currencies of the countries with the smallest gross private fixed investment vis-à-vis the US (INV1) and goes short in the currencies of the countries with the highest gross private fixed investment relative to the US (INV5). Similarly, the *EQLMH* (*STLMH)*factor is given by the return difference between a quintile portfolio that goes long in the currencies of the countries with the smallest equipment (structure) investment vis-à-vis the US and goes short in the currencies of the countries with the highest equipment (structure) investment relative to the US. In the first pass, we run a time series regression of currency excess returns in levels on the risk factors to estimate the factor betas (Panel A). In the second pass, we run a cross sectional regression of average excess returns on the estimated betas from the first pass to estimate the prices of risk (Panel B). The test assets are the excess returns on quintile portfolios sorted on the lagged forward discount, P1 to P5. Panel A provides the Fama and MacBeth (1973) standard errors with the Heteroscedasticity and Autocorrelation (HAC) adjustment of Newey and West (1987) (with optimal lag selection) denoted FMB, as well as the Shanken (1992) standard errors under general distributional assumptions, denoted (Sh), which are adjusted for errors in variables. Panel A also provides the Hansen and Jagannathan (1997) distance, denoted *HJ*, and its *p*-value in brackets as well as the rank test for the covariance matrix between the returns and the factors. Panel B provides the HAC standard errors with a Bartlett kernel and the parametric, data dependent, bandwidth selection of Andrews (1991). *,**,*** denote statistical significance at 10%, 5% and 1% levels, respectively.

Panel A: Cross-Sectional Regression Results and Prices of Risk

One-Factor Investment Model				Two-Factor Investment Model					Benchmark: Lustig, Roussanov, and Verdelhan Model				
	INVLMH	*HJ*	R^2		*EQLMH*	*STLMH*	*HJ*	R^2		*DOL*	*HML*	*HJ*	R^2
λ	-2.973	0.951	0.739	λ	-5.651	-4.311	0.966	0.714	λ	0.996	0.016	0.886	0.811
(FMB)	0.007***	[0.000]		(FMB)	0.015***	0.022***	[0.000]		(FMB)	0.002***	0.008	[0.000]	
(Sh)	0.467***	Rank Test		(Sh)	1.519**	2.352	Rank Test		(Sh)	0.002***	0.008	Rank Test	
(MR)	0.647**	7.675***		(MR)	2.652	3.966	0.838		(MR)	0.002***	0.008	0.000	

Panel B: Betas

One-Factor Investment Model				Two-Factor Investment Model					Benchmark: Lustig, Roussanov, and Verdelhan Model				
	Constant	*INVLMH*	R^2		Constant	*EQLMH*	*STLMH*	R^2		Constant	*DOL*	*HML*	R^2
P1	-1.427***	-0.044	0.002	P1	-1.435***	0.061	-0.110	0.011	P1	-0.310**	0.695***	-0.519***	0.856
	0.435	0.128			0.423	0.081	0.131			0.154	0.077	0.022	
P2	-0.141	-0.366***	0.144	P2	-0.229	-0.189***	0.106	0.073	P2	0.303	1.211***	-0.060*	0.575
	0.358	0.094			0.382	0.060	0.126			0.232	0.108	0.033	
P3	-0.222	-0.437***	0.217	P3	-0.316	-0.283***	0.141*	0.177	P3	0.005	1.171***	0.046	0.690
	0.356	0.092			0.377	0.053	0.084			0.253	0.103	0.039	
P4	0.058	-0.393***	0.144	P4	-0.009	-0.224**	-0.008	0.123	P4	0.311	1.224***	0.052	0.626
	0.402	0.107			0.434	0.104	0.182			0.233	0.135	0.047	
P5	0.371	-0.459***	0.144	P5	0.288	-0.433***	0.244**	0.244	P5	-0.310**	0.695***	0.480***	0.906
	0.489	0.129			0.485	0.087	0.135			0.154	0.077	0.022	

Table 3: Asset Pricing Results for One- and Two-Factor Models using Excess Returns on Individual Currencies as Test Assets

The table provides the asset pricing results for: a one-factor total investment (*INVLMH*) model, a two-factor investment model in equipment (*EQLMH*) and structures (*STLMH*), and the LRV (2011) model. We estimate the models using the two-pass approach of Fama and MacBeth (1973). The two-pass regressions are estimated using Generalized Least Squares (GLS), and we report the GLS R^2 for the cross-sectional regressions. The *INVLMH* factor is the return difference between a quintile portfolio that goes long in the currencies of the countries with the smallest gross private fixed investment vis-à-vis the US (INV1) and goes short in the currencies of the countries with the highest gross private fixed investment relative to the US (INV5). Similarly, the *EQLMH* factor is given by the return difference between portfolio EQ1 and portfolio EQ5, which are quintile portfolios formed by sorting currencies on the lagged difference of investment in equipment vis-à-vis the US. The *STLMH* factor is given by the return difference between portfolio ST1 and portfolio ST5, which are quintile portfolios constructed by sorting currencies on the lagged difference of investment in structures vis-à-vis the US. In the first pass, we run a time series regression of currency excess returns in levels on the risk factors to estimate the factor betas (Panel A). In the second pass, we run a cross sectional regression of average excess returns on the estimated betas from the first pass to estimate the prices of risk (Panel B). The test assets are the excess returns (in levels) on individual currencies. Panel A provides the Fama and MacBeth (1973) standard errors with the Heteroscedasticity and Autocorrelation (HAC) adjustment of Newey and West (1987) (with optimal lag selection) denoted FMB, as well as the Shanken (1992) standard errors under general distributional assumptions, denoted (Sh), which are adjusted for errors in variables. Panel A also provides the Hansen and Jagannathan (1997) distance, denoted *HJ*, and its *p*-value in brackets as well as the rank test for the covariance matrix between the returns and the factors. Panel B provides the HAC standard errors with a Bartlett kernel and the parametric, data dependent, bandwidth selection of Andrews (1991). *,**,*** denote statistical significance at 10%, 5% and 1% levels, respectively.

Panel A: Cross-Sectional Regression Results and Prices of Risk													
One-Factor Investment Model				Two-Factor Investment Model					Benchmark: Lustig, Roussanov, and Verdelhan Model				
	$INVLMH$	HJ	R^2		$EQLMH$	$STLMH$	HJ	R^2		DOL	HML	HJ	R^2
λ	-0.345	1.041	0.008	λ	0.080	-1.086	1.042	0.044	λ	0.996	-0.293	1.008	0.249
(FMB)	0.004***	[0.000]		(FMB)	0.010***	0.007***	[0.000]		(FMB)	0.002***	0.011***	[0.000]	
(Sh)	0.019***	Rank Test		(Sh)	0.237	0.174***	Rank Test		(Sh)	0.002***	0.347	Rank Test	
(MR)	0.191	29.358***		(MR)	0.913	0.923	3.750***		(MR)	0.002***	0.886	7.875***	

Table 3: Asset Pricing Results for the One-Factor and Two-Factor Investment Models using Excess Returns on Individual Currencies as Test Assets (Continued)

Panel B: Betas													
	One-Factor Investment Model				Two-Factor Investment Model					Benchmark: Lustig, Roussanov, and Verdelhan Model			
	Constant	$INVLMH$	R^2		Constant	$EQLMH$	$STLMH$	R^2		Constant	DOL	HML	R^2
AUD	0.411	-0.835***	0.327	AUD	0.243	-0.519***	0.176	0.263	AUD	0.083	1.225***	0.319***	0.623
	0.461	0.108			0.537	0.086	0.138			0.334	0.213	0.069	
CAD	0.062	-0.365***	0.149	CAD	-0.028	-0.284***	0.259**	0.165	CAD	-0.125	0.664***	0.195***	0.483
	0.356	0.076			0.380	0.069	0.109			0.291	0.127	0.048	
CHF	-0.246	-0.481***	0.178	CHF	-0.328	-0.304***	0.020	0.173	CHF	0.371	1.621***	-0.092***	0.725
	0.412	0.106			0.416	0.053	0.145			0.244	0.117	0.027	
DKK	-0.337	-0.454***	0.145	DKK	-0.446	-0.381***	0.329*	0.186	DKK	0.230	1.741***	-0.030	0.825
	0.458	0.101			0.459	0.059	0.177			0.237	0.074	0.023	
EUR	-0.291	-0.454***	0.147	EUR	-0.400	-0.376***	0.323*	0.184	EUR	0.255	1.713***	-0.024	0.816
	0.455	0.101			0.455	0.061	0.177			0.243	0.076	0.023	
GBP	-0.155	0.292***	0.075	GBP	-0.081	0.335***	-0.358***	0.186	GBP	-0.158	-0.752***	-0.114	0.311
	0.446	0.104			0.405	0.096	0.130			0.486	0.151	0.106	
JPY	-0.511	-1.006***	0.551	JPY	-0.683	-0.263***	-0.451***	0.325	JPY	0.154	1.428***	-0.261***	0.389
	0.382	0.093			0.450	0.076	0.142			0.471	0.173	0.073	
NOK	-0.188	-0.421***	0.098	NOK	-0.280	-0.403***	0.319**	0.165	NOK	-0.060	1.534***	0.191***	0.750
	0.520	0.121			0.512	0.081	0.145			0.286	0.129	0.068	
NZD	-0.994**	0.856***	0.369	NZD	-0.815	0.546***	-0.239**	0.299	NZD	-0.589	-0.900***	-0.288***	0.433
	0.491	0.109			0.563	0.074	0.118			0.406	0.250	0.077	
SEK	-0.470	-0.532***	0.165	SEK	-0.584	-0.490***	0.364**	0.256	SEK	-0.161	1.723***	0.105*	0.814
	0.530	0.126			0.510	0.066	0.146			0.304	0.108	0.058	

Table 4: Asset Pricing Results for the One and Two-Factor Investment Models augmented with the HML Factor using Excess Returns on Currency Portfolios as Test Assets

The table provides the asset pricing results for a one-factor total investment model (*INVLMH*) and our two-factor investment model in equipment (*EQLMH*) and structures (*STLMH*), each of which have been augmented with the *HML* factor. We estimate the models using the two-pass approach of Fama and MacBeth (1973). The two-pass regressions are estimated using GLS, and we report the GLS R^2 for the cross-sectional regressions. The investment-based factors $[INVLMH, EQLMH, STLMH]$ are defined in the caption of Table 2. In the first pass, we run a time series regression of currency excess returns in levels on the risk factors to estimate the factor betas (Panel A). In the second pass, we run a cross sectional regression of average excess returns on the estimated betas from the first pass to estimate the prices of risk (Panel B). The test assets are the excess returns on quintile portfolios sorted on the lagged forward discount, P1 to P5. Panel A provides the Fama and MacBeth (1973) standard errors with the Heteroscedasticity and Autocorrelation (HAC) adjustment of Newey and West (1987) (with optimal lag selection) denoted FMB, as well as the Shanken (1992) standard errors under general distributional assumptions, denoted (Sh), which are adjusted for errors in variables. Panel A also provides the Hansen and Jagannathan (1997) distance, denoted *HJ*, and its *p*-value in brackets as well as the rank test for the covariance matrix between the returns and the factors. Panel B provides the HAC standard errors with a Bartlett kernel and the parametric, data dependent, bandwidth selection of Andrews (1991). *,**,*** denote statistical significance at 10%, 5% and 1% levels, respectively.

Panel A: Prices of Risk

	Two-Factor Investment Model				Three-Factor Investment Model				
	HML	$INVLMH$	HJ	R^2	HML	$EQLMH$	$STLMH$	HJ	R^2
λ	0.016	-3.373	0.863	0.879	0.016	-6.204	-2.258	0.720	0.968
(FMB)	0.008	0.008***	[0.029]		0.008	0.015***	0.024***	[0.538]	
(Sh)	0.008	0.578***	Rank Test		0.008	1.408**	2.329	Rank Test	
(MR)	0.009	0.580***	0.000		0.009	1.760*	3.541	0.000	

Panel B: Betas

	Two-Factor Investment Model				Three-Factor Investment Model				
	Constant	HML	$INVLMH$	R^2	Constant	HML	$EQLMH$	$STLMH$	R^2
P1	-0.607***	-0.455***	-0.233***	0.738	-0.618***	-0.474***	-0.173***	0.057	0.741
	0.173	0.023	0.050		0.178	0.025	0.041	0.050	
P2	-0.245	0.057***	-0.342***	0.156	-0.325	0.055	-0.161**	0.086	0.083
	0.338	0.060	0.098		0.363	0.068	0.072	0.119	
P3	-0.503	0.156**	-0.372***	0.310	-0.565*	0.144	-0.212***	0.089	0.250
	0.336	0.054	0.082		0.322	0.059	0.050	0.069	
P4	-0.255	0.174**	-0.321***	0.240	-0.308	0.173	-0.139	-0.070	0.211
	0.369	0.075	0.102		0.389	0.073	0.107	0.170	
P5	-0.607***	0.544***	-0.233***	0.829	-0.618***	0.525***	-0.173***	0.057	0.831
	0.173	0.023	0.050		0.178	0.025	0.041	0.050	

Table 5: Asset Pricing Results for the One and Two-Factor Investment Models augmented with the HML Factor using the Excess Returns on Individual Currencies as Test Assets

The table provides the asset pricing results for a one-factor total investment model (*INVLMH*) and our two-factor investment model in equipment (*EQLMH*) and structures (*STLMH*), each of which have been augmented with the *HML* factor. We estimate the models using the two-pass approach of Fama and MacBeth (1973). The two-pass regressions are estimated using GLS, and we report the GLS R^2 for the cross-sectional regressions. The investment-based factors $[INVLMH, EQLMH, STLMH]$ are defined in the caption of Table 2. In the first pass, we run a time series regression of currency excess returns in levels on the risk factors to estimate the factor betas (Panel A). In the second pass, we run a cross sectional regression of average excess returns on the estimated betas from the first pass to estimate the prices of risk (Panel B). The test assets are the excess returns in levels on individual currencies. Panel A provides the Fama and MacBeth (1973) standard errors with the Heteroscedasticity and Autocorrelation (HAC) adjustment of Newey and West (1987) (with optimal lag selection) denoted FMB, as well as the Shanken (1992) standard errors under general distributional assumptions, denoted (Sh), which are adjusted for errors in variables. Panel A also provides the Hansen and Jagannathan (1997) distance, denoted *HJ*, and its *p*-value in brackets as well as the rank test for the covariance matrix between the returns and the factors. Panel B provides the HAC standard errors with a Bartlett kernel and the parametric, data dependent, bandwidth selection of Andrews (1991). *,**,*** denote statistical significance at 10%, 5% and 1% levels, respectively.

Panel A: Prices of Risk										
	Two-Factor Investment Model					Three-Factor Investment Model				
	HML	$INVLMH$	HJ	R^2		HML	$EQLMH$	$STLMH$	HJ	R^2
λ	0.853	-0.332	1.021	0.015	λ	1.932	0.860	-1.638	1.021	0.124
(FMB)	0.011***	0.004***	[0.000]		(FMB)	0.011***	0.010***	0.007***	[0.000]	
(Sh)	0.094***	0.028***	Rank Test		(Sh)	0.579**	0.575	0.419***	Rank Test	
(MR)	0.889	0.192	9.858***		(MR)	1.118	1.294	1.145	2.084**	

Table 5: Asset Pricing Results for the One and Two-Factor Investment Models augmented with the HML Factor using the Excess Returns on Individual Currencies as Test Assets (Continued)

Panel B: Betas										
	Two-Factor Investment Model					Three-Factor Investment Model				
	Constant	HML	$INVLMH$	R^2		Constant	HML	$EQLMH$	$STLMH$	R^2
AUD	-0.310	0.401***	-0.668***	0.582	AUD	-0.433	0.392***	-0.325***	0.037	0.488
	0.343	0.061	0.080			0.402	0.074	0.073	0.085	
CAD	-0.389	0.251***	-0.261***	0.388	CAD	-0.443	0.240***	-0.165***	0.173*	0.366
	0.295	0.045	0.060			0.311	0.048	0.052	0.095	
CHF	-0.365	0.065	-0.454***	0.189	CHF	-0.402	0.042	-0.283***	0.005	0.178
	0.383	0.070	0.107			0.375	0.077	0.061	0.144	
DKK	-0.609	0.151**	-0.391***	0.199	DKK	-0.644	0.114	-0.324***	0.288*	0.215
	0.447	0.075	0.096			0.429	0.085	0.070	0.169	
EUR	-0.567	0.153**	-0.390***	0.204	EUR	-0.605	0.118	-0.317***	0.280*	0.215
	0.443	0.074	0.097			0.423	0.084	0.072	0.168	
GBP	0.181	-0.187*	0.214***	0.180	GBP	0.172	-0.147	0.263***	-0.306***	0.246
	0.478	0.100	0.097			0.429	0.094	0.071	0.110	
JPY	-0.146	-0.203**	-1.091***	0.627	JPY	-0.379	-0.176	-0.350***	-0.388***	0.377
	0.318	0.090	0.101			0.486	0.119	0.075	0.124	
NOK	-0.837*	0.360***	-0.271**	0.343	NOK	-0.852**	0.331***	-0.239***	0.201*	0.354
	0.427	0.085	0.114			0.414	0.083	0.078	0.108	
NZD	-0.416	-0.321***	0.723***	0.544	NZD	-0.296	-0.301***	0.398***	-0.132	0.441
	0.359	0.068	0.088			0.420	0.079	0.071	0.100	
SEK	-0.978**	0.282***	-0.415***	0.321	SEK	-0.989**	0.235***	-0.374***	0.281**	0.356
	0.464	0.080	0.106			0.426	0.082	0.067	0.131	

Table 6: Descriptive Statistics for Double Sorted Portfolios

The table provides the average quarterly excess returns, *t*-statistic for testing that the mean return is equal to zero, along with the standard deviation, skewness, excess kurtosis and Sharpe ratios for double-sorted portfolios. The returns on the portfolios are constructed by double sorting currencies based on their forward premium and the difference between country *k*'s and the US's total investment, investment in structures and equipment. Currencies with a forward premium, total investment, investment in structures and investment in equipment that is higher (lower) than the median are allocated to the high (low) portfolio. The table also provides summary statistics for long-short portfolio, referred to as Δ_{FP}, that assume that the investor goes long in the high forward premium and short in the low forward premium for a given level of investment (high or low). The table also provides the summary statistics of the returns on short-long portfolios in which the forward premium is held constant and the difference in returns are computed based on changes in total investment, equipment and structure. These portfolios are referred to as Δ_{INV}, Δ_{EQ} and Δ_{ST}.

Panel A: Double sorting in the forward premium and total investment			
	INV_H	INV_L	$\Delta_{INV\text{=Low-High}}$
FP_H	0.076	0.081	0.004
Std. Dev.	3.703	4.801	3.523
t-statistic	0.201	0.164	-0.013
FP_L	-0.744*	-0.949***	-0.205
Std. Dev.	3.663	3.138	3.420
t-statistic	-1.979	-2.948	0.584
$\Delta_{FP\text{=High-Low}}$	0.820*	1.030**	-0.210
Std. Dev.	4.662	5.017	4.473
t-statistic	1.715	2.002	-0.457
Panel B: Double sorting in the forward premium and investment in equipment			
	EQ_H	EQ_L	$\Delta_{EQ\text{=Low-High}}$
FP_H	0.079	0.221	0.141
Std. Dev.	3.985	4.274	3.112
t-statistic	0.194	0.504	-0.444
FP_L	-0.993**	-1.246***	-0.236
Std. Dev.	3.906	4.001	4.851
t-statistic	-2.479	-3.003	0.469
$\Delta_{FP\text{=High-Low}}$	1.073**	1.507**	-0.431
Std. Dev.	4.927	6.459	5.642
t-statistic	2.122	2.249	-0.737
Panel C: Double sorting in the forward premium and investment in structures			
	ST_H	ST_L	$\Delta_{ST\text{=Low-High}}$
FP_H	0.089	0.076	-0.012
Std. Dev.	3.711	4.801	3.534
t-statistic	0.235	0.155	0.035
FP_L	-0.737*	-1.256***	-0.518
Std. Dev.	3.660	4.029	4.579
t-statistic	-1.964	-3.038	1.103
$\Delta_{FP\text{=High-Low}}$	0.827*	1.332*	-0.505
Std. Dev.	4.668	6.931	5.668
t-statistic	1.727	1.874	-0.868

Table 7: Spanning Regressions for the Two-Factor Investment and LRV (2011) models

The table provides the results of the spanning regressions comparing our two-factor investment in equipment (*EQLMH*) and structures (*STLMH*) model to the LRV (2011) model. The models are estimated with the returns on the quintile portfolios constructed by sorting on the difference between currency *k* and the US's investment in equipment (EQ1 to EQ5) and the difference between currency *k* and the US's investment in structures (ST1 to ST5). The Heteroscedasticity and Autocorrelation (HAC) consistent standard errors of Newey and West (1987) with a Bartlett kernel and the parametric, data dependent, bandwidth selection of Andrews (1991) are reported. *,**,*** denote statistical significance at 10%, 5% and 1% levels, respectively.

	Two-Factor Investment Model					Benchmark: Lustig, Roussanov, and Verdelhan Model			
	Constant	$EQLMH$	$STLMH$	R^2		Constant	DOL	HML	R^2
EQ1	-0.440	0.649***	-0.029	0.571	EQ1	0.364	0.528**	-0.275***	0.135
	0.378	0.054	0.101			0.597	0.268	0.100	
EQ2	-0.550**	-0.443***	0.219*	0.398	EQ2	-0.392	0.923***	0.074	0.442
	0.269	0.056	0.114			0.359	0.176	0.073	
EQ3	-0.161	-0.209***	0.169*	0.094	EQ3	0.232	1.049***	-0.010	0.510
	0.418	0.074	0.088			0.283	0.162	0.060	
EQ4	-0.120	-0.258***	0.048	0.185	EQ4	-0.440	0.408***	0.252***	0.476
	0.352	0.078	0.099			0.320	0.126	0.053	
EQ5	-0.440	-0.350***	-0.029	0.297	EQ5	0.310*	1.578***	-0.144***	0.771
	0.378	0.054	0.101			0.188	0.100	0.037	
ST1	-0.541	-0.319***	0.935***	0.456	ST1	0.229	1.273***	-0.121	0.390
	0.366	0.053	0.096			0.438	0.210	0.078	
ST2	-0.453	0.012	-0.227*	0.083	ST2	-0.177	0.655***	-0.038	0.260
	0.296	0.055	0.126			0.318	0.149	0.062	
ST3	-0.191	-0.058	0.009	0.012	ST3	0.068	0.797***	0.017	0.419
	0.391	0.062	0.084			0.254	0.133	0.049	
ST4	-0.080	-0.392***	0.175*	0.328	ST4	-0.396	0.528***	0.271***	0.545
	0.331	0.073	0.096			0.305	0.132	0.057	
ST5	-0.541	-0.319***	-0.064	0.279	ST5	0.205	1.570***	-0.143***	0.791
	0.366	0.053	0.096			0.186	0.088	0.034	