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Joseph P Byrne and Boulis Maher Ibrahim and Ryuta Sakemoto

Department of Accountancy, Economics and Finance; Heriot-Watt University

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Abstract

This paper investigates the importance of commodity prices to the returns of currency carry trade portfolios. We adopt a recently developed empirical factor model to capture commodity commonalities and heterogeneity. Agricultural material and metal price risk factors are found to have explanatory power on the cross-section of currency returns, while commodity common and oil factors do not. Although stock market risk is strongly linked to currencies in developed countries, the agricultural material factor is more important for emerging currencies compared to the stock market factor. This suggests that emerging currencies are somewhat segmented from a common financial market shock.

JEL Codes: C58, F31, G12, G15

Keywords: Currency Carry Trade, Commodity price, Factor Model, Hierarchical Model, Emerging Currencies

*Byrne (corresponding author), J.P.Byrne@hw.ac.uk, Ibrahim, B.M.Ibrahim@hw.ac.uk, and Sakemoto, rs7@hw.ac.uk, Department of Accountancy, Economics and Finance, Heriot-Watt University, Edinburgh, EH14 4AS, United Kingdom. We are grateful to Craig Burnside and Serena Ng for sharing their Matlab Codes. We have benefited from discussion with Craig Burnside, Ephraim Clark, David Cobham, Ian Marsh, Jacques Pezier, William Rees, Mark Schaffer, Yongcheol Shin, Vasco Vendrame, and seminar participants at Cardiff University, Heriot-Watt University, University of Edinburgh, University of Sussex and University of the West of England.

1. Introduction

The carry trade is an investment strategy that involves borrowing in a low interest rate currency and investing in a high interest rate currency. Many studies present evidence that the carry trade yields positive excess returns, and linear risk-based models may explain these returns.[1] This rapidly expanding literature has identified several important factors in carry trade pricing. In this study, we extend this literature by building an empirical factor model in a data rich environment, with a particular focus upon the role of commodity prices.

Previous studies report that financial market or macro information, may be fruitful in modelling carry trade risk factors. In terms of financial market information, Menkhoff et al. (2012) find that global Foreign Exchange (FX) volatility innovations are negatively correlated with high interest rate currency portfolios. Other FX market information in the form of average U.S. dollar returns (DOL) and the return difference between high and low currency portfolios (HML_{FX}) have also been found important (see Lustig et al., 2011). Further, Atanasov and Nitschka (2014), Dobrynskaya (2014), and Lettau et al. (2014) show that equity market downside risk can price carry returns better than the conventional capital asset pricing model (CAPM).

In addition to financial market information, macro fundamentals, such as consumption and production, may also be related to currency carry trades. Lustig and Verdelhan (2007) show that excess returns of high interest rate currency portfolios are correlated with U.S. durables and nondurables consumption growth. Ang and Chen (2010), Burnside (2012), Jordà and Taylor (2012), and Sarno and Schmeling (2014) examine whether macroeconomic information is related to currency carry trades, but are more cautious in drawing the conclusion that macro variables can be successfully identified as risk factors in currency carry trades.

Commodity prices however are a possible source of macro-finance information that may be useful for carry returns and, as yet, have not been formally considered in the cross-sectional carry trade literature. Chen and Rogoff (2003) and Chen et al. (2010) present time series evidence that the

[1] Lustig and Verdelhan (2007) were the first to apply a risk-based model on the returns of currency carry trade portfolios. Other prominent papers in this field include Burnside (2011, 2012), Lustig and Verdelhan (2011), Lustig et al. (2011), Menkhoff et al. (2012), and Atanasov and Nitschka (2015).

currencies of commodity producing countries, such as Australia and Canada, are linked to commodity prices over time.[2] Also in a time series context, Bakshi and Panayotov (2013) show that the change in a commodity price index can predict excess returns of carry trades at quarterly frequency. Passari (2015) proposes the construction of currency portfolios based on currency returns as predicted by commodity prices. The high minus low commodity strategy factor in this context, however, does not price cross-sectional portfolios. In a recent theoretical contribution, Ready et al. (2016) propose a model in which a commodity importing country has more consumption risk compared to a commodity exporting country. They indicate that the interest rate in the commodity importing country is lower than that of the commodity exporting country due to precautionary savings. They also test their model and identify that commodity exports are related to carry returns.

The analysis in this paper contributes to the literature on carry trade returns on three fronts. First, we extend the work of Bakshi and Panayotov (2013), Passari (2015), and Ready et al. (2016) by utilising commodity prices as a risk factor for carry trade portfolios. We explore the cross-sectional relation between carry trade returns and commodity prices. In particular, this study investigates whether commodity common information can price cross-sectional currency portfolios. Given that the recent literature finds that commodity prices exhibit commonality (e.g., Byrne et al., 2013; Gospodinov and Ng, 2013; Alquist and Coibion, 2014; and West and Wang, 2014), this study focuses on a commodity common factor. However, different types of commodities may contain different information.[3] Our approach examines common factors across commodity sectors and within particular commodity sectors. This is the most significant difference from Passari (2015) and Ready et al. (2016) who also investigate cross-sectional currency portfolios and risk factors. Passari (2015) uses commodity price indices and Ready et al. (2016) employ an import ratio factor computed as the aggregate net exports of basic goods and net imports of finished goods relative to a country's output. Importantly, our factor is not based on trade data, which is published with lags, but on more readily available commodity prices, and accounts for both commonalities between, and heterogeneity across, different types of commodity. Moreover, we

[2]Chen et al. (2010) show that exchange rates can predict a commodity price index at quarterly frequency.

[3]Yin and Han (2015) report that commodity price movements have heterogeneity across types of commodity. Chen et al. (2014) show that the combination of commodity prices has much more information than the aggregate commodity index.

construct portfolios at a monthly frequency in contrast to Passari (2015) and Ready et al. (2016). Also, our portfolios take into account trading costs while Ready et al. (2016) do not due to their low frequency portfolio construction.

This paper's second contribution is to exploit an empirical factor model to summarise a wide range of information, including the macro-finance data highlighted in the prior literature on carry trade returns. Ludvigson and Ng (2007, 2009), Engel et al. (2015) and Filipou and Taylor (2015) use empirical factor models in time series forecast studies of stock markets, bond yields and exchange rates. When modelling a small number of cross-sectional portfolios, as with carry trades, the ability to effectively summarise a large array of risk factors becomes important. To this end, we employ the Dynamic Hierarchical Factor Model (DHFM) proposed by Moench et al. (2013). This model has a hierarchical structure that specifies common and block factors, which is useful in accounting for commodity heterogeneity. A further advantage is that empirical factors are more readily identifiable.

The paper's third contribution is that our approach to modelling commodities provides interpretation of the high minus low interest rate currency portfolio (HML_{FX}) in explaining carry returns. The HML_{FX} can capture the cross-sectional return differences of currency portfolios and is related to global market risk (see Lustig et al., 2011). Menkhoff et al. (2012) further report that HML_{FX} is also associated with FX market volatility. The exact content of HML_{FX}, however, is still unclear, as pointed out by Burnside (2012), possibly because it is constructed from the carry portfolios themselves. Accordingly, we examine, in a time series context, whether our commodity prices factors have additional information that accounts for HML_{FX}.

Our empirical results provide evidence that commodity price factors can price currency carry trades, and that there is heterogeneity across the types of commodity. We find that the agricultural material and metal factors are associated with the cross-section of currency excess returns. The agricultural material factor is especially linked to emerging currency portfolios, and the metal factor is related to developed currency portfolios. We also find the stock market risk is not linked to emerging currency portfolios. These findings are important, since the previous literature has not focused on the heterogeneity between developed and emerging currency portfolios. The related studies consider a world common factor, and

developed and emerging currency portfolios have exposure to the same risk. This common factor is considered to be related to financial market risk (e.g., Lustig et al., 2011; Atanasov and Nitschka, 2014 and Dobrynskaya, 2014). Our finding suggests that there is risk that is somewhat segmented from financial markets but related to commodity prices. This commodity price risk is tied to emerging market currencies. Our empirical results are supported by the findings of Bodart et al. (2012) and Habib and Stracca (2012). Bodart et al. (2012) focus on emerging countries that depend upon the export of a single commodity good and show a positive relations between commodity prices and emerging countries' exchange rates. Habib and Stracca (2012) demonstrate that a reversal of carry trades during the financial crisis has a clear pattern only in developed currencies.

The remainder of this paper is organized as follows: Section 2 presents the method of constructing carry trade portfolios, Section 3 lays out the econometric framework and presents the empirical factor model, Section 4 discusses the empirical results, Section 5 presents further analysis, and Section 6 concludes.

2. Currency Portfolios

We start by defining the currency excess return and describing the construction of carry trade portfolios. Let s_t be the log of the spot exchange rate at time t in foreign currency per unit of domestic currency, and f_t be the log of the forward exchange rate at time t to be delivered at time $t+1$. A rise in s_t is a domestic currency appreciation, and the domestic currency is assumed to be the U.S. dollar (USD). Following Lustig et al. (2011), the currency carry return is computed as:[4]

$$r_{t+1} = f_t - s_{t+1}. \tag{1}$$

This strategy is implemented by selling the dollar forward, f_t, in the current period and buying the dollar spot, s_{t+1}, in the next period. We sort currencies into six portfolios, P1 to P6, based on their

[4]This return is related to violation of the Uncovered Interest rate Parity (UIP). See Appendix A in the online supplement.

forward discounts, $f_t - s_t$. P1 contains the lowest interest rate currencies and P6 contains the highest interest rate currencies. These are rebalanced at the end of each month. The log excess return of a portfolio is calculated as the equally-weighted average of the log excess returns of the currencies in that portfolio.

As in Lustig et al. (2011), we use bid and ask quotes to account for transaction costs. A carry return pricing factor that is not robust to transaction costs is less appealing to investors. When an investor buys the foreign currency, she sells the dollar forward at the bid price, f_t^b, at time t and buys the dollar at the ask price, s_{t+1}^a, at time $t+1$. The excess return of going long in the foreign currency is:

$$r_{t+1}^l = f_t^b - s_{t+1}^a. \tag{2}$$

Conversely, when the investor sells the foreign currency, the excess return of going short is:

$$r_{t+1}^s = -f_t^a + s_{t+1}^b. \tag{3}$$

Following previous studies, we consider portfolio P1 as the short position with excess return, r_{t+1}^s, and the other portfolios as long positions with excess returns, r_{t+1}^l.

3. Econometric Framework

3.1. RISK PREMIUM ESTIMATION

This section describes Fama and MacBeth's (1973) two-pass estimation procedure to test risk premia, which we adopt in this paper. This procedure is used to estimate risk premia, λ, and factor beta β_i for portfolio i. The expected excess return for portfolio i is:

$$E[r_i] = \lambda' \beta_i. \tag{4}$$

The risk premia, λ, have the same values across portfolios, and β_i is the portfolio i's exposure to risk, which differs across portfolios. The factor betas are estimated by time series regressions, where each portfolio's excess return is regressed on the risk factor h_t:

$$r_{i,t} = \alpha_i + h_t'\beta_i + \epsilon_{i,t} \tag{5}$$

where $\epsilon_{i,t}$ is an error term. Burnside (2011) highlights the importance of checking whether betas are statistically and economically significant. The risk premia are then obtained by a cross-sectional regression where the portfolios' time series average excess returns are regressed on the estimated betas $\hat{\beta}_i$:

$$E[r_i] = \lambda'\hat{\beta}_i + \eta_i \tag{6}$$

where η_i is an error term. Since these betas are estimated variables, estimation uncertainty should be taken into account for statistical inference. Accordingly, we follow Burnside (2011) and use the Shanken (1992) standard errors to account for estimation uncertainty.[5]

3.2. EMPIRICAL FACTOR MODEL

Our empirical strategy in examining the importance of commodity prices and other factors is to adopt a data reduction method. This subsection describes our approach to estimate the empirical factors in the data rich environment. We estimate three types of common factors: across our entire macro-finance dataset, across all commodity prices, and within a particular group of commodity prices. To this end, we use the Dynamic Hierarchical Factor Model (DHFM) proposed by Moench et al. (2013). Conventional empirical factor models that extract factors using principal components have limited flexibility and present a difficulty in interpreting the factors. Instead, if we have some prior knowledge of the data structure, the DHFM can help with the identification of the empirical factor model. Moench et al. (2013) present a four-level model with common, block, subblock and idiosyncratic components, and we

[5]Jagannathan and Wang (1998) point out that the Shanken (1992) standard errors are inappropriate if heteroscedasticity is present. In the Online Appendix we also report the estimation results by the Generalized Method of Moments (GMM) as in Cochrane (2005).

adopt a similar four-level structure. Let $Z_{bkn,t}$ be the time-t observation of the nth series in subblock k, of block b. This is explained by the empirical factor ($H_{bk,t}$) and idiosyncratic variation ($e_{Zbkn,t}$). The four-level factor model is then written as:

$$Z_{bkn,t} = \Lambda_{Hbkn}(L)H_{bk,t} + e_{Zbkn,t} \tag{7}$$

$$H_{bk,t} = \Lambda_{Gbk}(L)G_{b,t} + e_{Hbk,t} \tag{8}$$

$$G_{b,t} = \Lambda_{Fb}(L)F_t + e_{Gb,t} \tag{9}$$

where $\Lambda_j(L)$, with j=$Hbkn$, Gbk and Fb, is a matrix of the time-invariant lag of loadings, and L is the lag order.[6] The matrix is lower triangular with ones on the diagonal to identify the factors and loadings.[7] The subblock factor $H_{bk,t}$ is the latent factor of subblock k at time t, and it captures the common movement in subblock k. This subblock factor $H_{bk,t}$ contains a block factor $G_{b,t}$ and a subblock-specific variation $e_{Hbk,t}$. Similarly, in Equation (9) the block factor $G_{b,t}$ contains a common factor F_t and a block-specific variation $e_{Gb,t}$. Using Equations (8) and (9), the relation between the subblock factor $H_{bk,t}$ and the common factor F_t can be written as:

$$H_{bk,t} = \Lambda_{Gbk}(L)\Lambda_{Fb}(L)F_t + \Lambda_{Gbk}(L)e_{Gb,t} + e_{Hbk,t}. \tag{10}$$

The first term on the right hand side of Equation (10) is a time-varying intercept. Moreover, the data series $Z_{bkn,t}$ is linked to the common factor by Equations (7) and (10).

The idiosyncratic subblock-specific and block-specific variations, as well as the common factors, are assumed to be stationary, normally distributed autoregressive processes of order one, and evolve as follows:[8]

$$e_{Zbkn,t} = \Psi_{Zbkn}e_{Zbkn,t-1} + \epsilon_{Zbkn,t} \tag{11}$$

[6]We set the number of lags to zero as in Moench et al. (2013).

[7]Moench et al. (2013) posit that even in a two-level dynamic factor model, we cannot identify $\Lambda_{Fb}(L)$ and F_t without restrictions.

[8]The DHFM can be set with different lag orders in $e_{Zbkn,t}$, $e_{Hbk,t}$, $e_{Gb,t}$ and F_t.

$$e_{Hbk,t} = \Psi_{Hbk} e_{Hbk,t-1} + \epsilon_{Hbk,t} \quad (12)$$

$$e_{Gb,t} = \Psi_{Gb} e_{Gb,t-1} + \epsilon_{Gb,t} \quad (13)$$

$$F_t = \Psi_F F_{t-1} + \epsilon_{Ft} \quad (14)$$

with $\epsilon_{jt} \sim N(0, \sigma_j^2)$, and j=$Zbkn$, Hbk, Gb and F. Ψ_j are AR(1) coefficients and all $\epsilon_{j,t}$ are uncorrelated across j and over t. Prior to estimation, we transform the data to ensure stationarity using the method of Stock and Watson (2005).[9]

A standard method to estimate latent factors from a large number of data series is principal components. Principal components, however, would not account for potential relations between common and block factors and a time series structure such as that described in Equations (11) to (14). Moench et al. (2013) propose a Markov Chain Monte Carlo (MCMC) method to estimate the factor model.[10] We follow this approach, employ the MCMC method and discard the first 20,000 draws as burn-in, and save every 100th of the remaining 50,000 draws.

4. Empirical Results

4.1. DATA

To calculate currency excess returns, daily spot and one-month forward exchange rates against the USD are obtained from Datastream. This data contains bid and ask quotes and end of month values extracted from the daily data series considered by Lustig et al. (2011). The dataset covers the same 37 countries in Lustig et al. (2011), and we also construct separate developed country portfolios from emerging country portfolios. The country list is reported in the Online Appendix.

The monthly dataset extends from February 1983 to December 2013. Since not all series start from February 1983, the total number of exchange rates varies during this period. As data on most of the emerging market exchange rates is available from January 1997, the emerging country portfolios start

[9]When we use series different from those used by Stock and Watson (2005), we ensure the data is stationary based upon the Augmented Dickey Fuller (ADF) test.

[10]Initial values of the common, block, and subblock factors are estimated by principal components.

from January 1997. Following Lustig et al. (2011) and Menkhoff et al. (2012), the older currencies of the Euro member countries are replaced by the Euro after January 1999, and outliers pointed out in Lustig et al. (2011) are deleted.[11]

Next, we describe the dataset used to estimate the risk factors by the empirical factor model. We include the log of real commodity prices, and use 23 non-fuel commodity prices, and three oil prices. We select 23 non-fuel commodities based upon the widely used Commodity Price Index of Grilli and Yang (1988). This data is from the IMF and the World Bank, and real commodity prices are computed using the U.S. Consumer Price Index (CPI).[12]

We also employ a balanced panel of 102 monthly series to test a wide range of information as in Stock and Watson (2005). We test whether a common factor across commodity prices and the other macroeconomic data contains useful information in pricing currency carry trades. The motivation is that these estimated factors may capture a wide range of alternative macro and financial factors associated with currency excess returns, as pointed out by Ludvigson and Ng (2007, 2009). In general, this dataset contains the following U.S. macroeconomic series: income, consumption, employment, production, housing starts, producer and consumer prices, interest rates, and money supply. Further, and as reported by Dobrynskaya (2014) and Lettau et al. (2014) that stock market information is linked to currency carry trade risk, we include four important potential stock market risk factors, namely market proxy equity index, size, value, and momentum factors, based upon the studies of Fama and French (1993) and Carhart (1997).

We start building the DHFM by arranging the data into three blocks: commodity price (COM), finance (FIN) and real economy (ECO). The commodity price block has the following four subblocks: food prices (FOO), agricultural material prices (AGR), metals (MET), and oil (OIL). The finance block has the following three subblocks: stock market (STO), interest rate (INT), and money (MON). The real economy block has the following five subblocks: income and consumption (INC), production (PRO), employment (EMP), house (HOU), and price (PRI). We partition the real economy and

[11]We also pre-treat the dataset using the approach of Darvas (2009) and Cenedese et al. (2014). See the Online Appendix.

[12]See the dataset in the Online Appendix .

finance blocks as in Stock and Watson (2005).[13]

4.2. DESCRIPTIVE STATISTICS

Table 1 provides descriptive statistics of the currency portfolio returns. Panel A contains statistics for all country results. The first and second rows report the annualized mean and standard deviation of excess return, respectively. We multiply the average monthly excess return by 12 and the monthly standard deviation by root 12 to obtain annualized values. Portfolio P1 contains the lowest interest rate currencies and portfolio P6 contains the highest interest rate currencies. P6 has the highest average excess return and the highest standard deviation. The return spread between P1 and P6 (i.e., High Minus Low, HML_{FX}) is statistically different from zero at the 10% level. The third and fourth columns show the skewness and kurtosis. High interest portfolios, P5 and P6, have more negative skewness, and this result is similar to that of Menkhoff et al. (2012) and Dobrynskaya (2014). This negative skewness reflects the unwinding of carry trades, as suggested by Brunnermeier et al. (2009).

The same return pattern is also seen for developed countries in Panel B of Table 1. The emerging countries' result in Panel C provides a high HML_{FX}. This result is consistent with Burnside et al. (2007) and Gilmore and Hayashi (2011). The mean excess returns in emerging countries are not monotonically increasing from P1 to P6 and the high trading cost might be the reason, as pointed out by Burnside et al. (2007).

[Table 1 about here]

4.3. VARIANCE DECOMPOSITION

Next, we present the results of a variance decomposition of our risk factors, which seeks to explain returns. Table 2 reports the posterior means and standard deviations of estimated variance shares relative to the total variance as in Moench et al. (2013). $Share_F$ is the variance share of common variations, and $Share_G$, $Share_H$, and $Share_Z$ are the variance shares of block, subblock, and idiosyncratic variations, respectively.

[13]The Online Appendix summarises the model structure.

First, we explore the commodity block. A single common factor does not appear to capture the commodity block variation. The block variation is important for oil, explaining 83% of total variance ($Share_G$ is equal to 0.825 for $SB-OIL$). The subblock variation has a larger share in the agricultural materials and the metals subblocks ($Share_H$ explains 15% and 23%, respectively). This implies that there is a common component in the agricultural materials and the metals subblocks, respectively. The food subblock, in contrast, is largely explained by the idiosyncratic variation ($Share_Z$ has a posterior mean of 0.920 for $SB-FOO$). These results present evidence of the extent of heterogeneity across different types of commodity groups.

We turn to the finance block in Table 2 and the influence of the common variation is small for this information set. The finance variation is more substantial than the common variation in this group. For instance, the finance variation accounts for 31% of interest rate movements and 18% of the stock market, implying that the main driver of the finance block is the interest rate.

[Table 2 about here]

4.4. CROSS-SECTIONAL RESULTS

We now turn to our core estimation results of the currency excess returns commodity linear factor model in Equation (6). Table 3 presents our first set of cross-sectional asset pricing test results using the commodity price factors. The estimated risk premia (λ), root mean-squared error (RMSE), and pricing error tests (χ^2 and p-value) are reported. The R^2 are computed by the predicted ($\hat{R}$) and actual mean ($\bar{R}$) excess returns, as in Burnside (2011):

$$R^2 = 1 - \frac{(\bar{R}-\hat{R})'(\bar{R}-\hat{R})}{(\bar{R}-\tilde{R})'(\bar{R}-\tilde{R})} \tag{15}$$

where $\tilde{R}$ is the cross-sectional average of the mean excess returns. We use excess returns adjusted for the bid-ask spread to account for transaction costs, and we estimate the cross-sectional model without a constant term.[14] Burnside (2011) highlights that if the constant term is included, it can account for

[14]Table A-2 in the Online Appendix, reports results that use currency portfolios without bid-ask spreads as in Ahmed and Valente (2015).

a large part of the variation and can inflate R^2.

We begin with the commodity price factors, which represent the main focus of this study. This estimation examines whether commodity group information is useful in pricing currency carry trades, and four commodity factors: food, agricultural material, metal, and oil, are compared. In addition, the average U.S. dollar factor DOL is included as in Lustig et al. (2011) and Menkhoff et al. (2012). DOL loads onto all portfolios equally, which implies that it represents the average currency excess return for a U.S. investor who invests in foreign currencies.

The results in Table 3 Panel A present evidence that the agricultural material ($SB - AGR$) and metal ($SB - MET$) factors can price currency portfolios. Column (1) reports the risk premium of the agricultural material factor to be statistically significant at the 1% level and the impact of the risk premium is 3.4% (=0.30 $\times$ 12) per annum. The high R^2 and the lower RMSE indicate a good model performance. Column (2) indicates that the metal factor has a statistically significant risk premium and its impact is similar to that of the agricultural material factor.[15] To study the agricultural and metal factors further, we investigate factor exposure of commodity importing and exporting countries. Ready et al. (2016) report that commodity importing and exporting countries have heterogeneous exposure to global productivity shocks. We replicate the Ready et al. (2016) results in the Online Appendix, and they indicate that our commodity factors are linked to global production shocks, since commodity importing and exporting countries have opposite exposure to these commodity factors.

The results for the food and oil factors are presented in columns (3) and (4) in Table 3. Although the food factor model has a high R^2 and a small RMSE, we interpret these results cautiously because the betas related to this factor are not estimated with high precision, and we present evidence of this below in Table 5. The oil factor is not associated with the cross-section of currency excess returns. This finding is intuitive, since oil exporting countries, such as Saudi Arabia and Kuwait, are not high interest rate countries.

[Table 3 about here]

[15]For robustness, the CRB Raw industrial material subindex return, which is used in Bakshi and Panayotov (2013) and IMF agricultural material and metal index returns are also adopted.

The results of the finance block factors are presented in Panel B of Table 3. As Lettau et al. (2014) and Dobrynskaya (2014) provide evidence that financial market information is linked to currency carry trades, we test whether financial factors extracted by the DHFM can price the cross-section of currency portfolios. Column (5) provides the result of the stock market factor ($SB - STO$), which confirms that this factor is related to cross-sectional currency excess returns. The risk premium is statistically significant at the the 1% level and is 3.8% per annum. Dobrynskaya (2014) reports that the CAPM cannot account for currency excess returns, but downside stock market risk is crucial. Since our stock market factor is negatively correlated with stock market volatility innovations, it could be related to downside market risk.[16] Our stock market factor, however, is not a simple downside risk factor, because it includes the size, value, and momentum factors of Fama and French (1993) and Carhart (1997). The remaining columns in Panel B report that the other finance subblock factors are less promising than the stock market factor. Finally, column (8) confirms that DOL cannot price cross-sectional currency returns, which is suggested by Lustig et al. (2011).

To visualise our results, Figure 1 plots the pricing errors of asset pricing models with the DOL and the various empirical factors that we identify, as in Menkhoff et al. (2012). The realized mean currency excess returns are on the x-axes, and the predicted mean currency excess returns by the asset pricing models are on the y-axes. If there is no pricing error, all six portfolios should lie on the 45-degree line. Figure 1 Graph A is the agricultural material factor, Graph B is the metal factor, and Graph C is the stock market factor. These graphs show that all portfolios, except P2, plot close to the 45-degrees line with small pricing errors, and these images illustrate our empirical findings.

[Figure 1 about here]

Given these promising commodity and stock market results, we next test whether a common factor across all blocks has information to price currency excess returns. Column (1) in Table 4 reports the results of the common factor ($COMMON$). These show that this common factor across the entire dataset is not related to the cross-section of currency excess returns, possibly because the broad common macro-finance factor is not sufficiently granular. For robustness, a common factor is also extracted from

[16] The correlation between $SB - STO$ and S&P500 volatility innovations is -0.43.

across the entire dataset by conventional principal component analysis and the results are reported in column (2). These confirm the conclusions drawn from the results reported in column (1) that commodity and stock market information need to be considered separately.

Next, the commodity common factor is tested and column (3) in Table 4 presents the results, which also show a weak relationship between this factor and currency excess returns. The main driver of the commodity common factor is the oil subblock as shown in Table 1. This weak relationship is consistent with the results in Table 3 suggesting that commodity subblock information is more important than common components. This implies that information heterogeneity across commodity blocks is crucial to the cross-sectional asset pricing model. It also implies that commodity prices are linked to a particular country's macro economic state and a country cannot hedge the specific-commodity price risk.

[Table 4 about here]

4.5. TIME SERIES RESULTS

In this section, we conduct time series analyses on the factors identified above. If a factor can account for currency excess returns, currency portfolios should have significant exposure to this factor over time. The currency excess returns are regressed on a constant, DOL, and the agricultural material, metal, food, and stock market factors. The results are reported in Table 5. Panel A reports the results using the agricultural factor. All estimated values of β_{DOL} are around one and significant at the 1% level. All portfolios have almost the same exposure to DOL, which is a result that is consistent with Lustig et al. (2011). The estimated betas on the agricultural material factor, β_{AGR} are statistically significant at the 1% level for P1 and P6. The negative coefficient of P1 and the positive risk premium imply that the lowest interest portfolio acts as a hedge against agricultural material risk. We also consider the economic impact of this factor. Since the standard deviation of the agricultural factor is 0.39, a one-standard-deviation change in the agricultural material factor would reduce the annualized excess return of P1 by 2.9% and increase that of P6 by 3.3%, all else equal.[17]

[17]This result is not reported in the table.

The results of the metal factor in Panel B have a similar pattern to those of the agricultural material factor. Interestingly, β_{MET} increase monotonically from P1 to P6, and those for P1 and P6 are statistically significant at the 1% and the 5% levels, respectively. In contrast, Panel C provides evidence that all factor betas on the food factor, β_{FOO}, are insignificant. This suggests that the factor betas used in the cross-sectional asset pricing model in Table 3 are not estimated with precision, because the betas using the cross-sectional regression in Table 3 have a weak relation with the food factor.

Finally, the results on the stock market factor are presented in Panel D. Apart from P1, the estimates of the coefficient on the stock market factor, β_{STO}, increase monotonically from -0.49 for P2 to 0.78 for P6. P1, P2 and P6 have statistically significant betas. As the risk premium on the stock market factor is positive, as shown in Table 4, this result means P1 and P2 act as hedges against stock market risk. The standard deviation of the stock market factor is 0.35 and if the stock market factor changes by one standard deviation, the annualized excess return to P1 increases by 1.9% and the annualized excess return to P6 decreases by 3.3%. This implies that the betas on the stock market factor have an economically significant impact on excess returns of currency portfolios.

[Table 5 about here]

Given the strong relationship between high and low interest rate currency portfolios, and the commodity factors, we conduct a further analysis to explore the relationship with HML_{FX}. HML_{FX} has been used in the cross-sectional literature to identify carry returns. HML_{FX} is computed as the return spread between high and low currency portfolios, and Lustig et al. (2011) links this popular factor to global stock market risk. The relationship with commodity prices, however, has not been investigated in the literature. We regress HML_{FX} on the agricultural material and metal factors. Rows (1) and (2) in Table 6 are our base results, and both agricultural material and metal factors are significant at the 1% level and the economic impacts are large. For instance, one standard deviation change in the agricultural material leads to 6.6% change in HML_{FX}. We also control for the effect of the global FX volatility innovations (ΔVOL_{FX}) of Menkhoff et al. (2012) in rows (3) and (4). The magnitude reduces slightly, but both coefficients remain statistically significant at the 1% level.

Next, we test which of the two factors is more important for HML_{FX} in rows (5) and (6). As the agricultural material and metal factors are correlated, the metal factor is orthogonalized to the agricultural material factor in row (5), which is the same approach of Menkhoff et al. (2012). Now, the orthogonalized metal factor, MET^{orth}, becomes insignificant. In contrast, the orthogonalized agricultural material factor, AGR^{orth}, remains significant at the 1% level in row (6). These results imply that the agricultural material factor drives out the metal factor. We also compare our factors and the IMF index in the Online Appendix and the results confirm that our factors have a dominant effect.

Finally, we examine whether the commodity factors remain significant with our stock market factor. The stock market factor is orthogonalized to the agricultural material and metal factors in rows (7) and (8). We repeat the opposite operations in rows (9) and (10).[18] These results show that the commodity and stock market factors have different information, and both are highly associated with HML_{FX}. Hence our approach in this paper is useful in explaining the time series movement in the widely cited HML_{FX} for carry returns.

A possible explanation for the difference between commodity and stock market information is that the former is mainly related to emerging currencies and the latter is tied to currencies in advanced economies. The previous literature does not point out this difference and focuses on the common risk. For instance, Lustig et al. (2011) propose a theoretical model based upon a no-arbitrage model, and the key assumption is that each currency has a different exposure to a common shock. They use stock market volatility as a proxy for the common shock. Subsequent empirical studies support this assumption and demonstrate that downside stock market is an important risk factor for carry trades (e.g., Atanasov and Nitschka, 2014; Dobrynskaya, 2014 and Lettau et al. 2014). However, some emerging countries' currencies may not be tied to world financial market risk, perhaps because they do not have developed financial markets. In fact, Habib and Stracca (2012) show that a reversal of carry trades during the financial crisis has a clear pattern only in liquid currencies. For the less liquid currencies of emerging countries, commodity prices instead are more important determinants of exchange rates. Bodart et al. (2012) focus on emerging countries that are dependent upon the export of a single commodity

[18]For further robustness, the world stock market volatility innovations are used in Table A-5 in the Online Appendix.

good and find that when commodity prices increase, the currencies appreciate. Hence, commodity price information is strongly linked to emerging currencies, while these currencies' link to stock market information is rather weak. In the next section we investigate this further and test whether the stock market and commodity factors price both developed and emerging currencies' portfolios.

[Table 6 about here]

5. Developed and Emerging Portfolios

Given evidence of the heterogeneous information contents of the commodity and stock market factors presented in Table 6, we explore whether they are linked to financial market development. To this end, we split the currency dataset into developed country currencies and emerging country currencies. Lustig et al. (2011) use the same developed country dataset as a robustness check. We also consider an emerging country category, since some emerging countries are commodity exporters and commodity prices may affect their interest rates and exchange rates.

Panel A in Table 7 reports estimates of risk premia on carry returns of currencies that belong to developed countries. The results in column (1) show that the agricultural material factor cannot price developed country portfolios. In contrast, columns (2) and (3) show that the metal and stock market factors can. This suggests that metal prices are related to the U.S. stock market, as pointed out by Fama and French (1988). This result does not mean that both factors contain the same information, because the previous section provides evidence that the metal factor remains significant while controlling for the stock market factor.

We turn to the emerging country results in Panel B of Table 7. The results in column (4) show that agricultural material can price the emerging currency portfolios. Surprisingly, the risk premia on the stock market and the metal factors vanish in columns (5) and (6). This implies that a risk factor for developed country currencies differs from that for emerging currencies, and that developed countries are connected to stock market risk. This link is intuitive, since developed country currencies are more liquid, and investors usually implement carry trades using mainly developed country currencies. Jylhä

and Suminen (2011) find money flows to hedge funds are related to carry trade returns in developed countries. Our result also implies that stock and commodity markets risks may be somewhat segmented. This conclusion is consistent with Gorton and Rouwenhorst (2006), who find a low correlation between equity and commodity market returns.

In summary, we find the agricultural material factor is strongly related to emerging countries, and the stock market and metal factors are mainly affected by advanced economies. This heterogeneity comes from developed country currencies, which are more liquid and regarded as an investable asset class.

[Table 7 about here]

6. Conclusion

This paper investigates a range of commodity price risk factors for portfolios of currency carry trades. Commodity exporting and importing are related to interest rates, as shown by Ready et al. (2016) in advanced economies. Moreover, several high interest rate emerging countries are commodity exporters, thus, commodity prices may affect currency carry trade returns. This study focuses on common information across commodity prices and within a certain type of commodity. Since the importance of commodity common information have been investigated recently (e.g., Byrne et al., 2013; Gospodinov and Ng, 2013; Alquist and Coibion, 2014 and West and Wang, 2014), we extract common factors from overall commodity prices, and from specific commodity groups. In addition, we explore the common factor between commodity prices and other macroeconomic data. Our motivation in using an empirical factor model is related to Ludvigson and Ng (2007, 2009), who show that empirical factors extracted from a large data set contain richer information. We also adopt a recently developed factor model to overcome the identification issue of a simple principal component. This model, developed by Moench et al. (2013), has a hierarchical structure that captures common components across data and within the sub-categories of the data.

We find commodity prices are important risk factors for the returns of currency carry trades. Al-

though Bakshi and Panayotov (2013) link a commodity price index with future currency excess returns, we focus on the cross-sectional relation between currency excess returns and commodity risk factors. We find agricultural and metal factors are related to currency trade risk, but broad commodity and oil price factors fail to explain currency excess returns. These heterogeneous results support the use of the dynamic hierarchical factor model.

We present evidence that the agricultural material factor is linked to currencies of emerging countries and the metal factor is related to currencies of developed countries. Although stock market information is important in pricing currency carry trades, as shown by Dobrynskaya (2014) and Lettau et al. (2014), this study reveals that this information is weakly associated with emerging currencies. We find commodity information is a more dominant factor for emerging currencies, since emerging countries do not have liquid financial markets and, hence, are somewhat segmented from world financial market risk. This result is supported by the finding of Habib and Stracca (2012) who present a significant reversal of carry trades during the financial crisis only in developed markets. Our findings are important, since the previous literature focuses on the common risk among developed and emerging markets while we focus on heterogeneity between these markets. Our results call for further research into theoretical models that link commodity price risk to financial market risk.

Table 1 Descriptive Statistics

	P1	P2	P3	P4	P5	P6	HML_{FX}
Panel A: All countries							
Mean	0.94	-1.19	1.15	2.71*	0.88	4.08*	3.13*
	[0.58]	[-0.71]	[0.78]	[1.78]	[0.47]	[1.90]	[1.85]
Std.dev.	9.17	8.28	8.20	8.20	9.14	10.46	8.35
Skewness	0.16	-0.06	-0.31	-0.29	-0.57	-0.57	-0.55
Kurtosis	4.14	4.19	3.90	4.60	4.97	5.27	5.36
Panel B: Developed countries							
Mean	1.69	-0.78	0.91	2.64	4.16**		2.48
	[0.90]	[-0.40]	[0.50]	[1.44]	[1.97]		[1.46]
Std.dev.	10.50	9.77	9.49	9.28	10.44		8.94
Skewness	0.20	-0.10	-0.32	-0.22	-0.51		-0.72
Kurtosis	3.46	3.55	3.85	5.27	4.55		5.02
Panel C: Emerging countries							
Mean	0.40	-1.82	-0.52	-0.90	-4.89	7.35**	6.59**
	[0.22]	[-1.55]	[-0.38]	[-0.44]	[-1.57]	[2.00]	[2.17]
Std.dev.	7.59	4.48	5.65	8.23	12.06	12.15	10.68
Skewness	-0.68	-0.17	-0.78	-0.26	-2.74	-0.85	-0.62
Kurtosis	8.80	4.78	5.44	5.16	19.23	6.24	4.77

Notes: This table reports annualized mean, annualized standard deviations, skewness, and kurtosis of USD excess returns of currency portfolios sorted monthly at $t-1$ by forward discounts. HML_{FX} denotes a portfolio that is long in portfolio 6 (5) and short in portfolio 1. Newey and West (1987) HAC t-statistics are reported in square brackets. *,**, and *** indicate significance at the 10%, 5% and 1% levels, respectively. The sample period of all and developed countries is February 1983 to December 2013. The sample period of emerging countries is January 1997 to December 2013.

Table 2 Decomposition of Variance

Block	Subblock	$Share_F$		$Share_G$		$Share_H$		$Share_Z$	
		Posterior Mean (Standard Deviation)							
$B-COM$	$SB-FOO$	0.001	(0.001)	0.039	(0.015)	0.040	(0.015)	0.920	(0.030)
$B-COM$	$SB-AGR$	0.001	(0.001)	0.022	(0.011)	0.147	(0.062)	0.831	(0.069)
$B-COM$	$SB-MET$	0.002	(0.002)	0.068	(0.020)	0.233	(0.034)	0.697	(0.043)
$B-COM$	$SB-OIL$	0.027	(0.023)	0.825	(0.025)	0.084	(0.006)	0.063	(0.009)
$B-FIN$	$SB-STO$	0.000	(0.000)	0.182	(0.021)	0.151	(0.017)	0.666	(0.037)
$B-FIN$	$SB-INT$	0.001	(0.001)	0.312	(0.012)	0.019	(0.002)	0.668	(0.011)
$B-FIN$	$SB-MON$	0.000	(0.000)	0.001	(0.002)	0.169	(0.009)	0.830	(0.008)

Notes: This table displays the decomposition of variance based on Moench et al. (2013). $Share_F$, $Share_G$, $Share_H$, and $Share_Z$ denote the average of variance share across all variables in the subblock due to common, block-level, subblock-level and idiosyncratic shocks, respectively. The commodity block has the following four subblocks: food prices (FOO), agricultural material prices (AGR), metals (MET), and oil (OIL). The finance block has the following three subblocks (SB): stock market (STO), interest rate (INT), and money (MON).

Table 3 Cross-sectional Asset Pricing: Commodity and Finance Subblocks

Panel A: Commodity Block				
	(1)	(2)	(3)	(4)
	λ	λ	λ	λ
DOL	0.15	0.15	0.15	0.16
	(0.12)	(0.12)	(0.12)	(0.12)
$SB-AGR$	0.30***			
	(0.12)			
$SB-MET$		0.31**		
		(0.12)		
$SB-FOO$			0.87*	
			(0.48)	
$SB-OIL$				1.73
				(1.58)
R^2	0.57	0.53	0.81	0.20
RMSE	0.10	0.11	0.07	0.14
χ^2	11.97**	12.30**	1.69	5.35
[p-value]	[0.02]	[0.02]	[0.79]	[0.25]
Panel B: Finance Block				
	(5)	(6)	(7)	(8)
	λ	λ	λ	λ
DOL	0.15	0.16	0.16	0.16
	(0.12)	(0.12)	(0.12)	(0.12)
$SB-STO$	0.32***			
	(0.11)			
$SB-INT$		-1.17		
		(0.96)		
$SB-MON$			-0.06	
			(0.11)	
R^2	0.85	0.18	0.09	0.09
RMSE	0.06	0.14	0.15	0.15
χ^2	4.88	9.52**	20.11***	22.23***
[p-value]	[0.30]	[0.05]	[0.00]	[0.00]

Notes: This table reports cross-sectional pricing results of the linear factor model based on the commodity prices or financial risk factors. The test assets are excess returns of six carry trade portfolios. The coefficient of factor risk premium λ in Equation (6) is estimated by the procedure of Fama and MacBeth (1973). Abbreviations of the factor variables are reported in the first column. DOL is the average dollar risk factor. $SB-AGR$ is the agricultural material prices, $SB-MET$ is the metal, $SB-FOO$ is the food prices, $SB-OIL$ is the oil, $SB-STO$ is the stock market, $SB-INT$ is the interest rate, and $SB-MON$ is the money factors estimated by the Dynamic Hierarchical Factor Model. Shanken (1992) standard errors are reported in parentheses. The R^2 is a measure of fit between the sample mean and the predicted mean returns. The RMSE is the root of mean-squared error and is reported in percentage points. The χ^2 test statistics of pricing errors are reported and the null hypothesis is that there is no pricing error. p-values are reported in square brackets. *,**, and *** indicate significance at the 10%, 5% and 1% levels, respectively. The sample period is from February 1983 to December 2013.

Table 4 Cross-sectional Asset Pricing: Common Factor

	(1) λ	(2) λ	(3) λ
DOL	0.16	0.16	0.16
	(0.12)	(0.12)	(0.12)
$COMMON$	0.10		
	(0.16)		
$PCAF_1$		0.15	
		(0.31)	
$B-COM$			0.48
			(0.30)
R^2	0.10	0.09	0.42
RMSE	0.15	0.15	0.12
χ^2	20.58***	20.03***	5.96
[p-value]	[0.00]	[0.00]	[0.20]

Notes: This table reports cross-sectional pricing results of the linear factor model based on the common risk factors. The test assets are excess returns of six carry trade portfolios. The coefficient of factor risk premium λ in Equation (6) is estimated by the procedure of Fama and MacBeth (1973). Abbreviations of the factor variables are reported in the first column. DOL is the average dollar risk factor. $COMMON$ is the common and $B-COM$ is the commodity factors estimated by the Dynamic Hierarchical Factor Model. $PCAF_1$ is the common factor obtained by a principal component. Shanken (1992) standard errors are reported in parentheses. The R^2 is a measure of fit between the sample mean and the predicted mean returns. The RMSE is the root of mean-squared error and is reported in percentage points. The χ^2 test statistics of pricing errors are reported and the null hypothesis is that there is no pricing error. p-values are reported in square brackets. *,**, and *** indicate significance at the 10%, 5% and 1% levels, respectively. The sample period is from February 1983 to December 2013.

Table 5 Time Series Results

Panel A: Factor Betas: $SB - AGR$					Panel B: Factor Betas: $SB - MET$				
P	α	β_{DOL}	β_{AGR}	adjR^2	P	α	β_{DOL}	β_{MET}	adjR^2
1	-0.13*	1.02***	-0.62***	0.77	1	-0.14**	1.03***	-0.63***	0.77
	(0.07)	(0.05)	(0.24)			(0.07)	(0.05)	(0.23)	
2	-0.21***	0.93***	0.02	0.80	2	-0.21***	0.93***	-0.09	0.80
	(0.06)	(0.05)	(0.19)			(0.06)	(0.04)	(0.18)	
3	-0.02	0.97***	-0.07	0.88	3	-0.02	0.97***	-0.05	0.88
	(0.04)	(0.02)	(0.11)			(0.04)	(0.02)	(0.10)	
4	0.13***	0.93***	0.04	0.83	4	0.13***	0.94***	0.01	0.83
	(0.05)	(0.03)	(0.14)			(0.05)	(0.03)	(0.14)	
5	-0.03	1.03***	-0.05	0.84	5	-0.02	1.02***	0.02	0.84
	(0.05)	(0.03)	(0.15)			(0.06)	(0.03)	(0.15)	
6	0.26***	1.12***	0.69***	0.76	6	0.26***	1.11***	0.53**	0.76
	(0.08)	(0.04)	(0.24)			(0.08)	(0.04)	(0.24)	
Panel C: Factor Betas: $SB - FOO$					Panel D: Factor Betas: $SB - STO$				
P	α	β_{DOL}	β_{FOO}	adjR^2	P	α	β_{DOL}	β_{STO}	adjR^2
1	-0.12*	1.01***	-0.23	0.77	1	-0.13*	1.01***	-0.44***	0.76
	(0.07)	(0.04)	(0.20)			(0.07)	(0.05)	(0.22)	
2	-0.21***	0.93***	-0.14	0.80	2	-0.22***	0.94***	-0.49***	0.80
	(0.06)	(0.04)	(0.21)			(0.06)	(0.04)	(0.19)	
3	-0.02	0.96***	0.09	0.88	3	-0.02	0.97***	-0.19	0.88
	(0.04)	(0.02)	(0.10)			(0.04)	(0.02)	(0.13)	
4	0.13***	0.93***	0.13	0.83	4	0.13***	0.93***	0.19	0.83
	(0.05)	(0.03)	(0.12)			(0.05)	(0.04)	(0.15)	
5	-0.03	1.03***	-0.08	0.84	5	-0.03	1.03***	0.23	0.84
	(0.05)	(0.03)	(0.13)			(0.05)	(0.03)	(0.15)	
6	0.25***	1.13***	0.21	0.76	6	0.26***	1.12***	0.78***	0.76
	(0.09)	(0.04)	(0.21)			(0.08)	(0.04)	(0.24)	

Notes: This table presents of time series regressions of excess returns of carry trade portfolios on a constant (α), the average dollar risk (DOL), and subblock factors. $SB - AGR$ is the agricultural material prices, and $SB - MET$ is the metal, $SB - FOO$ is the food prices, and $SB - STO$ is the stock market factors estimated by the Dynamic Hierarchical Factor Model. The standard errors are reported in parentheses and obtained by the Newey and West (1987) procedure with optimal lag selection according to Andrews (1991). The adjusted R^2 are also reported. *,**, and *** indicate significance at the 10%, 5% and 1% levels, respectively. The sample period is from February 1983 and December 2013.

Table 6 Time Series Regression with HML_{FX}

	AGR	MET	AGR^{orth}	MET^{orth}	STO	STO^{orth}	ΔVOL_{FX}	adjR^2
(1)	1.40***							0.05
	(0.42)							
(2)		1.28***						0.04
		(0.43)						
(3)	1.18***						-7.23***	0.15
	(0.32)						(1.29)	
(4)		0.87***					7.02***	0.13
		(0.31)					(1.32)	
(5)	1.19***			0.49			-6.90***	0.15
	(0.31)			(0.31)			(1.24)	
(6)		0.87***	1.00***				-6.90***	0.15
		(0.28)	(0.34)				(1.21)	
(7)	1.20***					0.87***	-6.69***	0.17
	(0.31)					(0.32)	(1.24)	
(8)		0.89***				0.78**	-6.60***	0.14
		(0.30)				(0.33)	(1.26)	
(9)			1.17***		0.92***		-6.70***	0.17
			(0.31)		(0.32)		(1.24)	
(10)				0.78***	0.93***		-6.60***	0.14
				(0.33)	(0.30)		(1.25)	

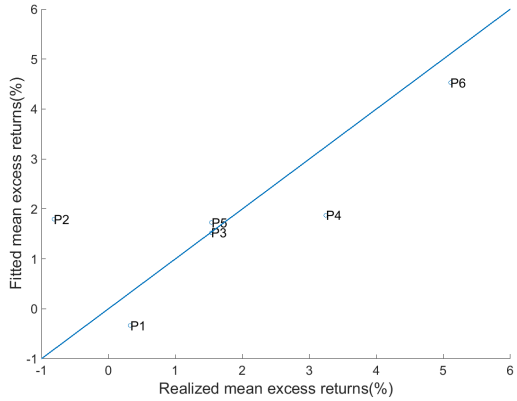
Notes: This table shows results for time series regressions of HML_{FX} on a constant and factors. HML_{FX} is the high minus low currency portfolios as in Lustig et al. (2011). AGR is the agricultural material prices, MET is the metal, and STO is the stock market factors estimated by the Dynamic Hierarchical Factor Model. This table also investigates the orthogonal factors, based upon Menkhoff et al. (2012). AGR^{orth} is the orthgonalized agricultural material prices, MET^{orth} is the orthgonalized metal, and STO^{orth} is the orthgonalized stock market factors. ΔVOL_{FX} is the global FX volatility innovations as in Menkhoff et al. (2012). The estimated coefficient for the constant term are not reported. The standard errors are reported in parentheses and obtained by the Newey and West (1987) procedure with optimal lag selection according to Andrews (1991). The adjusted R^2 are also reported. *,**, and *** indicate significance at the 10%, 5% and 1% levels, respectively. The sample period is from February 1983 and December 2013.

Table 7 Cross-sectional Asset Pricing: Developed and Emerging Currencies

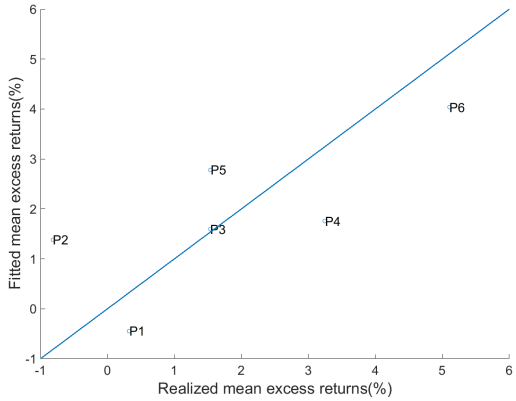
Panel A: Developed Countries			
	(1)	(2)	(3)
	λ	λ	λ
DOL	0.17	0.17	0.17
	(0.13)	(0.13)	(0.13)
$SB-AGR$	0.06		
	(0.11)		
$SB-MET$		0.27**	
		(0.13)	
$SB-STO$			0.24**
			(0.10)
R^2	0.04	0.56	0.70
RMSE	0.15	0.10	0.08
χ^2	15.12***	6.35*	4.26
[p-value]	[0.00]	[0.10]	[0.23]
Panel B: Emerging Countries			
	(4)	(5)	(6)
	λ	λ	λ
DOL	0.04	0.09	0.08
	(0.13)	(0.13)	(0.13)
$SB-AGR$	0.67**		
	(0.33)		
$SB-MET$		0.12	
		(0.13)	
$SB-STO$			0.10
			(0.26)
R^2	0.49	0.07	0.07
RMSE	0.24	0.32	0.32
χ^2	4.82	24.80***	25.43***
[p-value]	[0.31]	[0.00]	[0.00]

Notes: This table reports cross-sectional pricing results of the linear factor model based on the commodity prices or financial risk factors. The test assets are excess returns of five developed country carry trade portfolios or six emerging country carry trade portfolios. The coefficient of factor risk premium λ in Equation (6) is estimated by the procedure of Fama and MacBeth (1973). Abbreviations of the factor variables are reported in the first column. DOL is the average dollar risk factor. $SB-AGR$ is the agricultural material prices, $SB-MET$ is the metal, and $SB-STO$ is the stock market factors estimated by the Dynamic Hierarchical Factor Model. Shanken (1992) standard errors are reported in parentheses. The R^2 is a measure of fit between the sample mean and the predicted mean returns. RMSE is the root of mean-squared error and is reported in percentage points. The χ^2 test statistics of pricing errors are reported and the null hypothesis is that there is no pricing error. p-values are reported in square brackets. *,**, and *** indicate significance at the 10%, 5% and 1% levels, respectively. The sample period in developed countries is from February 1983 to December 2013 and that in emerging countries is from January 1997 to December 2013.

Graph A. $SB - AGR$



Graph C. $SB - MET$



Graph C. $SB - STO$

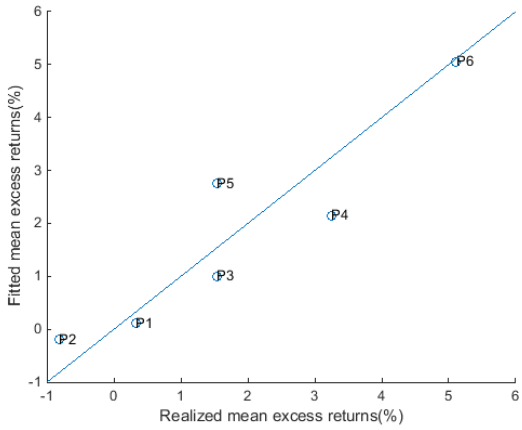


Figure 1. Pricing Error Plots.

Figure 1 displays pricing errors for asset pricing models with a combination of DOL and a subblock factor. The realized mean excess returns ($r_{i,t}$) are on the horizontal axis and the mean fitted excess returns are on the vertical axis. Both excess returns are annualized returns. Graph A uses the agricultural material prices subblock ($SB - AGR$), Graph B uses the the metals subblock ($SB - MET$), Graph C uses the stock market ($SB - STO$) factors estimated by the Dynamic Hierarchical Factor Model. The sample period is from February 1983 to December 2013.

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Carry Trades and Commodity Risk Factors

Joseph P. Byrne, Boulis Maher Ibrahim, and Ryuta Sakemoto

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This Online supplement provides further information and several robustness checks. Section A sets out the relationship to Uncoverd Interest rate Parity; Section B provides the detail on the Generalized Method of Moments estimation method; Section C shows the list of countries this study analyses; Section D describes the data treatment; Section E presents the relationship between our empirical results and commodity exporting/importing countries; Section F provides further robustness tests using individual currencies.

A. Uncovered Interest Parity

A carry trade is an investment strategy exploiting the empirical failure of Uncoverd Interest rate Parity (UIP). The failure of UIP is often observed in many currencies and is known as the forward premium puzzle. Lewis (1995) and Engel (1996) provide reviews of this puzzle. The currency excess return is written as:

$$r_{t+1} \approx i_t^* - i_t - \big(E_t s_{t+1} - s_t\big). \tag{A-1}$$

If the interest rate differential is positive (i.e., $i_t^* - i_t > 0$) and the USD depreciates against the foreign currency (i.e., $E_t s_{t+1} - s_t < 0$), the excess return will be positive. It will also be positive if the USD appreciates against the foreign currency and this appreciation does not offset the interest rate differential.

B. Generalized Method of Moments

In the paper we use the Fama-MacBeth approach with Shanken standad errors following Burnside (2011). However, we could also estimate our empirical asset pricing model using the generalized method of moments (GMM) proposed by Hansen (1982). As in Menkhoff et al. (2012), we use the first stage of the GMM procedure which has the identity weight matrix. Following Cochrane (2005) and Burnside (2011), the moment conditions are:

$$\big[1 - b'(h_t - \mu)\big] r_t = 0 \tag{A-2}$$

$$h_t - \mu = 0 \tag{A-3}$$

$$vec\big((h_t - \mu)(h_t - \mu)'\big) - vec(\Sigma_h) = 0. \tag{A-4}$$

The first condition (A-2) is an N-dimensional vector that ensures the currency excess return satisfies the Euler equation.[1] Equation (A-3) is an l-dimensional vector, indicating factor means μ are estimated values. The third condition (A-4) is an $l(l+1)/2$ dimensional vector and measures the estimation uncertainty of the factor covariance matrix. These conditions account for estimation uncertainty, since the factor means and the covariance matrix are estimated values. We compute heteroskedasticity consistent standard errors as in Burnside (2011).

C. Country List

The dataset covers the same 37 countries considered by Lustig et al. (2011): Australia, Austria, Belgium, Canada, Hong Kong, Czech Republic, Denmark, Euro area, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Kuwait, Malaysia, Mexico, Netherlands, New Zealand, Norway, the Philippines, Poland, Portugal, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, and the United Kingdom. Developed country portfolios include: Australia, Belgium, Canada, Denmark, Euro area, France, Germany, Italy, Japan, Netherlands, New

[1] N is the number of the portfolios and l is the number of the factors.

Zealand, Norway, Sweden, Switzerland, and the United Kingdom. Emerging country portfolios are constructed from the other 22 currencies.

D. Data Treatment

We pre-treat the spot and forward rate dataset by following the same methodology used by Darvas (2009) and Cenedese et al. (2014). This involves using the previous day's observation if an observation exhibits any of the following: bid and ask rates are equal; the spread of the forward exchange rate is less than the spread of the spot exchange rate;[2] the daily spot rate changes but the daily forward rate stays constant and vice versa.

E. Commodity Exporting and Importing Countries

Following Ready et al. (2016), the commodity exporting countries include Australia (AUS), Canada (CAN), New Zealand (NZL), and Norway (NOR), and the commodity importing countries include the Euro (EUR), Germany (DEU), Japan (JPN), Sweden (SWE), and Switzerland (CHE). These two categories are based on the level of net exports in basic goods and net imports in finished goods.

F. Country-level Asset Pricing

We adopt a country-level asset pricing model as a robustness check. Lustig et al. (2011), and Ahmed and Valente (2015) argue that the country-level model can deal with the data-snooping biases mentioned by Lo and MacKinlay (1990), and the information problems presented by Ang et al. (2010).[3]

Following the Fama and MacBeth (1973) procedure, we run the first-stage time series regressions.

[2]Although some currencies in forward markets may have enough liquidity and smaller spreads than those in spot markets, our dataset contains many emerging currencies, and we simply follow this rule to standardize the data cleaning method.

[3]Lo and MacKinlay (1990) present evidence that finding a portfolio construction idea and testing it on the same dataset, leads to a data snooping bias. The bias may be serious when we use the portfolio approach. Ang et al. (2010) provide evidence that a risk premium depends upon the cross-sectional distribution of beta and idiosyncratic volatility. If we use portfolios, we lose some information of the beta distribution.

The excess return $r_{i,t}$ of currency i is regressed on DOL, factors estimated by DHFM, and a constant. We then run the following second-stage cross-sectional regression:

$$r_{i,t} = \lambda_{DOL,t}\beta_{i,t}^{DOL} + \lambda_{h,t}\beta_{i,t}^{h} + \epsilon_t \tag{A-5}$$

where $\lambda_{j,t}$ is the risk premium and $j = DOL$ or h, and $\beta_{i,t}^{j}$ is estimated by the first stage regression. We estimate this cross-sectional model for each t and conduct statistical inference using mean λ_j and variance $\sigma^2(\lambda_j)$ as in Cochrane (2005):

$$\lambda_j = \frac{1}{T}\sum_{t=1}^{T}\lambda_{j,t}, \quad \sigma^2(\lambda_j) = \frac{1}{T^2}\sum_{t=1}^{T}(\lambda_{j,t} - \lambda_j)^2. \tag{A-6}$$

Similar to Lustig et al. (2011), we use the Newey and West (1987) procedure to correct for autocorrelations.

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Table A-1 Data and Model Structure

Block	Subblock	N
$B-COM$	$SB-FOO$	11
$B-COM$	$SB-AGR$	6
$B-COM$	$SB-MET$	6
$B-COM$	$SB-OIL$	3
$B-FIN$	$SB-STO$	6
$B-FIN$	$SB-INT$	15
$B-FIN$	$SB-MON$	13
$B-ECO$	$SB-INC$	9
$B-ECO$	$SB-PRO$	14
$B-ECO$	$SB-EMP$	25
$B-ECO$	$SB-HOU$	10
$B-ECO$	$SB-PRI$	14

Notes: This table summarizes the block structure of the four-level Dynamic Hierarchical Factor Model. N is the number of series in each subblock. There are three blocks (B): commodity price (COM), finance (FIN) and real economy (ECO). The commodity block has four subblocks (SB): food prices (FOO), agricultural material prices (AGR), metals (MET), and oil (OIL). The finance block has three subblocks (SB): stock market (STO), interest rate (INT), and money (MON). The real economy block has five subblocks: income and consumption (INC), production (PRO), employment (EMP), house (HOU), and price (PRI).

Table A-2 Cross-sectional Asset Pricing: Commodity and fFinance Subblocks without Bid Ask Spreads

Panel A: Commodity Block				
	(1)	(2)	(3)	(4)
	λ	λ	λ	λ
DOL	0.24	0.24	0.24	0.25
	(0.12)	(0.12)	(0.12)	(0.12)
$SB-AGR$	0.63***			
	(0.17)			
$SB-MET$		0.73***		
		(0.24)		
$SB-FOO$			1.37*	
			(0.70)	
$SB-OIL$				0.78
				(0.93)
R^2	0.90	0.87	0.73	0.09
RMSE	0.08	0.09	0.14	0.25
χ^2	2.84	3.55	2.20	27.72***
[p-value]	[0.58]	[0.47]	[0.70]	[0.00]
Panel B: Finance Block				
	(5)	(6)	(7)	
	λ	λ	λ	
DOL	0.23	0.24	0.24	
	(0.12)	(0.12)	(0.12)	
$SB-STO$	0.51***			
	(0.14)			
$SB-INT$		-3.93		
		(2.71)		
$SB-MON$			-0.48***	
			(0.17)	
R^2	0.86	0.50	0.31	
RMSE	0.10	0.18	0.22	
χ^2	5.82	2.02	13.62**	
[p-value]	[0.21]	[0.73]	[0.01]	

Notes: This table reports cross-sectional pricing results of the cross-sectional pricing results of the linear factor model based on the commodity prices or financial risk factors. The test assets are excess returns of six carry trade portfolios without trading costs. The coefficient of factor risk premium λ in Equation (6) is estimated by the procedure of Fama and MacBeth (1973). Abbreviations of the factor variables are reported in the first column. DOL is the average dollar risk factor. $SB-FOO$ is food prices, $SB-AGR$ is agricultural material prices, $SB-MET$ is metal prices, $SB-OIL$ is oil prices, $SB-STO$ is stock market, $SB-INT$ is interest rate, and $SB-MON$ is money factors estimated by the Dynamic Hierarchical Factor Model. Shanken (1992) standard errors are reported in parentheses. The R^2 is a measure of fit between the sample mean and the predicted mean returns. The RMSE is the root of mean-squared error and is reported in percentage points. The χ^2 test statistics of pricing errors are reported and the null hypothesis is that there is no pricing error. p-values are reported in square brackets. *,**, and *** indicate significance at the 10%, 5% and 1% levels, respectively. The sample period is from February 1983 to December 2013.

Table A-3 Cross-sectional Asset Pricing: GMM

	(1)		(2)		(3)	
	b	λ	b	λ	b	λ
DOL	-0.02	0.15	-0.06	0.15	-0.23	0.17
	(0.04)	(0.12)	(0.05)	(0.12)	(0.03)	(0.14)
$SB-AGR$	1.94*	0.30**				
	(1.05)	(0.14)				
$SB-MET$			2.08*	0.31**		
			(1.14)	(0.15)		
$SB-STO$					1.97*	0.24**
					(1.09)	(0.12)
R^2	0.57		0.53		0.85	
RMSE	0.10		0.11		0.06	
χ^2	6.24		8.27*		4.60	
[p-value]	[0.18]		[0.08]		[0.33]	

Notes: This table reports cross-sectional pricing results of the linear factor model based on the commodity prices or financial risk factors. The test assets are excess returns of six carry trade portfolios. Coefficients of SDF parameter b and factor risk premium λ are estimated by GMM, and the first stage GMM results are reported. Abbreviations of the factor variables are reported in the first column. DOL is the average dollar risk factor. $SB-AGR$ is the agricultural material prices, $SB-MET$ is the metal, and $SB-STO$ is the stock market factors estimated by the Dynamic Hierarchical Factor Model. GMM-VARHAC standard errors are reported in parentheses. The R^2 is a measure of fit between the sample mean and the predicted mean returns. The RMSE is the root of mean-squared error and is reported in percentage points. The χ^2 test statistics of pricing errors are reported and the null hypothesis is that there is no pricing error. p-values are reported in square brackets. *,**, and *** indicate significance at the 10%, 5% and 1% levels, respectively. The sample period is from February 1983 to December 2013.

Table A-4 Cross-sectional Asset Pricing: Commodity Index

	(1) λ	(2) λ	(3) λ	(4) λ	(5) λ
DOL	0.16	0.16	0.15	0.15	0.16
	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)
CRB	3.94				
	(2.60)				
$IMF - AGR$		0.81			
		(1.03)			
$IMF - MET$			4.03**	-0.65	
			(1.95)	(3.08)	
$IMF - MET^{orth}$					-3.57
					(3.01)
$SB - MET$					0.33*
					(0.18)
$SB - MET^{orth}$				0.38*	
				(0.22)	
R^2	0.38	0.10	0.43	0.61	0.61
RMSE	0.13	0.15	0.12	0.10	0.10
χ^2	7.75	19.61***	12.32**	5.35	5.35
[p-value]	[0.10]	[0.00]	[0.02]	[0.15]	[0.15]

Notes: This table reports cross-sectional pricing results of the linear factor model based on the commodity prices factors. The test assets are excess returns of six carry trade portfolios without trading costs. The coefficient of factor risk premium λ in Equation (6) is estimated by the procedure of Fama and MacBeth (1973). Abbreviations of the factor variables are reported in the first column. DOL is the average dollar risk factor. CRB is the CRB Raw industrial material subkinex return as in Bakshi and Pnayotov (2013). $IMF - AGR$ is the IMF agricultural material index, $IMF - MET$ is the IMF metal index, and both are computed as real returns. $IMF - MET^{orth}$ is the orthogonalized IMF metal index real return. $SB - MET$ is the metal factor estimated by the Dynamic Hierarchical Factor Model and $SB - MET^{orth}$ is the orthogonalized metal factor. The R^2 is a measure of fit between the sample mean and the predicted mean returns. The RMSE is the root of mean-squared error and is reported in percentage points.The χ^2 test statistics of pricing errors are reported and the null hypothesis is that there is no pricing error. p-values are reported in square brackets. *,**, and *** indicate significance at the 10%, 5% and 1% levels, respectively. The sample period is from February 1983 to December 2013.

Table A-5 Country-level Asset Pricing

	(1)	(2)	(3)
	λ	λ	λ
DOL	0.27**	0.24**	0.26**
	(0.13)	(0.13)	(0.13)
$SB-AGR$	0.18**		
	(0.09)		
$SB-MET$		0.18**	
		(0.07)	
$SB-STO$			0.08*
			(0.04)
R^2	0.25	0.28	0.29
RMSE	1.58	1.54	1.52

Notes: This table reports cross-sectional pricing results using individual currencies. The factor risk premium λ is obtained by Equations (A-5) and (A-6). Abbreviations of the factor variables are reported in the first column. DOL is the average dollar risk factor. $SB-AGR$ is the agricultural material prices, $SB-MET$ is the metal, and $SB-STO$ is the stock market factors estimated by the Dynamic Hierarchical Factor Model. The standard errors are reported in parentheses and obtained by the Newey and West (1987) procedure with optimal lag selection according to Andrews (1991). The R^2 and RMSE is average of time series. The RMSE is the root mean-squared error and is reported in percentage points. *,**, and *** indicate significance at the 10%, 5% and 1% levels, respectively. The sample period is from February 1983 to December 2013.

Table A-6 Time Series Regression with HML_{FX}

	Panel A: Stock Market Risk				
	$SB-AGR$	$SB-MET$	ΔVOL_{World}		adjR^2
(1)	1.34***		-1.23**		0.09
	(0.46)		(0.51)		
(2)		1.17***	-1.18***		0.08
		(0.41)	(0.43)		
	Panel B: CRB index				
	$SB-AGR$	$SB-MET$	CRB	CRB^{orth}	adjR^2
(3)	1.38***		0.96		0.05
	(0.46)		(5.32)		
(4)		1.25***	1.31		0.04
		(0.46)	(4.84)		
(5)	1.40***			0.96	0.05
	(0.41)			(5.32)	
(6)		1.28***		1.31	0.04
		(0.43)		(4.84)	
	Panel C: Orthogonalized IMF index				
	$SB-AGR$	$SB-MET$	$IMF-AGR^{orth}$	$IMF-MET^{orth}$	adjR^2
(7)	1.40***		-0.02		0.05
	(0.47)		(0.05)		
(8)		1.28***		-0.01	0.04
		(0.43)		(0.04)	
	Panel D: IMF index				
	$SB-AGR^{orth}$	$SB-MET^{orth}$	$IMF-AGR$	$IMF-MET$	adjR^2
(9)	1.46***		0.07		0.05
	(0.46)		(0.05)		
(10)		1.35***		0.08**	0.04
		(0.49)		(0.03)	

Notes: This table shows results for time series regressions of HML_{FX} on a constant (α) and factors. HML_{FX} is the high minus low currency portfolios as in Lustig et al. (2011). $SB-AGR$ is the agricultural material prices, $SB-MET$ is the metals factors estimated by the Dynamic Hierarchical Factor Model. $SB-AGR^{orth}$ is the orthogonalized agricultural material prices, $SB-MET^{orth}$ is the orthogonalized metals factors. ΔVOL_{world} is the global stock market volatility innovations using MSCI World index. CRB is the CRB Raw industrial material subkinex return as in Bakshi and Panayotov (2013), CRB^{orth} is the the orthogonalized CRB Raw industrial material subkinex return. $IMF-AGR$ is the IMF agricultural material index, $IMF-MET$ is the IMF metals index, and both are computed as a real return. $IMF-AGR^{orth}$ is the IMF agricultural material index, $IMF-MET^{orth}$ is the IMF metals index, and both are computed as a orthogonalized real return. The estimation results of constant term are not reported. The standard errors are reported in parentheses and obtained by the Newey and West (1987) procedure with optimal lag selection according to Andrews (1991). The adjusted R^2 are also reported. *,**, and *** indicate significance at the 10%, 5% and 1% levels, respectively. The sample period is from February 1983 and December 2013.

Table A-7 Data Sources, Transformation, and Definition

Number	Short name	Tran	Source	Description
Real Economy($B-ECO$)				
Income and Consumption ($SB-INC$)				
1	PI	lnFD	DS	Personal Income Account, SA, United States Dollar
2	PCE	FD	FRB	Real personal consumption expenditures, Percent Change from Preceding Period, SA
3	PCE	lnSD	FRB	Personal Consumption Expenditures: Chain-type Price Index,SA
4	PCE:D	lnSD	FRB	Personal Consumption Expenditures: Durable Goods,SA
5	PCE:ND	lnSD	FRB	Personal Consumption Expenditures: Nondurable Goods,SA
6	PCE:S	lnSD	FRB	Personal Consumption Expenditures: Services,SA
7	AHE	lnSD	DS	United States, Average Hourly Earnings of Production and Nonsupervisory Employees, SA, Total
8	AHE:const	lnSD	DS	United States, Average Hourly Earnings of Production and Nonsupervisory Employees, SA, Construction
9	AHE:mfg	lnSD	DS	United States, Average Hourly Earnings of Production and Nonsupervisory Employees, SA, Manufacturing
Production ($SB-PRO$)				
10	IP:total	lnFD	DS	Production, Overall, Total, Volume, SA, Index, 2007 = 100
11	IP:FP	lnFD	DS	Production, Market Groups, Final Products Total, Volume, SA, Index, 2007 = 100
12	IP:CG	lnFD	DS	Production, Market Groups, Consumer Goods Total, Volume, SA, Index, 2007 = 100
13	IP:CDG	lnFD	DS	Production, Market Groups, Consumer Durable Goods Total, Volume, SA, Index, 2007 = 100
14	IP:CNDG	lnFD	DS	Production, Market Groups, Consumer Nondurable Goods Total, Volume, SA, Index, 2007 = 100
15	IP:EB	lnFD	DS	Production, Market Groups, Equipment, Business Total, Volume, SA, Index, 2007 = 100
16	IP:MT	lnFD	DS	Production, Market Groups, Materials Total, Volume, SA, Index, 2007 = 100
17	IP:MF	lnFD	DS	Production, Manufacturing, Overall, Total (SIC), Volume, SA, Index, 2007 = 100
18	IP:RU	lnFD	DS	Production, Market Groups, Consumer Nondurable, Energy, Residential Utilities, Volume, SA, Index, 2007 = 100
19	IP:F	lnFD	DS	Production, Market Groups, Consumer Nondurable, Energy, Fuels, Volume, SA, Index, 2007 = 100
20	ISM:M	level	FRB	ISM Manufacturing: Production Index,SA
21	CU	FD	FRB	Capacity Utilization: Total Industry, Percent of Capacity, Monthly, Seasonally Adjusted
22	PMI	level	FRB	ISM Manufacturing: PMI Composite Index,SA
23	ISM:NO	level	FRB	ISM Manufacturing: New Orders Index,SA
Employment ($SB-EMP$)				

Continued: Data Sources, Transformation, and Definition

Number	Short name	Tran	Source	Description
24	EMP:total	lnFD	DS	Employment, Overall, Total (Civilian, Household Survey), SA
25	UER:total	FD	DS	Unemployed, Rate, Total, SA
26	U:mean	FD	DS	Unemployed, by Duration, Average in Weeks, SA
27	U:5wks	lnFD	DS	Unemployed, by Duration, For Less Than 5 Weeks, SA
28	U:5-14wks	lnFD	DS	Unemployed, by Duration, For 5-14 Weeks, SA
29	U:15wks	lnFD	DS	Unemployed, by Duration, For 15 Weeks or More, SA
30	U:15-26wks	lnFD	DS	Unemployed, by Duration, For 15-26 Weeks, SA
31	U:27wks	lnFD	DS	Unemployed, by Duration, For 27 Weeks or More, SA
32	UI:claims	lnFD	FRB	Initial Claims, Number, Monthly, Seasonally Adjusted
33	AWPR	lnFD	FRB	Indexes of Aggregate Weekly Payrolls of Production and Nonsupervisory Employees,SA, Index, 2002 = 100
34	NFP:goods	lnFD	DS	Non-Farm Payrolls, Goods-Producing, SA, Index, 2002 = 100
35	NFP:ML	lnFD	DS	Non-Farm Payrolls, Mining and Logging, SA, Index, 2002 = 100
36	NFP:C	lnFD	DS	Non-Farm Payrolls, Construction, SA, Index, 2002 = 100
37	NFP:Mf	lnFD	DS	Non-Farm Payrolls, Manufacturing, SA, Index, 2002 = 100
38	NFP:DG	lnFD	DS	Non-Farm Payrolls, Durable Goods, SA, Index, 2002 = 100
39	NFP:NDG	lnFD	DS	Non-Farm Payrolls, Nondurable Goods, SA, Index, 2002 = 100
40	NFP:BS	lnFD	DS	Non-Farm Payrolls, Professional and Business Services, SA, Index, 2002 = 100
41	NFP:TU	lnFD	DS	Non-Farm Payrolls, Trade, Transportation, and Utilities, SA, Index, 2002 = 100
42	NFP:WT	lnFD	DS	Non-Farm Payrolls,Wholesale Trade, SA, Index, 2002 = 100
43	NFP:RT	lnFD	DS	Non-Farm Payrolls, Retail Trade, SA, Index, 2002 = 100
44	NFP:FA	lnFD	DS	Non-Farm Payrolls, Financial Activities, SA, Index, 2002 = 100
45	NFP:GP	level	DS	Non-Farm Payroll, Goods Producing Industries Total, SA
46	AWO	FD	DS	Average Weekly Overtime of Production Workers, Manufacturing, SA
47	AWH	level	DS	Average Weekly Hours of Production Workers, Goods-Producing Industries Manufacturing, Total, SA
48	ISM	level	FRB	ISM Manufacturing: Employment Index,SA
House ($SB - HOU$)				
49	HS:total	ln	DS	Housing Starts, Total, AR, SA
50	HS:NE	ln	DS	Housing Starts, North East Region, AR, SA
51	HS:NE	ln	DS	Housing Starts, Midwest Region, AR, SA
52	HS:S	ln	DS	Housing Starts, South Region, AR, SA
53	HS:W	ln	DS	Housing Starts, West Region, AR, SA
54	BP:total	ln	DS	Building Permits, Total, AR, SA
55	BP:NE	ln	DS	Building Permits, by Region, Northeast, AR, SA
56	BP:MW	ln	DS	Building Permits, by Region, Midwest, AR, SA

Continued: Data Sources, Transformation, and Definition

Number	Short name	Tran	Source	Description
57	BP:S	ln	DS	Building Permits, by Region, South, AR, SA
58	BP:W	ln	DS	Building Permits, by Region, West, AR, SA
Price($SB-PRI$)				
59	PPI:FG	lnSD	FRB	Producer Price Index: Finished Goods,SA
60	PPI:FCG	lnSD	FRB	Producer Price Index: Finished Consumer Goods,SA
61	PPI:IM	lnSD	FRB	Producer Price Index: Intermediate Materials: Supplies and Components,SA
62	PPI:CM	lnSD	FRB	Producer Price Index: Crude Materials for Further Processing,SA
63	CPI:all	lnSD	FRB	Consumer Price Index for All Urban Consumers: All Items,SA
64	CPI:A	lnSD	FRB	Consumer Price Index for All Urban Consumers: Apparel,SA
65	CPI:T	lnSD	FRB	Consumer Price Index for All Urban Consumers: Transportation,SA
66	CPI:MC	lnSD	FRB	Consumer Price Index for All Urban Consumers: Medical care,SA
67	CPI:C	lnSD	FRB	Consumer Price Index for All Urban Consumers: Commodities,SA
68	CPI:D	lnSD	FRB	Consumer Price Index for All Urban Consumers: Durables,SA
69	CPI:S	lnSD	FRB	Consumer Price Index for All Urban Consumers: Services,SA
70	CPI:LF	lnSD	FRB	Consumer Price Index for All Urban Consumers: All Items Less Food,SA
71	CPI:LS	lnSD	FRB	Consumer Price Index for All Urban Consumers: All items less shelter,SA
72	CPI:LMC	lnSD	FRB	Consumer Price Index for All Urban Consumers: All items less medical care,SA
Finance($B-FIN$)				
Stock Market($SB-STO$)				
73	SP500	lnFD	DS	Standard and Poor's 500 Composite
74	SPID	lnFD	DS	Standard and Poor's Industrial
75	MKT	level	French	Fama and French Mkt-RF factor
76	SMB	level	French	Fama and French SMB factor
77	HML	level	French	Fama and French HML factor
78	MOM	level	French	Momentum factor
Interest Rate($SB-INT$)				
79	FF	FD	FRB	Effective Federal Funds Rate
80	3MTB	FD	DS	United States Treasury Bill SEC Market 3 Month
81	6MTB	FD	DS	United States Treasury Bill SEC Market 6 Month
82	1YTB	FD	DS	United States Treasury Constant Maturity 1 Year
83	5YTB	FD	DS	United States Treasury Benchmark Bond 5 Years
84	10YTB	FD	DS	United States Treasury Benchmark Bond 10 Years
85	Aaa	FD	FRB	Moody's Seasoned Aaa Corporate Bond Yield
86	Baa	FD	FRB	Moody's Seasoned Baa Corporate Bond Yield
87	3MTB-FF	level	-	3MTB-FF
88	6MTB-FF	level	-	6MTB-FF

Continued: Data Sources, Transformation, and Definition

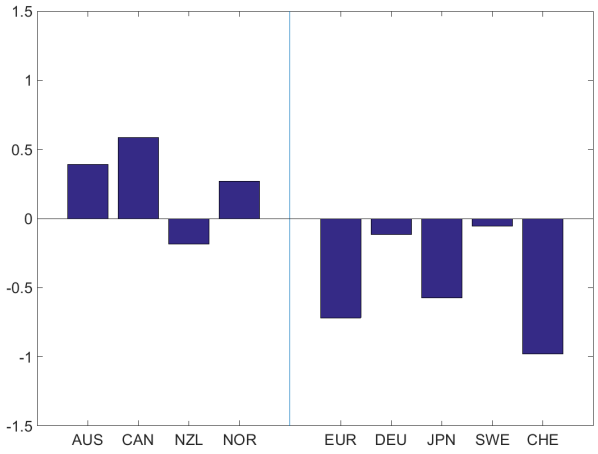
Number	Short name	Tran	Source	Description
89	1YTB-FF	level	-	1YTB-FF
90	5YTB-FF	level	-	5YTB-FF
91	10YTB-FF	level	-	10YTB-FF
92	Aaa-FF	level	-	Aaa-FF
93	Baa-FF	level	-	Baa-FF
Money($SB-MOT$)				
94	M1	lnSD	DS	Money Supply Money Supply M1, SA, United States Dollar
95	M2	lnSD	DS	Money Supply Money Supply M2, SA, United States Dollar
96	M3	lnSD	FRB	M3 for the United States,SA
97	MB	lnSD	FRB	St. Louis Adjusted Monetary Base,SA
98	BDI	lnSD	FRB	Total Borrowings of Depository Institutions from the Federal Reserve
99	RDI	FD	FRB	Reserves Of Depository Institutions, Nonborrowed
100	CIL	lnSD	FRB	Commercial and Industrial Loans, All Commercial Banks,SA
101	NCC	level	FRB	Nonrevolving Consumer Credit Owned And Securitized, Flow,SA
102	REER	lnFD	FRB	Real Narrow Effective Exchange Rate for United States
103	FX:Swiss	lnFD	FRB	Switzerland / U.S. Foreign Exchange Rate
104	FX:Japan	lnFD	FRB	Japan / U.S. Foreign Exchange Rate
105	FX:UK	lnFD	FRB	U.S. / U.K. Foreign Exchange Rate
106	FX:Canada	lnFD	FRB	Canada / U.S. Foreign Exchange Rate
Commodity($B-COM$)				
Food($SB-MOT$)				
107	Wheat	lnFD	IMF	Wheat
108	Maize	lnFD	IMF	Maize (corn)
109	Rice	lnFD	IMF	Rice
110	Palm oil	lnFD	IMF	Palm oil
111	Beef	lnFD	IMF	Beef
112	Lamb	lnFD	IMF	Lamb
113	Sugar	lnFD	IMF	Sugar
114	Bananas	lnFD	IMF	Bananas
115	Coffee	lnFD	IMF	Coffee
116	Cocoa beans	lnFD	IMF	Cocoa beans
117	Tea	lnFD	IMF	Tea
Agricultural Material($SB-AGR$)				
118	Sawnwood	lnFD	WB	Sawnwood (Malaysia)
119	Cotton	lnFD	IMF	Cotton
120	Wool	lnFD	IMF	Wool

Continued: Data Sources, Transformation, and Definition

Number	Short name	Tran	Source	Description
121	Rubber	lnFD	IMF	Rubber
122	Hides	lnFD	IMF	Hides
123	Tobacco	lnFD	WB	Tobacco (any origin)
Metal($SB-MET$)				
124	Copper	lnFD	IMF	Copper
125	Aluminum	lnFD	IMF	Aluminum
126	Tin	lnFD	IMF	Tin
127	Zinc	lnFD	IMF	Zinc
128	Lead	lnFD	IMF	Lead
129	Silver	lnFD	WB	Silver
Oil($SB-OIL$)				
130	Oil:DB	lnFD	IMF	Crude Oil (petroleum), Dated Brent, light blend 38 API, fob U.K., USD per barrel
131	Oil:Dubai	lnFD	IMF	Oil; Dubai, medium, Fateh 32 API, fob Dubai Crude Oil (petroleum), Dubai Fateh Fateh 32 API, USD per barrel
132	Oil:WTI	lnFD	IMF	Crude Oil (petroleum), West Texas Intermediate 40 API, Midland Texas, USD per barrel

Notes: This Table shows the short name of each series, the transformation applied to the series, data source and a brief data description. In the transformation column, level denotes level of the series, ln denotes logarithm, FD and SD denote the first and second difference, and lnFD and lnSD denote the first and second difference of the logarithm. In the source column, DB denotes Datastream, FRB denotes the Federal Reserve Bank St.Louis, IMF denotes the IMF commodity price table, WB denotes the World Bank commodity price data.The data period is from January 1983 to December 2013.

Graph A. Agricultural Factor



Graph B. Metal Factor

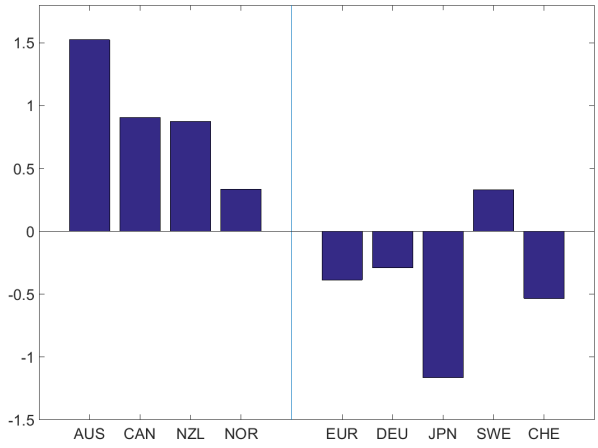


Figure A-1. Country Betas to Agricultural Material Price and Metal Factors.

Figure A-1 shows factor betas which are obtained by the time series regressions. The basic sample period is from February 1983 to December 2013. Australia starts from November 1989, Euro starts from February 1999, New Zealand starts from August 1990, and Germany ends December 1998.