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An investment-based explanation of currency excess returns

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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. To obtain valid factors for our proposed production model, we draw on an international investment-based asset-pricing model where representative firms in two countries choose structure and equipment capital to maximize profits. We empirically test the model for the factors constructed by sorting currencies based on differences in gross fixed capital formation, and investment in equipment and structures. Our findings show that 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.

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.[1]

Several competing risk-based explanations have been proposed in the literature to rationalize the existence of positive excess returns. An incomplete list includes risk factors related to equity (Burnside et al., 2011b), consumption (Lustig and Verdelhan, 2007), foreign exchange volatility (Menkhoff et al., 2012), liquidity (Mancini et al., 2013), credit default (Coudert and Mignon, 2013), and currencies (Lustig et al., 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). In this vein, 'Peso

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[1] 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 (see, for example, Burnside et al., 2011b).

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problems' (Burnside et al., 2011a), crash risk (Brunnermeier et al., 2009; Farhi et al. 2015; Farhi and Gabaix, 2016; Daniel et al., 2017), uncertainty (Berg and Mark, 2018a; Husted et al., 2018), and downside risk (Atanasov and Nitschka, 2014; Dobrynskaya, 2014; Jurek, 2014; Lettau et al., 2014) have been advocated as potential explanations for carry trade returns.

In this paper, we take a different approach and propose an investment-based explanation to pricing currency excess returns. Our primary contribution is empirical, where we study excess currency returns using factors constructed by sorting returns based solely on investment variables. To our knowledge, our manuscript is the first to use investment-based factors to analyze excess currency returns and appears to fill a void in the international asset pricing literature related to production. The relative dearth in the literature is surprising as 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 used an investment-based approach in studying US stock returns (Cochrane, 1996; Liu et al., 2009; Li and Zhang, 2010; Hou et al., 2019 and 2021), the value premium (Zhang, 2005), the equity premium (Jermann, 2010), the term premium (Jermann, 2013), firms' external financing constraints (Li et al., 2009), and international stock returns (Watanabe et al., 2013).

Extensions of the production-based approach to puzzles in international finance have yet to fully materialize. A major theoretical challenge appears to result from deriving appropriate stochastic discount factors (SDFs) 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. The simple extension of Jermann (2013) to two countries, which we offer in the online Appendix to the paper, can be used to motivate a two-factor model with risk factors for equipment and structure investment differences for countries relative to the US dollar. The two factors, denoted *EQLMH* and *STLMH*, respectively, are constructed as the difference between the returns on the low and high tercile portfolios sorted on the difference in lagged investment ratios in equipment and structures relative to gross domestic product (GDP) between each country and the United States (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. This implies that the beta estimates measure the sensitivity of currency excess returns to changes in the equipment and structure investment gaps with the US. The use of two different physical investment vehicles allows us to explore the sensitivity of risk-premia estimates to idiosyncratic types of capital. In fact, within the investment-based asset pricing literature, it is common to uncover risk prices in two-factor models with opposing signs (see, for example, Cochrane, 1996). Additionally, equipment and structure capital have distinct characteristics, and there are considerable differences in the cross-country dispersion of equipment versus structure investment making these variables ideal for our empirical design (see, for example, Mutreja, 2014). 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.

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. We find that there is a striking near monotone decrease in the estimated betas for the *STLMH* factor as we go from low to high interest rate portfolios, showing that the structure risk factor is at work in currency markets. More specifically, estimates of structure 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 model to 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 et al. (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 SDF 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 that can be used to justify suitable production-based factors for currency excess returns. Section 3 discusses the construction of our factors, whereas the full description of our data can be found in section 4. Section 5 provides the results of our empirical analysis. Section 6 offers evidence related to the ability of our factors to price international bond returns. A final section concludes, and an online appendix contains a theoretical sketch supporting our choice for structure and equipment-based factors, along with additional empirical results for alternative factors related to investment variables.

2. Theoretical background

In this section, we introduce our factor-pricing model for excess currency returns and discuss existing theoretical challenges. Let $E_t(Rx_{k,t+1})$ denote expected excess currency returns from a carry trade strategy that shorts the US dollar and goes long in currency k. More specifically, with s_t defined as the log spot currency-k price of the US dollar, and with i_t^k and i_t denoting interest rates on assets maturing in one period in country k and the United States, $E_t(Rx_{k,t+1}) = i_t^k - i_t - (E_t s_{t+1} - s_t)$. 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. As an alternative, one could consider a pure characteristics-based approach, where currency excess returns could be directly related to intrinsic production-based features for firms in relevant countries.[2]

An SDF, M_{t+1}, will satisfy the standard investment Euler equation for excess currency returns under the assumption that there are no arbitrage opportunities, with

$$E_t(M_{t+1} Rx_{k,t+1}) = 0 \tag{1}$$

The main proposition of any risk-based production 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:

$$E_t(Rx_{k,t+1}) = -\frac{cov(M_{t+1}, Rx_{k,t+1})}{E(M_{t+1})} \tag{2}$$

This equation implies that the explanation for the positive average currency excess returns is that these payoffs compensate for the risk resulting from negative covariance between M_{t+1} and $Rx_{k,t+1}$.

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. There have been recent theoretical contributions to the study of international capital flows and, as a corollary, currency movements in models with production. Notably, Colacito et al. (2018) study a production economy with recursive preferences that is further extended to allow for vintage capital. As observed in the data, their baseline model can capture an immediate decline in capital outflows for the most productive countries following an increase in long-run productivity news through a marginal utility channel. In contrast, to isolate the role of production without the specification of preferences, partial equilibrium production-based models attempt to link asset returns with marginal rates of transformation (see, Cochrane, 1991, and Cochrane, 2021).

A theoretical extension of the production-based approach to excess currency returns presents unique challenges, given the need to model technologies in multiple countries where output can be transformed across states of nature. With standard aggregate production functions equipped with exogenous technology shocks, for example, a kink exists in the production possibilities frontier across states. Identifying a unique SDF to price state contingent assets is typically not possible, as the derivative of the production possibilities frontier is not well defined. One possible solution entails equipping firms with a mechanism that allows them to select state contingent productivity levels relative to natural productivity subject to a constraint typically based on a CES aggregator.[3] The mechanism of allowing firms to choose state-contingent productivity was initially proposed by Cochrane (1993) and has been successfully applied to study asset prices and real business cycle dynamics in important contributions by Belo (2010) and Chen et al. (2021).

As an alternative to the approach considered by Cochrane (1993), an SDF can be obtained in production-based models if there are not more states of nature than technologies available to the firm. Specifically, Jermann (2010, 2013) considers investment decisions for firms equipped with two types of capital under exactly two states of nature. Although the assumptions regarding the number of states could limit the empirical applicability of Jermann's model, it does yield a straightforward production-based mechanism to price nominal bonds. More specifically, in the online appendix, we build on the approach of Jermann (2013) to study the bilateral carry trade risk premium, which is a function of the SDFs related to bonds in two countries. In the model of Jermann (2013) with two states, prices can ultimately be expressed as a function of the marginal products on two types of capital, taken to be equipment and structures.

[2] An example of this approach is Liu et al. (2009), who use q-theory to show equivalence between investment returns and a weighted average of the equity and corporate bond return. In turn, levered investment returns are linked to firm characteristics through firm first-order conditions. We are indebted to an anonymous referee for suggesting this promising approach for future research, which offers a potentially complementary alternative to the risk-based explanation we posit for excess currency returns.

[3] As an example, Cochrane (2021) considers firms that choose productivity level ε_t relative to natural productivity θ_t subject to the constraint $\left[\left(\frac{\varepsilon_t}{\theta_t}\right)^{1+\alpha}\right] \leq 1$, where α is a non-negative curvature parameter that governs the ability of firms to transform output across states of nature.

Analyzing the risk premium as above does not allow one to read the marginal rates of transformation to yield an SDF for excess currency returns. It does, however, provide key insight into our empirical analysis. Specifically, following Cochrane (1996), we assume that the SDF on excess currency returns is a linear function of investment-based factors related to structures and equipment capital. Admittedly, the assumption that the SDF is linear in investment is ad-hoc. Our factors are constructed as the returns to long-short equipment investment portfolios, $R_{t+1}^{Equipment}$, as well as long-short structure investment portfolios, $R_{t+1}^{Structue}$. This yields

$$M_{t+1} = a + b_1 R_{t+1}^{Equipment} + b_2 R_{t+1}^{Structure} \tag{3}$$

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

$$E\left[Rx_{k,t+1}\right] = b_1 cov\left(R_{t+1}^{Equipment}, Rx_{k,t+1}\right) + b_2 cov\left(R_{t+1}^{Structure}, Rx_{k,t+1}\right). \tag{4}$$

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:

$$E[Rx_k] = \frac{cov\left(R^{Equipment}, Rx_k\right)}{var\left(R^{Equipment}\right)} b_1 var\left(R^{Equipment}\right) + \frac{cov\left(R^{Structure}, Rx_k\right)}{var\left(R^{Structure}\right)} b_2 var\left(R^{Structure}\right) = \beta_1 \lambda^{Equipment} + \beta_2 \lambda^{Structure}. \tag{5}$$

In Equation (5), 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 the 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 currency excess 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 currency excess returns. To be specific, we investigate whether the well known "investment effect" common to equity markets, where high-investment stocks earn lower average returns than low investment stocks, 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, 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 three portfolios based on lagged differences for equipment investment to GDP 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 tercile portfolios, which are denoted EQ1, EQ2, and EQ3. That is, one third of the countries with the lowest investment in equipment are assigned to portfolio EQ1, the next third to portfolio EQ2 while the last third of the countries are assigned to EQ3. Next, we compute the currency excess returns for each portfolio by averaging the currency excess returns within the portfolio. The *EQLMH* factor is given by the return difference between portfolios EQ1 and EQ3.

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 tercile portfolios based on the lagged differences in structure investment to GDP 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 ST3. It is important to note that the two factors that we construct are returns. However, these factors are not traded due to data revisions in macroeconomic data and the fact that the investment variables are available with a time lag.[4]

[4] Gospodinov et al. (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 traded factors are not prone to the same identification issues.

To test our factor model, we first use the traditional two-pass regression methodology of Black et al. (1972) and Fama and MacBeth (1973) to examine whether the factors are priced in the cross section of currency excess returns. In the first pass, we run a time series regression of currency excess returns in levels[5], denoted as $Rx_{k,t}$, on the two risk factors:

$$Rx_{k,t+1} = c_k + \beta_{k,EQLMH} EQLMH_{t+1} + \beta_{k,STLMH} STLMH_{t+1} + \varepsilon_{k,t+1}. \tag{6}$$

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:

$$\bar{Rx}_t = \widehat{\beta}_{k,EQLMH} \lambda_{EQLMH} + \widehat{\beta}_{k,STLMH} \lambda_{STLMH} + \xi_t, \tag{7}$$

where λ_{EQLMH} and λ_{STLMH} are the prices of risk. Equations (6) and (7) 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 et al. (2010), we estimate the two-pass regressions using Generalized Least Squares (GLS) and report the GLS R^2 for the cross-sectional regression.[6]

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.[7] 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, denoted as *INVLMH*, analogously to the way we construct the *EQLMH* and *STLMH* factors. Our one-factor *INVLMH* model can be specified as follows:

$$Rx_{k,t+1} = a_k + \beta_{k,INLMH} INVLMH_{t+1} + \epsilon_{k,t+1}, \tag{8}$$

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.

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 et al., (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.[8] More recently, Hassan et al. (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 et al., 2006; Liu et al., 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).

Augmented Investment Model: We subject our baseline one 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

[5] The asset pricing models are estimated with the excess returns in level, as follows : $Rx_{k,t+1} = \frac{F_{k,t} - S_{k,t+1}}{S_{k,t}}$.

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

[7] 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 et al. (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) focuses 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 (see, Cochrane, 1991, Lamont, 2000, and Gomes et al., 2006).

[8] 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.

effect should disappear when we augment our models in Equations (6) and (8) with the *HML* risk factor.[9] We first augment the two-factor (*EQLMH* and *STLMH*) model with *HML*:

$$Rx_{k,t+1} = c_k + \beta_{k,HML}HML_{t+1} + \beta_{k,EQLMH}EQLMH_{t+1} + \beta_{k,STLMH}STLMH_{t+1} + \varepsilon_{k,t+1}. \tag{9}$$

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

$$Rx_{k,t+1} = a_k + \beta_{k,HML}HML_{t+1} + \beta_{k,INLMH}INVLMH_{t+1} + \upsilon_{k,t+1}. \tag{10}$$

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 that are largely successful in pricing the cross-section of excess currency returns.[10] These are 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) 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 LRV (2011) using spanning regressions. In an important contribution to the literature, Hou et al., (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 the four-factor model of Hou et al. (2015) 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 2019Q4 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.[11] 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 terms, as well as more granular investment data on dwellings, other buildings and structures, cultivated biological resources, intellectual property products and machinery, and equipment and weapons systems in nominal terms. In our empirical analysis, the investment variables are expressed as a percent of nominal gross domestic product (GDP).[12] Indeed, Hassan (2013) argues that persistent violations of UIP are related to the size of the country. Economies that account for a larger share of global wealth can issue domestic-currency bonds at a lower interest rate than smaller economies. This leads to persistently lower interest rates for larger countries. Therefore, scaling by GDP serves to ensure that our results are not merely ascribable to the country-size effect. This approach is also consistent with Hassan, Mertens, and Zheng (2016), whose theoretical account is cast in terms of the capital to output ratio, and with existing empirical research in which currencies are assigned to portfolios based on a variable scaled by GDP.[13]

[9] 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 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 et al., 2009).

[10] 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.

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

[12] Data on nominal GDP are collected from Datastream. The source of these data is also the OECD.

[13] For instance, Della Corte et al. (2016) assign currencies to baskets based on the net foreign assets to GDP.

Our definitions of investment in structures and equipment are broadly consistent with the OECD's classification of investment in equipment and structures[14], as well as with the NBER's definition of these variables.[15] 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 investment in equipment and structure for the sixteen Eurozone countries in our sample for which we can collect granular investment data. 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. In view of the significant data limitations, we exclude Japan when we compute the equipment factor. 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 Belgium, Cyprus and Malta.[16] 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.[17]

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 USD, from Thomson Reuters database of Datastream.[18] 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.

5. Empirical results

5.1. Common investment-based factors in currency returns

To set the stage, Table 1 provides summary statistics of 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 tercile portfolios constructed by sorting currencies on the basis of their country's lagged differences in investment relative to the United States for investment in equipment (EQ1, EQ2, and EQ3), investment in structures (ST1, ST2, and ST3), and total investment (INV1, INV2, and INV3). The *INVLMH*, *EQLMH, and STLMH* factors are constructed by taking return differences between portfolios with the smallest investment in each category (INV1, EQ1, and ST1) and the portfolios with the largest investment for each of our three investment variables (INV3, EQ3, and ST3). Note, throughout, all investment series are scaled by GDP.

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 factors, which are provided in Fig. 1, suggest they exhibit little persistence. This is confirmed by the low first-order autocorrelation coefficients for our factors, which are, -0.010, -0.132, and 0.002, for the *INVLMH*, *EQLMH*, and *STLMH* variables, respectively.

Turning to the results in panels B, C and D, we find that countries with the lowest past capital investment relative to the US (tercile 1) have higher returns compared to countries with the highest past capital investment relative to the US (tercile 3). We also find that the return differentials between the low and high terciles are 0.32%, 0.01%, and 0.21% per quarter for the equipment, structure, and total investment portfolios, respectively. Hence, the *EQLMH*, *STLMH* and *INVLMH* portfolios appear to earn investors a small positive return.

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

[15] 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.

[16] Data are available for total investment for Belgium, and it is therefore included in the computation of total investment for the Eurozone.

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

[18] 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.

Table 1

Descriptive statistics for currency portfolios and factors. 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, P3, P4 and P5). The table also provides the summary statistics for tercile portfolios constructed by sorting currencies based on the lagged difference between country *k* and the US's equipment investment relative to GDP (EQ1, EQ2, and EQ3), structure portfolios constructed by sorting currencies on the lagged difference between country *k* and the US's investment in structures relative to GDP (ST1, ST2, and ST3) and investment portfolios constructed by sorting currencies on the lagged difference between country *k* and the US's total investment relative to GDP (INV1, INV2, and INV3). The *INVLMH* factor is the return difference between a tercile 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 (INV3). Similarly, the *EQLMH* factor is given by the return difference between portfolio EQ1 and portfolio EQ3, which are tercile portfolios formed by sorting currencies on the lagged difference of investment in equipment relative to GDP vis-à-vis the US. The *STLMH* factor is given by the return difference between portfolio ST1 and portfolio ST3, which are tercile portfolios, constructed by sorting currencies on the difference of investment in structures relative to GDP vis-à-vis the US. 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	−0.540	−0.561	−0.264	−0.367	0.382	−0.270	0.922*
t-statistic	−1.188	−1.207	−0.546	−0.778	0.685	−0.655	1.704
Std. Dev.	4.428	4.534	4.710	4.597	5.441	4.016	5.276
Skewness	0.333	0.096	−0.583	−0.502	−0.295	0.012	−1.414
Excess Kurtosis	−0.219	−0.264	1.800	0.157	1.020	0.164	4.842
Sharpe Ratio	−0.121	−0.123	−0.056	−0.079	0.070	−0.067	0.174
Panel B. Equipment Portfolios- Single sorting on the lagged difference between country *k* and the US's equipment investment							
Portfolio	EQ1	EQ2	EQ3	EQLMH			
Mean	0.0027	−0.2574	−0.3263	0.3290			
t-statistic	0.0061	−0.5314	−0.6506	1.1412			
Std. Dev.	4.2582	4.7208	4.8885	2.8096			
Skewness	−0.6882	−0.3686	−0.0898	−0.2801			
Excess Kurtosis	3.1759	0.4219	0.0355	0.2942			
Sharpe Ratio	0.0006	−0.0545	−0.0668	0.1171			
Panel C. Structure Portfolios - Single sorting on the lagged difference between country *k* and the US's structure investment							
Portfolio	ST1	ST2	ST3	STLMH			
Mean	−0.228	−0.300	−0.240	0.011			
t-statistic	−0.543	−0.665	−0.492	0.037			
Std. Dev.	4.096	4.400	4.752	3.043			
Skewness	−0.077	−0.179	−0.175	0.217			
Excess Kurtosis	0.161	0.463	0.644	0.062			
Sharpe Ratio	−0.055	−0.068	−0.050	0.003			
Panel D. Investment Portfolios - Single sorting on the lagged difference between country *k* and the US's total investment							
Portfolio	INV1	INV2	INV3	INVLMH			
Mean	−0.185	−0.239	−0.395	0.210			
t-statistic	−0.445	−0.539	−0.857	0.761			
Std. Dev.	4.057	4.328	4.499	2.690			
Skewness	−0.478	0.228	−0.214	−0.040			
Excess Kurtosis	1.684	0.201	0.205	0.672			
Sharpe Ratio	−0.045	−0.055	−0.087	0.078			

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 to GDP, 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) 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 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. We report the prices of risk, the Fama and MacBeth (1973) standard errors with the Heteroscedasticity 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 et al. (2013).[19] 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, where the associated prices are negative and significant when the Fama and MacBeth (1973) standard errors are employed. The *INVLMH* and *EQLMH* risk factors command a

[19] 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 likely misspecified.

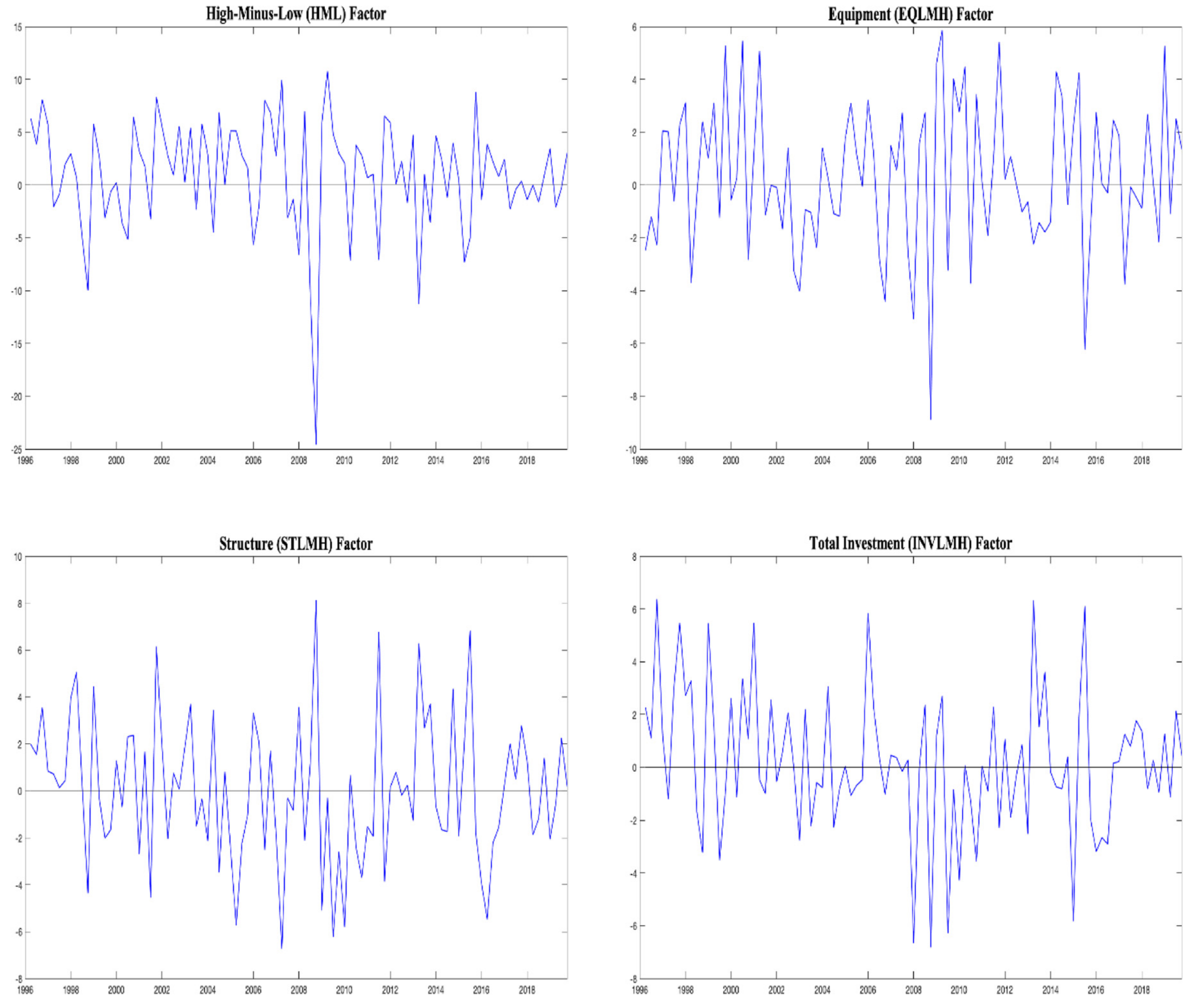

Fig. 1. Time series dynamics of the factor returns.

significant risk premium when the Shanken (1992) and misspecification-robust standard errors are employed. The negative prices of risk translate into higher (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. A good cross-sectional fit is generally achieved. The R^2 of the second pass cross-sectional regression exceeds 33% for the two-factor investment model, while the R^2 of the one factor model is larger than 18%.

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 SDF. In this vein, the findings reveal a near perfect monotone decline in the *STLMH* betas when moving from P1 to P5. Further, portfolios P1 and P5 exhibit a negative and highly statistically significant sensitivity to *INVLMH*. In addition, all portfolios, except P3, exhibit a negative and statistically significant sensitivity to the *EQLMH* factor. Overall, the betas on our P5 portfolio are unambiguously negative and large. 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 our factors, suggesting that they perform poorly on average in periods of investment risk. Our factors likely capture risk arising from differences between low and high investment countries, and potentially reflect a market-oriented outlook on future economic growth imbalances. Our negative factor betas, particularly for high interest currencies, indicate that investors likely decrease their holding of foreign assets and sell the foreign currency during periods when this investment risk increases. Turning to the LRV (2011) model, portfolios P1 to P5 exhibit a positive and highly statistically significant exposure to *DOL*. Except for P3, all portfolios also exhibit a statistically significant loading on the *HML* factor. While the betas associated with the *HML* factor are negative for P1 and P2, they are positive for P4 and P5. Finally, throughout, it is important to note that none of the constants in our time series regressions are statistically significant, indicating that the factor models are supported by the data.

Table 2

Asset Pricing Results for the One-Factor and Two-Factor Investment Models using Currency Portfolios as Test Assets. The table provides 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 tercile portfolio that goes long in the currencies of the countries with the smallest gross private fixed investment ratios vis-à-vis the US (INV1) and a tercile portfolio that goes short in the currencies of the countries with the highest ratios relative to the US (INV3). Similarly, the *EQLMH* (*STLMH)* factor is given by the return difference between a tercile portfolio that goes long in the currencies of the countries with the smallest equipment (structure) investment relative to GDP vis-à-vis the US and a tercile portfolio that goes short in the currencies of the countries with the highest equipment (structure) investment to GDP 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 B). 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 A). 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, the Shanken (1992) standard errors under general distributional assumptions, denoted (Sh), which are adjusted for errors in variables, as well as the misspecification robust standard errors of Kan, Robotti, and Shanken (2013), denoted (MR). Panel A also provides the Hansen and Jagannathan (1997) distance, denoted *HJ*, and its *p*-value in brackets as well as the *p*-value of the rank test. 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	−0.484	1.002	0.187	λ	−0.543	−0.244	0.975	0.338	λ	0.997	0.009	0.905	0.980
(FMB)	0.004***	[0.000]		(FMB)	0.005***	0.006***	[0.000]		(FMB)	0.004***	0.005	[0.086]	
(Sh)	0.062***	Rank Test		(Sh)	0.106**	0.128	Rank Test		(Sh)	0.004***	0.005		
(MR)	0.124**	[0.000]		(MR)	0.227*	0.271	[0.000]		(MR)	0.005***	0.005		

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	−0.391	−0.712***	0.187	P1	−0.320	−0.661***	−0.247	0.155	P1	0.226	0.999***	−0.538***	0.900
	0.405	0.200			0.408	0.166	0.160			0.149	0.033	0.042	
P2	−0.521	−0.196	0.014	P2	−0.292	−0.810***	−0.273*	0.222	P2	−0.147	1.056***	−0.141**	0.815
	0.475	0.178			0.403	0.172	0.138			0.220	0.053	0.054	
P3	−0.243	−0.099	0.003	P3	−0.167	−0.284	−0.287	0.041	P3	−0.074	1.005***	0.089	0.793
	0.544	0.226			0.526	0.243	0.199			0.265	0.061	0.087	
P4	−0.342	−0.121	0.005	P4	−0.247	−0.350**	−0.433**	0.085	P4	−0.231	0.940***	0.128***	0.765
	0.526	0.208			0.472	0.195	0.166			0.219	0.055	0.044	
P5	0.499	−0.553**	0.075	P5	0.605	−0.645***	−0.894***	0.245	P5	0.226	0.999***	0.462***	0.934
	0.620	0.252			0.521	0.241	0.180			0.149	0.033	0.042	

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* and *STLMH* factors continue to be negative and significant when the Fama and MacBeth (1973), Shanken (1992) and misspecification-robust standard errors are used. In contrast, the price of risk associated with the *EQLMH* factor is positive and significant. The results in Panel B indicate that all currencies' exposure to the *INVLMH* factor is negative, with results also indicating a high level of statistical significance for five of these currencies. Similarly, the betas associated with the *EQLMH* factor are significant and negative for all the currencies except AUD, CAD and GBP. The betas associated with the *STLMH* factor are also negative and significant for all the currencies except JPY and GBP. 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 in all cases. The sensitivity of the individual currency excess returns to the *HML* factor is smaller in magnitude than that of *DOL*. The betas associated with the *HML* factor are positive and highly significant for AUD, CAD and NZD, whereas they are negative and highly significant for CHF, DKK, EUR and JPY. Again, this shows that the sensitivities of the individual currencies to the *HML* factor exhibit some heterogeneity.

While our findings overall indicate that investment factors are negatively priced in the cross-section, results based on individual excess returns suggest possible idiosyncratic risk premia for multiple types of investment. The finding of opposing signs in multi-factor investment-based models is quite common within the literature and may be well grounded on a theoretical basis as well. In a production-based context, for example, Belo (2010) considers a two-factor model where producers choose state-contingent productivity levels. Under the assumption that the two technologies have a common factor, identification is achieved and resulting risk prices unambiguously have opposing signs.

5.2. Controlling for the forward premium effect

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 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

Table 3

Asset pricing results for one- and two-factor models using excess returns on individual currencies as test assets. The table provides 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 tercile portfolio that goes long in the currencies of the countries with the smallest gross private fixed investment ratios vis-à-vis the US (INV1) and a tercile portfolio that goes short in the currencies of the countries with the highest ratios relative to the US (INV3). Similarly, the *EQLMH* (*STLMH)* factor is given by the return difference between a tercile portfolio that goes long in the currencies of the countries with the smallest equipment (structure) investment relative to GDP vis-à-vis the US and a tercile portfolio that goes short in the currencies of the countries with the highest equipment (structure) investment to GDP 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 B). 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 A). The test assets are the excess returns 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, the Shanken (1992) standard errors under general distributional assumptions, denoted (Sh), which are adjusted for errors in variables, as well as the misspecification robust standard errors of Kan, Robotti, and Shanken (2013), denoted (MR). Panel A also provides the Hansen and Jagannathan (1997) distance, denoted *HJ*, and its *p*-value in brackets as well as the *p*-value of the rank test (also in brackets). 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	−0.185	1.038	0.025	λ	0.180	−0.586	1.028	0.135	λ	0.997	0.014	1.042	0.512
(FMB)	0.003***	[0.000]		(FMB)	0.003***	0.005***	[0.000]		(FMB)	0.004***	0.005**	[0.000]	
(Sh)	0.013***	Rank Test		(Sh)	0.029***	0.066***	Rank Test		(Sh)	0.004***	0.063	Rank Test	
(MR)	0.098*	[0.000]		(MR)	0.084*	0.290*	[0.000]		(MR)	0.005***	0.076		

Asset pricing results for the one-factor and two-factor investment models using excess returns on individual currencies as test assets

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	0.307	−0.724***	0.103	AUD	0.265	−0.310	−0.703***	0.110	AUD	0.064	1.073***	0.413***	0.778
	0.628	0.278			0.587	0.259	0.244			0.290	0.087	0.076	
CAD	−0.031	−0.091	0.004	CAD	−0.086	0.126	−0.430***	0.140	CAD	−0.086	0.582***	0.210***	0.528
	0.447	0.212			0.409	0.162	0.146			0.251	0.075	0.053	
CHF	−0.261	−0.637***	0.130	CHF	−0.123	−0.813***	−0.351**	0.207	CHF	0.229	1.064***	−0.364***	0.765
	0.452	0.153			0.438	0.176	0.150			0.230	0.073	0.049	
DKK	−0.441	−0.171	0.009	DKK	−0.159	−0.958***	−0.275*	0.259	DKK	0.046	1.182***	−0.221***	0.843
	0.513	0.198			0.428	0.191	0.149			0.213	0.042	0.039	
EUR	−0.400	−0.151	0.007	EUR	−0.113	−0.958***	−0.264*	0.264	EUR	0.076	1.169***	−0.207***	0.839
	0.509	0.198			0.421	0.191	0.152			0.217	0.044	0.041	
GBP	−0.232	0.492**	0.084	GBP	−0.157	0.086	0.017	0.003	GBP	−0.111	0.735***	0.197	0.555
	0.483	0.234			0.534	0.259	0.198			0.364	0.074	0.122	
JPY	−0.596	−1.070***	0.261	JPY	−0.655	−0.492**	−0.323	0.061	JPY	−0.046	0.835***	−0.595***	0.474
	0.499	0.190			0.541	0.205	0.231			0.458	0.092	0.102	
NOK	−0.286	−0.152	0.005	NOK	−0.148	−0.491*	−0.716***	0.147	NOK	−0.097	1.150***	0.097	0.738
	0.618	0.247			0.552	0.251	0.198			0.255	0.086	0.087	
NZD	0.535	−0.649**	0.087	NZD	0.692	−0.860***	−0.870***	0.240	NZD	0.211	0.953***	0.482***	0.761
	0.659	0.265			0.548	0.260	0.200			0.304	0.087	0.094	
SEK	−0.590	−0.208	0.011	SEK	−0.357	−0.830***	−0.353*	0.163	SEK	−0.284	1.257***	−0.012	0.850
	0.626	0.236			0.558	0.242	0.207			0.219	0.052	0.056	

proposed by LRV (2011) diminishes the significance of the investment factors. To do so, we subject our baseline one and two-factor models to a more stringent test by including the *HML* factor, as defined in Equations (9) and (10), as a control. Our goal is to examine whether the carry trade risk factor can explain our results. If the statistical significance of our investment-based risk factors disappears when we include the *HML* factor, this could imply that systematic risk is the primary determinant of our main 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-sectional currency excess returns and that the prices of risk continue to be negative. Interestingly, the *INVLMH* factor is 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 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 *EQLMH* factor tend to be negative and highly significant in the presence of the *HML* factor. The R^2 of the

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* and *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 B). 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 A). 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, the Shanken (1992) standard errors under general distributional assumptions, denoted (Sh), which are adjusted for errors in variables, as well as the misspecification robust standard errors of Kan, Robotti, and Shanken (2013), denoted (MR). Panel A also provides the Hansen and Jagannathan (1997) distance, denoted *HJ*, and its *p*-value in brackets as well as the *p*-value of the rank (also in brackets). 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	0.009	−0.490	1.001	0.191	0.009	−0.464	−0.419	0.950	0.359
(FMB)	0.005	0.004***	[0.000]		0.005	0.006***	0.008***	[0.000]	
(Sh)	0.005	0.063***			0.005	0.129*	0.187		
(MR)	0.005	0.134**			0.006	0.275	0.429		
Panel B: Betas									
Two-Factor Investment Model					Three-Factor Investment Model				
	Constant	*HML*	*INVLMH*	R^2	Constant	*HML*	*EQLMH*	*STLMH*	R^2
P1	−0.130	−0.293***	−0.666***	0.308	0.031	−0.379***	−0.655***	−0.492***	0.330
	0.402	0.073	0.138		0.375	0.083	0.151	0.129	
P2	−0.608	0.098	−0.212	0.026	−0.389	0.104	−0.812***	−0.205	0.234
	0.464	0.073	0.190		0.398	0.089	0.164	0.137	
P3	−0.522	0.313**	−0.149	0.125	−0.454	0.310*	−0.288	−0.087	0.144
	0.555	0.152	0.195		0.555	0.167	0.208	0.181	
P4	−0.644	0.339***	−0.175	0.155	−0.531	0.308***	−0.355**	−0.234	0.192
	0.466	0.094	0.179		0.451	0.105	0.166	0.145	
P5	−0.130	0.707***	−0.666***	0.541	0.031	0.621***	−0.655***	−0.492***	0.556
	0.402	0.073	0.138		0.375	0.083	0.151	0.129	

time series regressions are, not surprisingly, larger than those of the models that exclude *HML*. In a similar vein, the significance of the *STHML* and *INVLMH* factor is maintained at the 1% level for portfolios P1 and P5.

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 negative and significant at the 5% level or lower when the Fama and MacBeth (1973) and Shanken (1992) standard errors are employed and, for the *STLMH* factor, at the 10% level when the misspecification robust standard errors are employed. In line with our findings using individual currency returns in Table 3, the price of risk associated with the *EQLMH* factor is positive and highly significant when the inference is conducted using the Shanken (1992) standard errors and significant at the 10% level when the misspecification-robust 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, for which it is positive and significant. The significance of the betas associated with the *EQLMH* and *STLMH* factors is also generally maintained when the two-factor investment model is augmented with *HML*.

Following Gospodinov and Robotti (2021), we test the identification of all our models using the rank test.[20] More specifically, let the matrix β denote the covariance between the returns and the factors. If the matrix $\boldsymbol{\beta}$ 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 indicate that the prices of risk in our one and two-factor investment models are properly identified.[21]

Our two-factor model considers the idiosyncratic impact of different types of investment. However, the production technology need not be restricted to two technologies. To further understand the importance of more granular types of investment, we also considered a four-factor model. More specifically, for each country, we further disaggregated our equipment data into two categories that include investment to GDP ratios for intellectual products and machinery, equipment, and weapons systems. Investment in structures was split using associated data on dwellings and other buildings and structures. For these four variables, factors were constructed in an entirely analogous manner as above, where excess currency returns were grouped into terciles based on lagged investment to GDP ratios for each country relative to the United States. Estima-

[20] See also Burnside (2016) for a discussion of the rank test and the identification of asset pricing models.
[21] We do not report the *p*-value of the rank test for the LRV (2011) model or when we augment our investment models with the *HML* factor because of perfectly multicollinearity between the returns on the test assets and the *HML* and *DOL* factors.

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* and *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 B). 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 A). 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, the Shanken (1992) standard errors under general distributional assumptions, denoted (Sh), which are adjusted for errors in variables, as well as the misspecification robust standard errors of Kan, Robotti, and Shanken (2013), denoted (MR). Panel A also provides the Hansen and Jagannathan (1997) distance, denoted *HJ*, and its *p*-value in brackets as well as the *p*-value of the rank (also in brackets). 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	0.119	−0.191	1.038	0.030	λ	0.161	0.187	−0.618	1.024	0.150
(FMB)	0.005***	0.003***	[0.000]		(FMB)	0.006***	0.003***	0.005***	[0.000]	
(Sh)	0.019***	0.014***	Rank Test		(Sh)	0.052**	0.032***	0.073***	Rank Test	
(MR)	0.091	0.110			(MR)	0.105	0.085*	0.270*	[0.000]	

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	−0.298	0.681***	−0.832***	0.450	AUD	−0.292	0.602***	−0.320	−0.314*	0.344
	0.474	0.091	0.219			0.495	0.107	0.209	0.187	
CAD	−0.335	0.342***	−0.145	0.213	CAD	−0.338	0.273***	0.122	−0.254**	0.254
	0.367	0.085	0.156			0.368	0.070	0.131	0.127	
CHF	−0.165	−0.106	−0.620***	0.144	CHF	0.037	−0.173*	−0.810***	−0.463***	0.238
	0.460	0.093	0.1555			0.436	0.101	0.181	0.157	
DKK	−0.479	0.043	−0.178	0.010	DKK	−0.209	0.054	−0.958***	−0.240	0.262
	0.537	0.095	0.218			0.441	0.130	0.200	0.164	
EUR	−0.447	0.053	−0.159	0.010	EUR	−0.179	0.071	−0.959***	−0.219	0.269
	0.530	0.093	0.219			0.431	0.127	0.198	0.167	
GBP	−0.532	0.338**	0.438**	0.236	GBP	−0.538	0.412**	0.080	0.284	0.198
	0.461	0.143	0.188			0.522	0.165	0.193	0.198	
JPY	−0.265	−0.371***	−1.011***	0.380	JPY	−0.173	−0.521***	−0.484***	−0.660***	0.265
	0.460	0.072	0.147			0.509	0.092	0.151	0.171	
NOK	−0.602	0.355**	−0.208	0.117	NOK	−0.394	0.266	−0.495**	−0.544***	0.201
	0.583	0.154	0.202			0.542	0.165	0.233	0.154	
NZD	−0.106	0.721***	−0.763***	0.497	NZD	0.084	0.657***	−0.871***	−0.445***	0.534
	0.482	0.078	0.189			0.417	0.101	0.166	0.162	
SEK	−0.832	0.272**	−0.251	0.079	SEK	−0.623	0.287*	−0.834***	−0.167	0.229
	0.609	0.133	0.235			0.568	0.167	0.218	0.171	

tion of the four-factor beta-pricing model proceeded as above with results that are presented in the online Appendix. To briefly summarize, the findings continue to provide support for the assertion that the structure-based investment factors are negatively priced in the cross-section. The results are particularly strong when analyzing investment in dwellings when individual currencies serve as test assets. These findings point to the potential idiosyncratic impact on risk for different types of physical investment.

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, a direct comparison can be undertaken by examining whether one model is able to explain the returns of the factor-mimicking portfolios of the other. Admittedly, because our factors are not traded, the results from a horse race using spanning regressions must be interpreted with care, but it would still be instructive to examine how the investment models fare relative to LRV (2011)'s 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. The results in Table 2 suggest that the constant is not significant for the LRV, one and two-factor investment models. Our findings thus far suggest that the

Table 6
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 using the returns on tercile portfolios constructed by sorting currencies based on the lagged difference between country *k* and the US's equipment investment relative to GDP (EQ1, EQ2, and EQ3), and structure portfolios constructed by sorting currencies on the lagged difference between country *k* and the US's investment in structures relative to GDP (ST1, ST2, and ST3). HAC standard errors with a Bartlett kernel and the parametric, data dependent, bandwidth selection of Andrews (1991) are reported under the coefficients. *,**,*** 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	0.015	−0.022	−0.418***	0.086	EQ1	0.066	0.886***	0.190***	0.867
	0.450	0.207	0.161			0.196	0.037	0.070	
EQ2	−0.077	−0.528***	−0.542***	0.144	EQ2	−0.065	1.035***	0.095*	0.841
	0.460	0.189	0.155			0.200	0.051	0.053	
EQ3	0.015	−1.022***	−0.418***	0.306	EQ3	−0.082	1.123***	0.065*	0.894
	0.450	0.207	0.161			0.170	0.035	0.038	
ST1	−0.080	−0.450**	0.042	0.103	ST1	0.108	0.970***	−0.080**	0.860
	0.427	0.191	0.129			0.157	0.040	0.036	
ST2	−0.078	−0.661***	−0.389***	0.171	ST2	−0.112	0.969***	0.079	0.840
	0.423	0.177	0.142			0.191	0.049	0.053	
ST3	−0.080	−0.450**	−0.957***	0.333	ST3	−0.071	1.038***	0.121**	0.856
	0.427	0.191	0.129			0.196	0.049	0.057	

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.

We now turn to a more formal assessment using the test of Gibbons et al. (1989), henceforth GRS. The GRS statistic tests that all constants in the time series regressions are jointly equal to zero. Under an assumption of joint normality of the regressions' residuals, the test has an *F* distribution. When the two-factor investment model is estimated using the returns on the P1 to P5 portfolios, the GRS statistic is equal to 1.347, with a *p*-value of 0.265. The statistic for the heteroscedasticity-robust version of the GRS test is 1.610, with a *p*-value of 0.205. Both versions lead to the same conclusion, that the null should not 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, 0.227 (*p*-value of 0.797) and 0.224 (*p*-value of 0.799). The two versions of the test statistic yield the same conclusion. For the LRV (2011) model, we fail to reject in both instances, which provides evidence that the model captures the dynamics of the returns on the P1 to P5 portfolios. The results of the GRS statistic indicate that our two-factor investment and the LRV (2011) models explain the returns on the quintile carry trade portfolios.

Table 6 provides the results from estimating our two-factor investment and LRV (2011) models using the EQ1 to EQ3 as well as the ST1 to ST3 portfolios. The results in Table 6 show that none of the constants are significant for the two models. 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 EQ3 and ST1 to ST3 portfolios are employed as dependent variables to estimate our two-factor investment model, the GRS statistic and its heteroscedasticity-robust version are, respectively, 0.000 (with a *p*-value of 1.000) and 0.216 (with a *p*-value of 0.805). The two versions of the test statistic suggest that the joint null that alphas are equal to zero cannot be rejected. Thus, not surprisingly, our model is able to explain the returns on the EQ1 to EQ3 and ST1 to ST3 portfolios. When we estimate the LRV (2011) model with the returns on the EQ1 to EQ3 and ST1 to ST3 portfolios as dependent variables, the standard and heteroscedasticity-robust versions of the GRS test are 2.079 (with a *p*-value of 0.131) and 2.173 (with a *p*-value of 0.119), respectively. These findings imply that our two-factor investment and the LRV (2011) model explain the returns on the structure and equipment portfolios.

When all portfolios (P1 to P5, EQ1 to EQ3 and ST1 to ST3) are used, the heteroscedasticity-robust GRS statistics for the two-factor investment and LRV (2011) models are, respectively, 0.009 (*p*-value of 0.990) and 2.173 (*p*-value of 0.119). In sum, the two models' performance is similar. However, because our factors are not traded, the comparison between the LRV (2011) and the two-factor investment is likely to be more advantageous to the latter.

6. Extending the Investment-Based approach

Our analysis above provides compelling evidence that an investment-based approach is likely to bear fruit in the study of excess currency returns. Given the relative dearth of production-based models in the international asset pricing literature, additional exploration seems merited. One potentially promising avenue involves the use of factors that consider uncertainty emanating from the production-side of the economy. Of note, Berg and Mark (2018b) have recently provided evidence that risk-factors formed from higher order moments of important macroeconomic variables contain pricing power relevant to excess currency returns.

In light of this evidence, and given the potential importance of a production-based approach, we extended our analysis by forming factors based on the volatility of our investment variables. Results, which can be found in the online appendix along with a full discussion of our approach, are promising. In particular, our findings indicate that the volatility-based factors are

Table 7

Asset Pricing Results for the Two-Factor Investment Model using Bond Portfolios as Test Assets. The table provides the asset pricing results for the two-factor investment model in equipment (*EQLMH*) and structures (*STLMH*) using bond portfolios as test assets. 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 *EQLMH* (*STLMH*) factor is given by the return difference between a tercile portfolio that goes long in the currencies of the countries with the smallest equipment (structure) investment relative to GDP vis-à-vis the US and a tercile portfolio that goes short in the currencies of the countries with the highest equipment (structure) investment to GDP relative to the US. In the first pass, we run a time series regression of bond returns on the risk factors to estimate the factor betas (Panel B). 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 A). The test assets are the returns on the bond portfolios as defined in Section 6 of the paper. 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, as well as the misspecification robust standard errors of Kan, Robotti, and Shanken (2013), denoted (MR). Panel A also provides the Hansen and Jagannathan (1997) distance, denoted *HJ*, and its *p*-value in brackets as well as the *p*-value of the rank test (also in brackets). 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				
	EQLMH	*STLMH*	*HJ*	R^2
λ	−0.941	−0.867	0.887	0.842
(FMB)	0.005***	0.006***	[0.048]	
(Sh)	0.250**	0.252**	Rank Test	
(MR)	0.247**	0.250**	[0.001]	
Panel B: Betas				
	Constant	*EQLMH*	*STLMH*	R^2
P1	0.384	−0.724***	−0.124	0.192
	0.409	0.155	0.140	
P2	0.575	−0.629***	−0.291**	0.141
	0.425	0.181	0.127	
P3	0.160	−0.646***	−0.341***	0.159
	0.383	0.200	0.123	
P4	0.502	−0.829***	−0.303*	0.219
	0.411	0.166	0.155	
P5	0.196	−0.309*	−0.549***	0.152
	0.397	0.161	0.133	

positively priced for equipment investment and negatively priced for structures. The use of factors built on higher-order moments of relevant variables offers one promising path for researchers interested in extending the investment-based approach, especially considering the difficulties in obtaining a large cross-section of international production-based variables such as residential and non-residential investment.

Although obvious extensions to excess currency returns await, our current approach likely extends to other asset classes, most notably bonds. Indeed, if markets are complete, the SDF is unique. That is, in theory, the SDF should possess pricing power across asset markets. A recent flurry of research investigates, empirically, the existence of a common factor structure across asset markets.[22] Taking stock of this stream of studies suggests that, despite success in identifying risk factors that are priced in the cross-section of individual asset classes, the quest for a parsimonious common factor structure across asset classes has proven to be elusive (Gospodinov and Robotti, 2021).

Our factors reflect domestic investment. Of course, investment in equipment and structures is less mobile than financial capital. Therefore, among various asset classes, we conjecture that our investment factors may have strong pricing power for the cross-section of bond returns. In this section, we take a simple approach to examining whether our factors are priced in the cross-section of bond returns. We collect clean price data for the benchmark 5-year bond indexes for the countries that are comprised in our sample from Datastream. Because data for the Eurozone bond index are not available prior to 2004, we consider, for simplicity, that the German bond index as representative of the entire Eurozone. The bond indexes are denominated in USD in order to eliminate exchange rate risk.

We estimate the two-factor investment model in Eqs. (6) and (7) using bond return portfolios and individual bond returns portfolios. Quintile bond portfolio returns are constructed by sorting bonds based on the term spread, defined as the difference between the rates on 10-year government bond yields and three-month rates.[23] While the slope (or term spread) is not exactly equal to the carry for bonds, we use it as an approximation for carry.[24] Hence, portfolio P1 comprises bonds with the largest term spread relative to the US whereas portfolio P5 contains the bonds with the smallest spread relative to the US.

The results from estimating our main two-factor model using bond portfolio and individual bond returns are provided in Tables 7 and 8. To start with, the two-factor investment models pass the identification test using the rank statistic at the 1%

[22] A number of studies examine the pricing power of common factors across markets. For instance, Adrian et al. (2014) provide an empirical analysis of the cross-sectional pricing power of broker-dealer leverage shocks across asset classes whereas He et al. (2017) empirically assess whether two factors that are constructed from shocks to the equity capital ratio of primary dealers are priced across asset markets.

[23] The 10-year and three-month rate data are obtained from the FRED© database of the Federal Reserve of St. Louis. The source of these data is the OECD.

[24] Koijen et al. (2018) note that the exact definition of the carry of a bond is the sum of the slope and the "roll down". Nonetheless, Asness (2019) argues that while the slope is not precisely carry, it is a directionally correct measure of carry.

Table 8

Asset Pricing Results for the Two-Factor Model using Individual Bond Returns as Test Assets. The table provides the asset pricing results for the two-factor investment model in equipment (*EQLMH*) and structures (*STLMH*) using individual bond returns as test assets. 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 *EQLMH* (*STLMH)* factor is given by the return difference between a tercile portfolio that goes long in the currencies of the countries with the smallest equipment (structure) investment relative to GDP vis-à-vis the US and a tercile portfolio that goes short in the currencies of the countries with the highest equipment (structure) investment to GDP relative to the US. In the first pass, we run a time series regression of bond returns on the risk factors to estimate the factor betas (Panel B). In the second pass, we run a cross sectional regression of average bond returns on the estimated betas from the first pass to estimate the prices of risk (Panel A). 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, the Shanken (1992) standard errors under general distributional assumptions, denoted (Sh), which are adjusted for errors in variables, as well as the misspecification robust standard errors of Kan, Robotti, and Shanken (2013), denoted (MR). Panel A also provides the Hansen and Jagannathan (1997) distance, denoted *HJ*, and its *p*-value in brackets as well as the *p*-value of the rank test (also in brackets). 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				
	EQLMH	*STLMH*	*HJ*	R^2
λ	0.146	−0.570	1.159	0.126
(FMB)	0.003***	0.005***	[0.000]	
(Sh)	0.035***	0.070***	Rank Test	
(MR)	0.081	0.314	[0.000]	
Panel B: Betas				
	Constant	*EQLMH*	*STLMH*	R^2
AUS	0.281	−0.465**	−0.658***	0.142
	0.468	0.198	0.177	
CAN	0.483	−0.057	−0.445***	0.129
	0.365	0.123	0.115	
SWI	0.420	−0.892***	−0.365**	0.211
	0.466	0.202	0.156	
DEN	0.263	−0.960***	−0.262*	0.270
	0.423	0.175	0.134	
GER	0.596	−1.042***	−0.290**	0.295
	0.423	0.178	0.137	
UK	0.209	−0.045	−0.043	0.001
	0.432	0.214	0.151	
JAP	0.407	−0.616**	−0.316	0.082
	0.568	0.240	0.239	
NOR	−0.091	−0.560**	−0.653***	0.150
	0.520	0.218	0.173	
N. ZEAL	0.550	−0.966***	−0.854***	0.283
	0.492	0.217	0.163	
SWE	0.145	−0.942***	−0.330**	0.231
	0.484	0.209	0.164	

level. Further, the R^2 of the cross-sectional regression is 84.2% when bond portfolios are employed. For robustness, we estimate the models using bond excess returns. The results (available upon request) are qualitatively similar to those reported in the paper albeit with a modestly lower cross-sectional R^2.

The results in Table 7 and 8 provide consistent evidence that the investment factors are priced in the cross-section of bond returns. More specifically, when bond portfolios are employed as test assets, the prices of risk associated with the *STLMH* and *EQLMH* factors are negative and statistically significant at the 5% level when the Shanken (1992) and misspecification-robust standard errors are employed. Perfectly in line with our results in Tables 3, the price of risk for the *EQLMH* factor turns positive when individual bond returns are employed as test assets, while the price associated with the *STLMH* factor remains negative. Therefore, the results with individual bond and bond portfolio returns mirror perfectly our main results for currency portfolios and individual currencies in Tables 2 and 3.

We argue that these findings are not surprising. In fact, we offer in Section I of the online Appendix to the paper a theoretical overview in which bond yields in the domestic and foreign economies are employed to connect investment to currency returns. More broadly, currency and bond markets are tightly connected. While the deviations from UIP may be prevalent in the short-run, the existing research provides evidence that is more supportive of UIP in the long-run (Boudoukh et al., 2016; Chinn and Meredith, 2005). We employ five-year bond returns and, therefore, it is not surprising that, under UIP, our results with bonds mirror those of currencies. Indeed, exchange rates are forward-looking and when they are stationary, deviations from short-term UIP in the foreign exchange market and from the expectations hypothesis in the bond market may cancel out, in theory, and the long-run UIP is restored. In this scenario, exchange rates will reflect long yields today. Of course, exchange rates are not stationary, so this is an approximation.

7. 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 generally 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 instance, 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. Additionally, we endeavor to employ a risk-based approach, whereas excess currency returns could be directly tied to individual country specific traits. In this vein, we anticipate that future research could employ a characteristics-based approach as a potentially complementary tool to better understand the driving forces behind movements in international asset prices.

CRediT authorship contribution statement

Ibrahim Jamali: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing. **Ehab Yamani:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing. **Aaron D. Smallwood:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing.

Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jimonfin.2023.102830.

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